MICROMOBILITY PROMISES AND CHALLENGES IN THE PACIFIC NORTHWEST

FINAL PROJECT REPORT

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Sponsorship
PacTrans, Oregon State University, and University of Alaska Fairbanks

for

Pacific Northwest Transportation Consortium (PacTrans)
USDOT University Transportation Center for Federal Region 10
University of Washington
More Hall 112, Box 352700
Seattle, WA 98195-2700

In cooperation with U.S. Department of Transportation,
Office of the Assistant Secretary for Research and Technology (OST-R)

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TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.

2. Government Accession No.
01745559

3. Recipient's Catalog No.

4. Title and Subtitle
Micromobility Promises and Challenges in the Pacific Northwest

5. Report Date

6. Performing Organization Code

7. Author(s) and Affiliations

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8. Performing Organization Report No.
2019-M-OSU-3

9. Performing Organization Name and Address

PacTrans
Pacific Northwest Transportation Consortium
University Transportation Center for Federal Region 10
University of Washington More Hall 112 Seattle, WA 98195-2700

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
69A3551747110

12. Sponsoring Organization Name and Address

United States Department of Transportation
Research and Innovative Technology Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

13. Type of Report and Period Covered
Final Project Report

14. Sponsoring Agency Code

15. Supplementary Notes
Report uploaded to: www.pactrans.org

16. Abstract

This study used a questionnaire survey method to understand how people use micromobility and the opportunities and challenges associated with its adoption in the Pacific Northwest (Alaska, Oregon, Washington, and Idaho). With 527 respondents who generally represented the demographics of the area, this study found that micromobility is becoming an important mode share in daily life. Using micromobility is positively associated with the possession of a higher education degree, being employed, living in an urban area, and the perception that using micromobility can benefit environmental and social issues. It is negatively associated with increasing age, self-identifying as female, and having a disability. People use micromobility more for commuting and recreational purposes. Commuting use is significantly positively affected by respondents' perceptions of micromobility's benefits, but negatively affected by income, being female, and having a disability. Recreational use is significantly positively affected by age, being female, and marital status. We also found that younger respondents tend to use micromobility more for occasional purposes (e.g., recreation, shopping, and social visits), but older respondents use it more for commuting. In considering the impacts of COVID-19, we found a significant decrease in usage frequency when the stay-at-home orders were implemented in terms of four ride purpose categories (commuting, recreational, shopping, and social). Furthermore, this study identified three reasons people have for not using micromobility: lack of access, lack of ability or skills, and worry about safety. However, we also found the potential for a large mode shift toward micromobility if those issues were resolved. Combining the findings about the usage of micromobility and public transit, evidence was provided to support that micromobility can be an effective standalone mode or a first- and last-mile mode for public transit to address current transportation issues such as traffic congestion and emissions. Based on the findings from the survey, this study also provides recommendations for authorities to support policymaking and infrastructure. investment.

17. Key Words
Micromobility, Transportation Mode, scooter, bicycle, COVID-19

18. Distribution Statement

19. Security Classification (of this report)
Unclassified.

20. Security Classification (of this page)
Unclassified.

21. No. of Pages

22. Price
N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized.**

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ABBREVIATIONS

ACS	American Community Survey
ADA	Americans with Disabilities Act
COVID-19	Novel coronavirus-2019
DOT	Department of transportation
FHWA	Federal Highway Administration
GNSS	Global Navigation Satellite System
HUD	Department of Housing and Urban Development
NHTS	National Household Travel Survey
PacTrans	Pacific Northwest Transportation Consortium
PNW	Pacific Northwest
SAH	Stay-at-home (orders)
TNC	Transportation network company
TRB	Transportation Research Board
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

The rapid adoption of micromobility has occurred in many U.S. cities because of its numerous associated benefits, such as avoidance of traffic congestion, improved public health, reduced costs, and expanded ease of access. However, transportation facilities, policies, and resources may not be ready to accommodate this dramatic change in mode share, which has presented challenges for transportation planners and policymakers. Previous micromobility studies have explored the impacts of micromobility and corresponding travel behaviors focused on high-density urban areas. However, a significant knowledge gap exists for lower-density and small-urban areas, rural areas, and college campuses. To that end, this research project was designed to fill those research gaps by using a survey to understand how people use micromobility in the Pacific Northwest (PNW) and the opportunities and challenges associated with the adoption of micromobility modalities.

With 527 respondents who generally represented the demographics of the PNW, this study found that micromobility is becoming an important mode share in daily life. Use of micromobility was found to be positively associated with the possession of a higher education degree, being employed, living in an urban area, and the perception that using micromobility can benefit environmental and social issues. It was found to be negatively associated with increasing age, self-identifying as female, and having a disability. People were found to use micromobility more for commuting and recreational purposes. Commuting use was significantly positively affected by respondents' perceptions of micromobility's benefits, but negatively affected by income, being female, and having a disability. Recreational use was significantly positively affected by age, being female, and marital status. We also found that younger respondents tended to use micromobility more occasionally (e.g., for recreational, shopping, and social purposes), but older respondents used it more for commuting purposes. In considering the impacts of COVID-19, we found a significant decrease in usage frequency when pandemic stay-at-home orders were implemented in terms of four ride purposes (commuting, recreational, shopping, and social). Furthermore, this study identified three reasons people reported for not using micromobility: lack of access, lack of ability or skills, and concerns about safety. However, we also found potential for a large mode shift toward micromobility if those issues were resolved. Combining the findings regarding the usage of micromobility and public transit provided evidence to support micromobility as an effective standalone mode or first- and last-mile mode for public transit to address current transportation issues such as traffic congestion and emissions. Based on the findings from the survey, this study also provides recommendations for authorities to support policymaking and infrastructure investment.

CHAPTER 1. INTRODUCTION

The definition of micromobility varies by jurisdictions (Anderson-Hall, et al., 2018); however, most definitions classify vehicles that carry one user and are partially or entirely powered by physical user movement as forms of micromobility. Micromobility is a general term for an innovative form of transportation service that provides “accessible and affordable transportation” in cities and on college campuses. Common examples of micromobility modes include human-powered or electric bicycles, scooters, skateboards, and double-wheeled hoverboards. As a result of their benefits—such as avoiding traffic congestion, improving health, reducing costs, and easing access—micromobility modes have the potential to capture all trips made in the U.S. that are shorter than 5 miles, or the equivalent to $300 billion (Shaheen & Cohen, 2019). Because of this high market potential, private investment has increased the number of shared micromobility companies in the past ten years. Shared micromobility is a transportation strategy that allows users to gain short-term access to micromobility modes on an as-needed basis, including bikeshare and shared e-scooters (Shaheen, et al., 2020). Table 1-1 lists 12 of the current industry leaders in shared micromobility. By some measures, the shared micromobility fleet is expected to reach nearly 40 million vehicles by 2023 (Svegander, 2018).

Table 1-1 Popular shared micromobility vendor headquarters, market, funding, and valuation (Anderson-Hall, et al., 2018)

Vendor	Headquarters	Markets	Funding (USD)	Valuation (USD)
Bird	Venice, CA	11 cities, 0 campuses	265M	2B
Lime	San Mateo, CA	59 cities, 0 campuses	382M	-
Spin	San Francisco, CA	30 cities, 0 campuses	8M	43.2M
Skip	San Francisco, CA	2 cities, 0 campuses	31M	100M
GOAT	Austin, TX	1 cities, 0 campuses	-	-
Ofo	Beijing, CN	25 cities, 0 campuses	2.2B	-
JUMP	New York, NY	5 cities, 0 campuses	27.1B	-
Hope	Miami, FL	15 cities, 0 campuses	3.9B	-
Scoot	San Francisco, CA	1 cities, 0 campuses	4.5B	-
Lyft	San Francisco, CA	Not Yet Launched	4.9B	-
Razor	Cerritos, CA	Not Yet Launched	-	-
Ridecell	San Francisco, CA	Not Yet Launched	45.8B	-

As part of micromobility, e-scooters, bikes, and mopeds have been taking over our cities. After their emergence as a new shared micromobility service, e-scooters are operating in 65 cities in the United States. Figure 1-1 illustrates a dramatic increase in the number of Lime e-scooter users in 12 cities (nine from the U.S.) in 2018, and that is just one year after the introduction of this new shared mobility service in 2017 to the U.S.

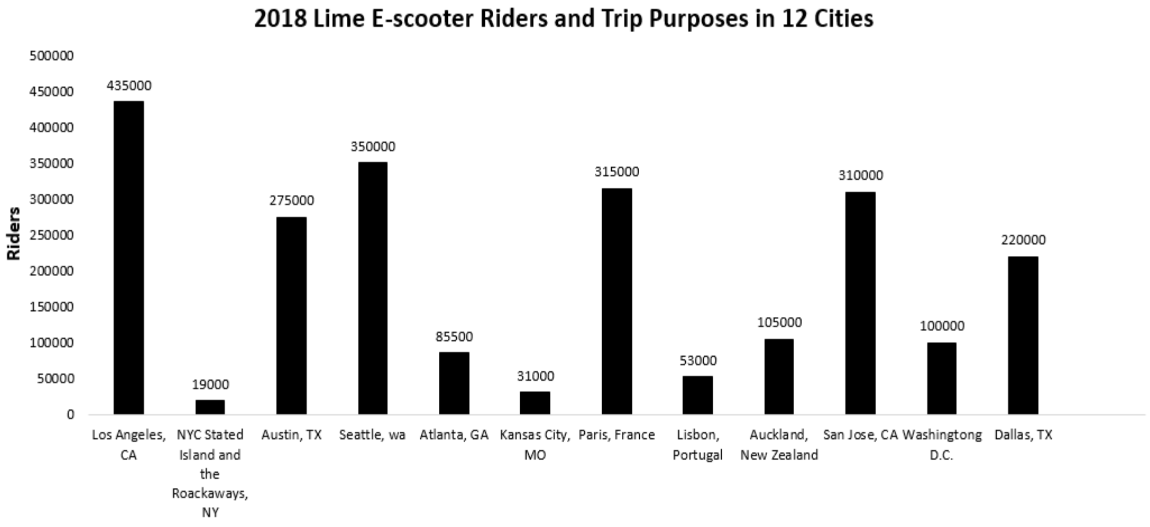


Figure 1-1, 2018 Lime electric scooter users in twelve cities. (Data adapted from Lime Reports (LIME, 2018))

Companies such as Bird and Lime began their announced pilot programs and testing operations in 43 markets without government consent or permits (i.e., a launch-first, permit-later deployment strategy). Micromobility services have great potential to fulfill first- and last-mile needs but also present safety concerns for riders and pedestrians. Several cities have responded with cease and desist orders, fines, or both. Despite the promises of micromobility, cities also face new challenges when this new mode changes the transportation ecosystem. For instance, figure 1-2 shows safety and public space issues during a pilot e-scooter program implementation in Portland in 2018: 1) Even though e-scooter riders knew they had to wear a helmet during riding, 44.81 percent of them never followed the rule; and 2) While 77.38 percent of them knew they could not ride on the sidewalk, 46.19 percent of them at least “sometime” rode on the sidewalk.

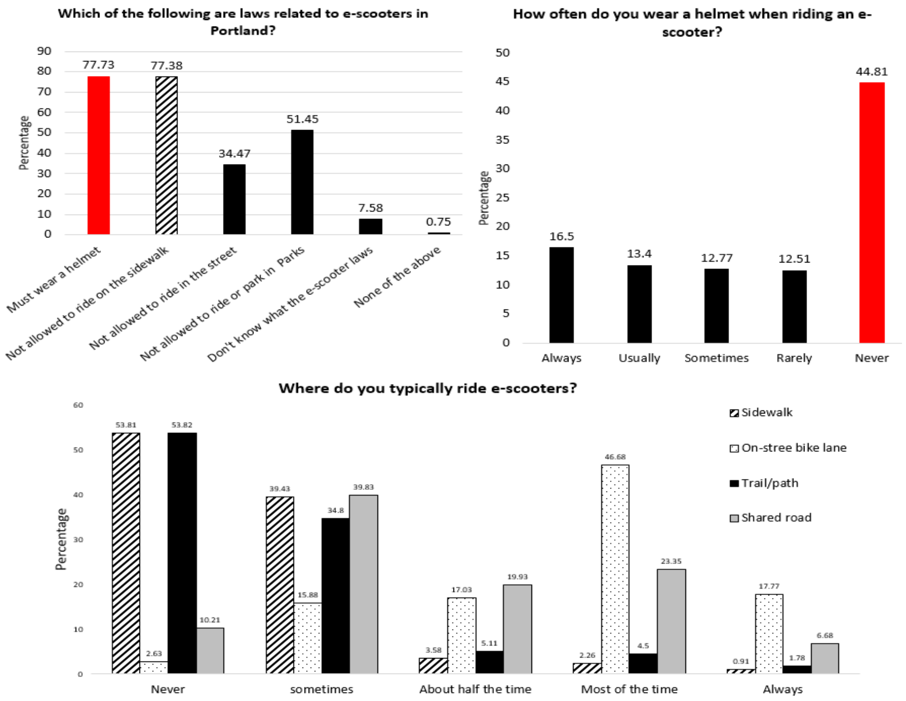


Figure 1-2 Space and user safety issues that appeared in Portland. (Data from PBOT User Survey (PBOT, 2018))

The arrival of this new shared mobility is disrupting the current ecosystem of modal share and shift. Micromobility products such as e-scooters and bikes provide faster and cheaper ways to lower carbon emissions, expand access to public transportation, and redesign cities for people instead of automobiles. Micromobility services are usually “dockless,” which means they often leverage GPS services and cellular connectivity for tracking their locations, and they require a credit card, driver’s license, and smartphone to access them, which could drastically limit access for people with low incomes or disabilities. The city of Portland E-scooter pilot study showed the potential and promises of this small, light, and electric shared vehicle to move people quickly and easily without adding to Portland traffic. Especially notable was the potential of e-scooters for younger users, people of color, and lower-income groups.

The rapid adoption of shared micromobility modes from private vendors has created unique challenges for transportation planners and policymakers. One such challenge is determining how and to what extent this new trend will affect urban transportation and mobility (Anderson-Hall, et al., 2018). These challenges have caused implementations of shared micromobility services to be poorly received or fail. Cities such as San Francisco, Nashville, and

Denver have implemented cease and desist orders regarding the deployment and use of e-scooters. Local complaints about sidewalk obstruction and dangerous riding behaviors have led to the issuance of numerous cease and desist orders (Anderson-Hall, et al., 2018).

Many unanswered questions surrounding micromobility remain, especially with respect to new trends such as shared micromobility and the electrification of micromobility modes (e.g., electric bicycles (e-bikes), e-scooters). The literature review presented in Chapter 2 summarizes what is known about micromobility impacts on transportation planning and policy, and the gaps in knowledge that remain. From these knowledge gaps, this study established five research questions that have not been answered, and these are addressed in the following sections.

CHAPTER 2. LITERATURE REVIEW

2.1. Market Adoption

Some have defined micromobility as utility-focused urban transport in sub-500-kg vehicles that is predominantly electrically powered (Bruce, 2018). It can cover a short travel distance, and it has the potential to be integrated with public transit unlike conventional personal motorized vehicles. Those micromobility modes have proved to offer wide benefits (Chen, et al., 2020) such as health benefits (Akar & Clifton, 2009; Chen, et al., 2017), reduced carbon, air, and noise pollution (Seebauer, 2015; Wolf & Seebauer, 2014), cheaper initial investment and operating costs, and a more mature and more reliable technology (Seebauer, 2015; Ahrens, et al., 2013)

2.1.1. Why Do Users Choose Micromobility?

In comparison to cars, micromobility provides more flexible and cheaper transport in urban areas and on short-range trips, is unimpeded by parking restrictions, and suffers less from battery range impediments. The electrical parts of micromobility modes (i.e., e-scooters, e-bikes, etc.) in comparison to conventional counterparts provide an extended range without physical exhaustion—even more so in hilly regions (Seebauer, 2015; Ahrens, et al., 2013). Even though these modes have the disadvantages of exposure to weather, lack of capacity for passengers or luggage, and risk of theft, the micromobility modes still play an intermediary role between conventional counterparts and cars, which makes them an attractive complement to other transport modes (Shaheen, et al., 2010; Ahrens, et al., 2013; Seebauer, 2015; Wolf & Seebauer, 2014). When a big program promoting transportation network companies (TNCs) (e.g., Uber and Lyft) to cover first-/last-mile transport and complement transit, transit ridership showed a decline when TNC ridership increased. Even though TNCs are a major reason for congestion (Castiglione, et al., 2019), the causality relationship remains unclear.

How micromobility modes complement public transit when they are adopted by cities (e.g., e-scooters in Atlanta, Austin, Denver, Chicago, D.C., Los Angeles, New York City, Portland, San Jose, Seattle, San Francisco, etc.) also still remains unclear. However, integration of bicycle and transit integration has the mutual benefit of encouraging more cyclists and transit riders (National Academies of Sciences, Engineering, and Medicine., 2005). It also offers more equality to low-income families by extending the catchment areas of rail stations and bus stops far beyond walking range. It also has a much lower cost than neighborhood feeder buses or park-and-ride facilities (Pucher, et al., 2011).

Previous studies found that shared micromobility users tended to be college-educated, upper- to middle-class young adults. These individuals also tended to have no children in their household, live in urban areas, and own either one or no vehicle (Shaheen, et al., 2014; Rayle, et al., 2016). Contradicting these findings, Clewlow found that while the majority of people in U.S. metropolitan areas perceived shared e-scooters positively, women and low-income populations showed even greater support (Clewlow, 2019). A more recent survey completed by the Portland Bureau of Transportation (PBOT) one year after the city adopted shared e-scooters found that there were two main reasons people chose to use shared e-scooters. The first reason was that, for certain trips, e-scooters offered shorter travel times than other modes. The second reason was that e-scooters looked fun and users were curious to try them. Of those who had tried shared e-scooters in Portland, a vast majority said they would recommend riding an e-scooter to friends or family (PBOT, 2018).

Portland residents who used shared e-scooter services tended to use the service to commute to the user's primary school or work, or to travel to social events (PBOT, 2018). However, the primary use for micromobility varied by vehicle type. For example, dockless shared micromobility was usually used for short trips (approximately 1 mile); however, if the dockless vehicle was an e-bike, then the average trip length increased significantly. Studies also indicated that docked bicycle share (bikeshare) tended to be used for trips much longer than 1 mile and was generally used for commuting purposes. In contrast, dockless shared micromobility services tended to be used by tourists or to travel to social events (Clewlow, 2018).

Bicycles provide users flexible and cheap transport in urban areas for short trips; however, hilly terrain and fatigue pose limits to the accessibility and attractiveness of bicycle transport. E-bikes mitigate these limitations and are more attractive for short trips or to complement trips with other transport modes such as buses or metro (Shaheen, et al., 2010).

2.1.2. Micromobility Impacts on Mode Choice

The U.S. Department of Transportation has suggested that micromobility has the potential to replace most U.S. car-based trips, as most car-based trips in the U.S. are 3 miles or less and occur in urban areas (FHWA, 2017). Already, station-based bikesharing has been shown to reduce driving and taxi service mode share (Shaheen & Cohen, 2019). In Santa Monica, half of the trips made by micromobility modes directly replaced trips that would have otherwise been made by personal vehicle or by taxi services (City of Santa Monica, 2019). Portland survey data echoed the findings from Santa Monica with respect to micromobility modes reducing driving and taxi service usage; however, shared e-scooter services also directly competed with bikeshare services and walking for mode share. Shared e-scooter service usage was not found to decrease the number of vehicles per household and was not typically used as a replacement for a car or public transportation (e.g., buses, metro) (PBOT, 2018), but the reason behind this observation was not clear.

In summary, current data have suggested that micromobility modes decrease personal vehicle and taxi service mode shares for short trips and may have little to no impact on public transportation or personal vehicle mode share for longer trips. Micromobility modes may also compete with one another (e.g., bikes and e-scooters) and with walking for mode share. These trends may change if current barriers to micromobility adoption are addressed. In the next section, we will review and discuss the current barriers to micromobility adoption.

2.1.3. Barriers to Adoption

The most prominent concern regarding e-scooter adoption is safety, especially considering the low rate of helmet use among shared micromobility users (Shaheen & Cohen, 2019) (PBOT, 2018). Over 80 percent of surveyed Portland residents stated that they relied on shared micromobility vendor apps to be informed about micromobility laws (PBOT, 2018). Half of e-scooter collisions in Austin resulted in severe injuries, with the most common injury being bone fractures. Most users involved in e-scooter collisions in Austin were between the ages of 18 and 29. Additionally, collision data from Austin suggested that e-scooter collisions tended to happen on the street (as opposed to on the sidewalk) with poor surface conditions (APH, 2018). That indicated that current issues in transportation infrastructure can be a potential barrier for this adoption. In Portland, residents who had not ridden e-scooters reported that they would be more likely to try them if more scooters were available, and if the infrastructure to ride on was safer (PBOT, 2018). Indeed, respondents reported similarly in our study.

The pace at which shared micromobility vendors are launching and promoting their product far exceeds the pace that public agencies are capable of implementing disruptive technologies (Clewlow, 2018). In terms of policy, dockless e-scooters create liability concerns for local governments and those who use them because of a lack of sufficient insurance covering vehicles and users (Fong, et al., 2019). Beyond safety issues, shared micromobility poses challenges for curb-space management. Poor curb space management during the implementation phase of shared micromobility services often leads to decreased public support for those services and poses Americans with Disabilities Act (ADA) liability and compliance issues (Shaheen & Cohen, 2019).

Both e-bikes and e-scooters have limitations with respect to battery life and range. The average e-bike today has a battery range of approximately 20 miles, while an e-scooter has an average range of approximately 10 miles. However, little charging infrastructure for e-bikes and e-scooters is available to the public. The City of Pittsburgh has identified the lack of charging infrastructure as a major operational challenge with the widespread adoption of micromobility (Bedmutha, et al., 2020).

Because shared micromobility relies on software to operate, it is open to potential manipulation. Many e-scooters on the market rely on battery power for safety mechanisms; therefore, malicious modules can easily be installed on e-scooters with little to no consequence. While this has not been an issue thus far, safety precautions should be considered as shared micromobility adoption continues to increase throughout the world (Vinayaga-Sureshkanth, et al., 2020).

2.2. Trip Behavior and Characteristics

While the new micromobility promises residents a more reliable, cheaper, and more convenient transportation system, infrastructure, regulations, plans, and public policy are still designed for a traditional transportation system. Decision makers need to lead under deep uncertainty. Departments of transportation (DOTs) and locals cannot fulfill their mission without understanding how the transportation system is being used and what is occurring on the system.

2.2.1. Trip Characteristics

Micromobility trips tend to be short in both distance and time. Trips made in Santa Monica by micromobility modes in 2019 were 14 minutes and 1.3 miles on average. Most users in Santa Monica used micromobility modes for either work-related trips or for recreation (City of Santa Monica, 2019). Portland found that the majority of shared e-scooter riders fell into two groups of rider frequency. These two groups had a rider frequency of one to three times per week, or never. Respondents in Portland reported that they would maintain or slightly decrease their usage of shared e-scooters after Portland's first year of the e-scooter pilot program (PBOT, 2018).

Trip characteristics vary by micromobility modes and whether users are subscribed to shared micromobility plans. For example, annual members of station-based bikeshare tend to use bikeshare for commuting purposes during weekday peak hours. Figure 2-1 illustrates how e-scooters do not follow the same weekday usage trends as bikeshares, based on data from Washington, D.C. (Chang, et al., 2019). Casual (non-subscription) shared e-scooter users tend to use the service on weekend afternoons (NACTO, 2018). Use of shared micromobility services by tourists further complicates trip characteristics models, and tourists are an often-overlooked user group of shared e-scooters (Reck, et al., 2020).

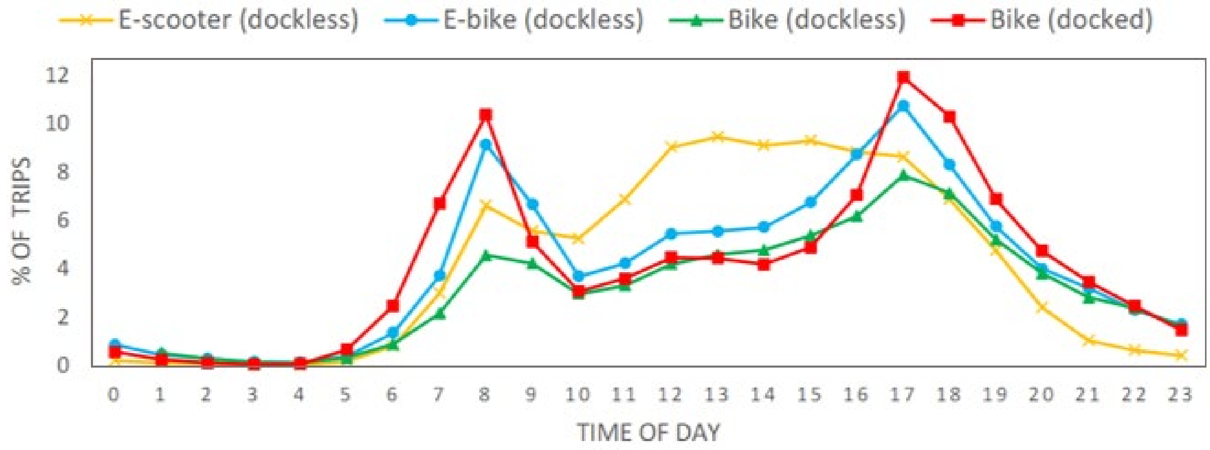


Figure 2-1 Distribution of weekday trips by time of day and mode in Washington, D.C. (Chang, et al., 2019)

This research sought to understand how significant changes might be in future travel patterns. Figure 2-2 shows e-scooter trip purposes split for nine cities (six from the U.S.) and that people used e-scooters as an important mode for commuter and recreational purposes. Little research has been conducted to understand the potential results if a large percentage of urban mileage shifted to lower speed vehicles, and the way that urban street right-of-way allocation would likely need to change.

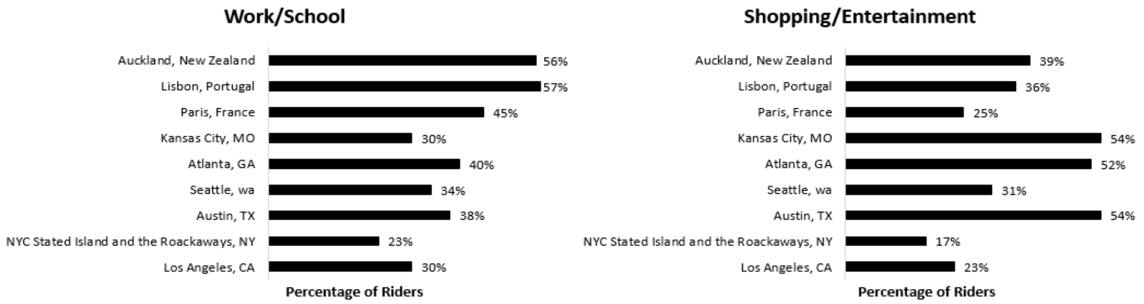


Figure 2-2 2018 Lime electric scooter trip purposes split for nine cities. (Data adapted from two Lime Reports (LIME, 2018))

2.2.2. Intermodality with Public Transportation

Micromobility is a logical complement to public transportation, given the similar cost per trip by mode. On average, e-scooters, e-bikes, and public transit trips cost $3.50, $2.75, and $2.75, respectively. In comparison, the average trip costs of driving alone and carpooling are $17.33 and $12.00, respectively (including parking costs), without considering the trip distance. Micromobility and public transit are especially more accessible to lower-income populations (Bedmutha, et al., 2020).

While research is still limited on the relationship between micromobility and public transportation, there is some evidence that bikeshare increases rail-based public transportation and decreases bus usage. However, this can vary by jurisdiction, depending on transportation options and cultures. Bikeshare has also been shown to have a greater positive impact on bus usage rates in low density communities outside of urban centers, suggesting that bikeshare serves as a first- and last-mile option in these communities. In contrast, bikeshare tends to decrease public transportation usage in higher density urban centers because it is often faster, cheaper, and more direct than public transportation (Shaheen & Cohen, 2019) within those areas. The City of Portland came to a similar conclusion with its survey data, finding that most shared e-scooter users do not use e-scooters in conjunction with public transportation (PBOT, 2018). However, in a more recent study, bus stops were found to generate a small number of e-scooter trips (Reck, et al., 2020).

2.2.3. Infrastructure

Along with population density and proximity to universities, the presence of bikeways is a strong indicator for micromobility adoption (Reck, et al., 2020). Portland residents indicated that they prefer to ride shared e-scooters in bicycle lanes over any other infrastructure type, including trails or paths (PBOT, 2018). Infrastructure that improves curb management for shared micromobility vehicles also improves public perceptions of micromobility (Shaheen & Cohen, 2019).

2.3. Impact of Stay-at-Home Orders

The outbreak of COVID-19 across the world led to the implementation of stay-at-home (SAH) orders (also known as safer-at-home, movement control, shelter-in-place, or lockdown orders) by multiple governments, which led to a general reduction in transportation activity and mobility (WHO, 2020). SAH orders are believed to have reduced daily risk for citizens by 6 to 7 percent based on limited available information (de Figueiredo, et al., 2020). While the complete impact of SAH orders on travel behavior has yet to be observed, several studies have given some insight based on early data.

In general, household travel for commuting, entertainment, and shopping decreased globally as a result of SAH orders, with the most significant drops seen in trips to transit, retail, recreation, and workplaces (Google, 2020). In Australia, private car, bus, and train trips showed the biggest decrease, while the number of trips by taxi, ferry, and active transportation modes remained relatively stable. Survey data in the same study suggested that the number of trips taken by households after SAH orders were fewer than the number of trips taken before SAH orders; however, the authors acknowledged that household outlooks on life after SAH orders were rapidly evolving (Beck & Hensher, 2020).

Many studies have examined impacts seen in China, where SAH orders were first implemented. A study in Beijing tracked bikeshare usage before, during, and after SAH orders were implemented and compared that usage to data from 2019. Figure 2-3 plots that usage and identifies important changes in dates and holidays.

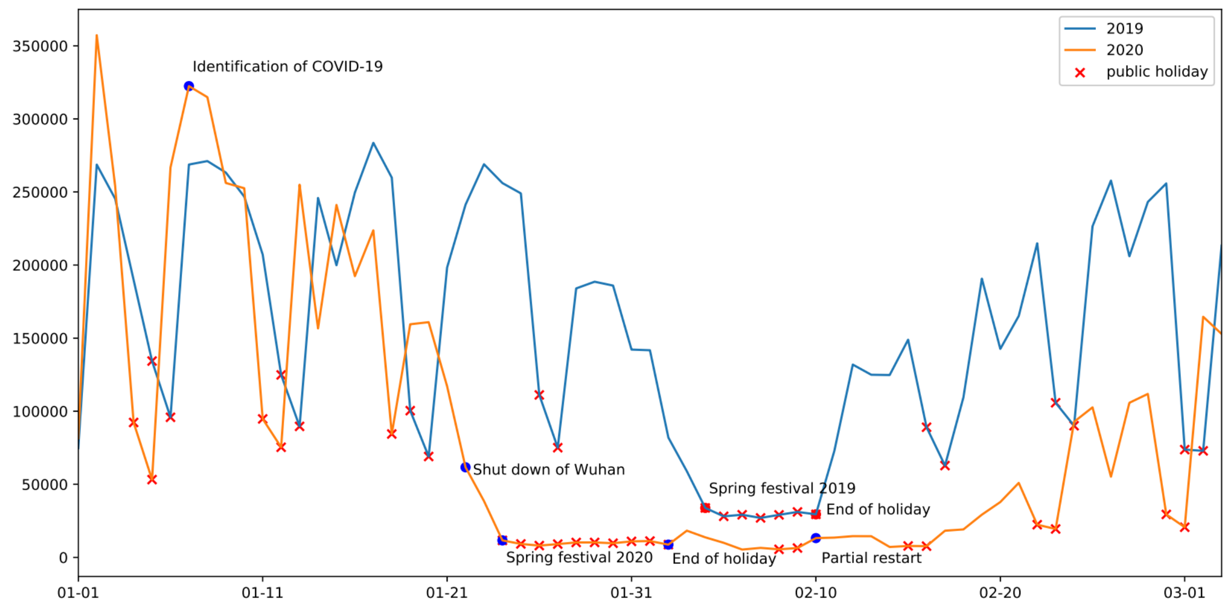


Figure 2-3 2019 and 2020 bikeshare usage in number of trips during morning peak hours between January and March, with key dates and holidays labeled (Chai, et al., 2020).

The study also analyzed bikeshare usage geospatially and compared changes in activity patterns relative to points of interest (e.g., tourist destinations, metro stations, shopping malls). It found that usage was falling naturally before the start of SAH orders because of the Spring Festival holiday, but usage remained significantly decreased during and after SAH orders (up to a 40 percent reduction). Additionally, usage at points of interest generally saw greater decreases in activity than that of other locations (Chai, et al., 2020).

Another factor to consider regarding how SAH orders impacted micromobility use is the re-design of public streets during the SAH orders. While cities such as Boston, London, Portland, and Vancouver temporarily reconfigured their streets to accommodate more cyclists and pedestrians, some cities such as Milan announced permanent street reconfigurations (Palominos & Smith, 2020). Reconfigurations may increase the adoption of shared micromobility services by alleviating major disputes over which infrastructure shared micromobility modes should be allowed to ride on (Honey-Roses, et al., 2020).

2.4. Identified Knowledge Gaps

Through this literature review, multiple knowledge gaps in understanding micromobility usage were identified. Many micromobility studies have focused on large urban areas, while very few studies have explored medium-sized urban areas, rural areas, and college campuses.

The benefits of micromobility are well known, but few studies have researched micromobility modes other than bicycles, and the knowledge gaps remain. One obvious reason is that most data in previous studies have been from the National Household Travel Survey (NHTS) (U.S. DOT, 2018) and The American Community Survey (ACS) (United State Census Bureau , 2020), which do not include non-motorized transportation modes except bicycles and walking. Although researchers have studied motor scooters (mopeds), such as (Lan & Chang, 2015), few studies have focused on electric stand-up scooters or e-bikes. Because many cities have been investigating the use of those micromobility modes, reviews and studies are urgently needed (Wolf & Seebauer, 2014). In addition, most articles that have mentioned micromobility have been based on survey data from 2010, but the new five-year, 2013 to 2017 ACS data haves not yet been studied. Because the NHTS has a limited bicycle-transit sample, Wang and Liu (Liu, et al., 2013) suggested that integration should be further emphasized, and researchers should collect detailed data and information that match transit access and egress trips to perform better in-depth analyses of micromobility and transit integration behavior. Furthermore, lots of questions were asked at the 2019 Transportation Research Board (TRB) conference about how shared mobility and micromobility, serving as first- and last-mile transport, can integrate with transit to provide better services. The answer remains unclear. The Pacific Northwest has more users combined on bicycles and transit than other regions in the U.S. (Wang & Liu, 2013), which presents opportunities for micromobility research.

This knowledge gap is especially prevalent for studies examining the Pacific Northwest. Studies have also tended to focus on resident usage and has not offered a complete understanding of tourists' use of micromobility. In terms of shared micromobility, much of the existing research has focused on understanding the public's attitudes toward both bikeshare and e-scooters. However, unlike bikeshare, there is an incomplete understanding of e-scooter trip characteristics and users' preferred infrastructure type when riding e-scooters. Specifically, there has been limited information and data on the adoption and use of new micromobility services as they have become available to cities, which has created challenges for public agencies wishing to develop data-driven policies and transportation plans. Furthermore, little work has been conducted to understand the relationship between shared e-scooters and public transit. Finally, there are large knowledge gaps in understanding how recent SAH orders affected micromobility use and will in the future.

CHAPTER 3. METHODOLOGY

3.1. Research Questions

To address the micromobility-related knowledge gaps identified by the literature review, the following research questions were identified, and these guided the development of the experimental procedures.

- Research Question 1 (RQ1): What are the ride characteristics (ride frequency, trip purpose, infrastructure type) of micromobility users in the Pacific Northwest (PNW)?
- Research Question 2 (RQ2): What are the barriers to micromobility adoption from a user perspective in the PNW?
- Research Question 3 (RQ3): Do geographic areas and trip purposes have an impact on user mode choice?
- Research Question 4 (RQ4): How does public transportation availability impact micromobility use?
- Research Question 5 (RQ5): How have stay-at-home orders during the COVID-19 pandemic affected the ride characteristics (ride frequency, trip purpose) of micromobility users in the PNW?

3.2. Method and Data

The survey questionnaire was designed in Qualtrics and was distributed to four states (Alaska, Washington, Oregon, and Idaho) in the Pacific Northwest through Facebook and Instagram. The survey was open for responses between September and December 2020, And 699 respondents returned the questionnaire and 527 respondents fully completed the survey. The number of respondents from each state in the PNW is summarized in Table 3-1.

Table 3-1 Questionnaire sample summary for each state in the PNW

State	Sample	Sample percent	Population (Census)	Population percent
AK	29	6%	730,000	5%
WA	244	46%	7,600,000	53%
OR	199	38%	4,200,000	30%
ID	22	4%	1,700,000	12%
Others	33	6%		
Total	527	100%		

Note: biases may impact the number of respondents in each state and are discussed below in the text

The collected sample could generally represent the population percentage of each state in the PNW, with a slight bias for some. The sample under-represented Idaho, slightly under-represented Washington, and slightly over-represented Oregon. The summary in Table 3-2 is based on the coordinates of each participant when they finished the questionnaire based on Qualtrics (devices IP/coordinates), so two potential biases may involve the following:

(1) People may have started the survey in the state where they lived but traveled to another state when they finished the questionnaire, and that is a potential reason why about 6 percent of the total respondents were recognized as outside of the PNW.

(2) The accuracy of the coordinate system may have been low in some areas with poor mobile device signals. Our team discovered that the mobile phone-based coordinates system (GNSS) sometimes provided inaccurate location coordinates for Alaska users.

Therefore, these sample summary analyses can only be a rough reference.

Table 3-2 Sample and census demographics of the study sites

Demographics	Sample	Pacific Northwest	US
Age <65	82%	84%	84%
Gender (Female)	61%	49%	51%
Race(white)	83%	85%	76%
high school or higher	99%	59%	56%
Bachelor or higher	65%	32%	32%
Median household income	$60,000	$70,000	$62,800

Table 3-3 summarizes the demographic characteristics of the sample and how they differ from the PNW and the U.S. Census averages. Specifically, the states in the PNW have more Caucasians and a slightly higher income than the overall U.S. population. In contrast to other online surveys, the age distribution was consistent between the PNW and the U.S. However, the sample over-represented females and a more highly educated population. Nevertheless, because the large sample size (527 in four states) could provide enough variance for reliable analyses, sample bias had little effect on correlation coefficients as long as it was not so severe that it substantially attenuated the variances of the variables (Lindell & Perry, 2000).

Table 3-3 Variable descriptive analysis

Description	N	Range	Min.	Max.	Mean	Std.
Commute Distance (1-6 scale. 1: less than 1 mile; 6: more than 25 mile)	527	6	1	7	2.42	1.43
Commute Time (1-6 scale. 1: less than 10 min; 6: more than 60 min)	527	6	1	7	2.37	1.44
Used public transportation in 2020 (1: yes; 0: no)	527	1	0	1	0.52	0.50
Used public transportation before stay-at-home order (1: yes; 0: no)	275	5	1	6	3.43	1.56
Used public transportation during stay-at-home order (1: yes; 0: no)	275	5	1	6	5.01	1.29
Used lightweight transportation in 2020 (1: yes; 0: no)	527	1	0	1	0.55	0.50
Used public micromobility before stay-at-home order (1: yes; 0: no)	289	5	1	6	3.17	1.53
Used public micromobility during stay-at-home order (1: yes; 0: no)	289	5	1	6	3.64	1.48
Difference in micromobility use frequency before and after SHO (YYY - XXX)	289	9	-4	5	-0.47	1.44
Difference in micromobility use frequency before and after SHO (commute)	289	10	-5	5	-0.93	1.89
Difference in micromobility use frequency before and after SHO (recreation)	289	10	-5	5	-0.32	1.28
Difference in micromobility use frequency before and after SHO (shopping)	289	10	-5	5	-0.32	1.09
Difference in micromobility use frequency before and after SHO (social)	289	9	-5	4	-0.58	1.25
Ride micromobility on bike path as ranked first or second	289	1	0	1	0.69	0.46
Reason of not using micromobility (Do not have access)	231	1	0	1	0.53	0.50
Reason of not using micromobility (Do not have skill)	231	1	0	1	0.40	0.49
Reason of not using micromobility (Worry about Covid-19)	231	1	0	1	0.39	0.49
Reason of not using micromobility (worry about safety)	231	1	0	1	0.23	0.42
Reason of not using micromobility (no infrastructure)	231	1	0	1	0.13	0.34
Reason of not using micromobility (high cost)	231	1	0	1	0.15	0.36
Whether would choose to ride micromobility if issues solved	239	1	0	1	0.61	0.49
Use purpose if issues are solved (commute)	145	5	1	6	3.84	1.69
Use purpose if issues are solved (recreation)	145	5	1	6	3.54	1.33
Use purpose if issues are solved (shopping)	145	5	1	6	4.35	1.38
Use purpose if issues are solved (social)	145	5	1	6	4.12	1.18
Benefit perception: Micromobility can improve traffic congestion	525	1	0	1	0.59	0.49
Benefit perception: Micromobility can improve Emissions	524	1	0	1	0.81	0.39
Benefit perception: Micromobility can improve Noise Pollution	527	1	0	1	0.74	0.44
Benefit perception: Micromobility can improve Travel Times to Public Transportation Stops	525	1	0	1	0.60	0.49
Benefit perception: Micromobility can improve Transportation Options for Underserved Communities	527	1	0	1	0.63	0.48
Benefit perception: Micromobility can improve Public Health	526	1	0	1	0.66	0.47
Benefit perception: Micromobility can improve Traffic Injuries	525	1	0	1	0.21	0.41

Description	N	Range	Min.	Max.	Mean	Std.
Benefit perception: Micromobility can improve Personal Transportation Costs	525	1	0	1	0.60	0.49
Benefit perception: Micromobility can improve Infrastructure Operations and Maintenance Costs	523	1	0	1	0.45	0.50
Sum of all benefit perception variables (1-9 scale)	513	9	0	9	5.31	2.67
Age	487	68	17	85	46.84	16.76
Highest degree obtained (1: less than high school; 6: advanced degree)	527	6	1	7	5.42	1.62
Annual household income (1: less than $10,000; 12: more than $150,000)	510	11	1	12	6.59	3.50
1: female; 0: others	525	1	0	1	0.62	0.49
Having kid(s) in household	275	1	0	1	0.13	0.34
House hold size	501	21	0	21	1.99	1.68
Having disability	527	1	0	1	0.27	0.44
Married	523	1	0	1	0.45	0.50
Employed	527	1	0	1	0.51	0.50
White	526	1	0	1	0.83	0.37
Whether residents in urban area	527	1	0	1	0.50	0.50

Table 3-3 documents the descriptive statistics of the variables included in the analyses, including sample size (N), variable value range, maximum (Max.), minimum (Min.), mean, and standard deviation (std.). While some variables were available from all respondents (e.g., commute distance N = 527), because all respondents were required to answer those questions, some variables were available for only a subset of participants. For example, questions about reasons for not using micromobility were provided only to participants who had not used micromobiluty in 2020; therefore, those variables had an N smaller than 527.

When asking participants whether they lived in urban, suburban, or rural areas, 46 percent of them correctly reported that they lived in an urban area, and 6 percent correctly reported that they lived in a rural area (see figure 3-1). In sum, only 53 percent could accurately define the classification as defined by the U.S. Census Bureau. This is probably because the 34 percent of respondents who reported living in a suburban area may not have been able to accurately match the U.S. Census Bureau's land-use definition: "urbanized areas (UAs) that contain 50,000 or more people and urban clusters (UCs) that contain at least 2,500 people." (US Census Bureau, 2019).

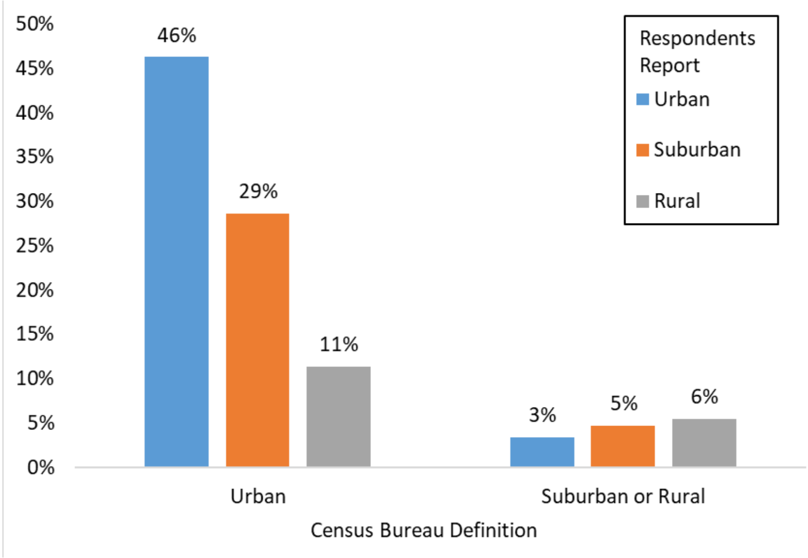


Figure 3-1 Land-use definitions between respondents and authority.

This study used t-test, Chi-square test, correlation, linear regression, and binary logit regression analyses as statistical tools to answer the research questions. T-test and Chi-square tests are used to compare the mean and distribution between two samples, respectively. Correlation (Pearson) analysis is used to identify the correlation between any two variables. Correlation analysis cannot identify the colinearity issue of a latent variable, so regression analyses are used to control any observable variables in order to identify the impact of a variable (Greene, 2012). Specifically, logit regression is used when the dependent variable is binary (0 or 1, no or yes) or categorical, whereas linear regression is used when the dependent variable is discrete or continual. Logit regression is used to measure the categorical dependent variable (Y) and multiple independent variables (X) by using the logit function. It is created based on the idea of the likelihoods of events. Specifically, the likelihood or odds indicate how often something (e.g., y = 1) happens relative to how often it does not happen (e.g., y = 0) (Wang, et al., 2018). The logit regression equation can be written as:

$$logit[P_n] = \ln\left[\frac{P_n}{1-P_n}\right] = \beta_0 + \beta_1 x_{1,n} + \cdots + \beta_i x_{i,n}$$

The parameters can be estimated with the maximum likelihood method to determine the probability that the outcome takes the value 1 as a function, using the equation below (Wang, et al., 2018; Greene, 2012):

$$P_n = \frac{e^{(\hat{\beta})}}{1 + e^{(\hat{\beta})}} \; where \; \hat{\beta} = \beta_0 + \beta_1 x_{1,n} + \cdots + \beta_i x_{i,n}$$

where P_n is the probability that a variable has the value 1 (or an event happens) for observation n, e is the exponential base, b_0 is the model constant, and b_1 ... b_i indicates unknown independent variables for observation n.

CHAPTER 4. RESULTS AND ANALYSIS

This study used bivariate analysis, statistical tests, and correlation matrices to identify the potential impact factors of each research question and then utilized regression analyses to justify the relationship with consideration for endogeneity and collinearity issues. The regression analysis also provided evidence for comparing the impact scale between different variables in relation to the standardized variables. Appendix A summarizes the correlations between variables.

4.1. Research Question 1 (RQ1): What are the ride characteristics (ride frequency, trip purpose, and infrastructure type) of micromobility users in the Pacific Northwest (PNW)?

The result revealed that within the 54 percent of total respondents who used a micromobility mode in 2020, the majority (60 percent) used it at least two to three times a week and some (17 percent) of them used it daily before SAH orders. In a comparison of before and during SAH orders, people reported that they used slightly less micromobility when the orders were implemented. The most significant decrease showed in the "Daily" use category, shown in figure 4-1. The change seems plausible because the overall trip number deceased during the pandemic period. However, there was no sharp decrease in ride frequency before and during the orders. One possible explanation is that the overall micromobility trip number decreased in 2020 because of the SAH orders; however, the decrease was offset by a considerable proportion of users who switched to micromobility to avoid public transit or carpooling during the COVID-19 pandemic. Indeed, one study reported an overall 16percent growth in bicycle counts in the U.S. from 2019 to 2020 (Buehler & Pucher, 2021) based on sensor counters. This inconsistency indicates the differences between results from questionnaire surveys and counter equipment. Future research is needed to investigate this phenomenon.

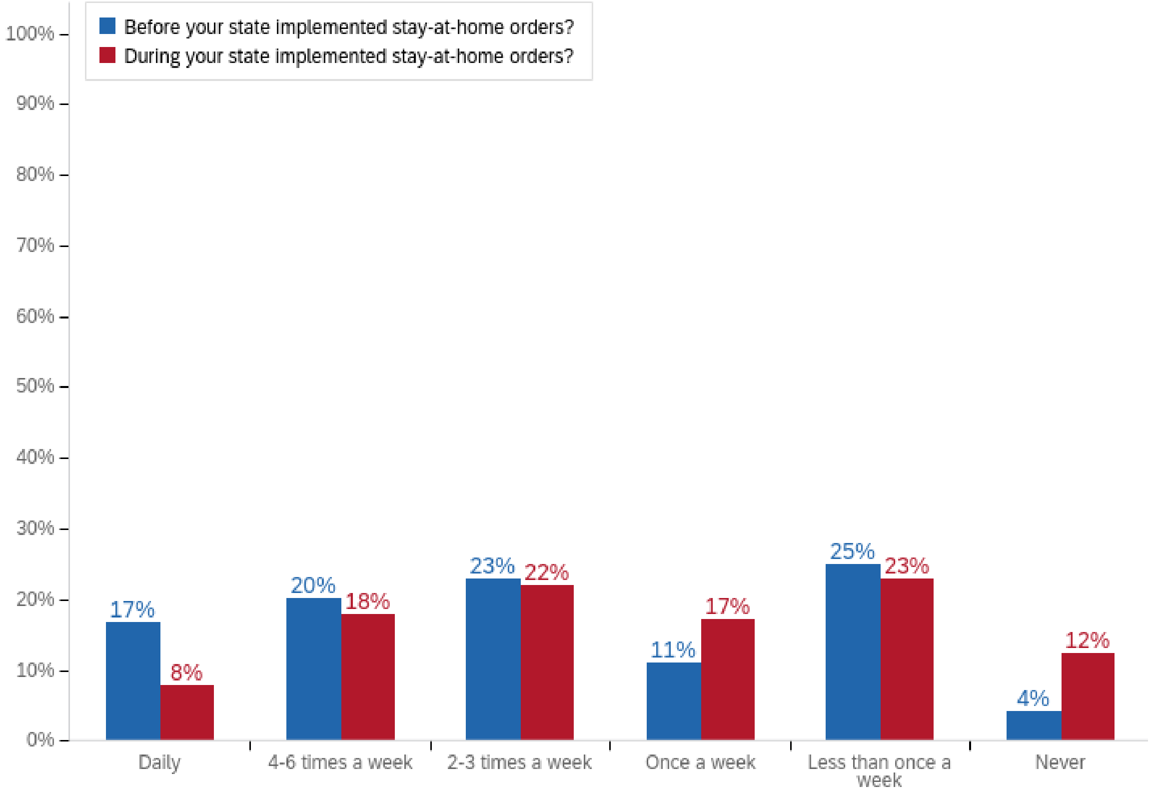


Figure 4-1 Micromobility ride frequency in the PNW

Fifty-four percent of respondents reported that they used micromobility during 2020. Using micromobility was positively correlated with the use of public transit ($r = 0.15$, $\rho < 0.01$), employment ($r = 0.15$, $\rho < 0.01$), living in an urban area ($r = 0.1$, $\rho < 0.05$), and the perception that micromobility can decrease congestion ($r = 0.2$, $\rho < 0.01$), reduce emissions ($r = 0.1$, $\rho < 0.01$), improve public health ($r = 0.2$, $\rho < 0.01$), reduce travel costs ($r = 0.12$, $\rho < 0.01$), decrease infrastructure maintenance costs ($r = 0.17$, $\rho < 0.01$), and increase transportation equality ($r = 0.12$, $\rho < 0.01$). Having used micromobility was also negatively correlated with increasing age ($r = -.19$, $\rho < 0.01$), gender (female) ($r = -.21$, $\rho < 0.01$), and having a disability ($r = -.16$, $\rho < 0.01$).

Binary logistic regression was employed to analyze the factors that impacted the use of micromobility in the PNW by coping the potential endogeneity and collinearity issues due to the correlation between independent variables. Table 4-1 shows that use of micromobility was significantly positively associated with having a higher education degree (+), being employed (+), and the perception that using micromobility can help address issues, but it was significantly negatively associated with increasing age (-), gender (female) (-), and having a disability (-).Consistent with previous studies (Shaheen & Cohen, 2019; Shaheen, et al., 2014), we also found that people with a higher education level, higher income, and younger age were more likely to use micromobility modes.

Table 4-1 Binary logistic regression of variables affecting the use of micromobility modes

Dependent variable (1: use micromobility; 0: otherwise)	**B**	**S.E.**	**Exp(B)**	**std. B**	**std. Exp(B)**	**Sig.**
Using transit	0.36	0.23	1.43	0.18	1.20	0.12
Commute Distance	-0.10	0.11	0.91	-0.14	0.87	0.38
Benefits*	0.11	0.04	1.12	0.31	1.36	0.01
Age*	-0.02	0.01	0.98	-0.34	0.71	0.01
Degree*	0.18	0.07	1.20	0.30	1.34	0.01
Income	-0.02	0.04	0.98	-0.07	0.93	0.58
Female*	-1.22	0.23	0.30	-0.60	0.55	0.00
Household size	0.03	0.08	1.03	0.06	1.06	0.66
Disability*	-0.54	0.25	0.58	-0.24	0.79	0.03
Married	0.25	0.25	1.30	0.13	1.13	0.31
Employed*	0.47	0.23	1.60	0.24	1.27	0.04
White	-0.12	0.30	0.88	-0.05	0.95	0.68
Urban	0.21	0.23	1.23	0.10	1.11	0.37
Constant	0.07	0.67	1.07	0.19	1.22	0.91

*significance level 0.05

-2 Log likelihood	524
Cox & Snell R Square	0.17
Nagelkerke R Square	0.22
Correctly predicted	68%

A comparison of the results from the regression analysis with the correlation matrix showed that two variables that were significant (using public transit, living in an urban area) in the correlation matrix were not significant in the regression model. This indicated the collinearity issue that other variables were correlated with (or explained) the two variables; therefore, the impact of the two variables on using micromobility was eliminated when the other variables in the regression equation were considered. In other words, the variables of using public transit and living in an urban area were not the underlying variables determining the use of micromobility; instead, a “mediator” was in between the underlying variable and the use of micromobility.

Indeed, the variable of using transit was significantly correlated with demographics such as age ($r = -.13$, $\rho < 0.01$), gender ($r = -.11$, $\rho < 0.01$), and employment ($r = .12$, $\rho < 0.01$). Those three demographic variables showed significance in regression results for using micromobility. Similarly, the variable of living in an urban area correlated with education degree ($r = .09$, $\rho < 0.05$), disability ($r = -.11$, $\rho < 0.05$), marriage ($r = -.09$, $\rho < 0.05$), and employment ($r = .09$, $\rho < 0.05$).

Belief that micromobility can benefit the environment and society was a significant variable that impacted the likelihood of someone choosing micromobility modes. Psychological theory indicates that people's choice is determined by their psychological variables (such as beliefs, perceptions, and knowledge), and their psychological variables are determined by people's characteristics and situational variables (such as demographics, knowledge, social economics, social context, and environmental context) (Ajzen & Fishbein, 2005; Lindell & Perry, 2012). In this data set, 15 out 96 (16 percent) pairs of variables between psychological variables and characteristics were significantly correlated. Sixteen percent is higher than the 5 percent threshold that is considered to be a random correlation. In other words, the data supported the social psychological theory mentioned above.

For those who used micromobility in 2020, table 4-2 shows which factors impacted *usage frequency* (1: use micromobility at least two times a week; 0: use less than two times a week). Consistent with the use of micromobility shown in table 4-1, the variables of age ($\beta = 0.03$, $\rho < 0.05$) and gender ($\beta = -0.65$, $\rho < 0.05$) were significantly associated with usage frequency when other variables were controlled; however, age showed a positive association relationship that indicated a negative association with use of micromobility in the previous analysis. That means that for those who used micromobility, older people used micromobility more often, other variables kept constant. That is probably because younger people may have used it more for occasional recreational purposes ($\beta = 0.02$, $\rho < 0.05$), whereas older people may have used it more for commuting purposes. Hence, people who used it for commuting purposes may have used it more often and more stably in terms of usage frequency.

Table 4-2 Variables influencing how often people use micromobility (Binary logistic regression)

Dependent variable (1: use micromobility at least 2 times a week; 0: less than 2 times a week)	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(B)**
Using transit	-.08	.32	.06	.81	.93
Commute Distance	-.05	.10	.27	.60	.95
Benefits	.04	.05	.58	.45	1.04
Age*	.03	.01	10.63	.00	1.03
Degree	.09	.10	.84	.36	1.10
Income	-.03	.05	.29	.59	.98
Female*	-.65	.30	4.67	.03	.52
Household size	-.04	.10	.14	.71	.96
Disability	-.54	.38	2.04	.15	.58
Married	-.53	.33	2.65	.10	.59
Employed	.38	.32	1.40	.24	1.46
White	.40	.38	1.08	.30	1.49
Urban	-.05	.33	.03	.87	.95
Constant	-1.22	.89	1.88	.17	.29

*significance level 0.05

-2 Log likelihood	294
Cox & Snell R Square	0.11
Nagelkerke R Square	0.15
Correctly predicted	66%

Table 4-3 shows the impacts of variables on micromobility usage for four trip purposes: commuting, recreational, shopping, and social purposes before the SAH orders. Perception of micromobility's benefit, gender, and age were significant variables in at least three of the four categories, which was consistent with the model of who used micromobility in 2020. The model showed that people with a higher perception of micromobility benefits used it more for three of four different trip purposes. Interestingly, for people who used micromobility, an increase in age was negatively associated with an increase in micromobility use for recreational, shopping, and social purposes, but positively associated with the commuting purpose. The results from table 4-1 indicated that older people were less likely to use micromobility. Comparing table 4-1 with table 4-3 shows that as long as people used micromobility, younger people tended to use it more for occasional purposes, but older people used it for commuting purpose. Being female was negatively associated with usage frequency for different purposes, which was consistent with the model in table 4-1.

Table 4-3 Use of micromobility for different trip purposes (linear regression)

Dependent variable (Use frequency - 1: least often; 6: most often)	**Commute**			**Recreation**			**Shop**			**Social**		
	B	**Std. Error**	**Std. B**	**B**	**Std. Error**	**Std. B**	**B**	**Std. Error**	**Std. B**	**B**	**Std. Error**	**Std. B**
(Constant)	-4.31	.74		-4.13	.55		-4.85	.56		-4.54	.55	
Using transit	.05	.26	.01	-.09	.19	-.03	.21	.20	.07	.18	.19	.06
Commute Distance	-.15	.09	-.11	-.07	.06	-.08	-.09	.07	-.09	**-.13***	.06	-.13
Benefits	**.14***	.05	.19	.04	.03	.08	**.08***	.03	.16	**.10***	.03	.19
Age	-.00*	.01	-.00	**.02***	.01	.27	**.02***	.01	.25	**.02***	.01	.20
Degree	.10	.08	.08	.02	.06	.02	-.03	.06	-.03	-.02	.06	-.03
Income	**-.11***	.04	-.20	-.03	.03	-.08	-.04	.03	-.10	-.03	.03	-.07
Female	**-.52***	.24	-.14	**-.46***	.18	-.17	**-.38***	.18	-.13	-.28	.18	-.10
Household_size	-.01	.09	-.01	.12	.06	.13	-.06	.07	-.06	-.02	.06	-.02
Disability	**-.81***	.32	-.17	-.23	.23	-.07	-.19	.24	-.05	.10	.23	.03
Married	.20	.27	.05	**-.52***	.20	-.19	-.24	.20	-.09	-.26	.20	-.10
Employed	.27	.26	.07	.08	.19	.03	.03	.20	.01	.02	.19	.01
White	.21	.32	.04	.04	.24	-.01	-.16	.24	-.04	-.04	.24	-.01
Live in urban	.09	.27	.02	.15	.20	-.05	.05	.20	.02	-.23	.20	-.08
model	F(13, 225) = 2.78, p < 0.001			F(13, 225) = 2.52, p < 0.05			F(13, 225) = 2.78, p < 0.01			F(13, 225) = 2.13, p < 0.05		
statistics	R2 = 0.14			R2 = 0.13			R2 = 0.14			R2 = 0.11		

4.2. Research Question 2 (RQ2): What are the barriers to micromobility adoption from a user perspective in the PNW?

For respondents who did not use micromobility in 2020 (45 percent), we asked them to rank their reasons. The results are shown in figure 4-2. The top three reason are were lack of access, lack of ability or skills, and worry about safety. This was similar to the finding from previous studies, that availability and safety were the two main reasons for not using e-scooters (PBOT, 2018; Shaheen & Cohen, 2019). However, cost seemed the least concern for those who did not use micromobility.

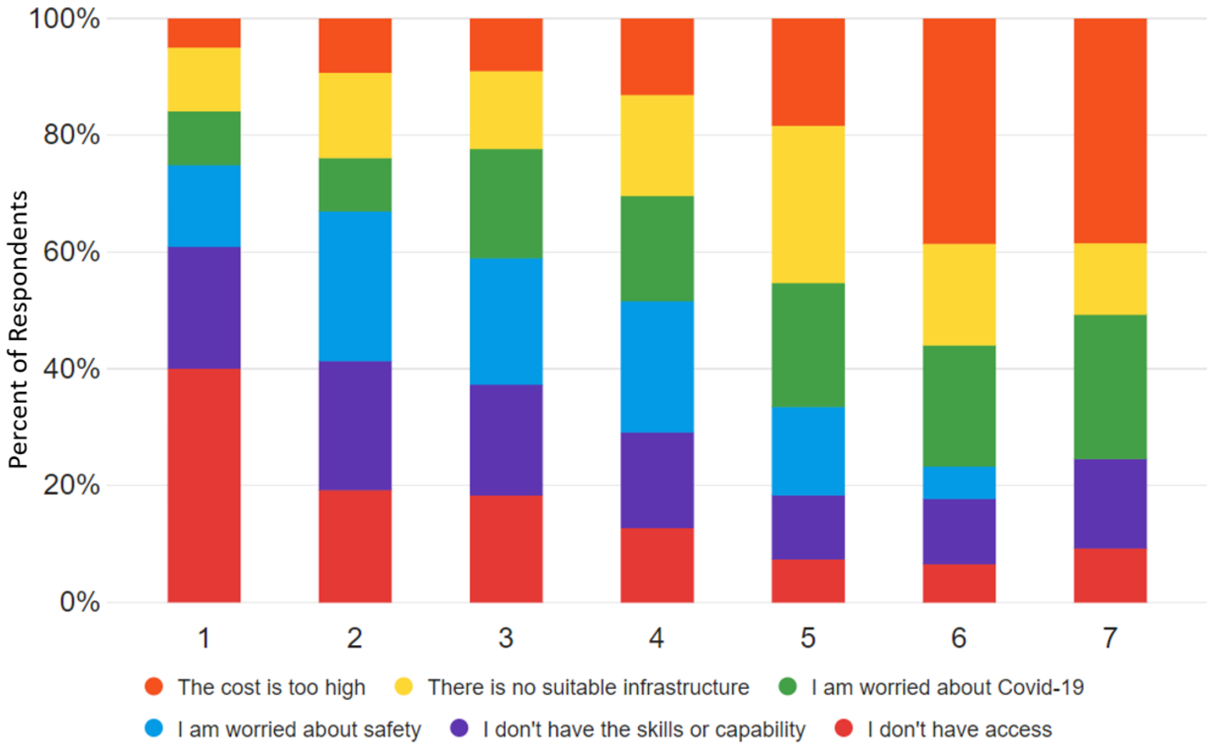


Figure 4-2 Reasons for not using micromobility (1: the most; 7: the least)

Sixty percent of respondents who did not use micromobility reported that they would use micromobility if the issues they mentioned were addressed. As figure 4-3 indicates, people who would use micromobility after issues were resolved also reported that they would use it more for commuting and recreational purposes than for shopping and social purposes. Specifically, for example, in the "daily" category in figure 4-3, a larger percentage of respondents appear under commuting and recreational purposes. This trend is also shown for the "4-6 times a week" and "2-3 times a week" categories. In contrast, there are larger percentages of people under "once a week" and "less than once a week" for shopping and social purposes. In other words, people who intended to use micromobility after barriers had been addressed were more likely to use micromobility for commuting and recreational purposes. This was consistent with the actual choice of respondents who used micromobility, as evidenced by the similarity between the stated preference survey and revealed preference survey (Chen, et al., 2021).

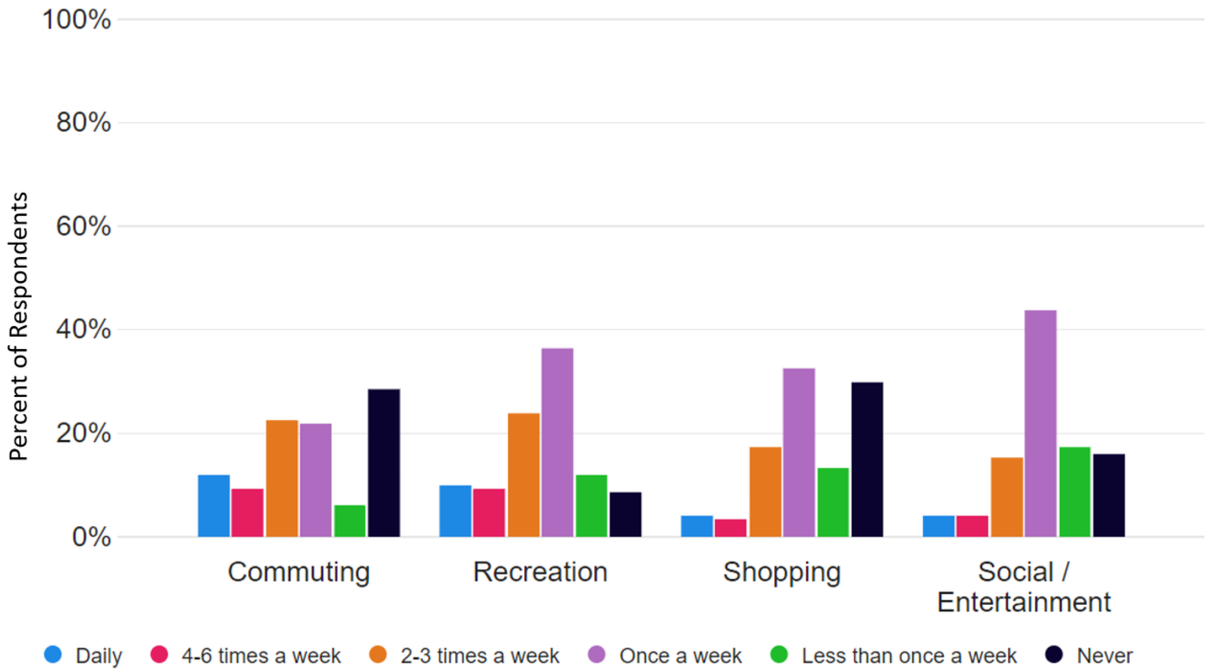


Figure 4-3 Expected trip purposes for using micromobility after issues have been fixed

Twenty-seven percent of all respondents (60 percent of the 45 percent total respondents who did not use micromobility in 2020) said they intended to use micromobility if the issues they mentioned were resolved, and thus they will contribute to a potential increase in micromobility trips. Based on the numbers of trips they reported to take the future, we built table 4-4 to analyze potential micromobility trip increases. Because respondents reported in a week-based format, the table converts the trip increase per week to trip increase per day for convenience. Conservative values (when the response was a range of numbers, the lowest number was the conservative value, e.g., 4 was conservative of "4-6 times a week") were selected to compute the number of trips. The table shows that for the respondents who did not use micromobility but intended to use it in the future, they intended to use micromobility 0.89 times per day per person for four trip purposes on average. Assuming that the sample can represent the general public, a potential 27 percent of residents who did not used micromobility would use it 0.89 times per day after issues were resolved. That indicates a large amount of mode share shift, which does not even consider increases in trip by people who already used micromobility and might use it more when issues were resolved. In other words, addressing the barriers to using micromobility mentioned by respondents would likely make it more accessible or convenient for people who already used micromobility, in turn increase micromobility trips even more. Therefore, we anticipate that the 0.89 trip increase per day is a conservative estimate.

Table 4-4 Intended micromobility trip types and frequencies after issues have been resolved

	Commuting	**Recreation**	**Shopping**	**Social**	**Daily Trip Equivalent Value**
Daily	12%	10%	4%	4%	1
4-6 times per week	9%	9%	3%	4%	4/7 = 0.57
2-3 times per week	23%	24%	17%	15%	2/7 = 0.29
Once a week	22%	36%	32%	44%	1/7 = 0.14
Less than once a week	6%	12%	13%	17%	1/14 = 0.07
Daily trip equivalent increase	12%×1 + 9%×0.57 + 23%×0.29 + 22%×0.14 + 6%×0.07 = 0.273	0.28	0.16	0.18	Total increase = 0.89 trip per day

One may argue that the intention to use micromobility does not mean actual behavior. However, social scientists have suggested that attitudes and beliefs are causal factors behind the intention to perform a behavior, which will lead to actual performance of the action (Ajzen & Fishbein, 2005). Indeed, research has found consistency between an intended survey and an actual behavior survey (Chen, et al., 2021; Huang, et al., 2016). These significant potentials would justify local authorities resolving those issues that respondents reported in order to increase micromobility usage.

This study also asked respondents which transportation facility they used to ride micromobility. Figure 4-4 shows that people reported riding mostly in a bike lane, followed by a trail/path, car lane, and sidewalk. This finding was consistent with the e-scooter study from Portland (PBOT, 2018). As mentioned above, safety was one of the important reasons that people said they did not ride micromobility, after access and skill. While local authorities have less power to increase peoples' riding skills, more resources can be invested toward bicycle or active mode facilities to enhance safety in order to encourage more people to ride (Shaheen & Cohen, 2019).

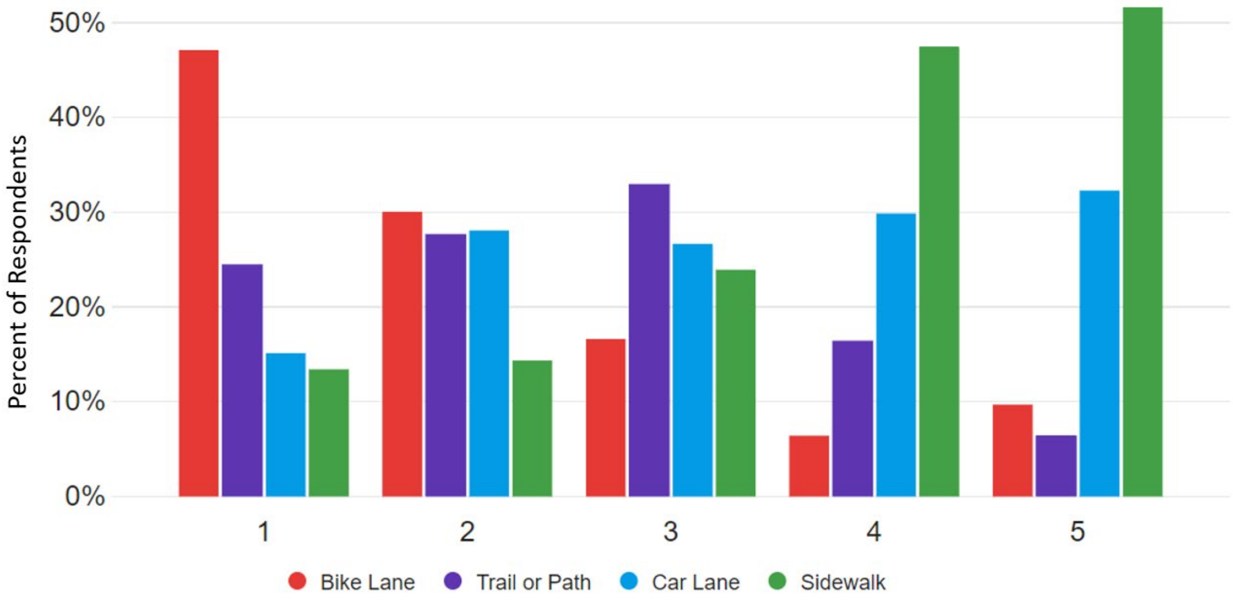


Figure 4-4 Where people ride micromobility (1: the most; 5: the least)

4.3. Research Question 3 (RQ3): Do geographic areas and trip purposes have an impact on the choice of micromobility?

The features of micromobility (i.e., speed and energy cost) significantly affect the way that people use it. For example, it is rare that people will use it for interstate travel because of the slow speed of the micromobility modes. This section answers the following questions: For what trip purposes do people use micromobility? Does the variable of living in an urban/sub-urban/rural area have an effect on the trip purpose of using micromobility?

Consistent with findings from a previous study (PBOT, 2018), the survey results indicated that people who reported using micromobility used it more for commuting (mean = 2.07) and recreational (mean = 2.42) purposes than for shopping (mean = 1.53) and social (mean = 1.82) purposes, as shown in table 4-5. Figure 4-5 also shows the pattern that respondents used micromobility more for commuting and recreational purposes. To support this observation, a Chi-square test was used to compare the distribution difference between the four trip purposes. The results of significance among the four pairs of comparison groups indicated that people, indeed, used micromobility more for commuting and recreational purposes than for the other two purposes in the PNW.

Table 4-5 Micromobility trip purpose descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Commuting	289	1	6	2.07	1.869
Recreational	289	1	6	2.42	1.385
Shopping	289	1	6	1.53	1.453
Social	289	1	6	1.82	1.368

1: never; 2: less than once a week; 3: once a week; 4: 2-3 times a week; 5: 4-6 times a week; 6: daily

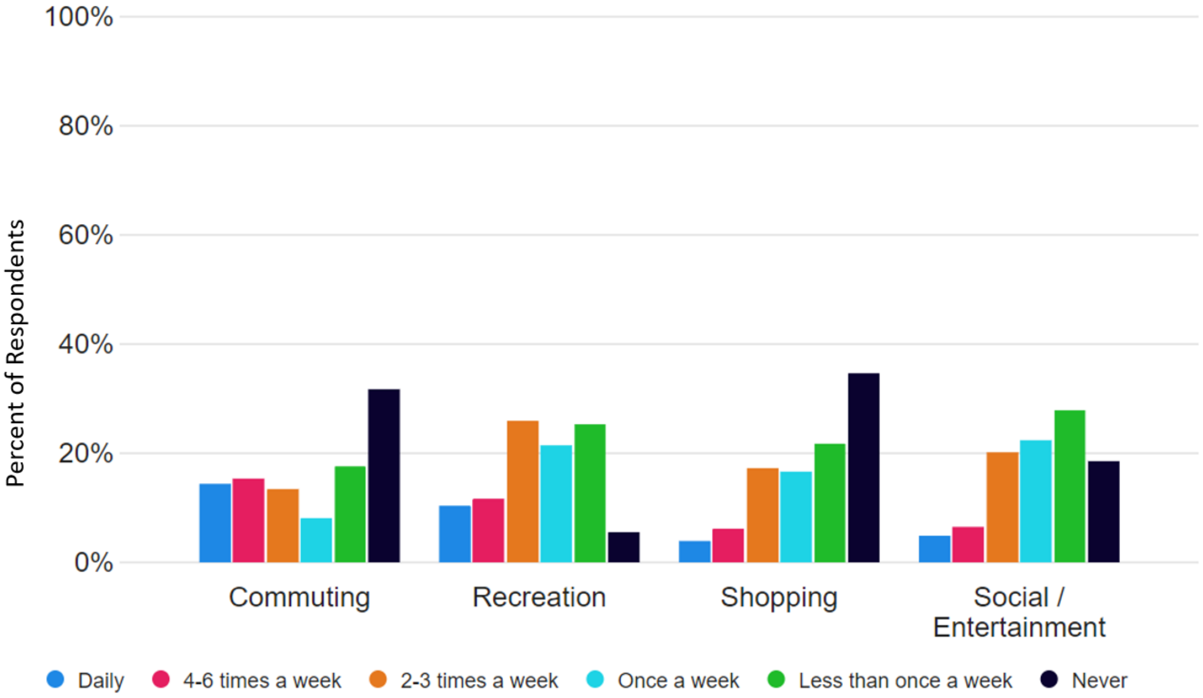


Figure 4-5 Micromobility trip purposes

Table 4-6 Chi-square test for comparing trip purposes for using micromobility

Compared Groups	**df**	**Pearson Chi-Square**	**P**
Commute vs. Shopping	25	136	p<0.001
Commute vs. Social	25	93	p<0.001
Recreation vs. Shopping	25	208	p<0.001
Recreation vs. Social	25	285	p<0.001

When the difference between living in urban or non-urban areas (self-reported) was analyzed, the correlation result indicated that people who lived in an urban area were more likely to use micromobility for recreational purposes than people who lived in non-urban areas ($r = 0.17$, $\rho = 0.01$). This was possibly related to the differences between lifestyle types in non-urban and urban area in the PNW. That is, people living in non-urban areas generally rely more on cars than on micromobility modes. However, as table 4-3 indicates, the variable of living in an urban area was not significant for any of the four trip purposes when other variables were kept constant. Combined with previous research questions, we found that living in an urban area did not significantly impact whether people used a micromobility mode, the usage frequency, or trip purposes.

Note that the availability of different kinds of micromobility in urban or non-urban areas may have affected the analysis. While the term “micromobility” in the survey include bikes, scooters, skateboards, etc., people living in rural areas may not have had access to e-scooters because limited service was provided; however, bicycles can be prevalent in some suburban areas where bicycle facilities are provided, such as the suburban areas around Portland, Oregon, and Seattle, Washington. Future studies may differentiate e-scooters and bicycles for trip purpose analysis specifically.

4.4. Research Question 4 (RQ4): How does public transportation availability impact micromobility use?

Fifty-one percent of respondents from the PNW reported that they had used public transit in 2020. Using public transit was significantly correlated with using micromobility ($r = 0.16$, $\rho < 0.01$). Within those respondents, we also asked the frequency of their public transit use before and after the SAH orders. Figure 4-6 shows that people used less public transit during the SAH orders, and the spike of the “Never” category indicates a 45 percent increase in people who never used public transit during that time.

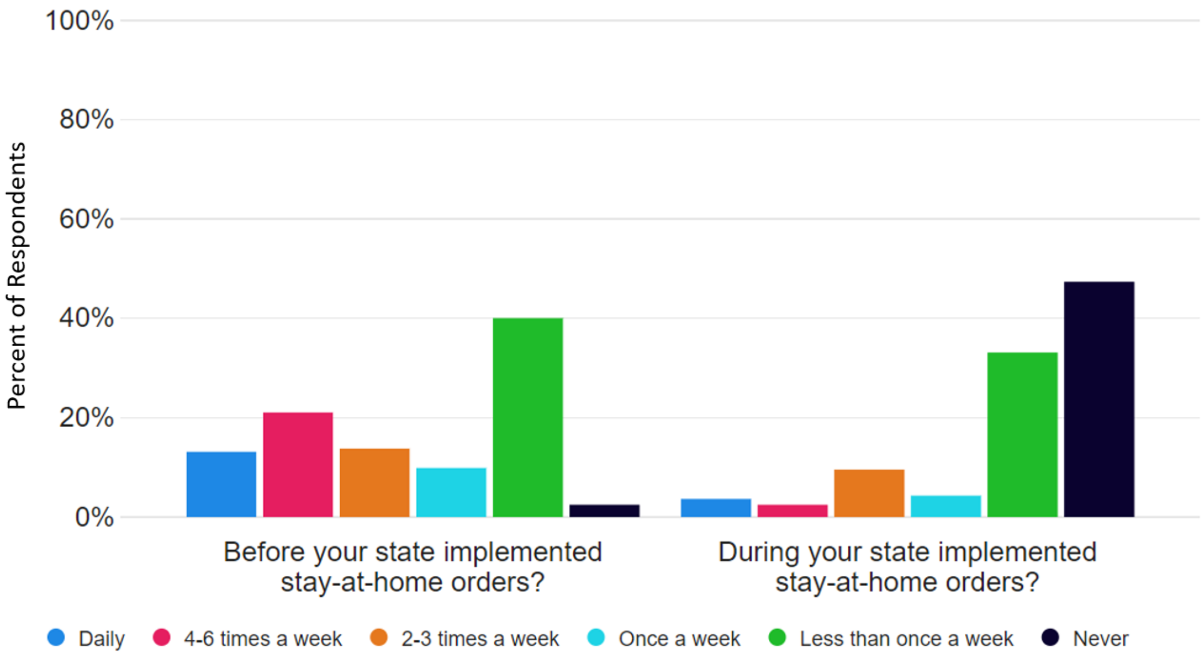


Figure 4-6 Public transit use frequency in 2020

When people were asked to rank the reasons for not using public transit, the top two reasons were “I am worried about COVID-19”and “Stops are too far away from origin or destination,” as shown in figure 4-7. In contrast, COVID-19 was not a critical reason given for not using micromobility. Indeed, riders have more interaction when riding public transit than when using a micromobility mode. Respondents also ranked the high cost as a top reason for not using micromobility, whereas that was not the case for not using public transit.

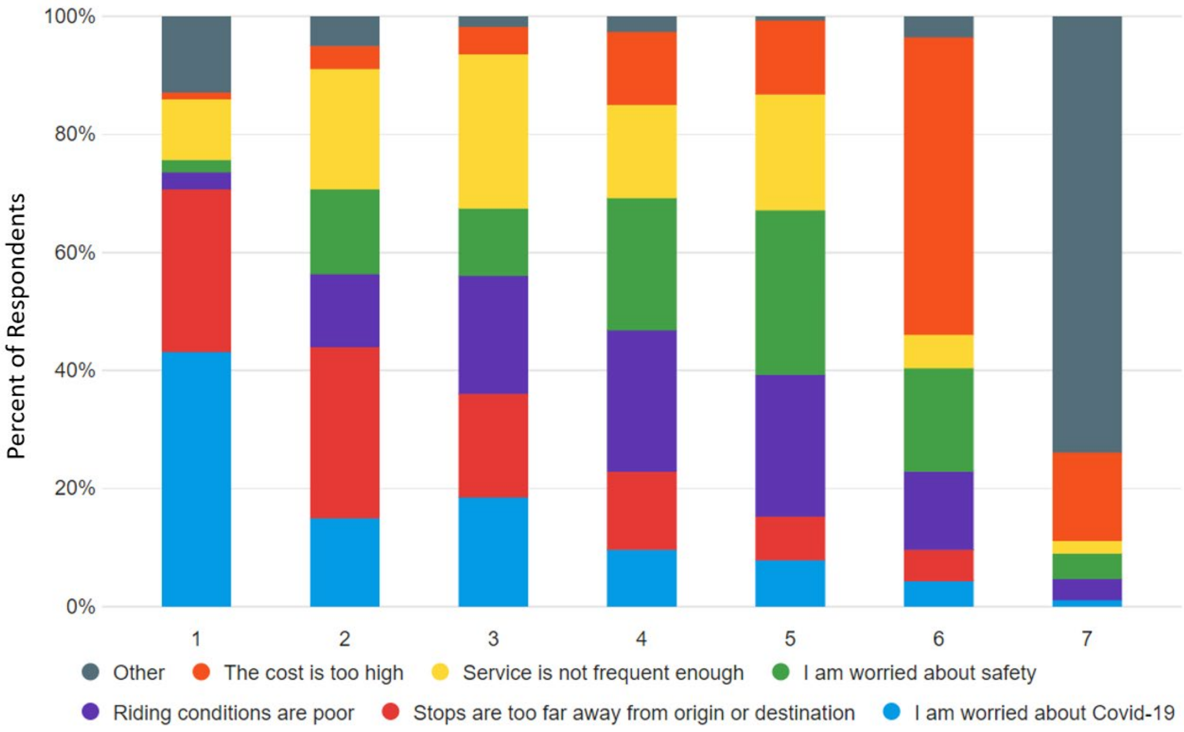


Figure 4-7 Reasons for not using public transit (1: highest rank, 7: lowest rank)

More than half of respondents reported that there were bus stops within 5 minutes' walking distance from their home (54 percent) or primary work or school (52 percent). On the other hand, only a small proportion of respondents reported that there were railway station stops within 5 minutes' walking distance from their home (5 percent) or primary work or school (10 percent). In general, the majority of respondents had access to public transit within walking distance; however, micromobility could potentially serve as a last- or first-mile mode (Shaheen & Cohen, 2019) for those whose walking time to a bus stop was 5 to 15 minutes (or even longer) away from home (28 percent) and from primary work or school (23 percent). Micromobility has not only the ability to cover this distance of travel, but it can also provide a shorter travel time than other modes (PBOT, 2018). While e-scooter users did not use e-scooters in conjunction with public transportation in Portland a couple of years ago, a recent spatial study found more e-scooter trips were generated around bus stops (Reck, et al., 2020).

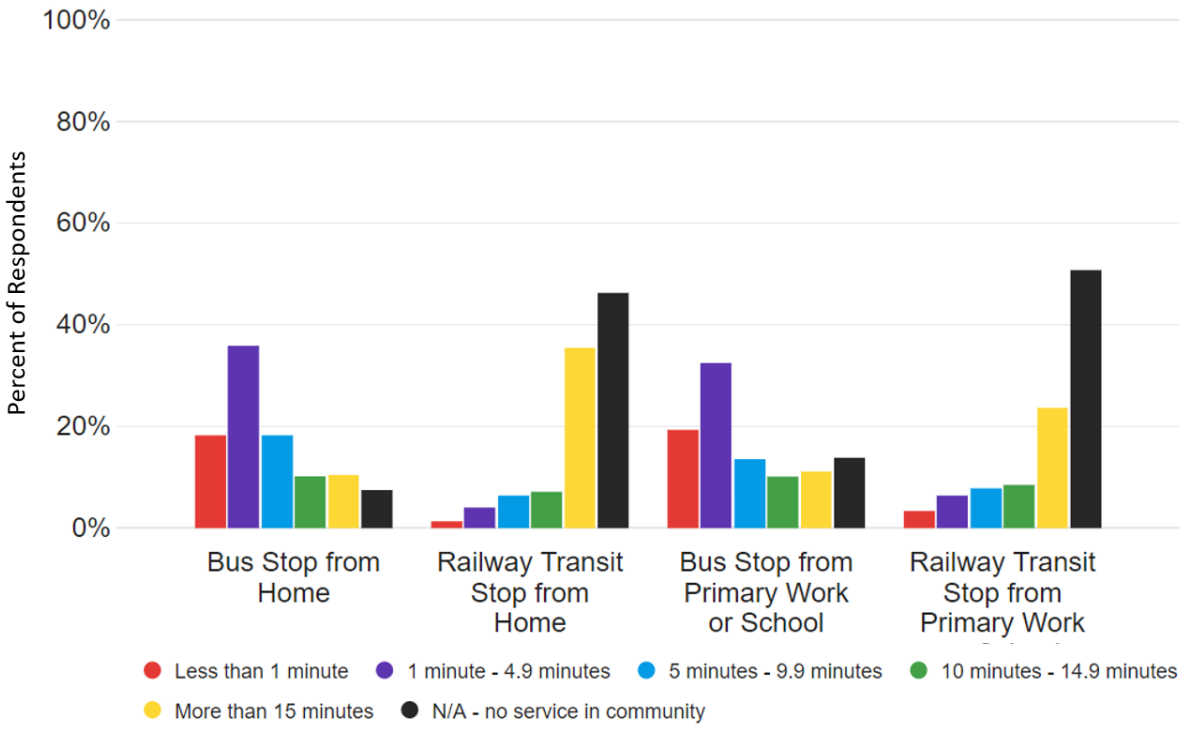


Figure 4-8. Walking time to the nearest transit stations

To answer the research question RQ4, “How does public transportation availability impact micromobility use,” we analyzed how transit availability correlated with the frequency of using micromobility. Table 4-7 shows that some people who used transit before SAH orders still used the mode during the orders ($r = 0.43$, $\rho < 0.01$), and this finding was similar for use of micromobility ($r = 0.64$, $\rho < 0.01$). This finding indicates transportation mode stickiness, regardless of the COVID-19 pandemic. In the U.S., the majority of transit trips were taken by lower-income populations (Di Baldassarre, et al., 2015), as shown in table 4-8, and they were likely to own no personal vehicle, which means that they could not switch transportation mode even during the pandemic. “Low-income population” (poor) is defined on the basis of the 1995 poverty threshold defined by the U.S. Census Bureau. “Low income” is based on the Department of Housing and Urban Development’s (HUD) definition of low income.

Table 4-7 Correlation results between transit availability and frequency of micromobility use

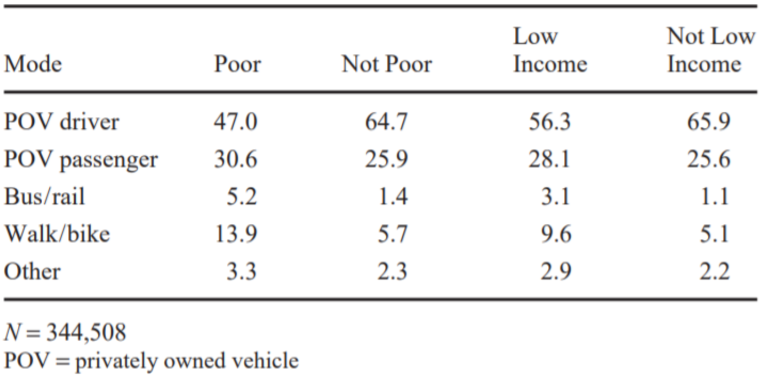
Variable	Transit_often_be	Transit_often_af	Micro_often_be	Micro_often_af	Transit_available
Transit_often_be	1				
Transit_often_af	.43**	1			
Micro_often_be	0.02	0.03	1		
Micro_often_af	0.08	0.04	.64**	1	
Transit_available	0.08	.09*	0.01	0.02	1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

("Transit_available" = 1: bus/railway station within 5 minutes walking distance; = 0: otherwise)

Table 4-8 Income versus mode share in U.S. from National Household Transportation Survey (Di Baldassarre, et al., 2015)



Mode	Poor	Not Poor	Low Income	Not Low Income
POV driver	47.0	64.7	56.3	65.9
POV passenger	30.6	25.9	28.1	25.6
Bus/rail	5.2	1.4	3.1	1.1
Walk/bike	13.9	5.7	9.6	5.1
Other	3.3	2.3	2.9	2.2

N = 344,508
POV = privately owned vehicle

The result that public transit availability did not correlate with the frequency of using micromobility (before SAH $r = 0.01$, $\rho > 0.05$; during SAH $r = 0.02$, $\rho > 0.05$) indicates that the public transit system had no obvious impact on how often micromobility was used. However, using public transit was significantly correlated with use of micromobility in 2020 ($r = 0.12$, $\rho = 0.01$), but not in the regression analysis.

4.5. Research Question 5 (RQ5): How have stay-at-home orders impacted the ride characteristics (ride frequency, trip purpose) of micromobility users in the PNW?

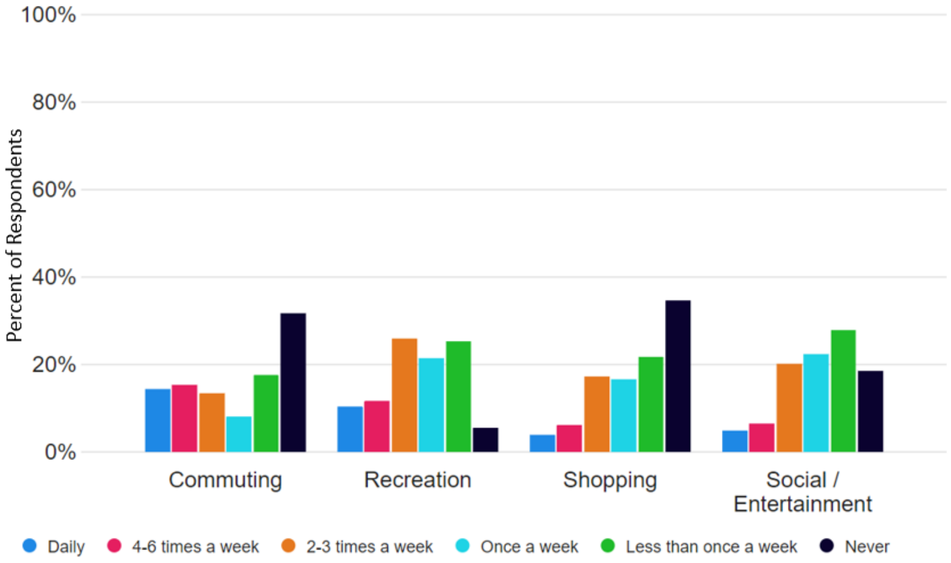
Regarding the impact of SAH orders, respondents who had used micromobility in 2020 reported a significant decrease in usage frequency during the orders (before M = 3.17, during M = 3.64, $t_{288} = -5.55$, $\rho < 0.01$). The use frequency was a proxy established by a Likert scale (1 = daily, 2 = 4-6 times a week, 3 = 2-3 time a week, 4 = once a week; 5 = never). That means a scale of 1-5 did not reflect the exact trip number per week; however, it could be a proxy to measure overall micromobility use frequency. Furthermore, the questionnaire was designed to measure the average mode usage for a long period, so the 1-5 scale may have been a more reasonable measure than asking for exact trip frequency per week because of potential inaccuracy caused by memory decay. There was a significant difference between the distribution of the general usage frequency before and during the implementation of SAH orders (χ^2 (25) = 158, ρ < 0.01), shown in table 4-9.

Table 4-9 χ^2 test for micromobility use frequency before and during stay-at-home orders

Variable	**df**	**Pearson Chi-Square**	**P**
General use frequency	25	158	p<0.001
Commute use frequency	25	143	p<0.001
Recreation use frequency	25	219	p<0.001
Shopping use frequency	25	316	p<0.001
Social use frequency	25	237	p<0.001

Figure 4-9 shows trip purposes and changes in each purpose for using micromobility in the four states in the PNW. A significant decrease existed in each purpose category, shown in table 4-10. The most differences were a 54 percent decrease in recreation trips (before M = 2.4, after M = 1.1, t600 = -6.6, p < 0.01) and a 48 percent decrease in commuting trips (before M = 2.1, after M = 1.1, t600 = -6.6, p < 0.01) on a 1-5 scale during the implementation of SAH orders. In contrast, the decreases in trip frequencies for shopping (before M = 1.5, after M = 1.2, decrease = 20%, ρ < 0.01) and social/entertainment (before M = 1.8, after M = 1.2, decrease = 33%, ρ < 0.01) were relatively smaller than those of the other two categories. A hypothesis is that most people who drove for shopping trips still used personal vehicles for this purpose during the COVID-19 period because of fewer COVID-19 safety concerns of using a personal vehicle, whereas people who biked to shopping could have been carless or of lower income, so they may not have had the option to switch modes. The Chi-square test showed significant differences in the distributions of all four trip purpose categories before and during SAH orders, as shown in table 4-10.

(a) Before the Stay-at-Home order



(b) After the Stay-at-Home order

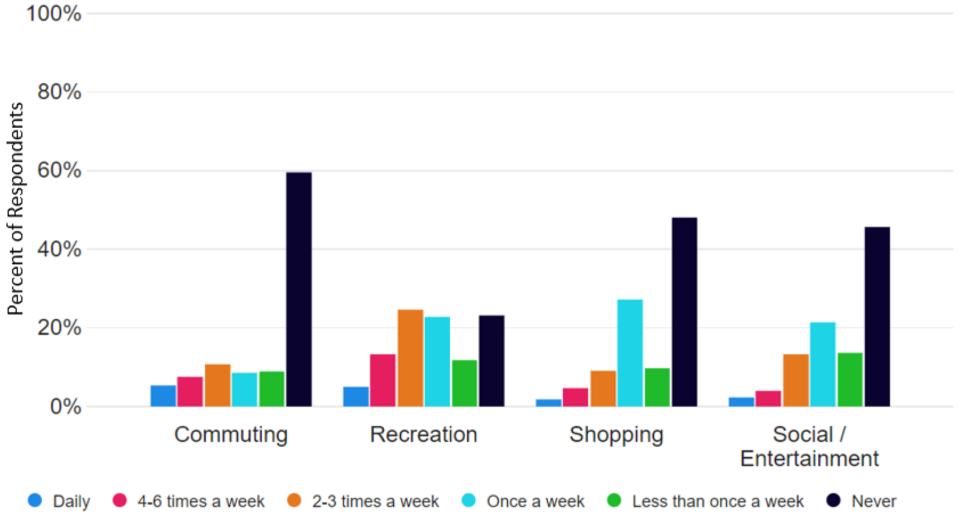


Figure 4-9 Micromobility ride purposes before (a) and after (b) stay-at-home orders

Table 4-10 Differences in trip purposes before and during stay-at-home orders

	Commuting	Recreation	Shopping	Social/Entertainment
Before	2.1	2.4	1.5	1.8
During	1.1	1.1	1.2	1.2
Difference	-48%	-54%	-20%	-33%
p-value for Paired sample t-test	<0.01***	<0.01***	<0.01***	<0.01***

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

The rapid adoption of shared micromobility modes in recent years has created unique challenges for transportation planners and policymakers. Research is needed to understand how people use a novel mode of transportation, and how this mode impacts transportation and mobility. Previous micromobility studies have focused on large urban areas, while very few studies have explored medium-sized urban areas, rural areas, and college campuses. This knowledge gap is especially prevalent for studies examining the Pacific Northwest. To address knowledge gaps, this study used a survey to answer the following research questions:

- What are the ride characteristics of micromobility users in the PNW?
- What are the barriers to micromobility adoption from a user perspective in the PNW?
- Do geographic areas and trip purposes have an impact on user mode choice?
- How does public transportation availability impact micromobility use?
- How have stay-at-home orders impacted the ride characteristics of micromobility users in the PNW?

This survey was developed in Qualtrics and was distributed to four states (Alaska, Washington, Oregon, and Idaho) in the PNW through social media platforms between September and December 2020. The questionnaire was returned by 699 respondents, and 527 respondents fully completed the survey.

Based on the 527 samples from the four PNW states, we found that more than half of the respondents had used micromobility in 2020, and more than of those who had used micromobility used it at least two to three times a week. This indicates that micromobility has been an important mode share in daily life for people living in the PNW. Consistent with previous studies, this study found that using micromobility was significantly positively associated with having a higher education degree, being employed, and the perception that using micromobility can benefit environmental and social issues. It was found to be significantly negatively associated with increasing age, identifying as female, and having a disability. Within those variables, age and gender were also significantly correlated with micromobility usage frequency. The data also showed that perception of micromobility's benefits, gender, and age were stable and significant variables that affected micromobility use for different trip purposes (commuting, recreational, shopping, and social). However, younger people tended to use it more for occasional purposes (recreational, shopping, and social), whereas older respondents used it more for commuting.

We also found that respondents who used micromobility in 2020 used the mode for commuting purposes and recreational purposes more than for shopping and social purposes. Respondents who lived in urban areas tended to use micromobility for recreational trips more frequently than people who lived in non-urban areas. By comparing the ride characteristics between before and during COVID-19-related stay-at-home orders, this study found a significant decrease in usage frequency after the orders were implemented in terms of four ride purpose categories (commuting, recreational, shopping, and social). A greater decrease occurred for commuting and recreational purposes than for shopping and social purposes.

This study also found that the top three reasons for not using micromobility were a lack of access, a lack of ability or skills, and concerns about safety. However, cost seemed not to be a concern for people living in the PNW. Those who did not already use micromobility said they intended to use micromobility in the future if those issues were resolved. We found that those potential users, accounting for 27 percent of all respondents, would use micromobility 0.89 times per day after issues had been resolved. Local authorities could consider this to be evidence of a potentially significant mode shift to support policy making or engineering design to benefit those active transportation modes. Consistent with current micromobility users, those potential users would use micromobility modes for commuting and recreational purpose more than for shopping and social purposes.

Whether people used public transit was correlated with whether they used micromobility in the PNW, but not with usage frequency. Combined with the finding that transit use was not a significant variable in the regression analysis with micromobility use, we concluded that there was a weak correlation between transit use and micromobility use, but not a causal relationship. This was in line with findings from previous studies that e-scooters do not replace trips made by public transit (PBOT, 2018).

In a comparison between before and during the stay-at-home orders, the reported decrease in public transit use was greater than the decrease in micromobility use. The difference seems plausible, as respondents ranked, “I am worried about COVID-19” as the first reason they did not use public transit, whereas respondents reported that COVID-19 was not a great concern when using micromobility. This study also found that people who used public transit and micromobility before the pandemic still used the two modes during the pandemic, respectively. Given that public transit users are mainly from lower-income population, they may not have had the option to switch modes to cope with the pandemic. As the reason, “Stops are too far away from the origin or destination” was one of two top reasons for not using public transit, city planners and micromobility agencies could consider using micromobility to solve first- and last-mile issues for public transit. As most car-based trips in the U.S. are 3 miles or less and take place in urban areas (FHWA, 2017), using micromobility could significantly contribute to reducing traffic congestion and emissions.

One limitation of this study was that the term “micromobility” in the questionnaire included several modes, such as bikes, scooters, skateboards, etc., but people living in rural areas may not have had access to e-scooters because of limited service. Future studies may differentiate the use of e-scooters and bicycles for trip purpose analysis specifically. Furthermore, this study was conducted through an actual and hypothetical survey, so memory decay and the difference between intended and actual behavior may have affected the accuracy of the findings. Future research may also use other methods to account for those biases. While we discovered a social-psychological pattern from the data indicating that whether respondents chose micromobility was affected by psychological variables (such as perceptions of the benefits of using micromobility), and psychological variables are impacted by respondents’ characteristics, this pattern was not clearly supported by the data set nor in previous research. Future studies may set the hypothesis and test whether this pattern appears in other transportation mode choices. Another limitation of this study involved using revealed preference and stated preference surveys. The majority of the questions in our survey asked about people’s actual behavior, which may have be less accurate because of memory decay. However, the time that people received the survey was close to the period of stay-at-home orders, so the time impact was limited. In addition, some may argue that intention questions may not fully capture actual behaviors; however, intention questions (such as, How often would you use lightweight transportation for the following purposes after the issues you mentioned were resolved?) have been found to be positively correlated with actual behavior by previous research (Lindell, 2017; Chen, et al., 2021).

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APPENDIX A – CORRELATION MATRIX

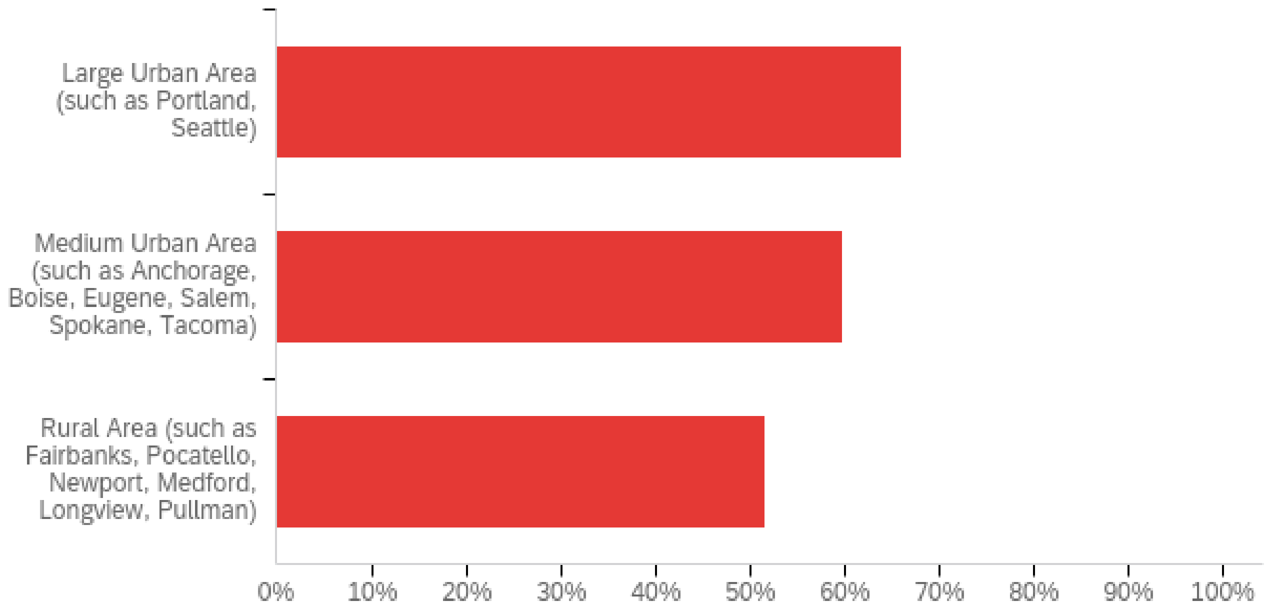
Table A-1 Correlation Matrix

	Micro	Micro_Δ	Com_Δ	Rec_Δ	Sh_Δ	So_Δ	Com_du	Rec_du	Shop_du	Soc_du	Com_be	Rec_be	Shop_be	Soc_be	Ride_pa	Access	Skill	Covid	Safety	Infras	Cost	Use_so	Transit	Tran_be
Micro	1																							
Micro_Δ	.a	1																						
Com_Δ	.a	.35**	1																					
Rec_Δ	.a	.22**	.43**	1																				
Sh_Δ	.a	.20**	.53**	.56**	1																			
So_Δ	.a	.19**	.41**	.61**	.58**	1																		
Com_du	.a	-.27**	.42**	.27**	.32**	.28**	1																	
Rec_du	.a	-.31**	.28**	.60**	.38**	.40**	.40**	1																
Shop_du	.a	-.06	.36**	.48**	.70**	.45**	.43**	.56**	1															
Soc_du	.a	-.22**	.19**	.42**	.28**	.59**	.33**	.63**	.47**	1														
Com_be	.a	.57**	.64**	.20**	.25**	.17**	-.44**	-.06	-.02	-.09	1													
Rec_be	.a	.59**	.14*	.39**	.17**	.19**	-.18**	-.50**	-.13*	-.28**	.29**	1												
Shop_be	.a	.34**	.26**	.16**	.47**	.21**	-.1	-.18**	-.30**	-.20**	.35**	.39**	1											
Soc_be	.a	.45**	.23**	.20**	.32**	.45**	-.06	-.26**	-.02	-.46**	.28**	.52**	.45**	1										
Ride_pa	.a	-.09	-.06	.05	.04	.08	.08	.06	.01	.12*	-.13*	-.02	.04	-.05	1									
Access	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	1								
Skill	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	-.19**	1							
Covid	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	-.51**	-.09	1						
Safety	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	0	-.32**	-.14*	1					
Infras	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	-.06	-.16*	-.24**	-.21**	1				
Cost	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	-.30**	-.17**	-.07	-.12	.01	1			
Use_so	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.03	-.19**	-.02	.09	.03	-.05	1		
Transit	.15**	.02	-.04	.03	-.07	-.02	-.1	.03	-.07	.01	.04	.01	-.01	-.03	.03	-.05	.06	.15*	-.11	.01	-.01	.11	1	
Tran_be	.03	-.15*	.03	-.11	-.1	-.09	.13	.05	-.01	.03	-.08	-.18*	-.11	-.14	-.11	-.08	.02	.13	.01	-.05	-.02	-.23*	.a	1
Tran_du	.08	-.08	.12	.19*	.18*	.22**	.34**	.21**	.21**	.23**	-.18*	-.03	-.01	-.01	.14	.02	.01	.06	.02	-.13	-.21*	-.16	.a	.36**
Com_d	-.04	-.01	.12*	.01	.07	.09	.01	0	.1	.05	.12*	.01	-.03	.04	-.01	.02	-.03	-.04	.07	-.02	.02	.04	-.01	0
Com_t	.02	-.08	.01	0	-.03	.05	-.03	-.03	-.01	0	.04	.03	-.02	.05	0	-.06	0	-.02	.06	-.02	.03	.09	.14**	-.24**
Be_Cong	.20**	.06	-.14*	-.1	-.17**	-.16**	-.18**	-.13*	-.08	-.11	.01	.05	-.13*	-.06	0	.01	-.06	-.06	.11	-.13	-.02	.12	.04	.05
Be_Em	.02	.06	-.11	-.02	-.03	.01	-.14*	-.06	.03	0	.01	.05	-.08	0	.02	.08	-.09	-.03	.09	-.06	-.03	.18**	.02	0
Be_Noise	.10*	.02	-.09	-.04	-.04	-.06	-.14*	-.07	0	-.05	.02	.03	-.06	-.01	-.02	.12	-.12	-.05	.12	0	-.06	.23**	.04	.03
Be_tran	.08	-.09	-.17**	-.06	-.13*	-.09	-.12*	-.11	-.07	-.06	-.07	.06	-.09	-.04	-.02	-.01	-.08	-.12	.07	.05	-.01	.18**	.08	-.08
Be_equ	.12**	.03	-.18**	-.07	-.13*	-.1	-.1	-.13*	-.03	-.06	-.1	.08	-.13*	-.04	.01	.09	-.12	-.06	-.02	.02	.01	.20**	-.01	-.09
Be_Health	.12**	-.06	-.18**	-.12*	-.15*	-.16**	-.08	-.16**	-.03	-.07	-.11	.04	-.17**	-.11	.17**	.09	-.08	-.04	-.07	.06	-.05	.34**	.06	-.02
Be_inj	.06	.11	-.11	-.04	-.12*	-.13*	-.18**	-.12	-.09	-.09	.04	.09	-.05	-.04	0	.11	-.02	-.08	-.01	.04	-.14*	.15*	-.05	-.09
Be_cost	.12**	.04	-.19**	-.12*	-.15*	-.15**	-.17**	-.17**	-.13*	-.16**	-.05	.07	-.03	.01	.03	.07	-.09	-.02	.14*	-.15*	-.02	.12	0	.03
Be_inf	.17**	-.03	-.22**	-.07	-.13*	-.14*	-.16**	-.08	-.04	-.09	-.08	.01	-.11	-.05	.03	.09	-.03	-.05	0	-.01	-.1	.17**	.04	.11
Age	-.19**	-.08	-.01	-.20**	-.20**	-.11	-.01	-.13*	-.23**	-.14*	0	-.07	.02	.04	.01	-.01	.03	.16*	0	-.11	-.13	-.24**	-.13**	.22**
Degree	.08	-.11	0	.06	.1	.08	.16**	0	.05	.01	-.14*	.06	.06	.08	.12*	-.02	-.14*	.08	.06	.09	.01	-.11	-.03	.07
Income	.08	.05	.11	.1	.15**	.1	.13*	.02	.06	-.01	0	.08	.13*	.12*	.13*	-.23**	0	.16*	.03	-.11	.11	-.12	-.04	.01
Female	-.21**	-.1	.12*	.17**	.17**	.11	.20**	.15*	.20**	.16**	-.05	.01	-.02	-.06	-.07	0	.11	.06	0	-.14*	-.08	-.09	-.11*	.05
Kid	-.02	.12	.12	.16	.16	.21*	.07	-.04	.06	.05	.06	.24**	.14	.18*	-.12	-.04	-.05	-.05	.11	-.14	.20*	-.19*	-.17**	.1
Senior	-.09	-.04	.04	-.11	.04	.09	.04	-.07	.03	.07	0	-.04	.02	.02	-.01	-.05	.08	.11	-.03	-.09	.03	-.26**	-.16**	.15
Ho_size	-.01	.07	.06	-.05	.13*	.05	.01	-.07	.13*	.04	.05	.03	0	.01	-.08	-.09	-.14*	.03	.01	.03	.03	.01	-.12**	.06
Disability	-.16**	.04	.16**	0	0	-.04	0	.05	-.05	-.03	.16**	-.05	.05	-.01	-.01	.01	.18**	-.11	-.05	-.04	.05	-.02	-.04	.07
Married	0	.02	.03	.1	.14*	.13*	.07	.05	.11	.05	-.03	.04	.06	.09	.08	-.05	.02	.01	.08	-.15*	.06	-.06	-.21**	.1
Employed	.15**	.01	-.03	.08	.09	.04	-.03	-.01	.04	-.01	-.01	.11	.07	.05	.04	.01	-.26**	.12	.11	.07	.05	.09	.12**	-.03
White	-.04	-.02	-.04	-.01	-.01	.01	.01	.04	.05	.01	-.05	-.06	-.07	-.01	-.02	-.07	.09	.08	.08	-.09	-.06	-.15*	-.08	.13*
Urban	.10*	.08	-.09	.04	-.09	-.01	-.13*	-.11	-.12*	-.08	.02	.17**	.02	.08	.07	-.09	-.04	-.04	-.18**	.18**	.13*	-.06	.30**	-.18**

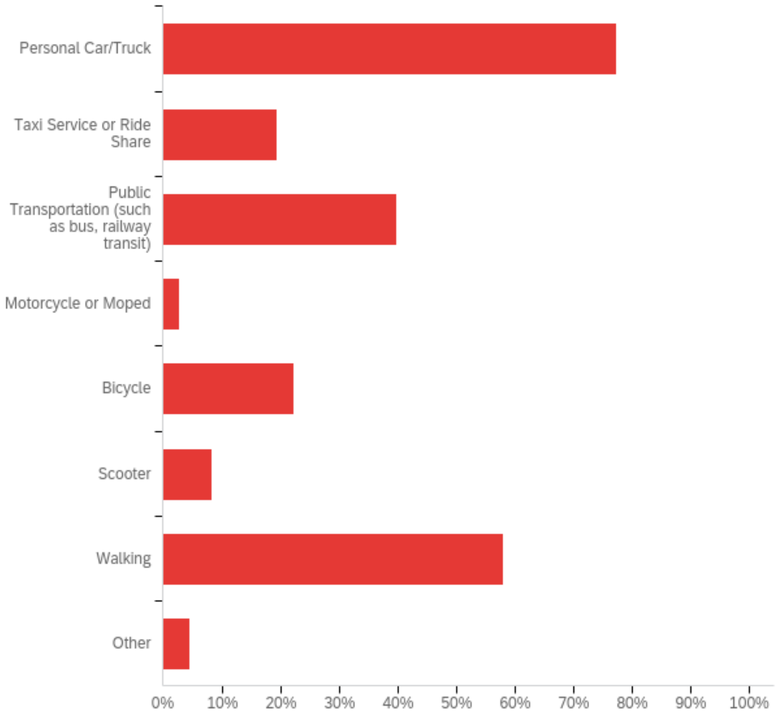
	Tran_du	Com_d	Com_t	Be_Cong	Be_Em	Be_Noise	Be_tran	Be_equ	Be_Health	Be_inj	Be_cost	Be_inf	Age	Degree	Income	Female	Kid	Senior	Ho_size	Disability	Married	Employed	White	Urban
Tran_du	1																							
Com_d	.04	1																						
Com_t	-.09	**.70****	1																					
Be_Cong	.04	-.05	0	1																				
Be_Em	0	0	-.01	.49**	1																			
Be_Noise	-.01	-.01	0	.45**	.66**	1																		
Be_tran	-.02	-.07	.02	.33**	.24**	.31**	1																	
Be_equ	.03	-.02	.03	.35**	.34**	.33**	.38**	1																
Be_Health	.03	.02	.04	.36**	.31**	.36**	.27**	.44**	1															
Be_inj	-.04	.07	.09*	.27**	.19**	.22**	.20**	.26**	.28**	1														
Be_cost	.04	-.02	.03	.28**	.28**	.33**	.23**	.39**	.38**	.31**	1													
Be_inf	0	.02	.05	.43**	.27**	.29**	.26**	.34**	.40**	.44**	.44**	1												
Age	.05	0	-.04	-.11*	-.06	-.06	-.15**	-.03	-.01	-.03	.05	-.06	1											
Degree	.18**	-.07	-.07	-.01	.01	.01	-.05	-.04	.06	-.02	.02	-.04	.15**	1										
Income	.1	.08	.03	.05	.09*	.04	.06	-.06	.03	-.09*	.06	-.04	-.02	.26**	1									
Female	.13*	.01	-.01	-.07	.01	.03	-.08	0	0	-.01	-.06	-.05	0	.10*	-.03	1								
Kid	.1	-.04	-.09	.04	.01	-.03	-.12	0	-.03	-.13*	-.06	-.12*	-.12	-.04	.14*	.14*	1							
Senior	.18*	.05	.03	-.11	-.11*	-.11*	-.19**	-.01	-.06	-.11	.01	-.15**	.60**	.09	.09	.03	.13*	1						
Ho_size	.09	.12**	.05	.09*	.03	0	-.01	.05	.05	.02	.02	.02	-.18**	-.10*	.08	-.01	.45**	.09	1					
Disability	-.01	0	-.06	-.07	-.11*	-.07	-.14**	-.15**	-.08	-.05	-.03	-.05	.18**	-.16**	-.20**	-.02	-.1	.06	0	1				
Married	.12*	.04	0	-.04	.02	-.03	-.07	-.07	.01	0	.11*	-.06	.24**	.21**	.41**	.02	.25**	.32**	.14**	-.04	1			
Employed	-.06	.12**	.08	.01	.01	.11*	.06	0	.01	-.03	-.04	.03	-.27**	.16**	.24**	.07	.05	-.32**	.01	-.18**	-.02	1		
White	.02	-.06	-.03	.05	.05	.06	-.01	.04	0	-.01	.04	-.02	.25**	.02	.06	-.02	0	.08	-.14**	-.01	.11*	-.02	1	
Urban	-.15*	-.17**	.04	.07	0	.01	.17**	.05	.01	.03	-.05	.06	-.05	.09*	0	-.06	-.09	-.09	-.08	-.11*	-.09*	.09*	-.01	1
** Correlation is significant at the .01 level (2-tailed).																								
* Correlation is significant at the .05 level (2-tailed).																								
a Cannot be computed because at least one of the variables is constant.																								

APPENDIX B – SURVEY RESULTS

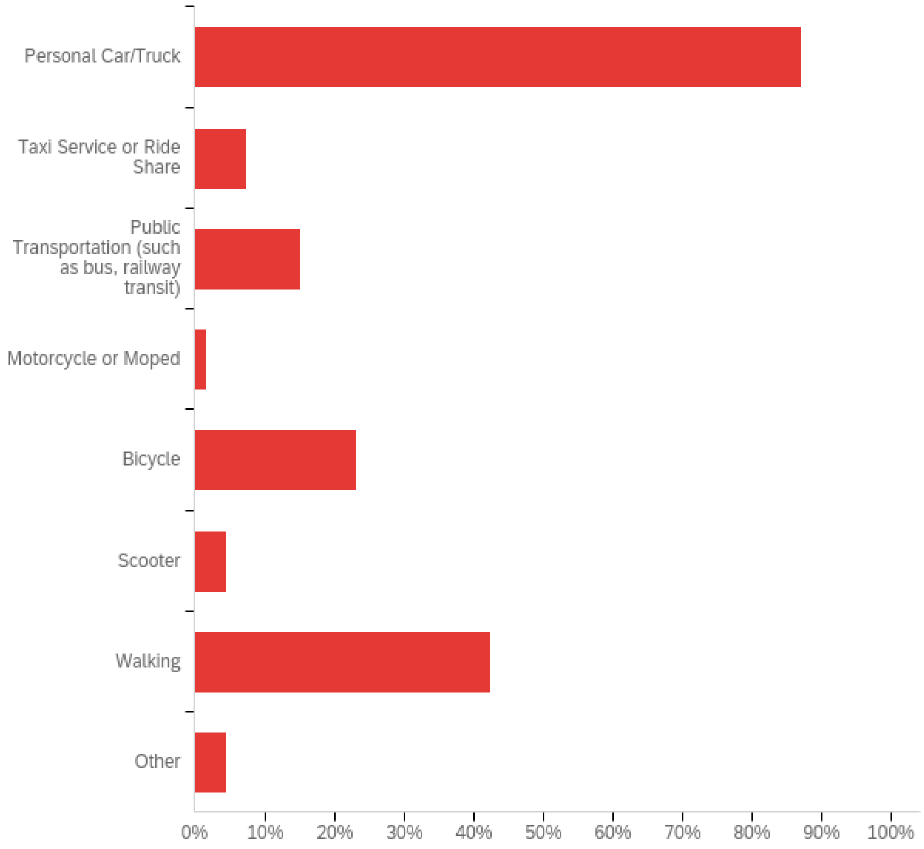
Q2.1 - Q: Please select all of the area types you have traveled to in 2020. (check all that apply)



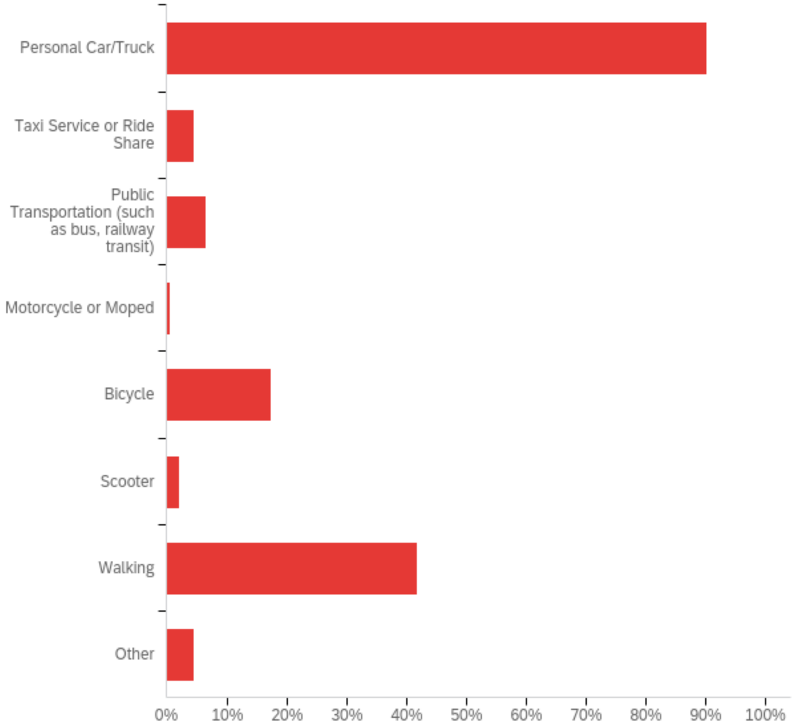
Q2.2 - Q: What mode(s) did you use the last time you traveled in a large urban area (such as Portland, Seattle)? (check all that apply)



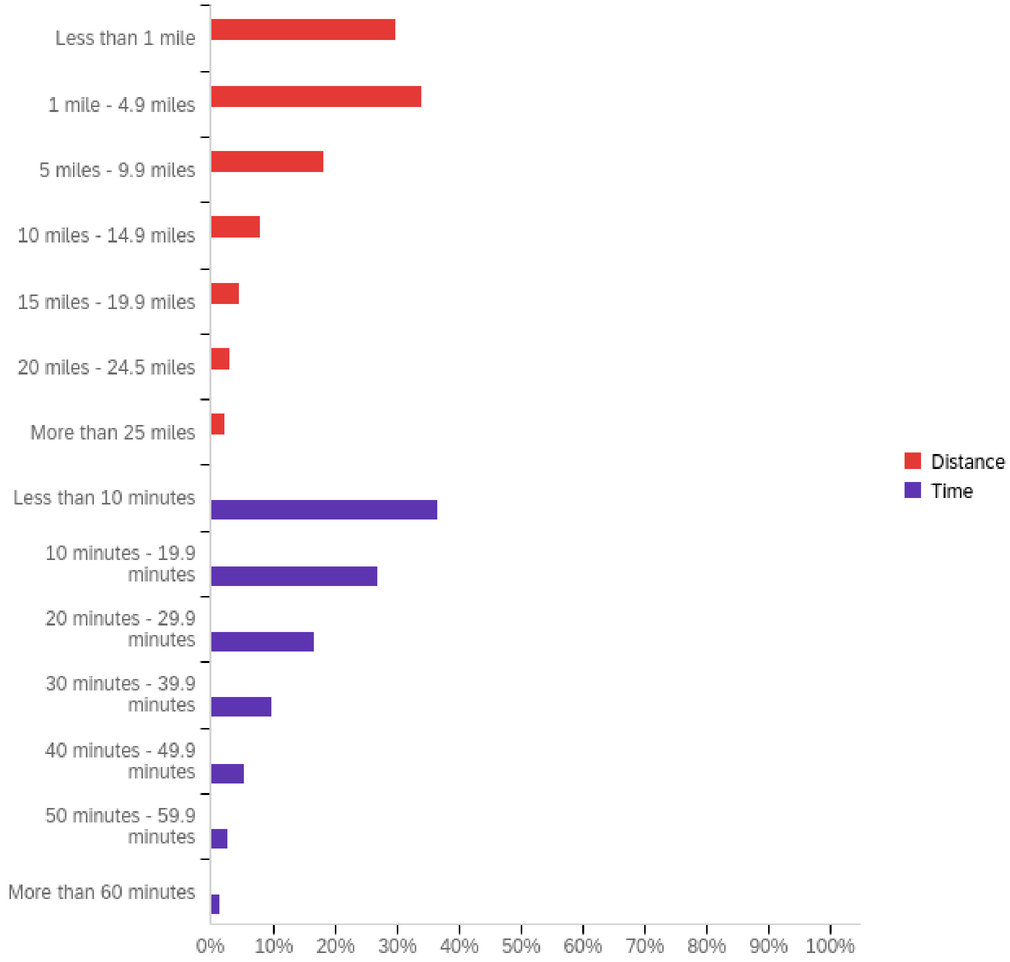
Q2.3 - Q: What mode(s) did you use the last time you traveled in a medium urban area (such as Anchorage, Boise, Eugene, Salem, Spokane, Tacoma)? (check all that apply)



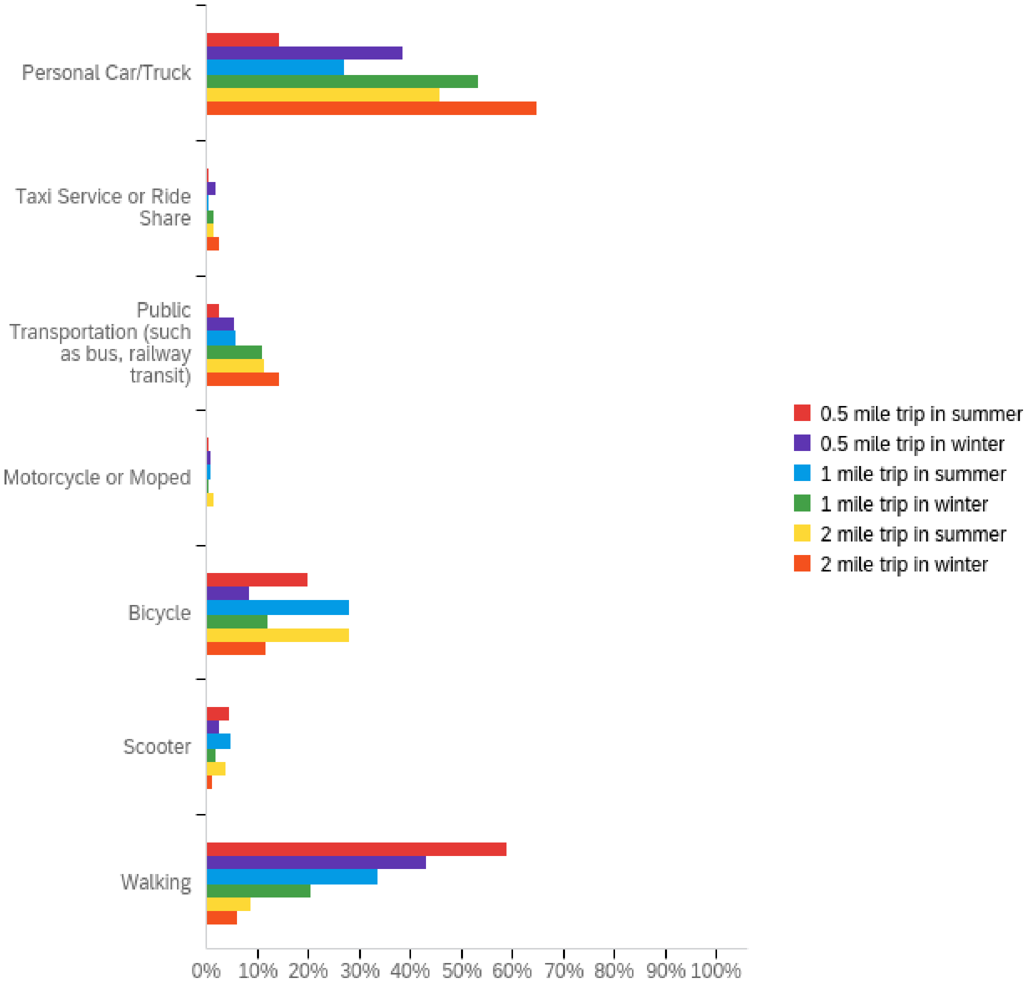
Q2.4 - Q: What mode(s) did you use the last time you traveled in a rural area (such as Fairbanks, Pocatello, Newport, Medford, Longview, Pullman)? (check all that apply)



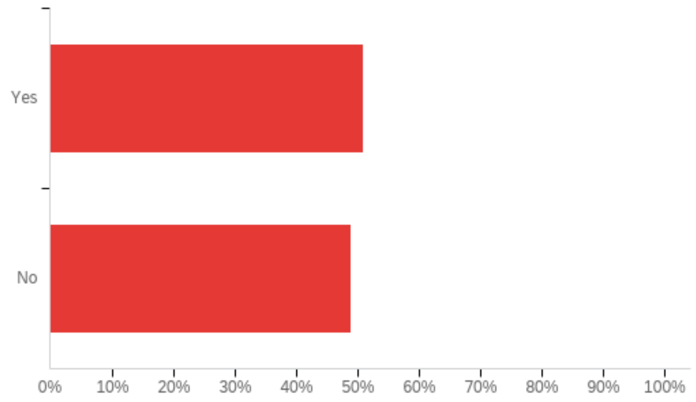
Q2.5 - Q: Approximately how long is your commute to your primary work or school (or other daily routine places) from home?



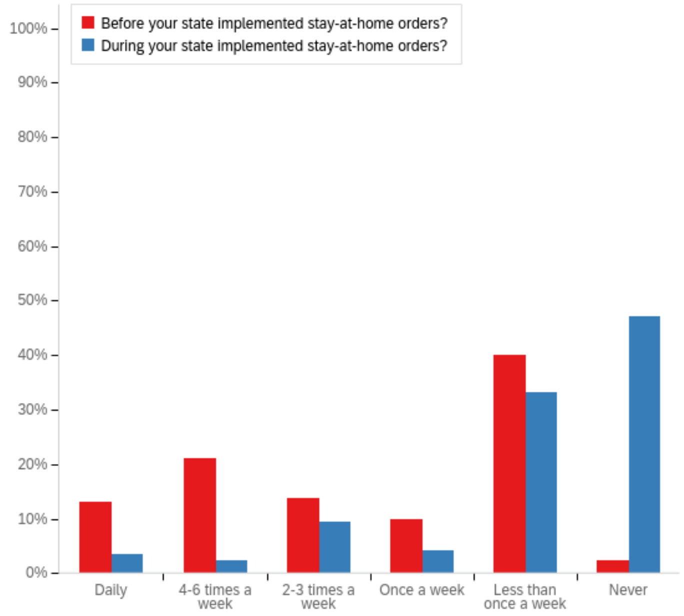
Q2.7 - Q: Please select one mode which you are most likely to use for each of the following scenarios:



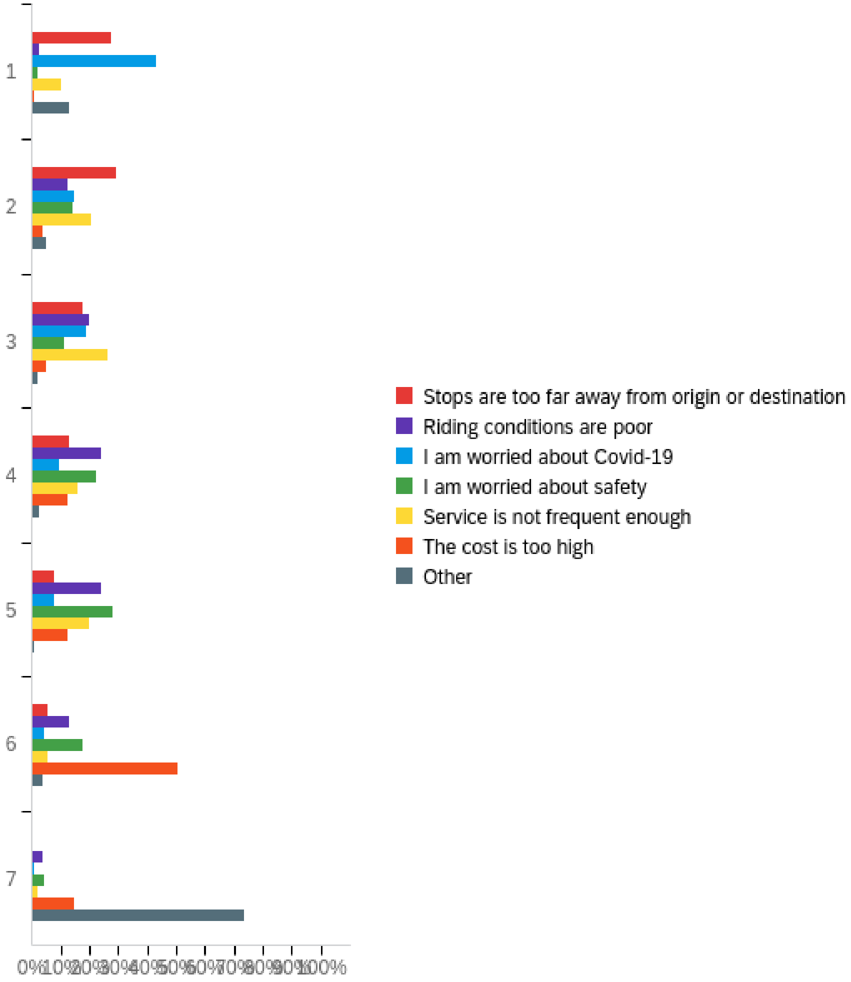
Q3.1 - Q: Have you used public transportation (such as bus, railway transit) in 2020?



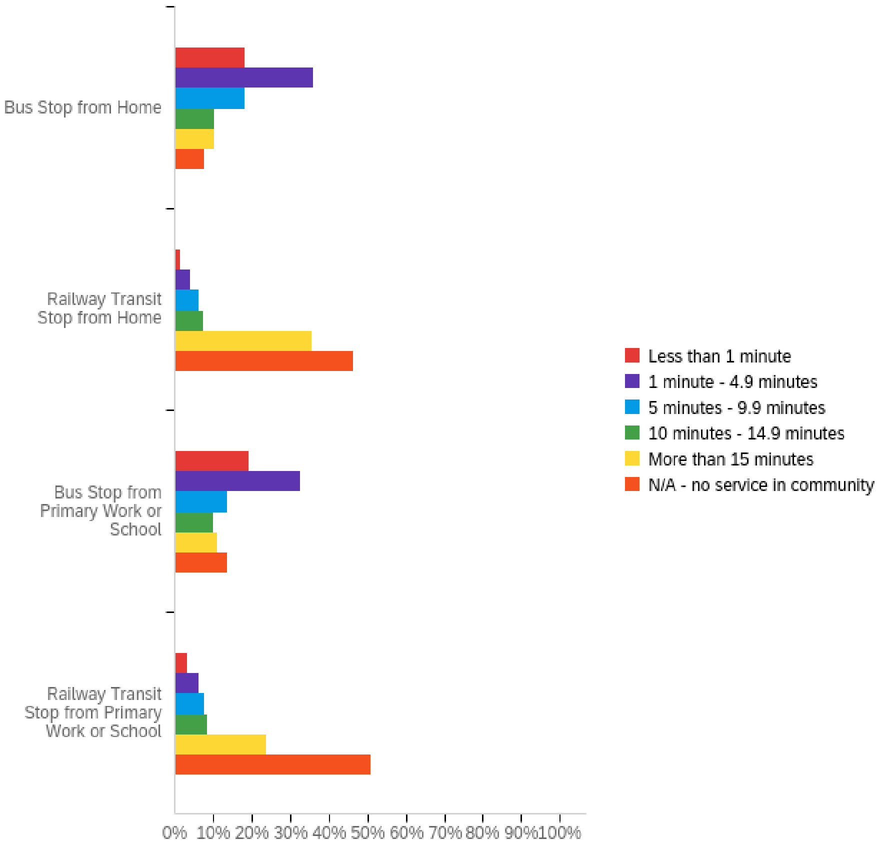
Q3.2 - Q: In 2020, how often have you used public transportation (such as bus, railway transit):



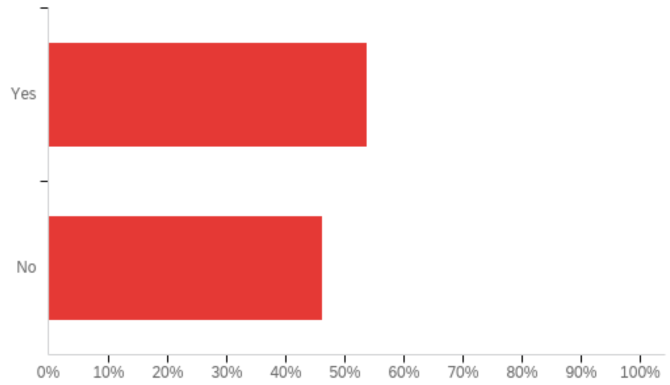
Q3.3 - Q: Please rank the reasons you have not used public transportation (such as bus, railway transit) in 2020: (drag options to rank)



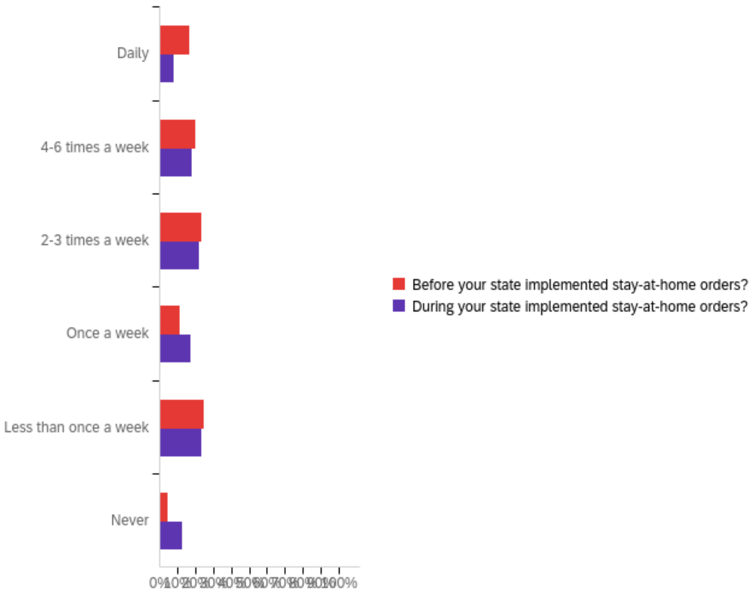
Q3.4 - Q: How many minutes would it take you to walk to the nearest:



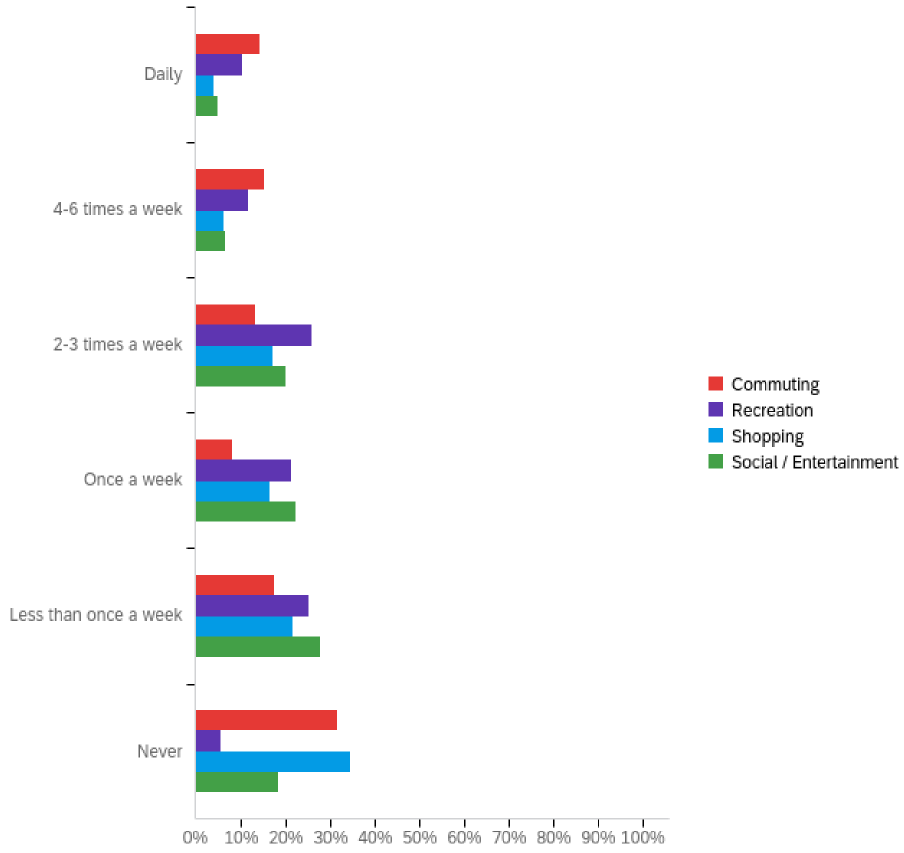
Q4.2 - Q: Have you used lightweight transportation in 2020?



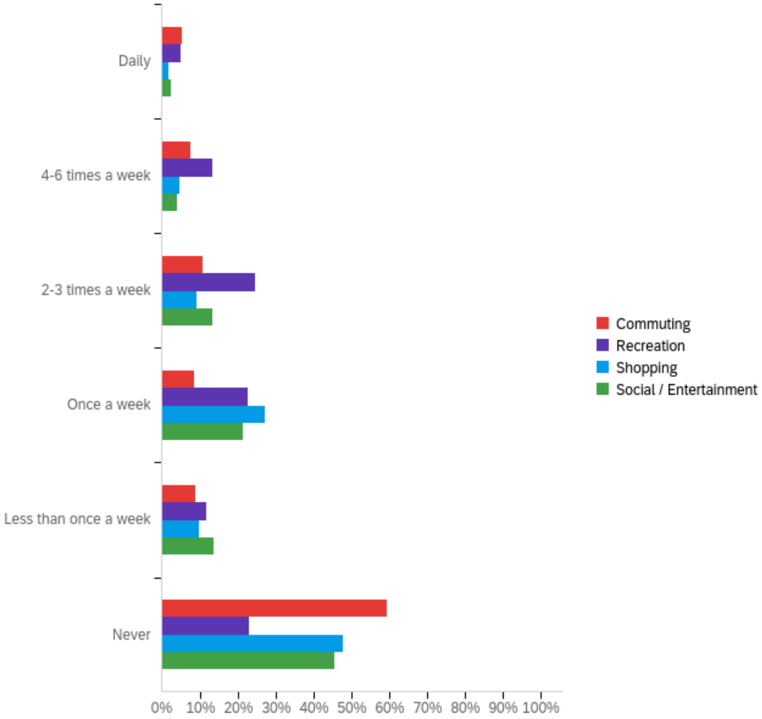
Q4.3 - Q: How often did you use light-weight transportation:



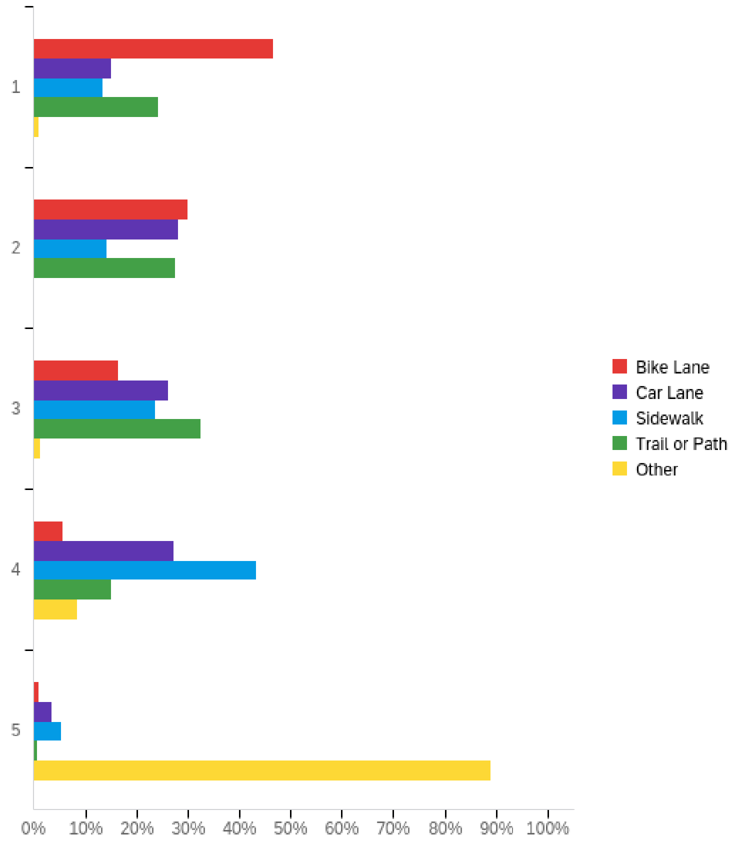
Q4.4 - Q: How often did you to use lightweight transportation for the following purposes before your state implemented stay-at-home orders?



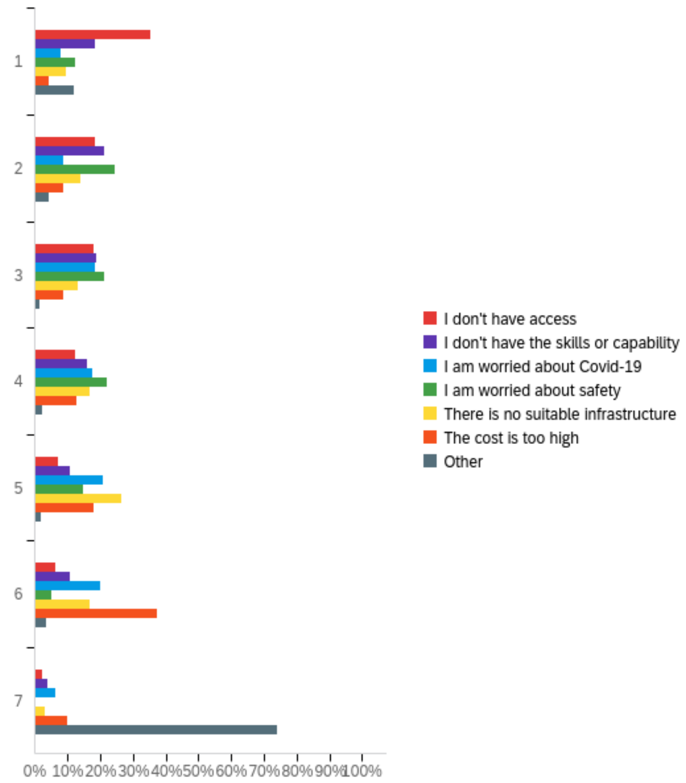
Q4.5 - Q: How often did you to use lightweight transportation for the following purposes during the stay-at-home orders was implemented ?



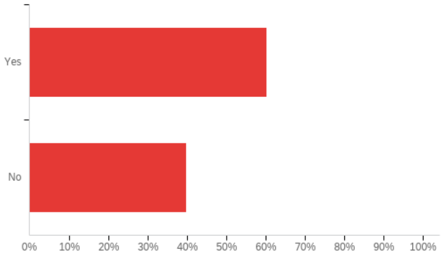
Q4.6 - Q: Please rank where you typically ride lightweight transportation: (drag options to rank)



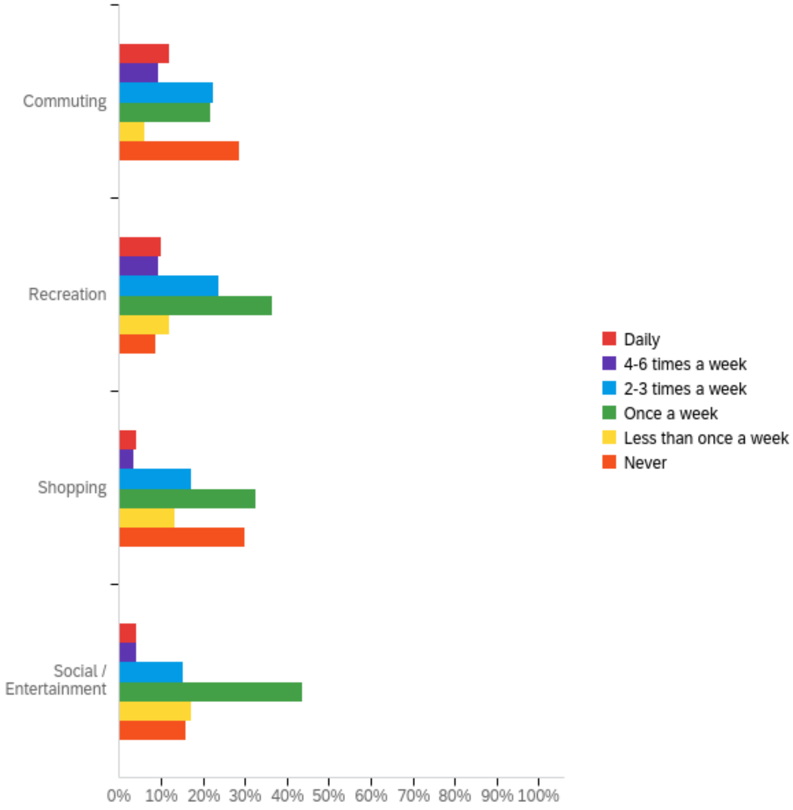
Q4.7 - Q: Please rank the reasons you have not used lightweight transportation in 2020: (drag options to rank)



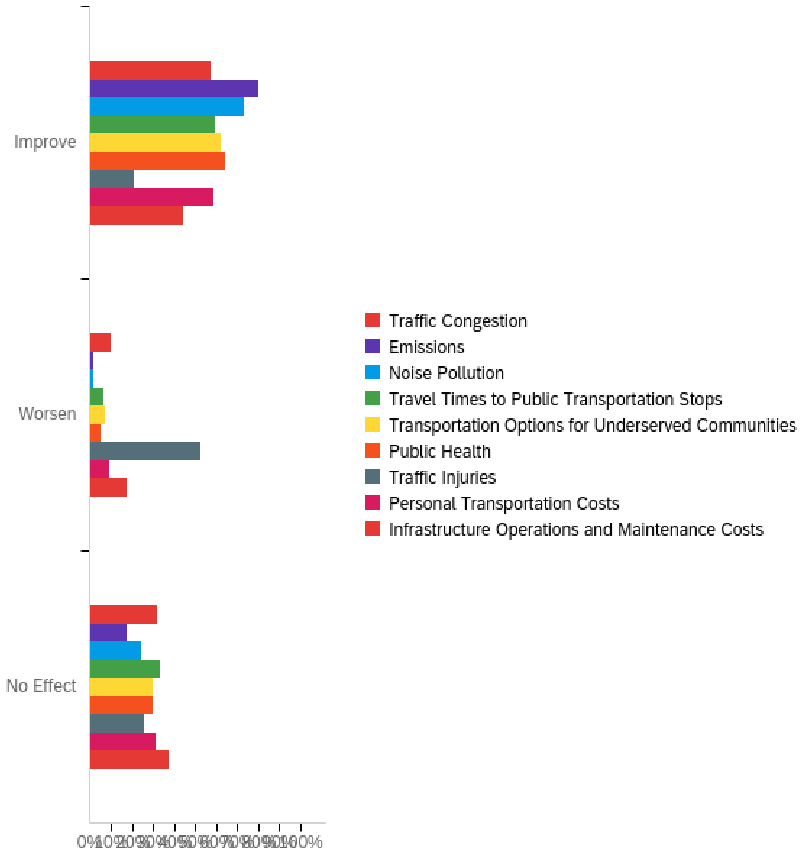
Q4.8 - Q: Would you use lightweight transportation if the issues you select in last question are solved?



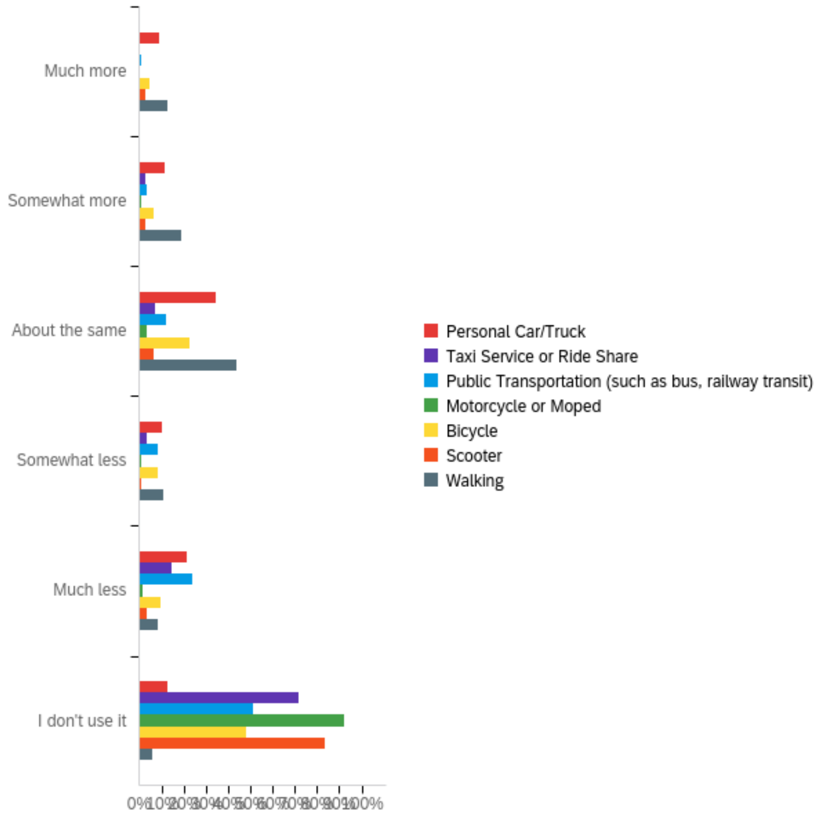
Q4.9 - Q: How often would you to use lightweight transportation for the following purposes after the issues you mentioned are solved?



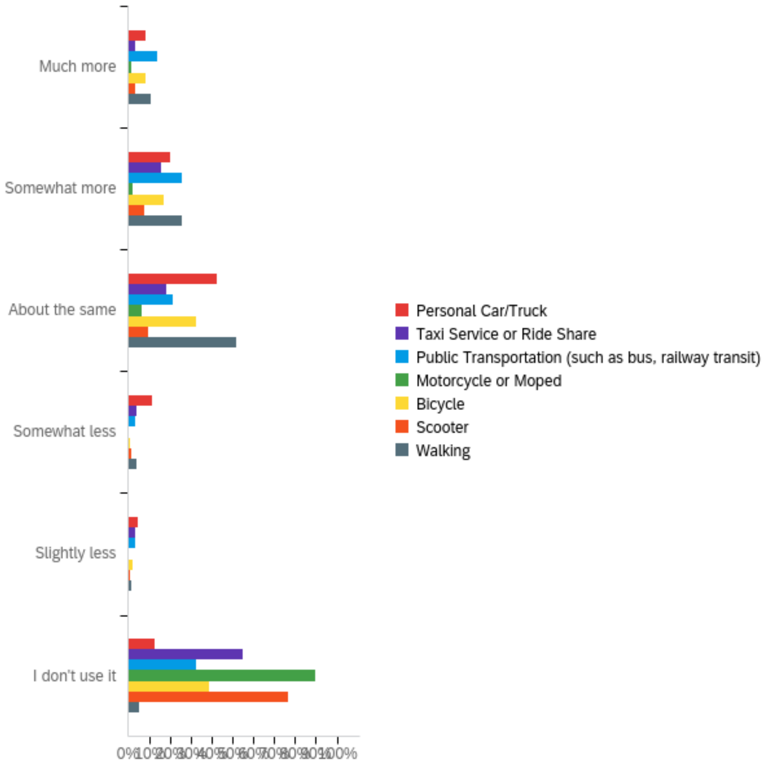
Q41 - Q: Do you think lightweight programs (such as bikeshare, scootershare) will improve or worsen:



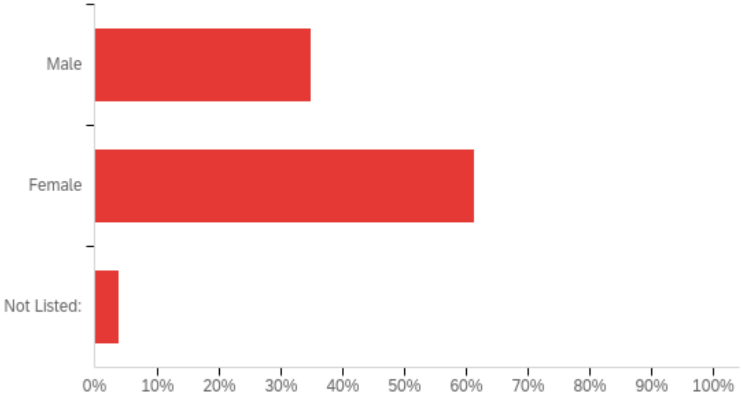
Q4.11 - Q: Think about the last two weeks, did you use more/less of the following transportation modes than when the stay-at-home order was implemented?



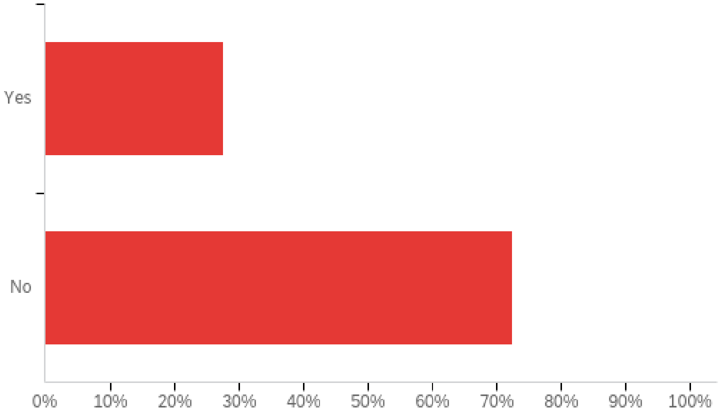
Q40 - Q: Do you anticipate that you use more/less of the following transportation modes after the social-distancing order is lifted in the future?



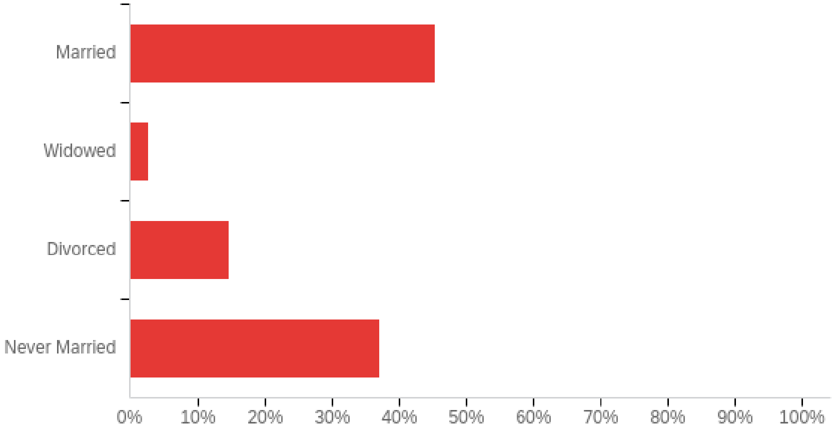
Q5.2 - To which gender do you most identify with?



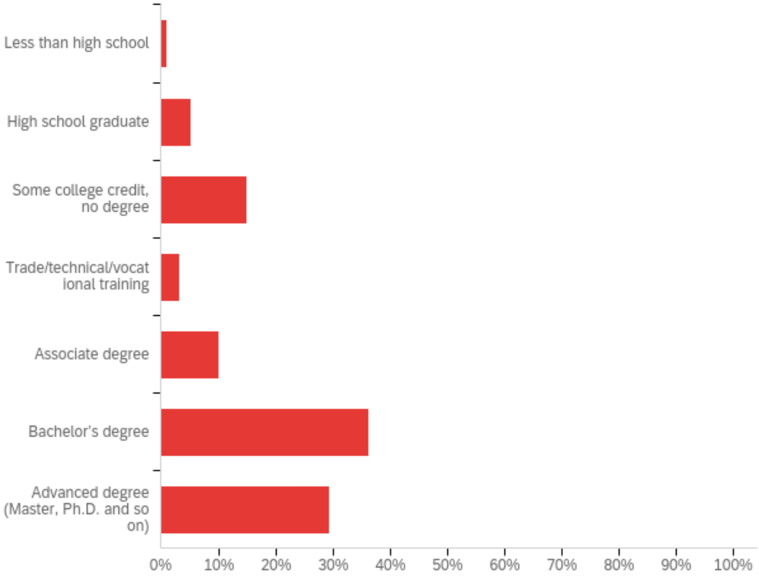
5.4 - Do you or any members in your household have difficulty moving because of a physical disability?



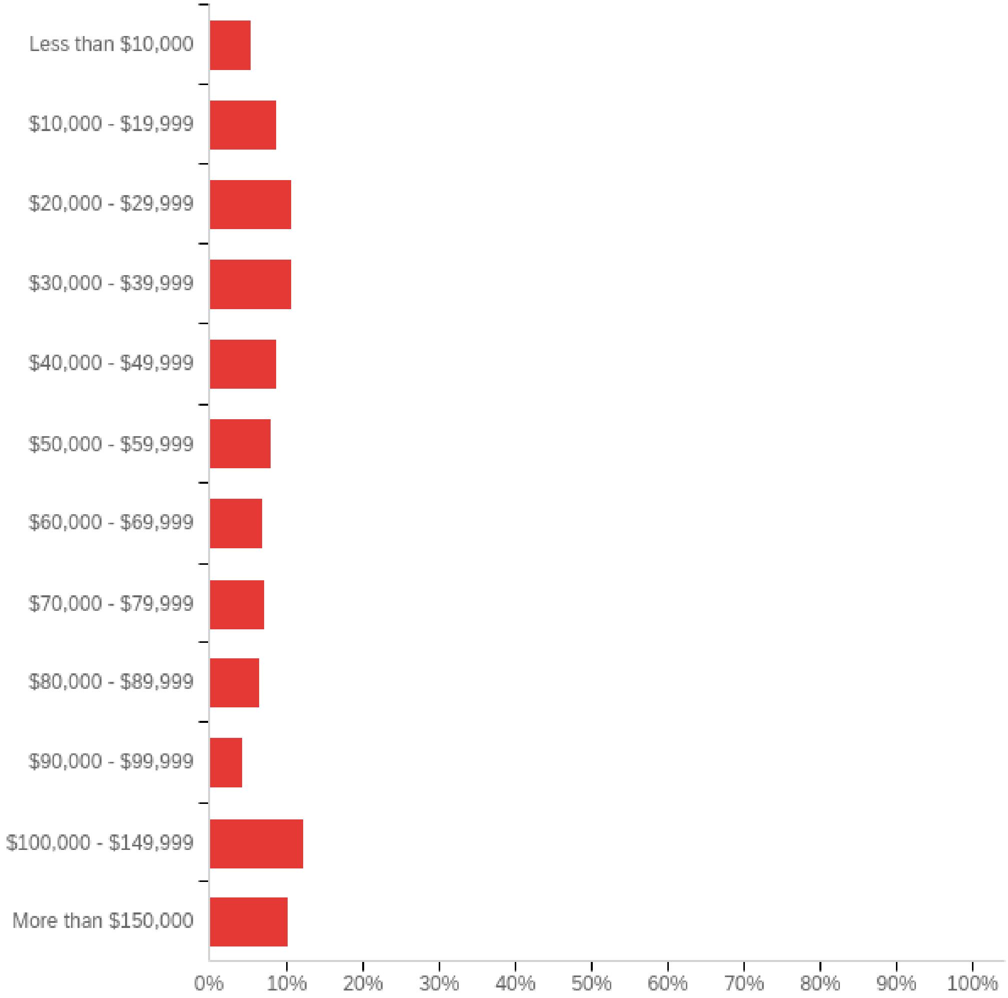
Q5.5 - What is your marital status?



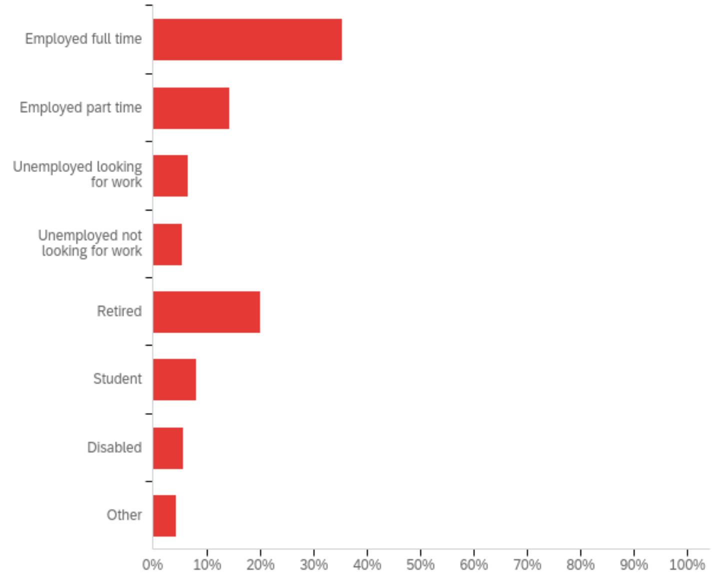
Q5.6 - What is the highest degree you have completed?



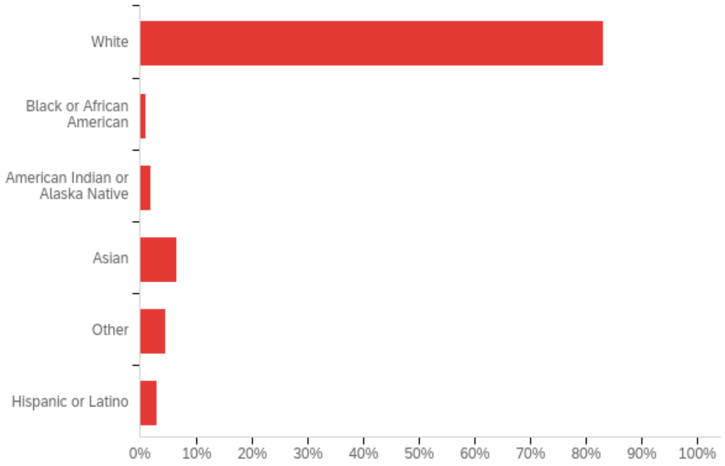
Q5.7 - What is your annual household income before taxes?



Q5.8 - What is your employment status?



Q5.9 - How would you describe your ethnicity?



Q5.10 - How would you describe the area in which your primary residence is located?