Sunday Drivers, or Too Fast and Too Furious?

Analyzing Speed, Rider Behaviour, and Traffic Conflicts of E-Scooter Share

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May 2019

Sunday Drivers, or Too Fast and Too Furious?

Analyzing Speed, Riding Behaviours, and Traffic Conflicts of E-Scooter Riders in Downtown San Jose, CA

A Planning Report

Presented to

The Faculty of the Department of

Urban and Regional Planning

San José State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Urban Planning

By

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May 2019

Acknowledgments

First and foremost, I would like to acknowledge the support and encouragement from my husband Adam; without him, I would have not been able to pursue a whole new career path in urban planning. I would like to thank my research supervisor, Dr. Kevin Fang, for his encouragement to pursue this research effort and for the opportunity to present my research findings at the 2019 Annual Transportation Research Board Meeting. Moreover, I would also like to thank my Planning Report Advisor, Rick Kos, for his meticulous and thoughtful mentoring and guidance throughout the composition of this report.

I would like to extend my personal gratitude to the members of my URBP 298B group (Tonya, Danielle, Carolyn, and Evan) for keeping me accountable through the writing process. Finally, I would like to thank my friends Clelia and Fran – I would not have been able to get through this program without their support.

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Executive Summary

In recent months, mobility companies have been rapidly introducing shared electric scooter (e-scooter) programs in cities across the United States. While there appears to be strong interest, they have attracted a wide range of opinions. Some view e-scooters favourably, specifically pertaining to their benefit of providing alternative forms of mobility as opposed to driving, and the potential to address first-mile and last-mile access.[1] Others view them as nuisances "obstructing entryways" or creating "clutter".[2]

Shared e-scooter systems are still in the early stages of deployment and many governments are just beginning the process of debating how scooters should be regulated.[3] This debate over whether individuals view e-scooters as compatible or incompatible with other road users and whether they support or do not support specific policies is likely formed by how they see the attributes of e-scooters versus that of similar modes of micro-mobility. However, there is a lack of data on how e-scooters riders actually behave, and how that compares to other road users. As a result, this study sought to observe e-scooters on sidewalks, streets, and mixed-use paths in San Jose with a goal of revealing how operational characteristics, riding behaviours, and traffic conflicts could inform those debates.

Research Question

This research effort sought to answer the following question:

What are the "operational characteristics" exhibited by e-scooter share users using streets, sidewalks, and mixed-use paths in downtown San Jose, California and what are the potential implications of the findings on the future development of e-scooter regulation and micro-mobility (bicycle) infrastructure design?

To address this gap in research, the operational characteristics of e-scooter users were investigated including speed, and other qualitative measures of behaviour that might influence safety such as helmet use, riding style, group travel, traffic conflicts, and rider distraction.

Methods

In total, 330 e-scooter riders were observed in downtown San Jose during a mix of both dry and wet weather conditions on streets (n=110), sidewalks (n=110), and mixed-use paths (n=110) between October 2018 and February 2019. Only Lime's Lime-S, and Bird scooters were observed as part of this study. Additionally, 110 observations of cyclists were observed on the street only.

Results

Concerning average speed:

- riders traveled between 9 to 11 mph ($p<0.01$) with a different speed per facility
- male riders traveled faster than females and varied less by facility ($p<0.01$)
- operator speeds were similar at 10 mph ($p=0.69$)
- older adult riders (10.5 mph) traveled faster than younger riders (9.4 mph) ($p<0.01$)
- e-scooter riders traveled slower on streets (11.1 mph) than bicyclists (12.2 mph) ($p<0.01$)
- riders traveled faster in colder temperatures than warmer temperatures ($p=0.04$)

Furthermore, concerning riding behaviours:

- 2 percent of e-scooter riders wore helmets compared to 55 percent of cyclists
- 97 percent traveled in a straight line as opposed to traveling in a less predictable side to side motion
- 16 percent of riders traveled in groups
- 3 percent of riders traveled with two riders on one scooter
- only one person was seen using a cellphone
- 16 percent of riders were observed using headphones

In terms of traffic conflicts (n=134), 71 percent of riders that encountered conflicts slowed down while 29 percent swerved out of the way. Furthermore, 70 percent of riders who encountered conflicts on facilities with mixed pedestrian traffic slowed down for pedestrians (a positive finding). Of note, the few collisions observed (n=3), were as a result of a rider colliding with a curb or due to a rider colliding with a parked car's side view mirror. This finding was similar to that of skateboarder collisions.

Implications

Based on the observation results, this study looked at the potential implications as it pertained to regulatory debates over e-scooters and the design of urban infrastructure and found:

- riders are not traveling as fast as what some people perceive, and are comparable to other modes of micro-mobility (where some are permitted to operate on sidewalks)
- new conflicts are created as a result of pitting slow scooters against fast moving vehicles
- age may not be the best way to regulate e-scooter share due to the inconsistency of riding behaviours among different age groups regarding speed
- sidewalk riders are yielding to pedestrians on sidewalks
- placing e-scooters riders on street could potentially be increasing their risk of collisions
- people are not distracted by cell phone use, but could be potentially distracted from headphones, and be violating state laws
- with helmet compliance being low among all riders, existing laws need to be revisited as they are not working towards encouraging more helmet use
- there was evidence of talking while observing group riding, suggesting a potential for distractions
- e-scooter share is not the only observed emerging mode of mobility; cities might have to rethink naming conventions for existing bicycle infrastructure

Recommendations

Based on a review of e-scooter riding results of speed, riding behaviours, and traffic conflicts, along with an understanding of the implications, this study made seven recommendations for the regulation of e-scooters along with design of urban micro-mobility infrastructure:

- allow sidewalk riding where it makes sense by using posted speed limits
- to avoid sidewalk riding, build safer infrastructure on streets
- to avoid e-scooter collisions, separate vehicle traffic
- building multi-speed lanes to accommodate all types of riders
- increase the width of existing micro-mobility infrastructure to promote more e-scooter use
- reconsider age restrictions concerning helmet laws
- rename the bicycle lane to the green lane

Research Limitations and Future Research

Additionally, this research effort discussed both research limitations and future research considerations. Concerning the speed results, observed riders on the mixed-use path (paseo off of 7th Street) were younger in age due to the proximity of the street facility near San Jose State University. This may have resulted in over sampling of similar age ranges. Also, there might have been a potential for human error due to the reaction time required to start and stop the stopwatch as riders crossed the observation zone. As it pertains to determining the age of e-scooter riders, there is some subjectivity over the classification of observed riders by age due to the observer determining these age ranges. As a result, there might be a larger proportion of riders represented in the adult category (25 to 50 years of age) that could have fallen either into the younger (adolescent) category of less than years of age, or the older adult category of individuals over the age of 50.

Moving forward, there is still much to learn about shared e-scooter programs and e-scooters in general. In terms of operational characteristics, data on the ability of e-scooters to brake and maneuver could be a particularly useful topic for future research. For example, what stopping distance is required for an e-scooter rider on a sidewalk to react to a sudden movement by a nearby pedestrian? Could an e-scooter rider navigate facilities with certain design specifications? Moreover, regarding safety, do e-scooter riders refuse to wear helmets for the same reason as cyclists?

Chapter 1
The E-Scooters are Coming!

In recent months, mobility companies have been rapidly introducing shared e-scooter programs in cities across the United States. The arrival of shared e-scooters continues the trend toward shared mobility (such as bike share, ride share, and car share) and "micro-mobility"— low-speed transportation for individual travelers on short trips.[4] Populus, a U.S. transportation analytics firm, finds strong interest in shared e-scooters from the public.[5] Populus estimates that in less than one year since their introduction, 3.6 percent of adults in U.S. cities where shared e-scooters are available have used the service. This estimate points to a much more rapid adoption rate than seen in other shared micro-mobility services.[6]

While there appears to be strong interest with the arrival of e-scooters, they have attracted a wide range of opinions. Some have responded to e-scooters favourably, specifically pertaining to their benefit of providing alternative forms of mobility as opposed to driving, and the potential to address first-mile and last-mile access.[7] Moreover, some have pointed to the ability of these power-assisted devices to assist riders in overcoming physical obstacles.[8] The Populus study also finds that scooters are popular among the public at large with approximately 70 percent of survey respondents in 11 major U.S. cities holding favourable views of e-scooters.[9] On the other hand, there are those that have reacted less favourably, viewing e-scooters as nuisances "obstructing entryways" or creating "clutter".[10] Beverly Hills, California Mayor Julian Gold, claimed scooters "put everybody at risk, and they put your kids at risk, and there's no responsibility for it, at all".[11] Moreover, there is an issue concerning the public perception over the safety of these devices with injuries associated with e-scooter riding.[12] Recently, San Jose State University's Chief Financial Officer, Charlie Faas, was quoted stating that e-scooters riders pose a safety risk due to the fact people are riding on sidewalks and not wearing helmets.[13] Figures 1, 2, 3, and 4 depict some of the issues associated with e-scooter share such parking, litter, and blocking the sidewalk.

One of the more contentious points about e-scooter operation pertains to

FIGURE 1. E-SCOOTER OBSTRUCTING THE ENTRYWAY TO ORIGINAL GRAVITY IN DOWNTOWN SAN JOSE, CA. PHOTOGRAPHY BY AUTHOR.

the compatibility of scooters with other road users, particularly pedestrians on sidewalks.[14] Some jurisdictions view e-scooters as strictly incompatible with pedestrians. For example, California state law prohibits e-scooters outright on sidewalks.[15] Similarly, other jurisdictions implicitly view e-scooters as incompatible with other road users. For example, the City of Denver, Colorado defines e-scooters as "toy vehicles" and mandates they be ridden on sidewalks.[16] E-scooters are also prohibited on bicycle paths in Denver. Other cities such as Milwaukee and San Francisco have outright banned e-scooters altogether, at least on a temporary basis.[17] As of August 30, 2018, San Francisco has lifted its e-scooter ban and instituted a pilot program.[18]

Shared e-scooter systems are still in the early stages of deployment and many governments are just beginning the process of debating how e-scooters should be regulated.[19] Since e-scooter share has not been around for very long, there is also a lack of literature on how best to regulate e-scooters, especially when there is a lack of understanding on how riders behave; however, there are methodologies for similar modes of mobility that may be used to establish comparisons for developing such a methodology. What literature is available, such as that from the National Association of City Transportation Officials (NACTO), codifies the day to day operation of "shared active transportation" devices from existing regulations based on right-of-way regulation, zoning regulation, small-vehicle regulation, and existing contracts with operators.[20] While NACTO's guide strives to inform cities on their choices of regulating e-scooter share, the report relies on using a city's existing set of regulations that are not necessarily reflective of the operating characteristics of e-scooter share, nor rider behaviour.[21]

The argument over whether individuals view e-scooters as compatible or incompatible with other road users and whether they support or do not support specific policies is likely formed by how they see the attributes of e-scooters versus that of different modes. The maximum capabilities of most e-scooters are published in technical specification documents. However, there is a lack of data on how e-scooter riders actually behave, and how that compares to other road users.

To address this gap in research, this research effort investigated the physical

FIGURE 2. E-SCOOTER IN A TRASH RECEPTICLE IN SAN JOSE, CA. PHOTOGRAPHY BY THE AUTHOR.

FIGURE 3. E-SCOOTER IN THE GUADALUPE RIVER IN SAN JOSE, CA. PHOTOGRAPHY BY AUTHOR.

FIGURE 4. WIND E-SCOOTERS KNOCKED OVER IN SAN JOSE, CA. PHOTOGRAPHY BY THE AUTHOR.

"operational characteristics" of e-scooter users. The operational characteristics measured here include speed and other qualitative measures of behaviour that might influence safety such as helmet use, riding style, group travel, traffic conflicts, and rider distraction. Specifically, this report seeks to answer the following question:

What are the "operational characteristics" exhibited by e-scooter share users using streets, sidewalks and mixed-use paths in downtown San Jose, California and what are the potential implications of the findings on the future development of e-scooter regulation and micro-mobility (bicycle) infrastructure design?

Of note, this will be the first research effort of its kind to investigate the operational characteristics and riding behaviours of e-scooter riders. The data measured to answer those questions came from downtown San Jose, California, where at least two companies have operated shared dockless e-scooter systems since early 2018. The data in this report reflects observations of e-scooter riders on three different kinds of transportation facilities: streets, sidewalks, and mixed/shared-use paths in both dry and wet weather conditions. Also examined are shared e-scooter systems currently utilizing motorized versions of "kick scooters," which are comprised of a long narrow platform that riders stand on, rolling on two wheels, with a vertical beam at the front rising to handlebars.[22] Note, only two e-scooter operators were included as part of this study, Lime (and their Lime-S e-scooter) and Bird.

Chapter 2 explores the arrival and development of micro-mobility and e-scooter share. Chapter 3, a literature review of e-scooter share, covers two important topics pertinent to this research effort: the regulatory debates over e-scooters in cities, and the measurement of operational characteristics and riding behaviours in similar modes of micro-mobility. Importantly, the reviewed literature suggests that the recording of operational characteristics may prove useful in the urban planning profession regarding the design of transportation facilities and regulations for alternate modes of mobility.[23] Chapter 4 describes the project methodology, followed by a discussion of the results in Chapter 5. Chapter 6 covers the potential implications of the findings as they pertain to urban planning policy for regulating e-scooter share, e-scooter design impacts, and micro-mobility infrastructure design. Chapter 7 summarizes recommendations, and Chapter 8 covers research limitations and future research considerations.

Chapter 2

The Scootorial

2.1 A Brief Introduction to Shared Micro-Mobility

The introduction of shared active transportation vehicles has proven popular in U.S. cities as people discover alternative ways to travel to their destinations.[24] The National Association of City Transportation Officials (NACTO) defines shared active mobility devices as "a network of small vehicles" for rent used for travel over short distances.[25] Shared active transportation devices can also be referred to as "micro-mobility" devices such as "pedal or electrically powered bicycles, scooters, and mopeds."[26]

The emergence of shared active transportation mobility devices in the U.S. commenced in 2009 with the introduction of Capital Bikeshare in Washington, D.C.[27] Initial variants of this pioneering service featured systems that required users to use docking stations to secure their rental bicycles.[28] The evolution of bike share, "dockless bicycle share", can be traced back to 2011 with the introduction of Social Bicycles (SoBi) in Buffalo, NY. SoBi stood apart from existing bicycle sharing systems at the time as SoBi did not require a dock and therefore was a dockless-based system.[30]

Micro-mobility evolved during 2016 and 2017 as new entrants Lime and Spin introduced their concepts of dockless devices.[31] Unlike the existing dockless bicycle sharing systems at the time by Motivate (purchased by Lyft in June of 2018) and SoBi (now Jump, and purchased by Uber in April of 2018), newer companies are all privately financed through venture capital.[32] Bicycles, and more recently e-bikes, are operated on public rights-of-way.[33] NACTO notes that these initial entrants entered the market without the necessary permitting as required by many cities today.[34] One can attribute the birth of the e-scooter share phenomena to Bird in Santa Monica, CA. Bird launched its dockless shared e-scooter system in 2017. Similar companies began to spread across the U.S. including Spin, Bird, and Lime.[35]

2.2 What the Scoot is an E-Scooter?

An e-scooter is a motorized standing kick scooter with two wheels and handlebars that features a long flat board that people stand on while they ride.[36] The first set of e-scooters distributed in San Jose, from both Lime and Bird, featured a manual handbrake on the left-hand side to manually brake the e-scooter. Additionally, riders controlled the throttle by using an electronic thumb pad to accelerate and decelerate. In the next e-scooter wave in San Jose, both Lime and Bird opted to modify their e-scooter designs and move towards a custom designed Segway version.[37] The most noticeable difference is the additional battery packs to boost the operating performance of e-scooters in order to travel longer distances (35 miles).[38] Additionally, new e-scooters no longer have a manual brake lever on the handlebars; instead, there are two brakes on both wheels which are electronic and are controlled by a thumbpad similar to the accelerator. In order to apply the brake, riders have to press down on the brake thumbpad. See Figure 5 for examples of e-scooter operators in San Jose, CA.

2.3 The E-Scooter Outbreak: E-Scooter Cities and Operators

As of 2018, the following U.S. cities feature e-scooter share programs:

- Austin, TX
- Boston, MA
- Charlotte, NC
- Chicago, IL
- Dallas, TX
- Denver, CO
- Los Angeles, CA
- Miami, FL
- Oakland, CA
- Palo Alto, CA
- Portland, OR
- Nashville, TN
- San Diego, CA
- San Francisco, CA
- San Jose, CA
- Santa Monica, CA
- Washington, D.C.

The U.S. market features a variety of e-scooter share companies including: Bird, Lime, Lyft (Motivate), Uber (Jump), Scoot, Skip, Spin, and Wind. Note, while Palo Alto features an e-scooter share program ordinance, it has yet to grant permits to operators.

2.4 The E-Scooter Share Service Model of Operation

The current e-scooter share market provides an on-demand e-scooter service. Unlike previous bike share programs, monthly subscriptions are not available.42 Typically, operators offer their services starting with a flat fee of one dollar before charging a 15 cent rate for every minute after that.43 Bird deviates from this model and currently offers a promotion where riders can pre-book a delivery of an-e-scooter in the morning for commuting to work.44 Additionally, certain cities like Austin, Denver, San Francisco, Los Angeles, and Palo Alto impose affordability requirements on e-scooter share operators to ensure equal spatial coverage across cities. For example, Austin requires that e-scooter share operators provide a non-mobile option to pay for services for anyone that is at or below the federal income poverty level.[45] Denver, on the other hand, is less specific about its equity requirements and instead leaves discount programs up to the operator to propose for those without smartphones and "unbanked" users.[46] The California cities of Los Angeles, Palo Alto, and San Francisco provide a hybrid of the two earlier mentioned systems by stipulating a non-mobile (non-credit card) option for those below the poverty level, but also dictate that service will provide unlimited trips under 30 minutes while waiving any fees or security deposits.[47] In San Francisco, Lime proposed to provide student discounts by allowing students to register through their academic institution ".edu" email address.[48]

2.5 Not All E-Scooters are Built the Same

While most e-scooter share units appear to be similar, they do possess unique characteristics. In the City of San Francisco, CA, both Scoot and Skip's e-scooters feature a bike lock that is attached to the e-scooter itself.[49] The idea behind this addition is that users can lock e-scooters to surrounding street furniture, thus confining these devices to areas outside of the pedestrian travel path.[50] A key difference between the

Figure 5. Bird and Lime e-scooter operators in San Jose, CA. Photography by the author.

two is that Skip's lock-to technology is a retractable steel wire whereas Scoot's lock-to technology is a standard bicycle lock with a combination.[51] Furthermore, Skip touts their e-scooter as being "better built" with a custom design that features a wider standing board, dual suspension, adjustable handlebar height, and tail lights to tell those around the rider when they are slowing down.[52] Additionally, when comparing Lime-S e-scooters to Bird, Lime-S e-scooters possess an electronic speedometer, while Bird e-scooters do not.

2.6 Scootering Along: Signing-Up, Starting, Traveling, and Ending Your Ride

The section discusses the e-scooter riding experience as it pertains to the sign-up process, travel experience, and ending the ride.

2.6.1 Signing-Up

The sign-up process for an e-scooter starts by users downloading the operator's respective mobile phone application (see Figures 10, 11, and 12).[53] Only Lime and Bird were included in this discussion as they are currently operating in the City of San Jose, CA. Both Bird and Lime require riders to provide identification (such as a driver's license) that users must scan with their smartphone's camera as part of the sign-up process.[54] The process also forces riders to swipe through rules and regulations regarding appropriate riding facilities, parking, and helmet use in the local jurisdiction before beginning to ride.[55] Once the legal agreements and regulation reminders have been reviewed and accepted, riders are free to start their ride. Once a rider has signed up for an e-scooter share mobile phone application, finding e-scooters is merely a matter of launching the application and searching the built-in map function to find the nearest e-scooter.[56]

2.6.2 Starting a Ride

Starting an e-scooter ride requires riders to scan a QR code which is typically located near the handlebars.[57] Once the code is scanned, the rider is required to wait a few seconds prior to the e-scooter unlocking. A jingle will sound to notify riders that they can now start their e-scooter ride (see Figure 8).[58]

2.6.3 Riding Experience

Depending on the type of surface of the transportation facility, e-scooters will provide a different riding experience. On smoother types of surfaces, a rider can expect a quiet and smooth enjoyable

FIGURE 6. SCOOT'S LOCK-TO LOCK IN SAN FRANCISCO, CA. PHOTOGRAPHY BY THE AUTHOR.

FIGURE 7. SKIP SCOOTER IN SAN JOSE, CA. PHOTOGRAPHY BY THE AUTHOR.

FIGURE 8. LIME E-SCOOTER QR CODE. PHOTOGRAPHY BY THE AUTHOR.

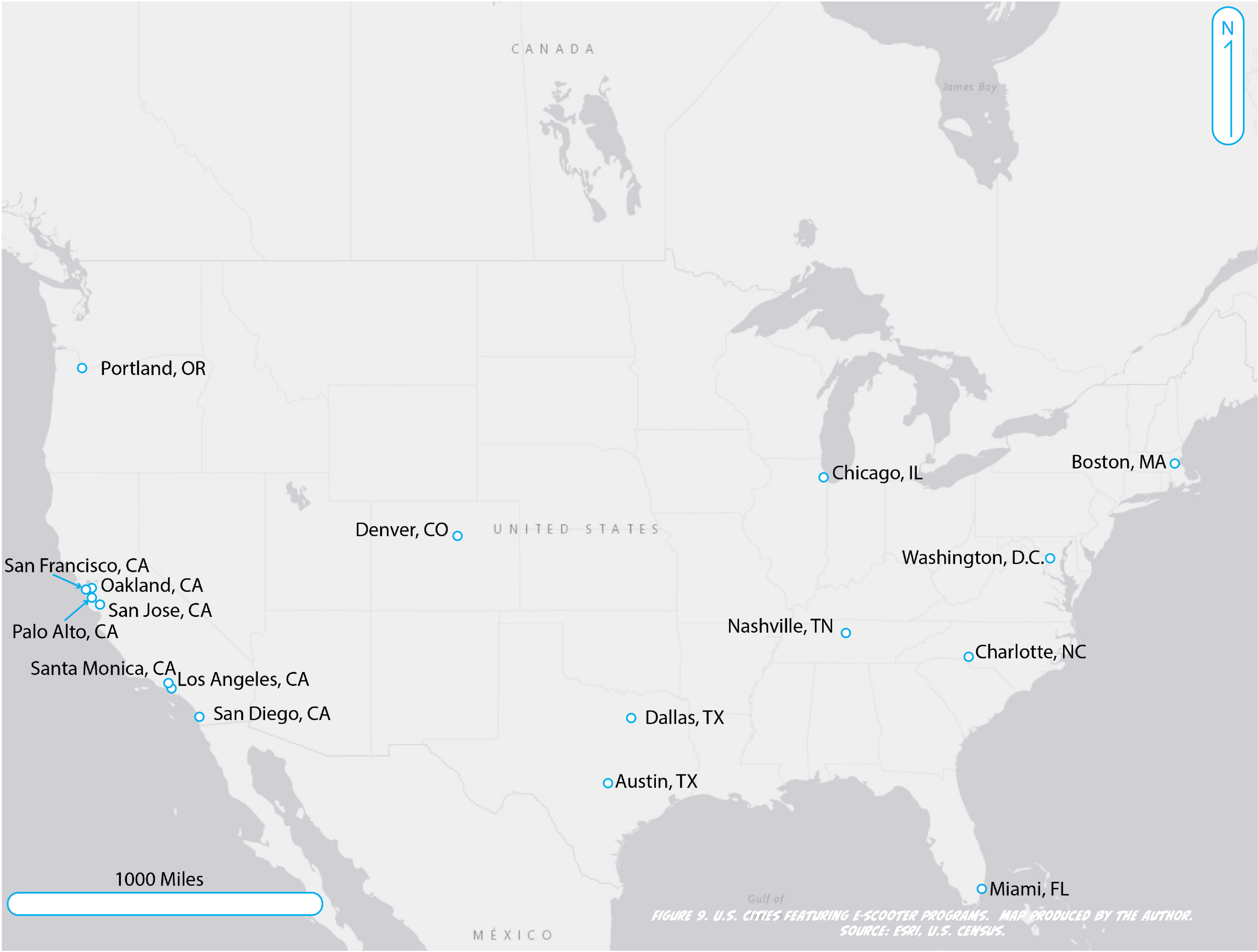

FIGURE 9. U.S. CITIES FEATURING E-SCOOTER PROGRAMS. MAP PRODUCED BY THE AUTHOR. SOURCE: ESRI, U.S. CENSUS.

ride.[59] When moving onto a road however, the experience can be a different matter. Currently, certain types of e-scooters from Segway do not feature much in the way of shock absorption. While riding on a rough street or sidewalk, one feels every single bump along the way. In wet weather conditions, riding conditions can vary widely as wet surfaces can prove to be slippery.

2.6.4 Ending the Ride

Upon reaching a destination, riders are required to first park their e-scooters in a location that does not obstruct the sidewalk.[60] In San Jose, there are no specifically designated parking areas, unlike other cities where they provide painted boxes to park them. E-scooters also feature a kickstand that riders can engage to let the scooter right itself while parked. Once the vehicle is parked, riders are required to open the mobile phone-based application to end their ride.[61] Riders tap their smartphone screen to end their ride and are provided with a summary of their trip length and travel time.[62] Riders are also prompted to rate their ride experience from one to five stars. Lower starred rides prompt users to input feedback on how to improve their experience for the next time.[63] Additionally, riders are also required to provide a photo of where their e-scooter is parked for two reasons: to show the next rider where the scooter is located in case they cannot find it, and a form of self-policing to ensure scooters are parked in an area that is not obstructing the right-of-way.[64]

2.7 The Scootorial Findings

This chapter served as an introduction to the emergence of shared micro-mobility in the U.S. The "scootorial" started by looking at early shared micro-mobility systems such as bike-share before delving into e-scooter share. The chapter then discussed the availability of e-scooter share across the U.S. along with the operators of the service. The chapter concluded with a summary of the e-scooter share ride service experience from start to finish.

While this chapter covered the basics of e-scooter share in the U.S., there still remains many unanswered questions over regulatory debates of e-scooter share. Chapter 3 will not only cover what cities are doing to regulate e-scooter share, but also the methods most commonly used to regulate similar modes of micro-mobility such as bicycles, e-bikes, skateboards, and Segways.

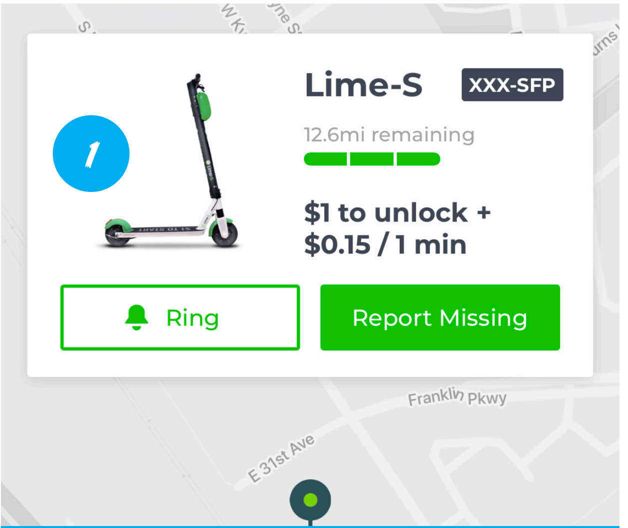

Figure 10. Step 1-Select your e-scooter. Photography by author. Source: Lime.

Figure 11. Step 2-Read the rules. Photography by author. Source: Lime.

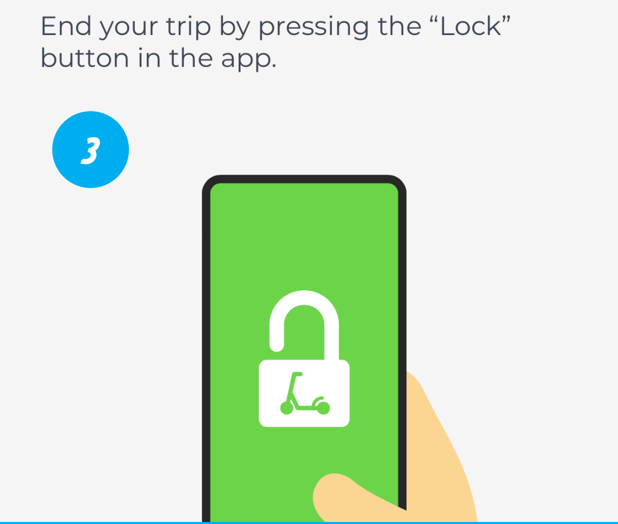

Figure 12. Step 3-Lock your ride. Photography by author. Source: Lime.

Chapter 3
What the Scoot is Going on?

A review of the most recent literature was conducted to identify what governments (both municipal and state) in the United States are currently doing to regulate e-scooter share, and the relevance of measuring operational characteristics from a planning perspective by looking at similar modes of micro-mobility. Different methodologies were then reviewed for measuring operational characteristics, riding behaviours, and analysis reduction strategies. Importantly, the reviewed literature points towards the notion that the recording of operational characteristics may prove useful in the urban planning profession regarding the design of transportation facilities and regulations concerning alternate modes of mobility.[65] Furthermore, this addresses a gap in the literature where e-scooter share travel behaviour data is currently non-existent.

3.1 Regulation Debates: What are Cities Doing to Regulate E-Scooter Share

A review of the most recent literature regarding how cities are adapting to the e-scooter influx reveals a mixed bag of approaches ranging from imposing facility restrictions, speed limitations, restricting the number of operators and scooter units and, in the most extreme cases, outright bans.

3.1.1 Facility Debates: Where to Scoot? Streets, Sidewalks, or Mixed-Use Paths?

In cities where e-scooter share currently operates, users can be seen operating them on various types of transportation facilities, including sidewalks, pedestrian paths, bicycle paths or lanes, and streets. Regulations in some areas limit e-scooters to certain types of facilities and not others. Existing policy or frameworks are temporary, and what is available in terms of literature is limited.

For example, the state of California, as of mid-2018 prohibits the use of e-scooters on sidewalks. During the 2018 legislative session, California Assembly Bill 2989 was introduced with the goal of clarifying where and how e-scooters can operate. The first version of the bill proposed permitting sidewalk operation.[66] However, this was removed from later versions of the bill over concerns from some groups that the legislation would result in e-scooters traveling 25 miles per hour (mph) on sidewalks (the bill defined e-scooters as devices that could have up to a maximum speed of 25 mph).[67] This statewide approach to regulation, however incorporated clauses for cities to implement their own operation restrictions.[68] At the municipal level within California, cities such as Santa Monica, Los Angeles, and San Francisco have sought to restrict e-scooter share operation to streets and prohibit sidewalk operation as part of temporary pilot programs.[69] Amongst these three California cities, Santa Monica had the most restrictive legislation, confining all forms of e-scooter riding to streets only.[70] On the other hand, some cities implicitly view e-scooters as incompatible with other road users. For example, the City of Denver, Colorado defines e-scooters as "toy vehicles" and mandate they be ridden on sidewalks.[71] Additionally, Denver also prohibits the operation of e-scooter share on bicycle paths.[72] In the City of San Jose, e-scooters are banned from operating on sidewalks, while San Jose State University has completely banned the operation of all e-scooters on campus effective March 2019.[73]

3.1.2 By Maximum Operational Technical Specifications

In the absence of actual operational characteristic data, debates over the regulation of a device often falls upon the maximum capabilities of that device, as was the case in California over A.B. 2989. At the statewide level in California, e-scooters are limited to streets with a posted 25 mph per hour speed limit; with A.B. 2989, this speed was increased to 35 mph.[74] A brief glance at the technical specification documents for e-scooters reveal that they have maximum operating speeds between 15 and 18 mph.[75] Shared e-scooter operators typically limit the top operating speed of their scooters. For example, operators such as Lime and Bird limit the top operating speed to 15 mph.[76] In the City of Los Angeles, unlike the current state-level regulation, e-scooters are capped at a maximum operating speed of 15 mph as part of their pilot program.[77] Moreover, the City of San Jose also utilizes speed restrictions, limiting e-scooters to 12 mph.[78] As it pertains to speed, the State of California and Los Angeles have adopted two different approaches. California's approach regulates the facility e-scooters can operate on by the use of street speed limits, versus Los Angeles's approach of capping the maximum operational speed of e-scooters.

While technical specification documents are informational, basing regulations on them is not necessarily consistent with how other modes of transportation are regulated. For example, automobiles are generally not prohibited in residential neighbourhoods because they can reach speeds more than 100 miles per hour. Rather, cities apply behavioural regulations in the form of speed limits. On the flip side, regulations on electric bicycles, including model regulations recommended by the League of American Bicyclists, which have been adopted in 20 states, regulate devices at least in part on the maximum capabilities of different e-bike models.[79]

3.1.3 By the Numbers: Limiting E-Scooter Units

Another common method for regulating e-scooters has been limiting the number of units and operators available as part of daily operations. For example, the City of San Francisco limited its pilot program to two operators, Skip and Scoot, with 625 scooters each.[80] The City of Santa Monica allowed for more operators (Bird, Lime, Lyft, and Jump [Uber]) with 750 scooters allotted for each of the first two operators and 250 scooters allotted for each for the last two operators.[81] Austin, Texas, has also adopted a similar approach, yet does not restrict the number of operators, only restricting the number of scooters allowed per operator (500 units per operator).[82]

3.1.4 Absolutely Not! Temporary E-Scooter Bans

While some cities have chosen to allow these devices, others have chosen to do the exact opposite by adopting outright bans such as in Milwaukee, West Hollywood, and Beverly Hills, at least on a temporary basis.[83] The one exception is that West Hollywood allows scooters

to travel through their city, yet e-scooters are not permitted to be left in the area.[84] A key characteristic, regardless of the method of regulation, is that whatever measures cities have adopted, they are temporary and form part of a pilot program. The relevance of this finding points towards the flexibility of pilot programs and their ability to allow for experimentation with different methods of regulating e-scooter share.

3.2 E-Scooter Safety Regulation Considerations: Riding Behaviour

While cities have adopted regulation to control how e-scooters operate, there are different characteristics that warrant further investigation. Part of this behaviour directly impacts safety regulation when it comes to the wearing of helmets.

Comparing helmet regulations in different states reveals different rules of enforcement altogether, where riders are either required or not required to wear helmets. For example, legislation in California required e-scooter riders to wear helmets, yet with the latest law, A.B. 2989, the state no longer requires adult riders (18 and over) to wear them.[85] Compared to California, the State of Oregon dictates that helmets must be worn while riding scooters.[86] Additionally, in Portland, Oregon, riders can be fined for not wearing helmets.[87] Helmet laws which are meant to protect riders do have one shared quality in all cities: low compliance. In Santa Monica, rider compliance with helmet laws is low, estimated to be around approximately two percent.[88] This is also the case in Portland.[89] This phenomenon is not new, and is also the case for Seattle, Washington's dockless bike program, with low compliance despite laws mandating helmet use.[90] The relevance of this finding is that whether or not the law regulates the use of helmets while riding e-scooters, compliance is low.

3.3 Operational Characteristics in Similar Modes of Mobility and Planning

Operational characteristics have been discussed in planning for other modes of micro-mobility. A 2004 study commissioned by the Federal Highway Administration (FHWA) measured the operational characteristics of several low-speed devices with the goal of capturing data to inform the design and building of transportation facilities that meet their needs.[91] Devices they studied included human-powered kick scooters, in-line skates, skateboards, human-powered and motorized mobility devices for the disabled, and Segways (often referred to in regulations as electronic personal assistive mobility devices [EPAMDs]).[92] Segway devices that can perform user-controlled stops were cited as having short stopping distances than the rest of the observed devices.[93] Furthermore, the State of California permits the operation of EPAMDs on sidewalks.[94]

If e-scooters have similar operational characteristics to existing-regulated devices, that could point to regulatory approaches that could be applied to scooters. Table 1 identifies speeds of other modes which may be relevant comparisons for e-scooters, as they either serve similar purposes or could potentially share space with e-scooters.

3.4 Measuring the Observational Characteristics of Micro-Mobility Devices

A total of twelve studies were reviewed to identify methods used for measuring the operational characteristics of different modes of micro-mobility. These include video recording equipment, direct site observation, conducting surveys and/or questionnaires, use of on-board Global Position System (GPS) recording equipment, and use of smartphone-based applications.

3.4.1 Video Recording

Regarding the use of video recording equipment, six of the studies focused on video recording observations. Of these five studies, both De Waard et al. (2010) and Landis et al. (2004) focused on bicycles, Miller et al. (2008) focused on Segways, Birriel et al. (2008) focused on in-line skating, and Finnis and Walton

TABLE 1. SPEED OF PEDESTRIANS, CYCLISTS, AND OTHER MICRO-MOBILITY DEVICES

Mode/Device	Average Speed	Range (15th-85th Percentile)	Source
Pedestrians (younger, 13 to 64)	2.8 mph (4.5 kph)	-	Knoblauch, Pietrucha, and Nitzburg, 1996[95]
Pedestrians (older, 65+)	3.4 mph (5.4 kph)	-	Knoblauch, Pietrucha, and Nitzburg, 1996[95]
Bicycles	10.6 mph (17 kph)	7.0 - 13.7 mph (11 to 22 kph)	FHWA, 2004[97]
In-line skates	9.86 mph (15.9 kph)	7.13 -12.59 mph (11.5 - 20.3 kph)	Birriel, Pernia, Lu, and Petritsch, 2001[98]
Kick scooters	7.5 mph (12 kph)	5.6 - 9.3 mph (9 - 15 kph)	FHWA, 2004[99]
Skateboards	9.7 mph (15.6 kph)	8.0 - 11.4 mph (12.9 - 18.3 kph)	Fang and Handy, 2017[100]
Electric bicycles (E-Bikes)	13.6 mph (22 kph)	-	Dill and Rose, 2012[101]
Electric Personal Assistive Mobility Devices (e.g. Segways)	9.3 mph (15 kph)	8.7 - 10.6mph 14 - 17 kph)	FHWA, 2004[102]

(2008) focused on walking. Of note, only Landis et al. (2004) and Lin et al. (2008) measured multiple modes of mobility. Video recording of operational characteristics of e-scooter share has been successfully used to measure comparable modes of micro-mobility that mimic e-scooter share. However, this is not to say that video recording is not without its faults. One of its limitations is the potential for those individuals being observed to alter their behaviour and act differently, as identified by both De Waard et al. (2010) and Finnis and Walton (2008).[103] Out of the six studies using video cameras, only one, Finnis and Walton (2008), prescribed a methodology for trying to reduce the incidence of altered riding behaviour: hide or obscure the camera from participants to make it less noticeable.[104]

3.4.2 Site Observations, GPS, Surveys, and Smart Phone Applications

On the other hand, of the studies that did not use video recording methods for measuring operational characteristics, two used volunteers to record measurements on-site: Fang & Handy (2008), and Knoblauch, Pietrucha, and Nitzburg (1996).[105] The rest of the studies used more obscure methods such as Broach, Dill and Gliebe's (2012) method of mounting GPS units to bicycles, Aultman-Hall and La Mondia's (2005) and Weinert et al.'s (2007) use of either questionnaires or surveys, and Ai et al.'s (2008) use of a cell phone-based application.[106] Of these studies, the majority focused on either walking or bicycling, while Fang and Handy (2008), and Ai et al. (2018) focused on making comparisons between at least two modes of mobility.[107] In sum, these findings point to the potential use of video recording of multiple modes of mobility, and potentially e-scooter share. However, unlike video recording, Fang and Handy's (2008) and Knoblauch, Pietrucha and Nitzburg's (1996) method does not have to deal with the issue of altered subject behaviour due to the subjects not being aware that they are being observed. The other three studies all relied on volunteer participation prior to the start of observational measurements, thus they are still subject to participants altering their actual or reported behaviour.

Regarding the more obscure methods of recording observations, since this research effort focuses on a newer mode of mobility, the use of GPS units is questionable as it would require an agreement with e-scooter-share operators to request this information and could lead to potential lengthy conversations limiting the time window for data collection. As it pertains to questionnaires and surveys, this method would require volunteers, but that could also lead to bias due to the tendency for self-reported data to be inaccurate. Moreover, there is a potential for lower response rates due to the fact that e-scooters are relatively new, and rider ownership rates might be lower than that of bicycle owners, as noted in Weinert et al.'s (2007) study.[108] Additionally, Aultman-Hall and LaMondia (2005) noted that there is a potential for bias due to the over-representation of one particular group due to conducting on-site surveys and questionnaires at specific locations.[109] While Ai et al.'s (2008) method of using phone-based applications could overcome the problem of human error associated with self-reporting observations, it faces the same limitation regarding ownership – bicycle users can own their vehicles unlike the riders of e-scooter share.[110]

3.5 Operational Characteristics for Measurement: Speed

Concerning speed, ten of the twelve studies reviewed looked at measuring speed.[111] Of the studies that looked at speed, only four of them looked at measurements applicable within the United States, including Fang and Handy (2008), Landis et al. (2004), Birriel et al. (2001), and Miller et al. (2008).[112] While each study measured speed, they utilized different methods. Where Fang and Handy (2008) used a stopwatch and a predefined distance over different transportation facilities, the other three studies used video recording equipment to later record riders traveling over a specified distance and tabulate the speed result. Unlike Fang and Handy's (2008) study, the other three studies used obstacle courses or marked locations (visible to participants) designed ahead of time, versus the former's method of picking a particularly busy spot and recording observations. Other considerations such as Miller et al.'s (2008) study noted that the length or distance of an observation zone has an impact regarding the measurement of speed. Additionally, Miller et al. (2008) noted that their study was hindered by the Internal Review Board's speed safety regulations, effectively limiting the potential to measure the true maximum operational speed of a Segway device.[113]

This research effort also seeks to answer how these characteristics are relevant to the field of urban planning. Of the studies mentioned in this section, several of them justified the need to measure speed in order to improve the planning and design of transportation facilities. For example, Birriel et al. (2001) noted that these characteristics could be used to derive better design guidelines for mixed-use paths if one knows just how quickly one travels.[114] Moreover, Landis et al. (2008) noted the need to design for "emerging" modes in order to safely accommodate all users and not just bicycles.[115] Miller et al. (2008) also noted that characteristics such as speed can facilitate a rational discussion regarding the integration of Segway devices in terms of "regulation, planning, and designing" on mixed-use paths and streets with other modes of mobility.[116] Additionally, Fang and Handy (2008) made a point about the compatibility of bicycles and skateboards by comparing their speeds, and postulating that in instances in which the measurements are similar, it may not make sense to regulate these modes differently.[117]

3.6 Data Analysis Reduction: Age, Gender, and Travel Behaviours (Conflicts)

Another critical component of the literature revealed further criteria used to link findings from observations in order to establish trends or patterns. This method was often referred to throughout the literature as analysis reduction. When it comes to developing criteria for analysis reduction, this research effort looked at previous studies and found several common metrics such as age, gender, rider experience, and travel behaviours (such as conflicts with other users, and rider distractions). Of the twelve studies reviewed, only six of them covered the metrics mentioned above, including Miller et al. (2008), Fang and Handy (2017), De Waard et al. (2010), Birriel et al. (2001), Lin et al. (2008), Knoblauch, Pietrucha, and Nitzburg (1996), and Finnis and Walton (2008). Lin et al. (2008) noted that age is important to measure because it impacts speed based on a rider's physical attributes such as strength, and the rider's mental state such as the ability to make risky decisions.[118] Most importantly, the authors of these papers used analysis reduction metrics to determine any correlations among operational characteristics such as speed.

Miller et al. (2008) chose to use Segway riders' level of experience to categorize their findings for speed measurement.[119] Miller et al. (2008) found experienced riders traveled at an average speed that was faster than non-experienced riders.[120] Note that this study was able to segregate riders by experience level through a pre-screening questionnaire.[121] While Birriel et al. (2001) also used rider experience (related to in-line skaters), they used site observations and gender to gauge this metric.[122] Birriel et al. (2001) found women traveled at lower speeds than men.[123]

Unlike the previous two studies, in addition to recording gender, Fang and Handy (2017) used distraction conflicts to make comparisons among skateboarders and bicycle riders.[124] Fang and Handy (2017) focused on observing skateboarder "traffic conflicts" with other users by recording whether they rode in a straight line or evaded the conflict by swerving out of the way.[125] Additionally, Fang and Handy (2017) recorded "distraction conflicts" about multi-tasking such as eating and cell phone use.[126] While Fang and Handy (2017) found that men traveled faster than women on bicycles when compared to skateboards, no findings among gender were made for skateboarders due to the over-representation of males (97 out of 100) among observed skateboarders.[127] Concerning distraction conflicts, few were found among skateboarders.[128]

De Waard et al. (2010) also looked at distraction conflicts but focused on bicycle riders' age, gender, and the number of hands on bicycle handlebars.[129] In this study, the authors cited secondary tasks as distraction conflicts such as cell phone use, listening to music, and chatting with another bike rider.[130] Concerning age categories, the authors used four classifications: less than 15, 15 to 30, 30 to 50, and 50 plus.[131] De Waard et al. (2010) found a tiny percentage of riders were distracted while riding, similar to Fang and Handy's (2017) study.[132] However, De Waard et al. (2010) did establish a link between gender and handlebar use, where more women than men were founding riding with one hand on their bicycles.[133]

Knoblauch, Pietrucha and Nitzburg (1996), Finnis and Walton (2008), and Lin et al. (2008) also measured apparent gender and age as did De Waard et al. (2008), but not all authors used the same levels of age classifications. Knoblauch, Pietrucha and Nitzburg (1996) focused strictly on pedestrian walking speeds for people 64 years and younger or 65 and older. Their study showed adolescent males walked faster than older females, and people who traveled in groups walked slower than those walking by themselves.[134] Finnis and Walton (2008) also measured pedestrian walking speeds but followed the exact age classifications as De Waard et al. (2010).[135] Finnis and Walton shared similar results to Knoblauch, Pietrucha, and Nitzburg's (1996) study where men walked faster than women while older individuals walked slower than younger individuals.[136] Note, Finnis and Walton (2008) did not measure group travel among pedestrians.[137] Lin et al. (2008) used three age categories for observations, less than 25, 25 to 50, and 50 plus.[138] Lin et al. also found similar results to Finnis and Walton's (2008), and Knoblauch, Pietruch and Nitzburg's (1996) studies, that bicycles riders also exhibit similar traits: males travel faster than females, and youths travel faster than older adults.[139]

3.7 Why the Scoot Should Cities Care

In summary, this literature review answered several questions of the e-scooter share debate concerning regulation, the role of operational characteristics in planning in similar modes of micro-mobility, measurement methodologies for operational characteristics and riding behaviours, and analysis reduction metrics. These findings would serve as a basis for developing a testing methodology as discussed in Chapter 4.
There is an apparent disagreement among local governments over where these devices should operate, pointing to compatibility issues between e-scooter share riders, pedestrians, and other similar modes of mobility sharing the same space. Different cities across the United States have regulated e-scooter share to segregate e-scooter riders to either streets or a mix of both streets and mixed-use paths. Sidewalk operation appears to be the most contentious issue as seen in Santa Monica, Los Angeles, and San Francisco, CA; however, there was an exception: Denver, CO. In Denver, e-scooters can only operate on sidewalks. On the other hand, governments have also tried to regulate these devices by using speed, limiting the number of operators and units, or by outright banning e-scooters, at least on a temporary basis.[140] While governments disagree on where and how to regulate, they also disagree on safety regulation of e-scooter share as it pertains to the wearing of helmets. State governments in Washington and Oregon require scooter riders to use helmets.[141] California back-pedaled and removed this requirement for adult riders.[142]

With so much disagreement, what alternatives exist to guide the development of the design and regulation of transportation facilities accommodating e-scooter share? The literature review revealed that the City of Los Angeles uses speed, an operational characteristic, to regulate e-scooter share. Furthermore, the most common methods to measure operational characteristics are using a camera to film riders or by manually observing and recording riders. While both methods have their drawbacks, this research effort followed Fang and Handy's (2008) and Knoblauch, Petri and Nietzburg's (1996) method of using on-site recording to measure operational characteristics rather than using a camera. Using site observations instead of video recording methods reduces the possibility of individuals altering their riding behaviour, helps avoid potentially lengthy discussion regarding privacy, and dealing with low response rates or inaccuracies associated with self-recording.[143]

The literature also revealed the relevance of measuring operational characteristics. In California, the fear over scooters traveling at 25 mph led the government to remove sidewalk operation from the bill.[144] This perception highlights an issue that is central to this project: how can one know whether this fear is founded in truth in the absence of data collection? Additionally, operational characteristics such as speed could be used to derive better design guidelines for different transportation facilities if one knows how quickly the average user travels.[145]

While measuring the operational characteristics of different modes of mobility is important, how is it possible to make it relatable to people? The studies summarized in this chapter revealed that analysis reduction metrics such as age, gender, and travel behaviours (e.g. concurrent cell phone use, travel conflicts) can be used to make associations with operational characteristics. Linked together, both operational characteristics and analysis reduction metrics can aid in establishing trends or patterns that help to develop an understanding for these relationships. Additionally, these metrics help fill a void in the literature pertaining to riding behaviour characteristics which will facilitate a discussion around the rational planning and regulation of transportation facilities, including e-scooter share.

Chapter 4 will build upon the findings from the literature in order to establish a testing methodology for measuring the operational characteristics and rider behaviour of e-scooter share.

Chapter 4

Methods

E-scooter riders were observed in downtown San Jose, California. Observations were based on speed and other safety-related rider behaviours. Three types of facilities were analyzed: streets, sidewalks, and mixed-use paths closed to vehicular traffic. E-scooters were observed on streets and sidewalks on Santa Clara Street from Almaden Avenue to San Pedro St. Additional observations were carried out on a pedestrian and bicyclist mixed-use paths section of Seventh Street through the San Jose State University campus, adjacent to the Student Union building.

Locations were chosen based on previous pilot observations conducted over the summer of 2018 to determine locations that exhibit a high number of e-scooter riders. Observations were conducted from October 2018 to February 2019. The methods used for measuring operational characteristics are derived from previous studies conducted on similar modes of mobility referenced in Chapter 3.

4.1 Speed

Regarding speed, observations focused on measuring the "space-mean speed", defined as "the average speed of vehicles traveling on a given segment of roadway during a specified period and is calculated using the average travel time and length for the roadway segment" by the Federal Highway Administration's (FHWA) Travel Time Data Collection Handbook.[146] To calculate speed, the elapsed time it took for an e-scooter rider to travel between two checkpoints over a defined distance was measured. Similar methods were used by FHWA (2004), Birriel, Pernia, Lu, and Petritsch (2001), and Fang and Handy (2017), to measure speed of multiple mixed-use trail users, in-line skaters, and skateboarders, respectively.[147]

Collecting speed observational data helps answer just how quickly e-scooter riders are traveling along all sidewalks, streets, and mixed-use paths. In order to establish a comparison against similar modes of micro-mobility, bicycle riders were observed on the street facility only. Speed results were used to identify any trends observed on different facilities and form the basis for a comparison against similar modes of micro-mobility.

FIGURE 13. SIDEWALK AND STREET OBSERVATION ZONE LENGTHS ALONG SANTA CLARA ST. IN SAN JOSE, CA. PHOTOS BY THE AUTHOR.

Time was also measured to determine how long it took a rider to cross the observation zone in real time using a smartphone (iPhone X) stopwatch application. Checkpoints in the various observation locations included existing, easily identifiable objects present in the streetscape including light poles, sign poles, trees, other street furniture, and pavement markings. Since pre-existing street furniture and markings were used in the various speed observation zones, the length of the speed observation zones varied between approximately 121 and 125 feet (36.9 – 38.1 m) in length (see Figures 13 and 14). In addition to the travel time, the date, facility type, temperature, recorded time, e-scooter operator (Lime or Bird), rider's apparent gender, apparent age, style of travel, helmet use, number of riders, conflicts, and distractions were also recorded. All observations were recorded on paper and later transferred to Excel.

In total, 330 e-scooter riders were observed for speed, including 110 on the street segment, 110 on the sidewalk segment, and 110 on the mixed-use path segment. Moreover, 110 bicycle riders were observed on the street facility only.

Concerning the analysis of speed results, several inferential statistical tests were used to determine the significance of the speed results. An Excel two-sample t-test assuming equal variances was used to determine the statistical significance when comparing street vs. sidewalk speeds, street vs. mixed-use path speeds, sidewalk vs. mixed-use path speeds, apparent gender speeds, operator speeds, and mode speeds (e-scooter versus vs. bicycle). An Excel single factor ANOVA test was used to compare e-scooter speeds among all three transportation facilities (streets, sidewalks, and mixed-use paths), apparent gender speeds (both male and female) across all three transportation facilities, and age categories and speed. Simple linear regression analysis in SPSS was used to examine the relationship between temperatures and speed.

4.2 Riding Behaviours

In addition to the speed, rider behaviours were recorded that may potentially influence safety. Behavioural observations took place in the same locations as speed, including street segments, sidewalk segments, and mixed-use path segments.

4.2.1 Helmet Use

Helmet use is a key safety indicator of rider behaviour that this report examined among e-scooter riders, expressed as a percentage, with the number of helmet users observed divided by the total number of observations.

This is particularly interesting in the study in San Jose, as riders not wearing helmets under the age of 18 are in violation of the current California Vehicle Code.[148] Removing that requirement for bicycle helmets for adults is under consideration in the latest draft of the state A.B. 2989 legislation. Helmet use findings may have implications that will play a role in the determination of future e-scooter regulation. Note that while this helmet requirement was removed with the passing of A.B. 2989, it is still illegal for those under the age of 18 to travel without a helmet. Additionally, there are growing concerns over e-scooter injuries as a result of riders not wearing helmets.[149]

4.2.2 Travel Style: Straight Forward or Side to Side

Additionally, travel style was observed, specifically whether e-scooter riders travel in a straight line or if they traveled in an irregular, less predictable "carving" motion, traveling in a S-shaped style motion from side to side.[150] Travel style findings may have implications that will play a role in the determination of future e-scooter regulation as carving proves to be a contentious issue over the regulation of similar modes of micro-mobility.[151] Each riding style was expressed as straight forward and side to side, and the results were calculated as a percentage, with the number of observed riders divided by the total number of observations.

4.2.3 Group Riding/Multiple Riders

E-scooter riders that traveled solo or in

Figure 14. Observation zone length along the mixed-use path at San Jose State University. Photos by the author.

groups were also observed. The groups were categorized as riders traveling solo where was is evident that there were no other e-scooter riders around them. Group riding was classified as those who travel in groups of two or more individuals traveling in apparent "packs" together. To differentiate a pack from two independent riders who happen to be riding alongside each other, evidence of users interacting with each other during travel was used to make that distinction.

Additionally, instances of different types of group riding were recorded; namely, two individuals sharing the same e-scooter. Pilot observations carried out in summer of 2018 revealed that riders traveled in groups or with multiple riders on one e-scooter. The potential implication of these observations may play a role in the development of e-scooter regulation operation, infrastructure design, and e-scooter design itself.

Group and multiple riders' results were expressed as a percentage, with the number of observed riders divided by the total number of observations.

4.2.4 Traffic Conflicts

Similar to Fang and Handy's (2017) study of skateboarders, traffic conflicts were also observed.[152] Traffic conflicts are defined as situations where riders encounter obstacles such as pedestrians or other vehicles and cause them to react by either party having to slow down or swerve out of the way.[153] Additionally, the type of conflict was also recorded, such as a pedestrian, another e-scooter, a cyclist, a parked car, or moving vehicular traffic. Traffic conflict findings may have implications that will play a role in the determination of future e-scooter regulation as it pertains to the interaction between e-scooters and other users on streets, sidewalks, and mixed-use paths.

Traffic conflicts were expressed as a percentage, with the number of observed riders divided by the total number of observations.

4.2.5 Rider Distractions

There are several activities other than operating a scooter that a rider could engage in that could potentially distract a rider, such as the use of headphones or smartphones.

E-scooter riders were observed for several types of multi-tasking including the use of smartphones and the wearing of headphones. Distractions warrant further investigation as the wearing of headphones is not prohibited for e-scooter riders, but bicyclists can only have a headphone in one ear.[154] Additionally, collecting this information allows for comparisons against other modes of micro-mobility. De Waard, et al. (2010) found approximately 2.2 percent of bicyclists talking on their cell phones.[155] Fang and Handy (2017) found that 3 percent of skateboarders were making phone calls while riding.[156] Potential distraction findings may have implications that will play a role in the determination of future e-scooter regulation.

Each rider distraction was expressed as a percentage, with the number of observed riders divided by the total number of observations.

4.3 Environmental Considerations: Wet, Dry Weather, and Temperature

As it pertains to weather considerations, riders were observed in a mix of both wet and dry weather conditions. Moreover, temperature was also recorded, which ranged between 39- and 78-degrees Fahrenheit (4 to 26 degrees Celsius).

4.4 Analysis Reduction Metrics: Age, Apparent Gender

Riders of different ages were observed and categorized into three groups: those younger than 25, those 25 to 50, and those over 50 years of age. Concerning apparent gender, riders were classified as either male or female. The identification of age groups and apparent gender was determined through observations by the observer.

4.5 Methodology Summary

In summary, this chapter established a testing methodology in order to measure the operational characteristics and riding behaviour of e-scooter share riders in San Jose on three types of facilities: sidewalks, mixed-use paths, and streets. The chosen method involved using on-site observations inspired by the literature review in Chapter 3.

Speed or the "space mean speed" was calculated by measuring the time it took to cross one of these facilities over a predefined length in feet.[157] At the same time, riding behaviour along with traffic conflict observations were observed in the same locations as speed measurements. Additional measurements such as apparent age, gender, and temperature were included in order to better understand any trends or patterns.

Chapter 5 will review the findings of these observations along with any potential trends or patterns linked to reduction metrics or environmental considerations.

Chapter 5
Not so Fast nor Distracted

This chapter explores the results from observing 330 e-scooter riders along three transportation facilities (streets, sidewalks, and mixed-use paths). Speed results cover several topics, including transportation facilities, ranges, gender, operator, age, scooters versus bicyclists, and temperature. Rider behaviour results cover helmet use, group riding versus multiple riders, distractions (cell phones and headphones), traffic conflicts, and riding styles (straight forward or side to side), and rider collisions. An additional 110 bicycle riders were observed on the street only in order to compare speed, gender, and helmet use.

5.1 Riders Travel Faster on Streets, Slower on Sidewalks, Between 9.0-11.1 mph

Rider speed varied on the three types of transportation facilities studied, with many of the differences resulting in statistically significant results. Riders traveled on average 11.1 mph (17.9 kph) on streets, 8.9 mph (14.5 kph) on sidewalks, and 9.6 mph (15.5 kph) on mixed-use paths (see Figure 15). In other words, riders traveled faster on streets and slower on sidewalks and mixed-use paths. Importantly, riders slowed down when traveling on facilities mixed with pedestrian traffic. Furthermore, comparing the two pedestrian facilities, riders traveled faster on the wider mixed-use path versus the narrower sidewalks.

5.2 Wide Range of Rider Speed Between 4 and 16 mph

As it pertains to the distribution of speeds among all 330 riders observed, there was wide variation (see Figure 16). The lowest measured travel speed was 4.0 mph (6.4 kph), similar to that of a pedestrian walking. The highest measured speed was 16.1 mph (25.9 kph).

This high speed is somewhat perplexing, as this is above the speed by which e-scooter share operators claim to limit their e-scooters. Overall, seven scooters (2 percent) exceeded the 15-mph speed limitation, while 50 scooters (15.2 percent) exceeded San Jose's current ordinance-imposed limit of 12 mph.[158] E-Scooters exceeding 12-15 mph could be due to

Figure 15. Speed results across all three transportation facilities (ANOVA p<0.01). Photography by the author.

a number of reasons. There could be an error in measurement technique, as it pertains to speed, due to either time calculations or measurement of distance between observation zone checkpoints. However, measurements would have had to be off by several seconds or tens of feet to make a difference, which is unlikely given the distances and lengths of time of individual observations. Alternatively, there could be a margin of error in how the devices limit speed. Also, it could be that devices limit speed by restricting motor power to a certain level that theoretically produces a certain speed rather than capping the top maximum speed. Additionally, it is a possibility that the target maximum speed could be exceeded in certain environmental conditions, such as a downslope in the direction of travel or a strong tailwind pushing the rider. Additionally, concerning San Jose's e-scooter speed ordinance, while approved by council in December of 2018, it was not enacted until after February of 2019, after site observations were completed.[159]

In general, most riders are traveling well below the maximum mechanical speeds of e-scooters. Among all 330 riders observed, regardless of location, the average speed was 9.9 mph (16.0 kph). Sixty-seven percent of riders were below 11.0 mph (17.7 kph).

5.3 Males Ride Faster, Vary Speed Less by Facility

As it pertains to apparent gender, there was a significant difference in terms of the mean speed between males and females ($p < 0.01$). Female riders traveled at a lower average speed than males, 9.3 mph (15.0 kph) for females, and 10.1 mph (16.3 kph) for males (see Table 2). When comparing the speeds of apparent genders to similar modes of micro-mobility, similar results were observed among in-line skaters and bicyclists. Birriel et. al (2001), found that male in-line skaters were faster than females, while Fang and Handy (2017) found that male cyclists rode faster than females.[160]

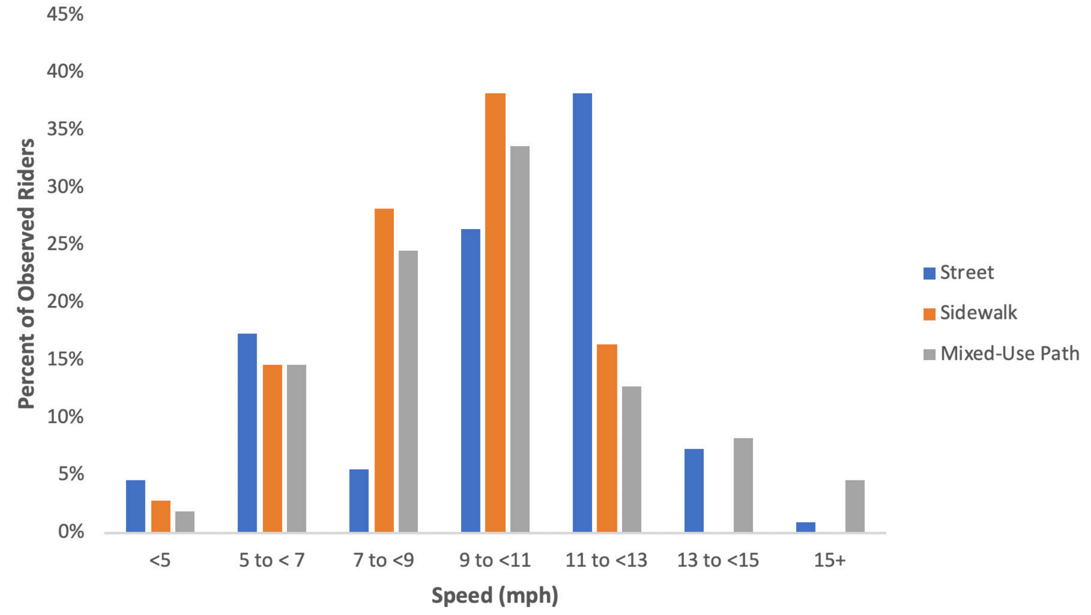

Figure 16. Distribution of e-scooter rider speeds on different types of transportation facilities.

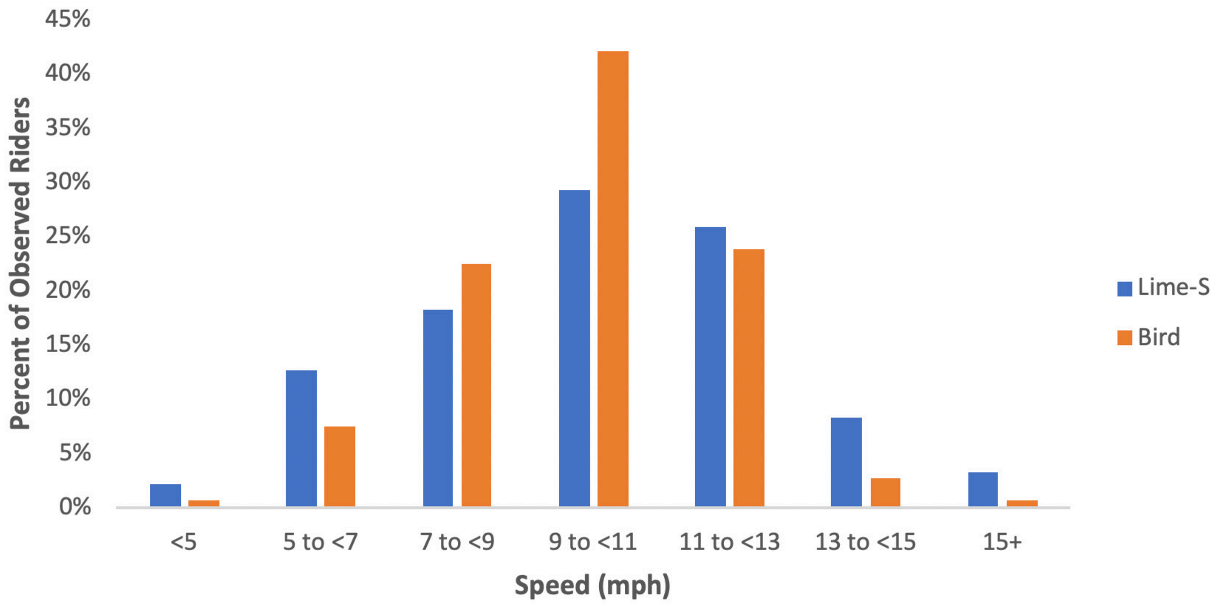

Figure 17. Distribution of E-scooter speeds by operator.

Furthermore, this study found variances when comparing gender and type of transportation facility (see Table 2). For both genders, riders were faster on streets than on mixed-use paths and sidewalks. However, the variance of the speed difference by facility was more pronounced among female riders. When compared to males, it appears that female riders slowed down more in the presence of pedestrian traffic. Additionally, female riders tended to travel faster on streets than male riders. Interestingly, female riders were 29 percent slower when traveling from streets to sidewalks, while male riders were just 23 percent slower (see Table 2). Ultimately, this finding is interesting because it appears that female riders tend be much more courteous riders than male riders (by slowing down more than men) when riding on facilities where pedestrians are present. Of note, San Jose's male versus female population is evenly split with 50 percent of the population identifying as male, and 49.7 percent of the population identifying as female.[161]

5.4 No Difference by E-Scooter Share Operator

No observed differences in speed were observed between Lime and Bird e-scooters. No e-scooters from recent entrants Skip or Wind were seen during the observation period. Riders that used Bird traveled at similar average speeds to those that used Lime e-scooters, 10.0 mph (17.9 kph) versus 9.9 mph (17.2 kph) respectively, but the slight difference was not significant (p=0.68). Interestingly, when looking at the speed distribution between Bird and Lime, visually there is less variance among Bird riders such that a higher proportion of observations are concentrated between 7 to 13 mph (see Figure 17). Lime riders show a greater variance in terms of speed amongst the entire distribution of measured observations. Of note, Lime scooters feature electronic speedometers, while Bird scooters do not.

Furthermore, Bird and Lime use different scooter models. Bird uses Xiaomi-Mi e-scooters which weigh approximately 26.9 (12.2 kg) pounds and feature

Table 2. Differences in speed by facility and gender

Speeds By Location (mph)	Female (n=79)	Male (n=251)
Sidewalk	8.0	9.3
Mixed-use path	9.1	9.9
Street	11.3	11.1
Overall	9.3	10.1
Percent increase in speed from...	**Female**	**Male**
Sidewalk to mixed-use path	14%	6%
Mixed-use path to street	24%	12%
Sidewalk to street	41%	20%
Percent decrease in speed from...	**Female**	**Male**
Street to mixed-use path	17%	11%
Street to Sidewalk	29%	23%

Comparison:
t-test (female vs. male, overall): p =<0.01.

a motor power of 250 watts.[162] Lime currently uses the latest version of scooter from Segway-Ninebot weighing approximately 28 pounds (12.5 kg) with a motor rated power of 300 watts.[163]

5.5 Older Riders Travel Faster Than Their Younger Counterparts

As noted in Chapter 3, age is an important characteristic to consider as it can impact a person's travel speed based on their physical ability.[164] Observed e-scooter riders were categorized into three age groups: adolescent riders younger than 25 (n=106), adults between the ages 25 to 50 (n=192), and older adults over 50 years of age (n=32). The results (see Figure 18) show a statistically significant finding (p<0.01) in terms of speed and age, where each group traveled at a different average speed. Younger (adolescent) riders traveled at an average speed of 9.4 mph (10.1 kph), those adults between the ages of 25 to 50 traveled at 10.6 mph (17.1 kph), and older adults over the age of 50 traveled at 10.4 mph (16.7 kph). Based on these observations, the results point to an interesting finding: that adults and older riders traveled slightly faster than adolescents. Of note, San Jose's population skews towards the second age bracket of adults with a median age of 35.4 and with the majority of the population falling between the ages of 18 to 64 (65 percent).[165]

Comparing e-scooter speeds based on age to that of similar modes of mobility, studies revealed an opposite trend. For example, compared to bicyclists, Lin et al. (2008) found that adolescents rode faster than adult bicyclists.[166]

5.6 E-Scooter Riders Travel Slower than Cyclists

Previous studies mentioned in Chapter 2 that have measured speed in similar modes of micro-mobility have also measured other modes in order to establish comparisons between the two such as Fang and Handy (2017), and Lin et al. (2008).[167] In this study, when comparing e-scooter speeds to bicycle speeds, the results show a

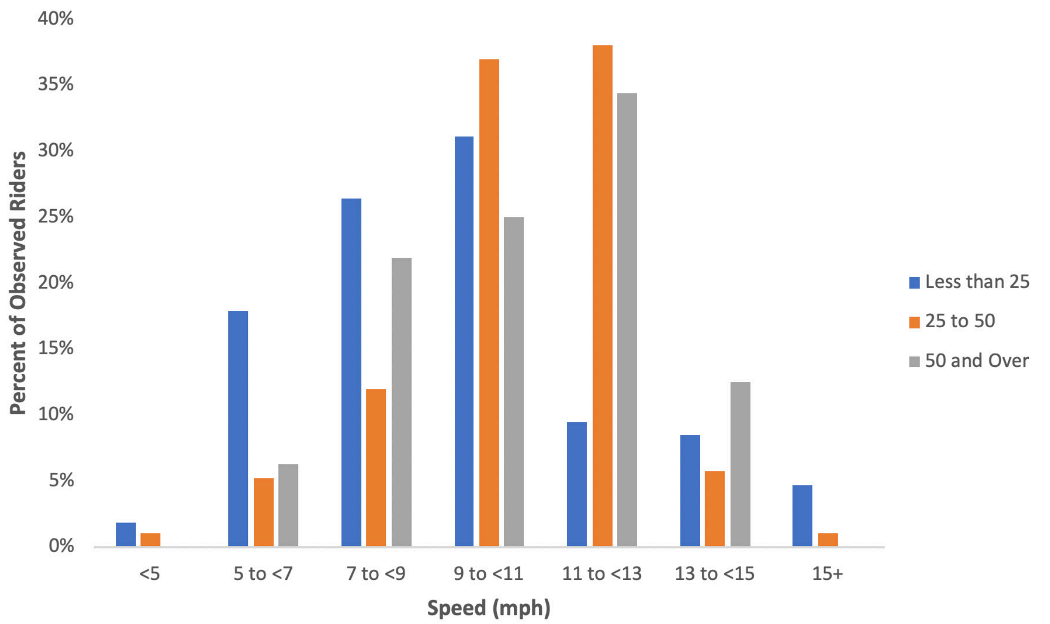

Figure 18. Distribution of e-scooter rider speeds by age in years (less than 25, 25 to 50, and 50 and over).

Figure 19. Speed results for e-scooters and cyclists (p<0.01). Photography by the author.

statistically significant finding ($p<0.01$), where e-scooter riders traveled on average about 11.1 mph (17.9 kph), versus cyclists who traveled at 12.2 mph (19.6 kph). In other words, e-scooter riders traveled slower than cyclists. Approximately half of all observed cyclists traveled at an average speed ranging between 9 to 13 mph (14.4 to 20.9 kph). Of note, cyclists (n=110) were only observed riding on streets for this comparison. Similarly, Fang and Handy (2017) found that skateboarders just like e-scooters traveled at slower speeds when compared to cyclists (on average 9.7 mph compared to 11.6 mph).[168]

5.7 Temperature Versus Speed

As it pertained to e-scooter riders and the ambient temperature, some variances were observed in terms of speed due to changes in temperature. After running a simple linear regression in SPSS to determine the impact that temperature had on speed, the results showed a statistically significant finding (see Figure 20). The results indicated that as temperature increased, e-scooter speeds decreased ($p=0.04$). While this result is statistically significant, the R^2 value was small, indicating there were other factors that could have contributed to the variance in speed that were not measured as part of this study.

5.8 More Cyclists Wear Helmets than E-Scooter Riders

Sidestepping the issue of whether wearing a bicycle helmet should be regulated, it is no longer California State law that e-scooter riders are required to wear them, except for those under the age of 18.[169] E-scooter share mobile applications inform users of this fact during the sign-up process. Acknowledging this is a requirement based on age, very few incidents were observed. Only seven incidents, or two percent, out of a total 330 observations were observed where scooter riders wore helmets (see Figure 21). Notably, six of these observations

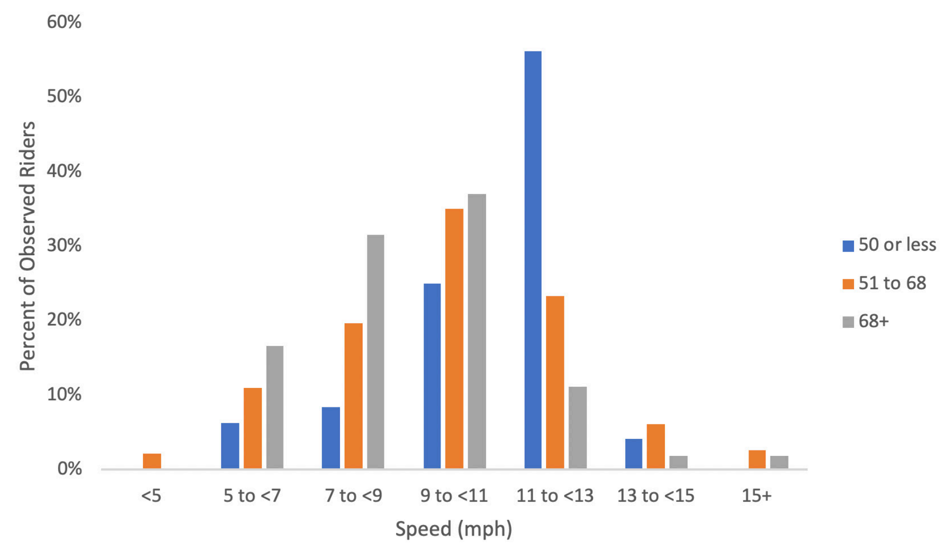

Figure 20. Distribution of e-scooter rider speeds ordered by temperature ranges.

Figure 21. Percentage of e-scooter riders and cyclists that wear helmets. Photography by the author.

occurred on the street, while only one occurred on the sidewalk. This low compliance value is similar to that of Trivedi et al.'s (2019) study on e-scooter safety in Los Angeles where only 5.6 percent of observed riders observed wore helmets.[170]

Additionally, none of the helmet wearing scooter riders were part of the younger population (less than 25 years of age), indicating the possibility that some riders may be in contravention of California State law. Comparatively, observing cyclists (n=110), more than half of all observed cyclists wore helmets, approximately 56 percent (see Figure 21). Moreover, out of the 60 observations where cyclists were found to be wearing helmets, 72 percent (n=43) fell into the younger adult population (25 years to 50), while 28 percent (n=17) were older adults over the age of 50. Of note, cyclists that wore helmets were observed using their own personal bicycle instead of a bike sharing services such as San Jose's Ford Go Bike.[171]

5.9 A Noticeable Amount of Group Riding

E-scooters are sometimes described as a type of "personal transportation device", providing mobility for individual travelers. Thus, it is not surprising that a majority of riders observed were traveling solo, approximately 83 percent (n=273). However, there was a noticeable number of riders traveling in packs. Out of the 330 observations made, approximately 16 percent of riders were found traveling in groups, with 11.5 percent in groups of two, 4.5 percent traveling in groups of three, and one apparent pack of five riders (see Figure 22).

Eleven incidents (3 percent) in which two riders would share one e-scooter were observed. The operator of the e-scooter would stand in the front grabbing onto the handle bars while the second individual would stand behind the operator either holding onto their shoulders or waist (see Figure 23). Comparing San Jose to Los Angeles, 7.3 percent of e-scooter riders in Los Angeles were found to be sharing an e-scooter.[172]

5.10 Minimal Rider Distraction: Some Wear Headphones, Very Few Use Cell phones

Travelers being distracted, particularly by cell phones, is often cited as a problem for many modes of transportation.

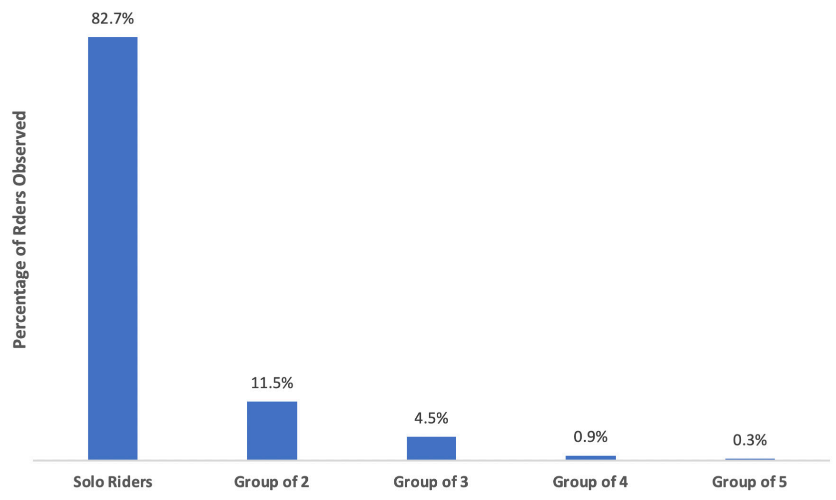

Figure 22. Percentage of e-scooter riders traveling solo or in groups.

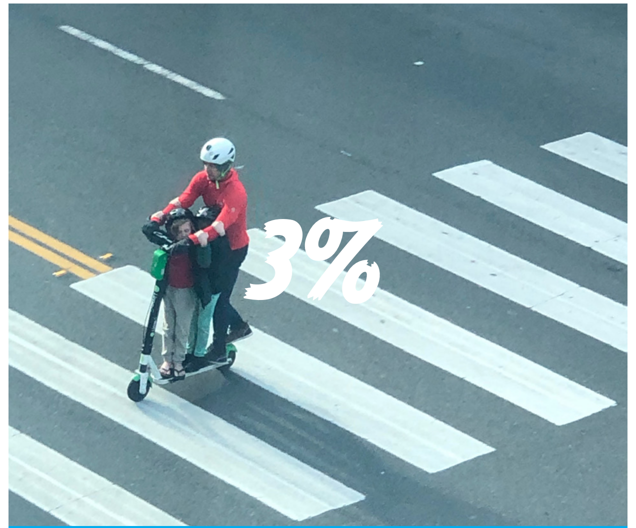

Figure 23. Percentage of multiple riders sharing one e-scooter. Photography by the author.

Interestingly, only one rider was observed holding a cell phone while riding an e-scooter (see Figure 24). Even then, it was observed that the rider still slowed down significantly in order to adjust their balance and place their body forward on the handle bars. This finding is similar to that of bicyclists observed using cell phones by De Waard et al. (2010) where riders were also showing significant decreases in speed.[173]

For comparison, De Waard, et al. (2010) found approximately 2.2 percent of bicyclists talking on their cell phones.[174] Fang and Handy (2017) found that 12 percent of skateboarders were holding cell phones riding.[175] Essentially, e-scooter riders are less distracted by cell phones when compared to these other modes. This could be attributed to the fact that an e-scooter requires a user to balance the scooter while having both hands on the handlebars. Additionally, this observation does not take into consideration whether a rider may have potentially used a cell phone at an intersection while at a crosswalk or at a red light.

Additionally, 53 incidents (16 percent) were observed where riders were wearing headphones (see Figure 25). Depending on what those headphones are connected to, they could be listening to music off a smartphone or making a phone call. In the study area, it would be illegal for a bicyclist to wear headphones in both ears according to state law.[176] Comparing e-scooters riders to bicyclists, Wolfe et al.'s study found approximately 17.7 percent of bicyclists were using headphones while riding, higher than the 7.7 percent of bicyclists observed by De Waard et al. (2010).[177]

5.11 Traffic Conflicts: Slowing Down vs. Swerving Out of the Way

Concerning traffic conflicts, e-scooter riders were observed concerning their interactions with other users in the public right of way. These interactions included evasive actions that e-scooter riders took to avoid conflicts with pedestrians, cyclists, other e-scooter riders, and motor vehicles by either slowing down or swerving out of the way. Out of 330 observations, there were 134 traffic conflicts; 71 percent of all observed (n=95) slowed down for conflicts, while 29 percent of all riders (n=39) swerved out of the way. Of note, of the 95 incidents where e-scooter riders slowed down when encountering a conflict, 70 percent (n=66) were incidents that occurred on facilities with pedestrian mixed traffic such as the sidewalk or

Figure 24. Percentage of e-scooter riders using cell phones. Photography by the author.

Figure 25. Percentage of riders using headphones. Photography by the author.

mixed-use path. Note, this is a positive result. E-scooter riders are yielding to pedestrians, and pedestrians are not necessarily jumping out of the way to avoid a potential collision. Moreover, of the 95 incidents where e-scooter riders slowed down for conflicts on streets (n=29), one quarter of the slowdowns were attributed to a mix of either parked cars or vehicular traffic that restricted the space which an e-scooter could travel through.

Of the 39 incidents where riders swerved out of the way to avoid a conflict, 31 of them (80 percent) occurred either on the sidewalk or on the mixed-use path, with the rest occurring on the street. Where riders encountered conflicts on the street, the majority of the incidents involved motor vehicles changing lanes or parking.

Interestingly, very few conflicts were observed with cyclists or other e-scooter riders. In total, only one incident for each of these cases was observed. In the case of the e-scooter rider conflict, on the sidewalk, both riders were observed slowing down to negotiate their path of travel. In the case of the bicycle conflict, on the street, the e-scooter rider slowed down to yield to the cyclist.

5.12 Most E-Scooter Riders Travel in a Straight Line

As noted by Fang and Handy's (2017) study on skateboarders, sometimes riders were observed engaging in what could be construed as dangerous riding behaviour (performing tricks) by moving in a less predictable side to side "S-shaped" motion.[178] This type of riding behaviour is sometimes used as an argument for banning skateboards from a particularly facility as it might pose a problem to those around them due erratic changes in travel direction.[179] Similarly, this study looked at whether e-scooter riders engaged in similar riding behaviour that could also be interpreted as a potential dangerous riding activity. Approximately 97 percent of riders (n= 318) predictably travel forward in a straight line, while 3 percent of riders (n=12) rode in a less predictable pattern from side to side. Interestingly, while very few riders were observed engaging in this more casual side to side riding, incidents occurred on the mixed-use path (n=9), and most riders were under 25 years of age (n=8). Ultimately, while a few riders were observed engaging in what could be considered dangerous riding behaviour, the majority did not. This result is comparable to that of skateboarders, where the majority rode in a straight line instead of riding in a side to side motion.[180]

5.13 Some Riders Fall While Others Collide

According to Trivedi et al.'s study on e-scooter injuries, the most common types include falls and collisions with moving objects or vehicles.[181] In this study, only one incident was observed where an e-scooter rider collided with the sidewalk curb and fell onto the ground while crossing an intersection; however, they quickly recovered and kept on riding. The other two incidents were observed on the street where riders were trying to negotiate the narrow travel path segment created by parked cars and moving vehicular traffic. In both cases, the riders collided with parked vehicles' side view mirrors sticking out in the e-scooters travel path. In both cases, the riders clipped their shoulder area, but proceeded to ride. Importantly, while this result is not a statistically significant finding, it does indicate a similar finding to that of Fang and Handy's (2017) analysis on skateboarder injuries, that vehicles pose a safety hazard for similar modes of micro-mobility on streets.[182] Note that these events were not included as part of the speed tabulations and were tracked and recorded separately from other riding behaviours. In all cases, the riders were male and did not wear helmets.

No collisions with pedestrians were observed. This is an important finding as 4.4 percent e-scooter collisions in Los Angeles were reported between pedestrians and e-scooters.[183]

5.14 The Results: E-Scooter Riders in San Jose

In total, 330 e-scooter riders were

observed in downtown San Jose during a mix of both dry and wet weather conditions across streets (n=110), sidewalks (n=110), and mixed-use paths (n=110) between the months of October 2018, and February 2019. Additionally, 110 cyclists were observed on the street facility only. Concerning average speed, riders traveled between 9 to 11 mph with a different speed per facility ($p<0.01$), male riders traveled faster than females and varied less by facility ($p<0.01$), operator speeds were similar at 10 mph, but not statistically significant ($p=0.69$), older riders (10.5 mph) traveled faster than younger riders (9.4 mph) ($p<0.01$), e-scooter riders traveled slower on streets (11.1 mph) than bicyclists (12.2 mph) ($p<0.01$), and riders traveled faster in colder temperatures than warmer temperatures ($p=0.04$).

Furthermore, regarding riding behaviours, 2 percent of e-scooter riders wore helmets compared to 56 percent of cyclists, and the majority of e-scooter riders (96 percent) traveled in a straight line as opposed to traveling in a less predictable side to side motion. Concerning group riding and multiple riders, 17 percent of riders were observed traveling in groups while 3 percent of riders traveled with two riders on one-scooter. Regarding rider distractions, only one person was seen using a cell phone. Moreover, 16 percent of riders were observed using headphones, which was slightly similar to cyclists.

In terms of travel conflicts, 71 percent of riders slowed down while 29 percent swerved out of the way. Furthermore, 70 percent of riders who encountered conflicts on facilities with mixed pedestrian traffic slowed down for pedestrians (a positive finding). Of note, the few collisions observed (n=3), were as a result of a rider colliding with a curb or due to a rider colliding with a parked car's side view mirror. This finding was similar to that of skateboarder collisions.

While it is apparent that speed is dependent on many factors and riders exhibit different riding behaviours, what is not clear is the implications of these findings. Chapter 6 will conclude with a look at the potential implications.


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Chapter 6

Conclusions and Implications

While cities are instituting temporary pilot programs and regulations to deal with the influx of e-scooters, they are still in the early process of debating the compatibility of these devices with other road users. This debate over whether individuals view electric scooters as compatible or incompatible with other road users and whether they support or do not support specific policies, is likely formed by how they see the attributes of e-scooters versus that of similar modes of micro-mobility. However, there is a lack of data on how e-scooters riders actually behave and how that compares to other road users. As a result, this research effort sought to observe e-scooters on sidewalks, streets, and mixed-use paths in San Jose with a goal of revealing how operational characteristics, riding behaviours, and traffic conflicts could inform those debates. Specifically, this research effort sought to answer the following question:

What are the "operational characteristics" exhibited by e-scooter share users using streets, sidewalks and mixed-use paths in downtown San Jose, California and what are the potential implications of the findings on the future development of e-scooter regulation and micro-mobility (bicycle) infrastructure design?

This study opened with a discussion about the U.S. history of micro-mobility from early bike-share systems to the explosion of e-scooter share. A literature review was then conducted to understand the regulatory debates concerning e-scooters. Literature was also reviewed to understand methodologies behind measuring the operational characteristics, riding behaviours, and traffic conflicts in similar modes of micro-mobility. Findings were summarized concerning the importance of using operational characteristics, riding behaviours, and traffic conflicts from an urban planning perspective.

Also using a review of the literature, a methodology was chosen for observing 330 e-scooter riders in downtown San Jose across streets, sidewalks, and mixed-use paths. Speed, riding behaviours, and traffic conflicts were then observed and reported in Chapter 5. In this chapter, implications were derived from the findings as it pertains to potential e-scooter regulation and the design of urban infrastructure.

6.1 Not so Fast and Furious, Speeds are Similar to Other Modes

Riders are not traveling at 30mph down sidewalks, let alone on streets. On average, riders traveled faster on streets and slower on sidewalks. In particular, riders on average rode just below 8.9 mph on sidewalks. This is much less than the figure of 25 mph originally proposed as part of legalization A.B. 2989 that spawned critics of the legislation. Furthermore, e-scooter riders traveled significantly slower in the presence of pedestrians. The average e-scooter speeds on sidewalks were slightly slower when compared to what previous studies have found for in-line skaters and skateboarders. Moreover, e-scooter sidewalk speeds were similar to that of EPAMDs (e.g. Segways). All three of these other micro-mobility devices are allowed on sidewalks in California pointing to a consistency issue with the existing regulations for different modes. Overall, it appears that riders are more Sunday drivers as opposed to being too fast and too furious.

6.2 Creating New Conflicts: Slow Scooters and Fast Cars

Currently, the City of San Jose regulates an e-scooter vehicles' speed to a maximum of 12 mph.[184] Additionally, the City also mandates that e-scooter riders must ride on the street.[185] However, the current speed limit for motor vehicles on Santa Clara St. between the Autumn and Market St. stretch that encapsulates one observation zone is 30 mph.[186] In a mixed traffic scenario such as Santa Clara St. without the presence of any micro-mobility infrastructure, and where you have motor vehicles that can travel or exceed the current posted speed limit, yet allow e-scooters to operate on the same facility well below the speed limit, does this not create a conflict between the two vehicles? In Santa Monica, e-scooters are limited to 20 mph, yet are expected to travel with the flow of traffic.[187] How do cities expect e-scooter riders to safely negotiate a lane change without the ability to accelerate to match current traffic speed conditions? Instead, cities regulate the operation of motor vehicles through speed limits on roads. It is not uncommon to regulate mixed-use paths or trails through the use of posted speed limits such as the City of Seattle implementing a 15 mph speed limit for all trail users.[188] In California, class I and class II e-bikes, capable of traveling up to 20 mph, are permitted on multi-use paths and trails as per California Code 212230.[189] Moreover, Oakland also permits e-scooters to use the Lake Merritt Trail.[190] While it may not make sense to allow sidewalk operation on a busy sidewalk, it may make more sense to allow sidewalk operation on underused facilities in low-density areas next to wide and high-speed arterial roads.

6.3 Is Age Truly the Best Way to Regulate E-Scooters?

Arguably there is a perception that adolescent e-scooter riders are more likely to be break the rules concerning the operation of e-Scooters.[191] For example, Trivedi et al.'s (2019) study found a "significant subset of injuries" among e-scooter riders under the age of 18 (the minimum required age for operating an e-scooter by operators).[192] Additionally, this study found that no adolescent riders (under the age of 25) were using helmets, possibly indicating that some could be violating helmet laws. However, when it comes to speed, this study found adolescent riders appear to be safer riders than adult riders. Regarding age and speed, older riders were found to travel faster than adolescent riders. Importantly, while this finding is more qualitative in nature due to fact the observer determined age groups through observations, it is indicative that age alone may not be the best method to regulate e-scooters due to its varying nature and inconsistency in relation to riding behaviours. There is a conflict present, one where age is not necessarily indicative that e-scooter riders will or will not follow the rules.

6.4 About Those Pesky Sidewalk Riders on Santa Clara St.

Concerning sidewalk versus street riding, one important finding became quite clear, that e-scooter riders will find the path of least resistance. During observations of sidewalk and street e-scooter riders along Santa Clara St., it was noticed that e-scooter riders opted to ride on the sidewalk when the street became far too crowded with vehicular traffic. In particular, there was a section of driveway prior to the street observation zone along Santa Clara St. that allowed for e-scooters to avoid traffic conflicts (such as parked cars in combination with moving vehicles). When e-scooter riders were faced with a restricted or narrowed travel path between parked cars and moving vehicles, they opted instead to jump onto the sidewalk to continue their travels. While this research effort did not specifically measure this phenomenon, it nonetheless proved to be an interesting observational finding, that e-scooter riders when faced with the option will opt to use the sidewalk instead of the street. Of note, there is no bicycle lane or buffer from traffic provided on Santa Clara St. where the current speed limit is 30 mph.[193] This finding was similar to a study conducted by the City Portland. The study that looked at the relationship between sidewalk riding and street speed limits (where there is a lack of bicycle infrastructure) and found that as street speed limits increased, so did the amount of sidewalk riding.[194] Of the 128 observed riders in Portland, 50% of riders were found to ride on sidewalks where the posted speed limit was 30 mph while, 18% of riders use the sidewalk where the posted speed limit was 20 mph.[195]

6.5 Traffic Conflicts on Sidewalks and Mixed-Use Paths

Different kinds of traffic conflicts were observed concerning e-scooter riders confronting other road users, including pedestrians, bicyclists, and other e-scooter riders. While traffic conflicts were found among e-scooter riders with those around them, e-scooter riders either slowed down or maneuvered out of the way of the conflict – a positive finding. Additionally, no e-scooter and pedestrian collisions were observed. Temporarily sidestepping the issue associated with sidewalks and narrow space restrictions, these two types of reactions exhibit a need for a change in the design of the standard mixed-use path and bicycle lane. Specifically, could any potential traffic conflicts on sidewalks or streets be remedied by simply widening these facilities?

6.6 Increasing the Risk of Injury? E-Scooters and Vehicle Collisions

Two collisions were observed on Santa Clara St. as a result of traffic conflicts between e-scooters and vehicles. No other forms of collisions were observed between other road users such as pedestrians, cyclists or other e-scooter riders. As a result, it is possible that by restricting e-scooter users to streets as opposed to more buffered facilities, e-scooter riders could be placed at a higher risk injury as a result of collisions with vehicles.

6.7 Voting with an Unprotected Head: E-scooters and Helmet Use

With regards to helmets, e-scooter riders rarely wear them, especially when compared to cyclists; however, this could be telling of many different stories. It could very well be that e-scooter riders are voting with their unprotected heads and view e-scooter riding as not a dangerous activity. Maybe riders need to be better educated about helmet use requirements, although e-scooter applications do inform riders of helmet requirements where they exist. Perhaps carrying around a helmet, for the short portion of a day for a rider is inconvenient and cumbersome, and maybe e-scooter share companies should provide helmets as a result.

This observed phenomenon was also seen in similar micro-mobility sharing schemes such as bike share.[196] For example, Fishman et al. (2013) noted that a survey conducted of Capitol Bike share members revealed 54 percent of users did not wear helmets.[197] This trend continued with Citi Bike in New York

City where 85 percent of users do not wear helmets.[198] Interestingly, Fishman et al. (2013) noted one important trend for low bicycle helmet use: short-term users are less likely to wear helmets when compared with long-term (private bicycle) users who are more likely to wear helmets.[199] Fishman et al.'s finding suggest that since bike share is conducive to more spontaneous trips, users are less likely to have a helmet available.[200] Relating the concept of the first and last-mile (which micro-mobility is meant to solve), the short distance traveled by these devices in combination with spontaneous trips could prove non-conducive to the use of bicycle helmets. Additionally, helmet laws do not encourage the use of bicycle helmets either. In Santa Monica, CA, rider compliance with helmet laws is low, estimated to be around approximately two percent.[201] Similarly, Portland, OR, also has a compliance issue.[202]

The results may call into question whether or not regulations should force users to wear helmets. However, it cannot be denied that helmet use is important as 40 percent of all e-scooter injuries are head injuries.[203]

6.8 E-Scooter Riders and Distractions are not so Much of a Problem

E-scooter riders were less distracted when compared to other modes of micro-mobility, specifically regarding cell phone use. While 16 percent of e-scooter riders wore headphones, it was not possible to determine whether riders were on a call or listening to music. Moreover, in California, it is illegal for bicycle riders to have headphones in both ears.[204] As a result, some observed e-scooter riders may be in contravention of the law. While this may pose a hazard to pedestrians and other users around them, cell phone use among e-scooter riders does not seem to pose a threat from a safety perspective. Surprisingly, given worries over distracted travel in other modes, only one rider was trying to use a cellphone, yet unsuccessfully. This may be a by-product of how a rider operates an e-scooter. Essentially, an e-scooter rider must have both hands on the handlebars as one controls the throttle and the other controls the breaks.

6.9 Talking While Scooting? A Potential for Distracted Riding

While this research effort can surmise that texting and scootering is not a major issue based on the results, some scooter riders could be distracted by interacting with other scooter riders. De Waard et al.'s (2010) studied noted that a survey among bicyclists involved in collisions revealed that 11.4 percent of riders were talking to other cyclists at the time of the collision.[205] As mentioned in Chapter 5, 17 percent of e-scooter riders were observed riding in packs of two to five people, yet at the same time riders traveling in groups conversed with one another. This number is higher among e-scooter riders when compared to cyclists, indicating that there could be a potential for collisions as a result of group riding.

6.10 Revisiting Infrastructure Naming Conventions

Observations not considered as part of this study included other emerging modes of micro-motility such as power-assisted unicycles and electric skateboards. These newer emerging modes were observed along with e-scooters. The implication of this finding points to a need to recognize there are many emerging modes of micro-mobility aside from e-scooters flooding city streets. As a result, should cities not be reconsidering existing naming conventions for the bicycle lane? After all, cities like San Jose are actively encouraging through regulations that e-scooters ride on the street, and to use bicycle lanes (where available); thus, does it not make sense to use a more inclusive term reflecting of all modes of micro-mobility?

6.11 But Wait, There's More!

Additional implications were determined based on observations that may have an impact on the design of e-scooters in terms of safety, and an apparent gender imbalance among e-scooter riders.

6.11.1 Move Out of the Way, I Can't Hear You!

The current e-scooter design consists of a bell attached to the e-scooter handle bars, but the bells are prone to vandalism and wear and tear. Currently, e-scooters do feature an onboard auditory signal that goes off as a chime to indicate when it is being moved without first being rented. This finding calls into question: how do e-scooter riders signal to others around them, especially on busy streets, of their presence to other road users?

6.11.2 Turning Signals

Another design issue to consider based on rider behaviour observations ☐ how are e-scooter riders expected to negotiate lane changes and turning without turn signals? While riders could take one hand off the e-scooter to notify drivers behind them, it does prove difficult to balance and operate the vehicle. Thus, riders are either faced with a choice: run the risk of possibly losing balance and falling off the vehicle by removing one of their hands off the handlebars, or do not signal.

6.12 Implications Summary

After observing 330 e-scooter riders in downtown San Jose, the implications of the findings (based on the results of speed, riding behaviour, and traffic conflicts) showed some inconsistencies with how cities are currently regulating e-scooter share. For one, e-scooters riders operate at comparable speeds to that of other modes of micro-mobility. Some of those comparable modes are allowed on the sidewalks in California, while e-scooters are currently restricted from operating on sidewalks (such as San Jose). Additionally, how can cities expect e-scooters (limited to 12 mph in San Jose and 15 mph by the operator) to safely operate in mixed traffic with vehicles that can travel faster than posted speed limits greater than 25 or 35 mph? This conflict has the potential for increasing the risk of injury to e-scooter riders. As mentioned earlier, if riders are provided an opportunity to avoid a high-risk activity such as operating in mixed traffic, they will follow the path of least resistance by riding on the sidewalk. Now, while riders respected the right-of-way for sidewalk users, nonetheless, one has to question whether the incidents of conflicts could be reduced with a simple re-design of existing facilities to accommodate all users.

When it comes to helmet use, it is important to note that some riders might be in contravention of local helmet laws, either due the fact they are underage or simply because the majority do not wear helmets (as shown in this study and by the injury study in Los Angeles). This trend of low compliance is also consistent with other modes of micro-mobility, yet it does call into question whether the age requirement is the best way to regulate. Simply, there's a conflict concerning the perception that age and alleged safer riding practices are somewhat correlated, despite that fact that in this study, adolescent riders were shown to ride slower than older riders, which one could argue is exhibiting safer riding behaviour.

Concerning e-scooter distractions, riders are less distracted compared to other modes when it comes to cell phone use, yet comparatively distracted when it comes to headphones. Interestingly, there was evidence of talking among group riding observations, which might suggest that e-scootering while talking could be considered a distraction. De Waard et al. noted that this kind of distraction may lead to potential injuries.[206]

Finally, with so many emerging modes of micro-mobility that were observed but not part of this study, it does call into question the language cities are using to denote spaces dedicated to micro-mobility. Specifically, does it make sense to call a bicycle lane a "bicycle lane" anymore? Bearing this in mind, the next and final chapter will cover the recommendations for e-scooter share regulations and the design of urban infrastructure as it pertains to speed, rider behaviours, and traffic conflicts.

Chapter 7

Rethinking the Status Quo

Based on a comprehensive observational study of e-scooter riding speed, riding behaviours, and traffic conflicts, along with an understanding of their implications, this study makes seven recommendations for the regulation of e-scooters along with design of urban micro-mobility infrastructure.

7.1 Allow Sidewalk Scootering Where and When it Makes Sense Using Posted Speed Limits

Since e-scooters operate at average speeds at or below 9 mph on sidewalks (well below mixed-trail/path speed limits), it would make sense to regulate the operation of these vehicles where sidewalks mimic the physical characteristics of a mixed-use path. Alternatively, cities may allow e-scooters to ride on sidewalks during off-peak hours (early in the morning or late at night) where the sidewalk facility may be wide enough to accommodate multiple users. Additionally, cities could consider sidewalk operation in less congested areas such as suburban low-density neighbourhoods with low pedestrian foot traffic

7.2 To Avoid Collisions and Sidewalk Riding, Separate Micro-Mobility Devices from Vehicles

Results showed no incidents of e-scooter riders colliding with other users on streets and sidewalks. One collision, as noted in Chapter 5, was a fall attributed to a sidewalk curb, the other two could have been easily avoided if e-scooter riders had a safe space that was buffered from parked and vehicular traffic. Specifically, parked cars' side view mirrors that were sticking out into the e-scooter travel path were a cause for concern as two riders hit these mirrors. Pucher and Bhueler's (2016) study of grade separated bicycle infrastructure from traffic noted that buffered and grade-separated facilities can save lives, promote both new and old users to cycle, and reduce the incidence of collisions.[207] Specifically, the authors found that in U.S. cities that provided a safe pathway that separated cyclists from high-speed traffic on arterial roads, the number of incidents of collisions dropped from 75 to 25 percent based on 100,000 rides.[208] Thus, not only is it necessary build adequate and safe infrastructure to separate e-scooters from parked and moving traffic, but it is also necessary to add adequate buffered spacing to prevent collisions with vehicles and potential protruding objects such as side view mirrors. If the City of San Jose expects riders to use Santa Clara St. instead of the sidewalk, then there needs to be adequate and safe facilities in place for riders to use. Otherwise, riders will follow the path of least resistance, and use the adjacent sidewalk.

7.3 Building Slow, Medium, and Fast Lanes to Accommodate All Types of Riders

In order reduce the number of conflicts with other users, lanes of variable speeds should be implemented in order to accommodate slow-moving traffic, medium-speed moving traffic, and a passing lane for faster-moving traffic on mixed-use paths and existing micro-mobility (bicycle) infrastructure on streets. By giving users the option to travel at their own pace in their own space, the potential for conflicts decrease as faster e-scooter riders can pass others without swerving out of the way in a less predictable fashion when compared to traveling in a straight line. Moreover, this also has the potential to solve any potential conflicts with bicycle riders on the street who were observed traveling at a higher average speed than e-scooter riders. Even then, only one bicycle conflict was found, and the e-scooter rider in that particular instance slowed down to yield to the cyclist.

7.4 Increase the Width of Micro-Mobility Infrastructure to Promote E-Scooter Riding

E-scooter observations showed group riding on all transportation facilities. While riders were observed chatting with each other, this behaviour could be construed as a distraction but also a tool to encourage more e-scooter riding. This finding implies that since there is evidence of group riding, and people want to converse with riders (which promotes group riding), then the design of current urban micro-mobility infrastructure needs to be reconsidered. The solution? Make bicycle or micro-mobility lanes wider! Currently, the design of bicycle infrastructure allows for riding in single file, but if cities want to encourage more users to utilize various micro-mobility options, then they should make existing micro-mobility infrastructure wider to accommodate more users. When pedestrians walk along the street with friends, family or coworkers, they typically do not walk single file while carrying on a conversation - why would e-scooter riders be any different?

7.5 Age Regulation: Re-Thinking Mandatory Helmet Laws

Current helmet laws do not appear to be encouraging more helmet use as shown among e-scooter riders and similar modes of micro-mobility. Few e-scooter riders are wearing helmets, regardless of age. This is a finding that was similar to that of the e-scooter riders in Los Angeles.

So, what can be done to encourage helmet use in e-scooter share? Helmet design must play a role. Since e-scooter trips are short (less than 3 miles), helmets need to adapt and become convenient for users to travel on short trips.[209] Newer helmets on the market are collapsible and can fit into someone's bag. Newer helmet designs could encourage the use of helmets while riding e-scooters.[210] Additionally, what if cities re-purposed the funds they spent on drafting and enforcing helmet laws, and instead invested in upgrading transportation facilities for all modes of micro-mobility? For example, why not build more grade-separated and barrier-separated micro-mobility lanes on streets?

7.6 From the Bicycle Lane to the "Green" Lane

Observations of other emerging micro-mobility modes were mentioned in Chapter 6 which included power-assisted unicycles and electric skateboards. Cities need to reconsider the existing naming conventions associated with bicycle lanes. With more than just e-scooters set to crowd the public right-of-way, not only will the design of the bicycle lane need to change but also a re-branding of the facility itself to better represent the mix of users: a green lane. Some cities currently use the bright green colour to denote bicycle lanes from the rest of the street, yet it is still called a bicycle lane. The bicycle lane perpetuates a perception that only bicycles should be allowed, and is not reflective of the current situation.

Chapter 8

Limitations and Future Research

This chapter covers research limitations concerning speed and riding behaviours along with future research considerations on emerging modes of micro-mobility and gender imbalances.

8.1 Speed Results

Concerning the speed results, observed riders on the mixed-use path (paseo off of 7th St.) were younger in age due to the proximity of the facility near San Jose State University. This may have resulted in over sampling of similar age ranges. Also, there might have been a potential for human error due to the reaction time required to start and stop the stopwatch as riders crossed the observation zone. As a result, the measured travel time to cross the observation zone may been impacted, yet, this method was chosen instead of video recording to reduce the chance of e-scooter riders altering their behaviour when known to be observed.

8.2 Riding Behaviours

As it pertains to determining the age of e-scooter riders, there is some subjectivity over the classification of observed riders by age due to the observer determining these age ranges. As a result, there might be a larger proportion of riders represented in the adult category (25 to 50 years of age) that could have fallen either into the younger (adolescent) category of less than years of age, or the older adult category of individuals over the age of 50.

8.3 Scooting Forward: Future Research

Moving forward, there is still much to learn about shared e-scooter programs and e-scooters in general. In terms of operational characteristics, data on the ability of e-scooters to brake and maneuver could be a particularly useful topic for future research. For example, what stopping distance is required for an e-scooter rider on a sidewalk to react to a sudden movement by a nearby pedestrian? Could an e-scooter rider navigate facilities with certain design specifications? Moreover, regarding safety, do e-scooter riders refuse to wear helmets for the same reason as cyclists? Additionally, what would be the operational characteristics of e-scooter share for riders at night?

8.3.1 What is Coming Down the Pipeline?

Cities need to consider all modes of micro-mobility, and not just e-scooters or bicycles. Many different kinds of devices were observed during this study, including:

- Electric skateboards (n=6)
- Electric unicycle (n=1)
- Skateboards (n=2)
- Roller-blades (in-line skates, n=1)

Electric skateboards were the third highest observed mode (aside from bicycles and e-scooters), and on average traveled at a speed of 15 mph. The presence of alternate modes of micro-mobility should encourage cities to think outside of the box of restricting devices to certain facilities or limiting the maximum operational speed and, instead, focus on developing legislation that is consistent with other modes of micro-mobility that share similar operational and travel behaviour characteristics.

8.3.2 A Gender Imbalance

When comparing the number of apparent females to male riders, results showed that 76 percent of e-scooter riders were male (n=251), while approximately 24 percent were female (n=79). As a result, there is an apparent gender imbalance among e-scooter riders. This issue is not uncommon when it comes to micro-mobility. A study by Prati (2016) also found a gender imbalance among cyclists, where the majority of riders tended to be males as opposed to females.[211] Prati (2016) identified two possible reasons for the imbalance among cyclists.[212] One comes from a study by Askar, Fisher, and Namgung (2013) where the authors noted that safety is a prime consideration for female cyclists regarding their choice to use cycling as a form of transport.[213] Moreover, Prati (2016) also stated that in addition to safety, Aldred, Woodstock, and Goodman's (2015) study found that increasing the amount of high-quality cycling infrastructure can lead to higher cycling participation among female riders.[214] Looking at the results, the gender balance by facility shows that out of 110 street observation (where no bicycle infrastructure was present) 84 percent of riders were male while 16 percent were female. When comparing facilities where pedestrians are present, and grade separated from the roadway, this study found that the percentage of female riders increased: 25 percent for sidewalks, and 32 percent of mixed-use paths. Thus, it prove pertinent to further investigate the gender imbalance among e-scooter riders and see if there is any correlation with other similar modes of micro-mobility.

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