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To scoot or not to scoot: Findings from a recent survey about the benefits and barriers of using E-scooters for riders and non-riders

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ABSTRACT

E-scooters are rapidly changing transportation in US cities and university campuses. Hailed as a convenient, inexpensive solution for "last mile" and other short trips, e-scooters are available in over 100 US cities and were used for nearly forty million trips in 2018. Yet relatively little is known about e-scooter use, including who uses them, for which types of trips, and the perceived benefits and barriers related to e-scooters. This information is particularly important in light of concerns about safety and the loss of physical activity (PA) due to replacing walking and biking with e-scooting.

In this paper, we aim to characterize trends in the barriers and benefits related to e-scooter use within a professional population. We surveyed 1,256 university staff in Tempe, AZ, finding that 36% of respondents had ridden e-scooters and 40% indicated that they would do so outside of campus in the next year. Overwhelmingly, e-scooters are seen as a convenient way to travel, particularly in the heat and compared to walking. However, demographic differences were notable, particularly regarding barriers. African American and non-white Hispanic respondents were significantly more likely than non-Hispanic white respondents to intend to try e-scooters and to be unhappy with current transportation options. E-scooters are also associated with concerns about traffic safety – particularly for women – and barriers related to being able to find working equipment when needed. These findings suggest that e-scooters fill an important transportation niche and may contribute to transportation equity, and that efforts to address barriers could further enhance that contribution.

1. Introduction

Dockless electric scooters (e-scooters) are a relatively new transportation option rapidly changing travel in US cities and on university campuses. Hailed as a convenient, inexpensive solution for "last mile" (i.e., to/from transit) and other short trips, e-scooters are available in over 100 US cities and were used for nearly forty million trips in 2018 (NACTO, 2019; Sandt & Harmon, 2019). A recent representative survey of ten cities found that e-scooters had achieved an adoption rate nearly equal to that of ride-hailing – i.e., much faster than past forms of shared mobility (Populus, 2018).

Academic research on trends in e-scooter use in North America is limited, but a few cities have conducted surveys as part of evaluating e-scooter pilot programs, finding that e-scooters are generally popular or seen as providing a valuable service, even among non-users (Portland Bureau of Transportation [PBOT], 2019; Denver Public Works [DPW], 2018; City of Austin, 2019; Baltimore

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DOT, 2019). For example, Portland, OR, found that over 30% of the population (in a representative sample) had tried e-scooters, with 9% riding them at least a few times per week (PBOT, 2019). A separate user survey (N = 3,444) from Portland found that 37% of e-scooter users rode them at least once per week (PBOT, 2018). An online snowball survey used to evaluate an e-scooter pilot program in Denver, CO, found that 46% of the 2,084 respondents had ridden e-scooters (DPW, 2018). In Austin, 38% of respondents to their community survey (N = 9,299) had ridden e-scooters, with 20% of people using them regularly or occasionally (City of Austin, 2019).

City reports also examined how e-scooters are used and where they are ridden. Over 70% of Portlanders who had ridden an e-scooter reported that they most frequently used them for transportation, rather than recreation (PBOT, 2019), and they ride them for reasons of speed and reliability, fun, cost, and convenience. The Portland data also revealed that men are more likely to use e-scooters for work-related trips (22% of men compared to 15% of women), whereas women were more likely to list their top trip type as "fun/recreation" (Dill, 2019). In Denver, 32% of respondents reported using e-scooters to get to/from work (the top trip type), followed by 20% using them to get to/from entertainment (DPW, 2018). A Lime user survey found that e-scooters get people to their destination 22% faster than traditional bikes, likely a factor in their popularity (Lime, 2018).

Less is known about how e-scooter use relates to sociodemographic characteristics, although surveys suggest unequal adoption. Data from Denver and Portland indicate approximate gender splits of 70/30 and 64/34, respectively, between males and females (DPW, 2018; Dill, 2019). Data on e-scooter user age skews younger, with 69% of respondents to Portland's user survey aged 20–39 and nearly half of survey respondents who had ridden e-scooters in Denver aged 25–39 (PBOT, 2018; DPW, 2018).

These evaluations reflect an initial understanding of e-scooter programs in a handful of cities, but additional exploration about e-scooter use is clearly needed to help cities and universities, health practitioners, and e-scooter companies better understand the impacts of e-scooters on individuals, sociodemographic groups, and communities. In particular, practitioners need to better understand who is using e-scooters for what purposes in different areas, what barriers and benefits are associated with e-scooter use, and how use and perceptions of barriers and benefits are associated with sociodemographic characteristics.

In this paper we aim to characterize trends in the barriers and benefits related to e-scooter use with evidence from a survey of university staff in a different geography (Arizona). The survey explored trends in e-scooter use, including frequency of use, trip type, and mode replacement, as well as the barriers and benefits related to e-scooting among current e-scooter users and non-users according to race/ethnicity, gender, age, and household income. The findings presented in this paper focus on e-scooter usage (trip types, how e-scooter usage has changed respondents' travel patterns, and future use), benefits and barriers associated with e-scooter use, and if and how each of those areas differ by sociodemographics and frequency of use.

These findings contribute to a foundation for future research and e-scooter monitoring. Additionally, they provide insights into e-scooter use and related benefits and barriers that can help cities and universities, health practitioners, and e-scooter companies better understand the challenges (e.g., disproportionate replacement of walking trips) and benefits (e.g., clear filling of an urban transportation niche for certain groups) of e-scooter use on individuals, sociodemographic groups, and communities in order to better plan for and accommodate e-scooters on/near university campuses and in urban areas.

2. Data & methods

2.1. Background

The survey was conducted among Arizona State University (ASU) staff in Tempe, Arizona. Staff were targeted because of the timing of the survey (late spring, near finals) and because they represent a range of income and education levels and work year-round, making them less likely than faculty or students to leave Tempe for extended periods of time (which could influence the survey results). ASU's campus is multi-modal and allows walking, bicycling, skateboarding, and other small modes throughout most of campus, but prohibits non-university motorized vehicles (including e-scooters). Additionally, while parking lots surround the campus, cars are not generally allowed on or throughout campus. As such, the responses herein should be viewed as reflecting e-scooter riding in Tempe and the surrounding areas, and not necessarily e-scooter riding on campus. ASU staff live throughout the Phoenix region, several cities of which allow e-scooters. Additionally, while e-scooting occurred on campus when e-scooters were first introduced to Tempe, despite university policy prohibiting their use, e-scooters were eventually banned from campus and removed or prohibited via geo-fencing. This survey was conducted *after* e-scooters were actively prohibited.

At the time of the survey, several hundred e-scooters were available to rent throughout the City of Tempe and surrounding areas. The cost of an e-scooter trip ranges with trip length and depends on each city's and company's fee structure; some companies also offer affordability plans. Currently, the four e-scooter companies operating in Tempe charge a range of prices, averaging $1 to start a ride and between $0.15 and $0.33 per minute depending on the type of e-scooter. For regular (i.e., not low-income) users, a one-mile trip (about 8 min) would cost about $3 on average. While some e-scooter companies now offer the option to rent a scooter on a monthly basis, monthly rental was not an option during the time period when the survey was conducted.

2.2. Survey construction and recruitment

On May 2, 2019, we administered an online survey via email to the 5,720 ASU staff (not including faculty) who work on the Tempe campus. The survey, hosted on Survey Gizmo, included $5 Amazon e-gift card incentives for the first 200 respondents, and a chance to be entered into a drawing for one of ten $20 Amazon e-gift cards for the remaining respondents. The survey was estimated to take about 15 min to complete and received 1,385 responses, of which 1,256 (response rate: 22%) were complete and analyzed in

this study.

The survey was developed based on a literature review of current e-scooter-related research (e.g., Portland Bureau of Transportation, 2018, 2019; Denver Public Works, 2018; City of Austin, 2019; Baltimore DOT, 2019; Trivedi et al, 2019) and past related work on bicycling (Sanders, 2016; Winters et al, 2010; Dill & Voros, 2007). The survey included approximately 170 questions, although skip logic reduced that number significantly for most respondents (due to the large number of questions about near misses and crashes that were inapplicable if not experienced). We asked questions about the following categories:

- e-scooter and bicycle usage (both personal and bike share);
- benefits and barriers to using e-scooters, bicycling, and walking;
- enjoyment and perceptions of safety while traveling via various modes;
- experiences with crashes and near misses while traveling via various modes;
- opinions about laws associated with e-scooters and bicycling; and
- sociodemographics.

This paper focuses on the findings about usage, benefits and barriers, and perceptions of safety.

2.3. Methods

Survey data were coded and analyzed using the statistical software programs STATA SE (StataCorp, College Station, TX) and R (R Core Team, 2019). Statistical tests included the Chi^2 and Kruskal Wallis tests, the latter of which is a non-parametric version of ANOVA that accommodates non-normally distributed variables like ordinal variables.

Part of the survey analysis included a segmentation of respondents by ridership frequency to examine perspectives by user experiences. Based on similar studies of bicyclists (Sanders, 2016; Winters et al, 2010; Dill & Voros, 2007), respondents were categorized by a simple combination of whether they have ever ridden an e-scooter and, if so, how often they have ridden an e-scooter in the last month. The number of regular e-scooter users is small, which constrains conclusions based on that group alone and underscores the need for additional research in this area. This classification resulted in the following categories:

- Non riders (n = 849, 68%): respondents who have never ridden an e-scooter.
- Past riders (n = 147, 12%): respondents who have ridden an e-scooter, but not in the last month.
- Occasional riders (n = 195, 16%): respondents who have ridden an e-scooter in the last month, but less than one time per week.
- Regular riders (n = 63, 5%): respondents who have ridden an e-scooter at least once per week in the last month.

To learn more about our survey respondents, we asked questions about age, gender, race/ethnicity, annual household income, main mode of travel, and number of children under age 16 in the household (categories for all variables shown in Table 2). Respondents could choose more than one response for race/ethnicity; when more than one race was selected, those respondents were coded as “Two or more races”, in keeping with the U.S. Census.

Note that this survey attempted to provide demographic options that reflect the diversity of humanity, particularly with regard to gender identification and race. However, due to very small sample sizes for some of these categories, they are not explicitly evaluated in the analysis in this paper. Analyses based on race when non-riders are included evaluate the categories non-Hispanic white alone (n = 846), Black/African American alone (n = 41), Hispanic/Latino alone (n = 123), Asian alone (n = 64), two or more races (n = 71) and some other race alone (combination of all other races, n = 25). Due to very small sample sizes for all races other than non-Hispanic white alone when looking at past and current e-scooter riders, analyses are restricted to non-Hispanic white alone vs. respondents of color (n = 275 vs. n = 111, respectively) for those significance tests. Similarly small sample sizes for non-binary gender options mean that analyses based on gender evaluate men and women.

3. Results

3.1. Characteristics of the survey population

Table 1 shows the sociodemographic information for the survey population compared to the ASU staff population at the Tempe campus (from which the survey was sampled) and the population of the City of Tempe. Information on the ASU staff at large was unavailable for household income and children under 16. However, available information shows similarity between sample demographics and ASU staff population demographics.

The US Census provides more information about the general area population, although it should be noted that many staff do not live in Tempe. In comparison with the City, the sample population overrepresents women and households with young children (although there are slight differences between the datasets in this way), but underrepresents participants aged 18–24 and over 65, as well as households earning less than $35,000 a year. The percentage of people who are non-Hispanic white alone in the sample is roughly equivalent to the Tempe population, but within respondents of color, the percentages of Black or African American alone and Asian alone are underrepresented within the sample.

Table 2 shows the demographics of the survey population by e-scooter usage. About 32% of the survey population had ridden an e-scooter, compared to 94% having ridden a bicycle (n = 407 vs. n = 1186, respectively). There is a clear pattern with regard to age,

Table 1
Comparison of Survey Sample to ASU Staff and Tempe, AZ, Population.

	Tempe city		ASU Staff Sample		ASU Staff Population		Survey:Census Ratio
	n	%	n	%	n	%	
Age[1]							
18–24	44,205	29%	66	5%	270	4%	0.2
25–34	36,215	24%	385	31%	2,089	27%	1.3
35–44	18,708	12%	318	25%	1,914	25%	2.1
45–54	18,001	12%	239	19%	1,592	21%	1.6
55–64	16,098	11%	196	16%	1,385	18%	1.5
65+	17,449	11%	22	2%	357	5%	0.2
Missing	NA	NA	30	2%	NA	NA	NA
Gender (18 + years of age)[1]							
Men	79,997	53%	432	34%	3,087	41%	0.6
Women	70,679	47%	776	62%	4,520	59%	1.3
Other	NA	NA	10	1%	NA	NA	NA
Decline to say	NA	NA	38	3%	NA	NA	NA
Race/Ethnicity (all ages)[2]							
Non-Hispanic white alone	122,605	69%	846	67%	4,915	65%	1.0
Black/African American alone	11,679	7%	41	3%	361	5%	0.4
Asian alone	14,167	8%	64	5%	383	5%	0.6
Some other race alone	22,816	13%	14	1%	123	2%	0.1
Two or more races	7,072	4%	71	6%	176	2%	1.5
Hispanic/Latino alone	*	*	123	10%	1,297	17%	*
Decline to say	NA	NA	86	7%	352	5%	NA
Annual Household Income[4]							
Less than $35,000	23,528	34%	68	5%	NA	NA	0.2
$35,000 - $49,999	9,425	14%	194	15%	NA	NA	1.1
$50,000 - $74,999	12,452	18%	273	22%	NA	NA	1.2
$75,000 - $99,999	8,324	12%	182	14%	NA	NA	1.2
$100,000 - $149,999	8,531	12%	215	17%	NA	NA	1.4
$150,000 or more	6,536	10%	125	10%	NA	NA	1.1
Decline to say	NA	NA	199	16%	NA	NA	NA
Young Children in Household[5]							
Households with Young Children	12,760	19%	379	30%	NA	NA	1.6
Missing	NA	NA	55	4%	NA	NA	NA

NA = Not available

[3] 2017 American Community Survey 5-Year Estimates, Table S1901

[1] 2017 American Community Survey 5-Year Estimates, Table S0101

[2] 2017 American Community Survey 5-Year Estimates, Table B02001

* "Hispanic/Latino alone" is not an option in the ACS. To compare the ACS to the survey population for Hispanic/Latino alone, we combine "Hispanic/Latino alone" with "Some other race alone" for the sample population and find a Survey:Census ratio of 0.9.

[4] 2017 American Community Survey 5-Year Estimates, Table S1101; note that ACS defines young children as under 18 while our survey looked at children under 16.

with e-scooter riding most prevalent among those aged 25–34. Male respondents were significantly more likely than female respondents to have ridden an e-scooter ($p \leq 0.001$) and to ride more often ($p \leq 0.05$). There were no significant differences in riding frequency by race, although this may have been impacted by small sample sizes for respondents of color. However, significant differences existed between riding frequency and main mode of travel, with those who mainly walk or bicycle being significantly ($p \leq 0.05$) more likely than those who mainly drive to have ridden e-scooters at least once a week in the past month. Income seems to be variably related to riding patterns, with the highest percentage of frequent riders among those with incomes between $50,000-$99,000. Having children below the age of 16 in the household was not significantly related to e-scooter ridership patterns.

3.2. Trip types and potential impacts on physical activity

The 32% of respondents who had ridden an e-scooter were asked about their last e-scooter trip, including the trip purpose and the mode they would have used had they not made the trip by e-scooter (Table 3). Note that the numbers do not add up to 100% because respondents could select multiple trip purposes. The results indicate that e-scooters are primarily used for transportation (72% of trips), with 42% of trips being either solely or also for leisure/fun. Within the transportation category, transportation to/from activities was the most prevalent trip type (33%), followed closely by transportation to/from work (30%).

When asked which mode they would have used for their last trip had an e-scooter not been available, approximately 25% of respondents stated that they would have used a car (personal or ride hail/taxi), while 65% stated that they would have walked (57%) or biked (8%). Although this varied by trip type (e.g., 62% of transportation to/from work trips would have been accomplished by walking, compared to only 42% of the shopping/running errands trips), it is clear that the majority of e-scooter trips would have been taken by walking. However, only 15% and 13% of respondents indicated that they walk and bike less overall, respectively, now that

Table 2
Survey Population Characteristics, by E-Scooter Usage.

	Non riders (n = 849) %	Past riders (n = 149) %	Occasional riders (n = 195) %	Regular riders (n = 63) %	Survey Sample (N = 1256) %
Age					
18–24	3	13	8	6	5
25–34	24	38	51	44	31
35–44	25	26	26	27	25
45–54	23	14	9	11	19
55–64	20	7	5	6	16
65+	2	–	1	–	2
Missing	3	1	–	5	2
Total	*100*	*100*	*100*	*100*	*100*
	Kruskal Wallis significant $p \leq 0.001$				
Gender identification					
Man	29	38	47	52	34
Woman	66	58	53	43	62
Other/decline to say	5	4	–	5	4
Total	*100*	*100*	*100*	*100*	*100*
	Chi^2 significant $p \leq 0.001$				
Race/Ethnicity					
Non-Hispanic white alone	67	65	70	67	67
Hispanic/Latino alone	9	11	11	10	10
Black/African American alone	3	3	3	5	3
Asian alone	6	5	4	3	5
Two or more races	5	7	6	10	6
Some other race alone	2	3	2	2	2
Decline to say	8	6	5	5	7
Total	*100*	*100*	*100*	*100*	*100*
	Chi^2 not significant				
Main Mode of Travel					
Walk	7	4	7	13	7
Bicycle	6	9	7	13	7
E-scooter	–	–	1	11	1
Public transit	4	5	5	8	5
Personal vehicle	80	80	75	49	77
Other	3	2	5	6	3
Total	*100*	*100*	*100*	*100*	*100*
	Chi^2 significant $p \leq 0.05$				
Annual Household Income					
Less than $35,000	4	12	7	8	5
$35,000 - $49,999	13	18	23	14	15
$50,000 - $74,999	20	22	26	30	22
$75,000 - $99,999	14	12	16	19	14
$100,000 - $149,999	19	13	13	11	17
$150,000 or more	11	10	8	6	10
Decline to say/missing	19	13	8	11	16
Total	*100*	*100*	*100*	*100*	*100*
	Kruskal Wallis significant $p \leq 0.001$				
Children Younger than Age 16 in Household					
Yes	32	27	27	32	30
No	68	73	73	68	70
Total	*100*	*100*	*100*	*100*	*100*
	Chi^2 not significant				

they use e-scooters (no significant difference according to gender; sample sizes too small for other tests). These results suggest potential ramifications for individual- and population-level physical activity that should be further examined.

3.3. Benefits of riding E-scooters according to use and sociodemographics

Given the potential for e-scooters to replace walking and bicycling, we asked the survey participants to indicate which of a list of benefits they "enjoy about riding e-scooters"; respondents could select more than one answer. Fig. 1 shows that e-scooters are enjoyed for many reasons, but particularly for speed, convenience, the ability to replace car trips, and being fun/relaxing. E-scooters are much less likely to be seen as options for active transportation or increased safety.

Responses varied significantly by frequency of use, although the general pattern of responses was similar between groups. For example, the benefit of being faster than walking was the most selected within each individual group, but regular riders were still significantly ($p \leq 0.001$) more likely to choose that response than other groups. Indeed, regular riders were the most likely to select

Table 3
Most Recent E-Scooter Trip Purpose & Replacement Mode.

Trip Purpose	Percentage of all trips	If an e-scooter hadn't been available, I would have[1]:		
		Walked	Biked	Driven/ride shared
Leisure / fun (n = 170)	42%	50%	8%	30%
Transportation combined (n = 294)	72%	58%	8%	27%
- Transportation to/from activities (n = 133)	33%	51%	10%	35%
- Transportation to/from work (n = 122)	30%	62%	10%	19%
- Socializing/meeting up with family/friends (n = 66)	16%	45%	6%	41%
- Shopping/running other errands (n = 26)	6%	42%	15%	42%
- Transportation to/from school (n = 24)	6%	67%	–	29%
Other (n = 36)	9%	67%	6%	17%
Total (n = 406)		57%	8%	25%

1 Percentage of the trip purpose that would have been replaced by walking, biking, and car trips.

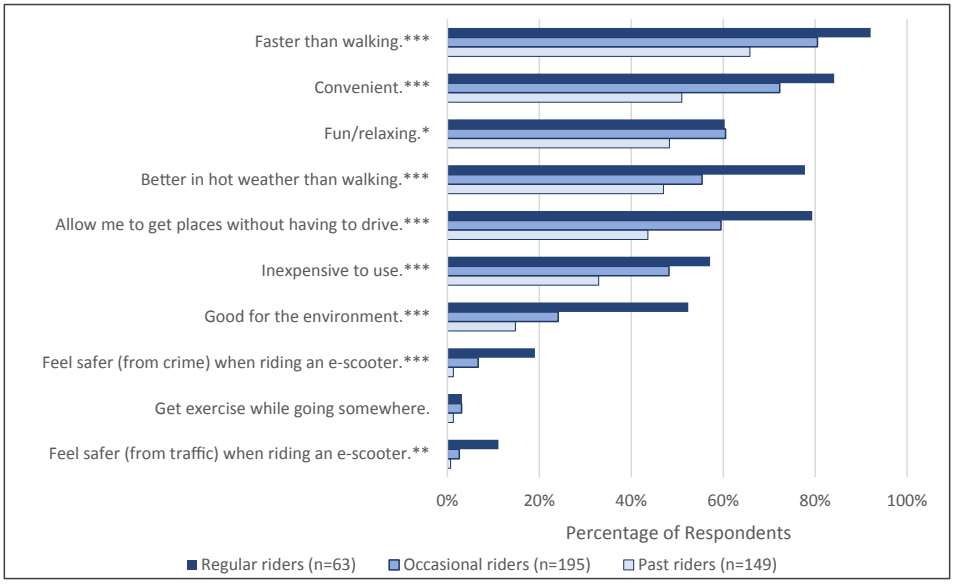

Fig. 1. Perceived Benefits of Riding E-scooters, by Frequency of E-scooter Usage. Significance between rider types indicated by the following: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

all of the benefits except "fun/relaxing", which was chosen by slightly more occasional riders, and "get exercise", which was chosen by few respondents overall. Similarly, occasional riders were more likely to select each benefit than past riders. Data do not indicate the directionality of the association, although it is likely mixed. It may be that less frequent riders value these benefits less, that they did not see these benefits realized and therefore have not ridden as often, that they have not realized the benefits to the same degree because they have not ridden as much, and/or that there are barriers that outweigh these benefits; these possibilities could be further explored in future research.

We also examined the perceived benefits by gender, age, income, race, the presence of children under 16 in the household, and whether main mode of travel was an automobile, with relatively few notable results. Of all of the perceived benefits of e-scooters, only feeling safer from crime differed significantly by gender (9% of women vs. 3% of men, $p \leq 0.05$), although the overall percentages are small enough to suggest that this is not seen as a primary benefit. Age was significantly related to respondents stating that e-scooters were fun/relaxing ($p \leq 0.001$) and safer from crime and traffic, convenient, and inexpensive (all $p \leq 0.05$), with respondents aged 18–34 the most likely to select these benefits. Income was significantly ($p \leq 0.05$) related to the idea that e-scooters are faster than walking, with generally greater agreement the higher the income. There were no significant differences between riders who were non-Hispanic white alone versus respondents of color. Respondents who mainly traveled by auto were significantly less likely to note the benefits of e-scooters being better in hot weather than walking ($p \leq 0.05$) and feeling safer from crime ($p \leq 0.01$). Consistency between responses of different sociodemographic groups may indicate that e-scooters have the potential to be an equitable and useful urban mobility option.

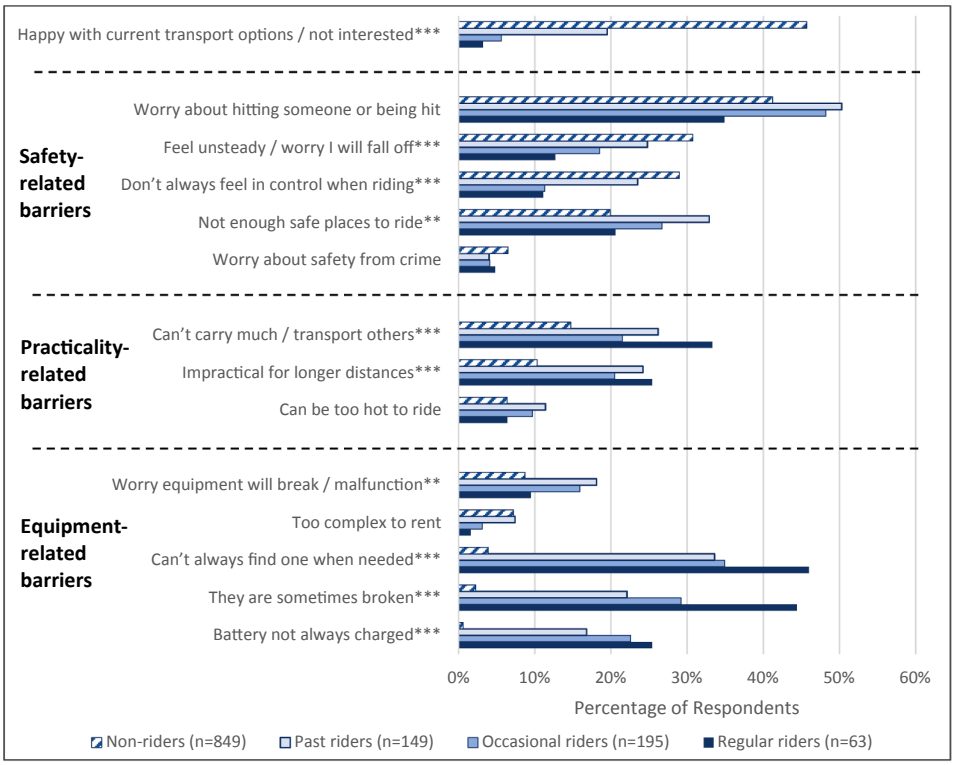

Fig. 2. Barriers to Riding E-scooters, by Frequency of E-scooter Usage. Significance between rider types indicated by the following: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

3.4. Barriers to riding E-scooters according to use and sociodemographics

Respondents were also asked to indicate which of a list of barriers they "don't like about riding e-scooters", and, if they have not ridden, which of a list of reasons why not (the barriers and reasons were approximately the same between the two groups, but adjusted for relevance). As with the benefits, respondents could select more than one answer. Fig. 2 shows that barriers to riding an e-scooter vary significantly by whether respondents had ridden an e-scooter and how often they had done so in the last month; note that respondents could select more than one barrier. Forty-six percent of non-riders answered that they were happy with their current options and not interested in e-scooters, significantly more than any other group (although still less than half of the non-rider population in the sample). Unsurprisingly, barriers pertaining to e-scooter equipment, such as a scooter being hard to find when needed or sometimes broken, were significantly more likely to be selected by those who have ridden e-scooters, and more likely to be selected the more often the participant rode.

Safety-related barriers, on the other hand, were much more evenly selected between the groups, although they differed according to experience. For example, non-riders were significantly ($p \leq 0.001$) more likely than riders to state that they worry about feeling unsteady or falling and not being in control, whereas past and occasional riders were significantly ($p \leq 0.01$) more likely to state that there were not enough safe places to ride. Over 40% of non-riders, about 50% of past and occasional riders, and 35% of regular riders indicated that they worried about hitting someone or being hit by someone while using an e-scooter.

We also examined barriers by gender, race, household income, whether children under 16 were present in the household, and whether main mode of travel was an automobile. As Fig. 3 shows, female riders were more likely than male riders to select most barriers, but only significantly so with regard to barriers related to their safety while riding – including both worrying about hitting or being hit by someone and feeling unsteady or worrying about falling. In contrast, male e-scooter riders were more likely to select barriers related to the practicality of e-scooters, significantly so with regard to e-scooters sometimes being broken.

Trends related to gender were magnified among non-riders, as shown in Fig. 4. Female non-riders are significantly ($p \leq 0.001$) more likely than male non-riders to list worries about safety from crime, falling, and hitting or being hit by someone, as well as to cite the need to carry things or people ($p \leq 0.01$).

There were few significant differences with regard to other demographics among current and past riders. Only one significant difference emerged by race, with respondents identifying as non-Hispanic white alone being significantly ($p \leq 0.05$) less likely to say that it was too complex to rent an e-scooter than respondents of color, although the percentages were small for both groups. Current and past riders with children under age 16 were significantly less likely to say that they were worried about personal safety from crime, or, somewhat counterintuitively, that they needed to carry things or people. The latter result may show self-selection in that those with young children who ride e-scooters have overcome or do not face that particular barrier. Younger current and past riders

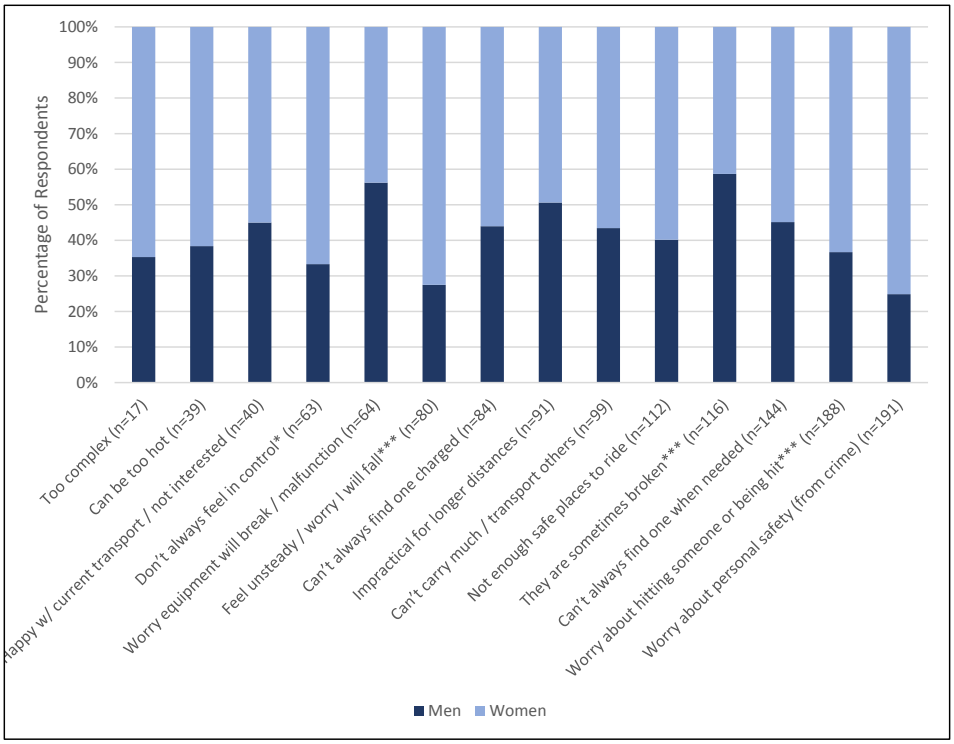

Fig. 3. Barriers to Riding E-scooters Among Past and Current Riders, by Gender. Significance between genders indicated by the following: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

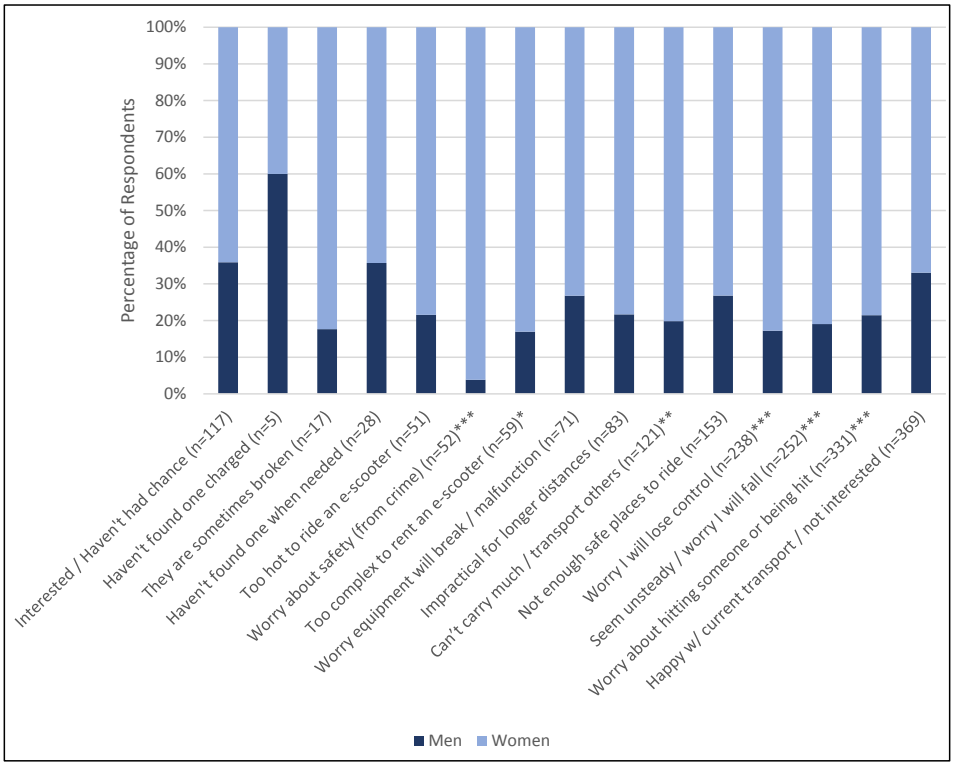

Fig. 4. Barriers to Riding E-scooters Among Non-Riders, by Gender. Significance between genders indicated by the following: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

were significantly more likely to cite e-scooters being broken as a barrier, while older current and past riders were significantly more likely to say that they were happy with current transportation options or not interested in e-scooters (all $p \leq 0.05$). Respondents who mainly drive were significantly ($p \leq 0.05$) less likely to select the barrier of e-scooters sometimes being broken.

There were more differences among non-riders, particularly with regard to age. For example, younger non-riders were significantly more likely to select barriers related to practicality, like the inability to carry much or transport others, that it can be too hot to ride an e-scooter (both $p \leq 0.001$), and that e-scooters are impractical for longer distances ($p \leq 0.05$). Younger non-riders were also significantly more likely to select barriers related to equipment, such as not being able to find one when needed, that e-scooters are sometimes broken, and the inability to find one with a charged battery (all $p \leq 0.05$). Respondents who mainly drive were significantly ($p \leq 0.01$) less likely to select the barrier of not enough safe places to ride.

As with current and past riders, there were some slightly counterintuitive findings related to having children under age 16 (as compared to not) among non-riders, such as a significantly lower likelihood of being worried about traffic safety (either being hit / hitting someone or having enough safe places to ride, $p \leq 0.05$ and 0.01, respectively), and a significantly higher likelihood of being interested in trying e-scooters in the future. These results may represent self-selection among parents who would consider using e-scooters.

Finally, a few significant differences emerged according to race, most notably that Hispanic/Latino and Black/African American non-riders were more likely ($p \leq 0.01$) to state they haven't had a chance to try e-scooters but were interested (26% and 25%, respectively), while non-Hispanic white alone non-riders were the least likely (11%). Relatedly, non-riders who were non-Hispanic white alone or Asian alone were significantly ($p \leq 0.001$) more likely than riders who were Black/African American alone and Hispanic/Latino alone to say that they were happy with their current transportation options/not interested in e-scooters (51% and 47% compared to 22% and 29%, respectively). Persons of two or more races (27%) and Asian alone (23%) non-riders were significantly more likely than other races to state there are not enough safe places to ride ($p \leq 0.05$).

3.5. Deeper exploration of perceived safety

Perceived safety was further explored among current and past riders via the question, "How safe do you generally feel riding an e-scooter?" (using a 4-part Likert scale including 'very' or 'somewhat' unsafe and 'very' or 'somewhat' safe). Just under 65% of current and past riders reported feeling 'somewhat' or 'very' safe while riding an e-scooter. The overall perceived safety of riding an e-scooter varied significantly ($p \leq 0.001$) among participants who use an e-scooter more regularly, with the proportion who feel "very safe" increasing with increasing frequency of e-scooter use. There were also significant differences in perceived safety between men and women ($p \leq 0.05$), with men being more likely to perceive using an e-scooter as very safe. Counterintuitively, participants who have young children in their household are more likely to perceive using an e-scooter as safe compared to those without ($p \leq 0.01$), which may again reflect self-selection within the sample or some other unmeasured difference. There were no significant differences in perceived safety by age, race, or income level.

3.6. Likelihood of using E-scooters in the future

Respondents were also asked how likely it was that they would use e-scooters at some point in the next year (using a 4-part Likert scale including 'very', 'somewhat', 'not very' and 'not at all' likely). Forty percent of all respondents stated that they were 'somewhat' or 'very' likely to ride an e-scooter at some point in the next year, including over 76% of past and current e-scooter riders and 23% of non-riders. Twice as many non-riders indicated that they would likely ride e-scooters in the next year as riders who said they would not likely ride again, suggesting an increasing trend for e-scooter usage. Specifically, there was a clear, significant ($p \leq 0.001$) trend related to age: 56% of those age 18–34 indicated that they were likely to ride in the next year, compared to 41% of those age 35–44 and only 25% of those age 45 + . Additionally, while men and women were closely split regarding riding e-scooters next year (45% of men vs. 38% of women), men were significantly more likely to be "very" likely to try them ($p \leq 0.001$).

There was no significant difference regarding the likelihood of using an e-scooter in the future according to race, the presence of children under 16 in the household, or main transportation mode. Nearly 40% of those who walk, bike, or drive as their main mode are likely to ride e-scooters in the next year, compared to 51% of those whose main mode is transit.

4. Discussion

This study is one of the first to evaluate trends in e-scooter usage and related barriers and benefits in a representative sample, and the first (to our knowledge) to do so in the southwest region of North America. The findings suggest important implications for transportation and public health planning and equity in urban areas. The survey results clearly indicate that e-scooters are filling a niche in urban transportation, with the majority of trips being used for transportation. Finding that e-scooters are being used for transportation corroborates the Portland survey (PBOT, 2019), and suggests a need for additional transportation options, particularly for those who do not have a car. However, our results differ substantially from Portland's with regard to trip substitution: we found that e-scooter trips are disproportionately replacing walking trips in comparison to car trips (personal and taxi/ride share), whereas Portland found an approximately even displacement. Disproportionate replacement of walking trips suggests a need for future research to understand the longer-term health impacts of e-scooter use, at least among frequent users, as well as further study of e-scooters across varying contexts (e.g., climate, topography, and city form).

This study also found that the benefits of e-scooter riding seem to be broadly perceived, while the barriers to e-scooter riding are

more pronounced for some groups than others. For example, respondents of all groups indicated that an e-scooter is a fast, fun, convenient travel option that allows people to travel without a car and is a good option in the heat (slight differences for age, as shown in Section 3.3). In contrast, the main barriers to e-scooter use, which related to safety and equipment, differed significantly by sex. Men were more likely to cite barriers related to equipment, suggesting that keeping e-scooters in good condition is also a prerequisite to e-scooters becoming a reliable part of any transportation system. In contrast, women were more likely to cite safety barriers related to worries about hitting or being hit by others, falling, and losing control. Additionally, men were significantly more likely to perceive e-scooting in general as "very safe." These findings about sex and perceived safety fit with past research on barriers to bicycling (Branion-Calles et al, 2019; Sanders, 2016; Winters et al, 2010) and particularly barriers to bicycling for women (Emond et al, 2009), and provide insights into ways that e-scooter infrastructure could be improved in order to encourage equity in transportation options – in particular, via providing more safe places to ride, more stable e-scooter options, and increased opportunities for training and e-scooter user education. The latter recommendation seems especially pertinent given findings that injured e-scooter users in Austin were much more likely to be novice users (Austin Public Health, 2019).

Furthermore, this study found that African American and Hispanic/Latino non-riders were significantly more likely to intend to try e-scooters and significantly less likely to be happy with their current transportation options. These findings about race and transportation options further underscore the potential role of e-scooters in filling a niche in urban transportation and increasing transportation equity. Finally, while e-scooters have a greater environmental footprint and are less active than walking or bicycling, they are far preferable in both areas to driving a car alone (Hollingsworth et al, 2019; Sanders & da Silva Brum de Bastos, unpublished). By addressing the barriers identified in this paper, cities may be able to increase transportation equity and reduce their transportation carbon footprint through accommodating e-scooters.

4.1. Limitations and next steps

As is common in surveys, there may be respondent bias from people who are more interested in a subject, and therefore more likely to participate in related research. Additionally, while the e-scooter statistics described in this paper do not necessarily represent travel in a university setting, it is possible that they reflect that setting more than a survey of city residents. Furthermore, this survey was not exhaustive and may have missed opportunities to explore connections to, e.g., university travel demand management strategies like free transit passes or reduced-cost parking passes. Additional research further investigating these findings with a more diverse sample and in different climates and geographies will help further clarify how the benefits and impacts of and barriers to e-scooter usage vary according to sociodemographics and context. The increased knowledge from a variety of contexts and populations would inform cities, universities, and regions about how to better accommodate e-scooters in a way that mitigates harm and maximizes equity and opportunity for all.

Our work also found evidence of physical activity and potential long-term health impacts due to e-scooter trips disproportionately replacing walking and bicycling trips among users. This trend, and the potential for increasing e-scooter use to exacerbate it, should be further explored in future research.

Finally, although perceived safety emerged as a clear barrier to e-scooter use in this study, particularly among women, few studies have examined e-scooter safety in the North American context. Those that have (e.g., Trivedi et al, 2019; Austin Public Health, 2019) have tended to examine emergency room data and/or interview e-scooter users who have crashed, but have not explored the role of near misses in forming perceptions of e-scooter safety among e-scooter riders and non-riders. Future research exploring near misses and crashes could contribute a more holistic understanding of safety and help practitioners better plan for safe travel for e-scooter users and for the pedestrians, bicyclists, and drivers who share space with them.

5. Conclusions

This paper provides one of the first explorations of e-scooter users within a larger population, including who is using e-scooters, how often, and for which trip purposes. We also explored perceived benefits of e-scooter use and barriers to future use among non-riders and past and current riders. The findings suggest that e-scooters are popular among men and women of a variety of ages and races/ethnicities. E-scooters are primarily valued for their convenience and the ability to get somewhere faster than walking while not having to drive; they are also generally considered fun to ride. Few of the perceived benefits differed significantly by sociodemographics, suggesting that e-scooters may help fill an urban transportation niche. This niche may be particularly relevant for areas where cars are discouraged or impractical, such as on or around university campuses, and in congested urban areas.

We also identified barriers to e-scooters, including safety-related barriers (e.g., not having enough safe places to ride, feeling unsteady while riding, worrying about being hit) and equipment-related barriers (e.g., not being able to find an e-scooter when needed, not having a charged battery). In contrast to the perceived benefits, many of the barriers to e-scooter use differed significantly according to gender, particularly when related to safety. These differences mirror gender differences seen in bicycling studies and reinforce the notion that street design is critical to encouraging gender equity in transportation and allowing women to take full advantage of this new mode. Additionally, Hispanic/Latino and Black/African American respondents were significantly more likely to state that they are interested in trying e-scooters in the future, supporting the idea that e-scooters, if barriers are addressed, have the potential to contribute to urban transportation equity.

CRediT authorship contribution statement

Rebecca L. Sanders: Conceptualization, Data curation, Methodology, Formal analysis, Writing - original draft. **Michael Branion-Calles:** Formal analysis. **Trisalyn A. Nelson:** Conceptualization.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tra.2020.07.009.

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