SURTCOM 20-04

RISK PERCEPTION OF BICYCLE/SCOOTER RIDERS RISKY BEHAVIORS

Prepared for:

U.S. Department of Transportation

Prepared by:

Ali Rahim Taleqani, Ph.D.
Jill Hough, Ph.D

Small Urban and Rural Center on Mobility
Upper Great Plains Transportation Institute
North Dakota State University
Fargo, ND

December 2020

Acknowledgements

Funds for this study were provided by the Small Urban, Rural, Tribal Center on Mobility (SURTCOM), a partnership between the Western Transportation Institute at Montana State University and the Upper Great Plains Transportation Institute at North Dakota State University. The Center is funded through the U.S. Department of Transportation's Office of the Assistant Secretary of Research and Technology as a University Transportation Center. The Small Urban and Rural Center on Mobility (SURCOM) located within the Upper Great Plains Transportation Institute at North Dakota State University conducted the research.

TABLE OF CONTENTS

List of Figures

List of Tables

ABSTRACT

Bicycle and scooter use entails significant safety and health risks. News stories have described the reckless behavior of users across the United States with the emergence of micromobility options. This paper investigates risky behaviors associated with U.S. bicycle and scooter riding adults. Two separate surveys were administered through the Qualtrics platform. Participants were asked to rate the severity and frequency of 20 risky behaviors of riders on five Likert scales. The risk matrix is built based on the magnitude and frequency of each risk, and ordered logistic regression is applied to identify significant factors. Regression analysis revealed that age and income are significant factors shared between both survey groups. Education level and living in urban areas are two statistically significant factors explaining the different risky behaviors with bicycles or scooters. In general, the survey results show that participants perceive there is a low risk associated with reckless behaviors. It may imply that they are exposed to fewer incidents, or the news media exaggerate the incidents. Further research on other aspects of risk, such as network geometry and safety education, would help better understand the underlying factors. The findings offer insight for developing new enforcement policies and safety education programs to enhance scooter/bicycle sharing programs and provide a safe environment for all road users.

INTRODUCTION

Shared micromobility options, such as bike and scooter sharing, are increasingly becoming an accessible mode of transportation in many cities and towns across the United States [1]–[4] . More than 207 million trips have been made on shared bikes and e-scooters since 2010. Riders took 84 million trips in 2018, more than double the number from the previous year, mostly because of the emergence of electric scooters [5].

City officials have a great interest in promoting sustainable shared micromobility modes for health and environmental reasons [6]. However, rider behavior is a recurring theme in public debate surrounding the growth of this mode of shared micromobility. In many of these discussions, the majority of riders are characterized as displaying lawless attitudes, which are the root of individual and public safety concerns associated with riding those vehicles. Many of these safety issues are related to unsafe riding behaviors, including, but not limited to, operating under the influence of alcohol, maneuvering recklessly, overloading with multiple riders, speeding, etc. The danger of risky riding to pedestrians and other road users is amplified in urban areas (with high population densities) and nighttime [7], [8].

In the United States there were 783 cyclist deaths in 2017, which accounted for 2.1% of all traffic fatalities during the year. Of pedal-cyclists who died in motor vehicle crashes in 2017, 75% were killed in accidents in urban areas [9]. The difference in data collection makes it challenging to compare statistics among different types of vehicles. For bike sharing, the average collision rate was 4.33 crashes per year among operators with more than 1,000 vehicles and fewer for operators with smaller fleets [10]. There are no reliable and consistent data available for electric scooters. For example, a pilot study attempted to measure the safety impacts of scooter sharing by reviewing reported scooter incidents in Multnomah County, Portland. On average, emergency room visits increased from less than one per week before the pilot to approximately 10 per week during the pilot period. However, exact numbers are difficult to quantify because of missing data related to other types of scooters, such as mopeds and non-motorized standing scooters. Of the entire sample of scooter-related emergency visits, 83% did not involve another mode compared to 13.6% involving a motor vehicle and 2.8% involving a pedestrian. Only one collision (0.6%) was reported involving two scooters. These statistics are difficult to be validated because the trips were diverted from other modes, such as automobiles, buses, or rail, and increased the risk of the individual riders [11]. Heesch et al. (2011) analyzed cycling accidents and found that regular cyclists were involved in a relatively high number of traffic crashes in Queensland, Australia [12]. While most of the accidents were not serious, the number of crashes was more elevated in Australia than in European and Asian nations. In Australia, approximately one in 40 road crash deaths were cyclists [13]. Because cyclists comprised only 2% of national fatalities and injuries while making less than 1% of all trips, the perception that cycling is dangerous is not unfounded [9].

Safety involving bike and scooter riders and other road users has been a prevalent topic in research and media reports in most countries. Some research described the conflict between motorists and cyclists as [14]–[16]. Salmon et al. suggested that such conflict is a long-standing problem, and cyclists are 12 times more at risk of death than car drivers [17]. MacMillan et al. researched the media's reporting of cyclist fatalities in London, suggesting media coverage and the way they portray various aspects of road behaviors was a relatively vital method of preventing reckless behaviors or promoting appropriate ones. The number of fatalities covered by the Evening Standard, one of London's major newspapers, has increased tenfold while the number of trips has only doubled [18]. Some research suggested that the fear of cars and possible accidents are barriers to cycling [18]–[20]. The number of negative representations of cyclists is almost double the positive ones; the former includes words like "irresponsible lawbreakers", "pariahs," and "dangerous to others" and the latter "brave," "harmless," and "healthy" [21]. In similar research, Bogdanowicz recognized the negative language toward cycling by media, which characterized it as a transport mode for "eccentrics" or "tree huggers" [22]. Skinner and Rosen noted that the negative language and hostile attitude toward cyclists are much more noticeable where cycling is rare [23].

The majority of existing studies have been conducted to help engineers and city planners design and improve roads and intersections. Researchers asked cyclists to rate their general risk perception of a route through a set of videos, surveys, test courses, and simulations. Each examined several network geometry and operation-specific factors related to the safety perceptions of cyclists [24]–[30]. There has been no systematic study on the interactions between cyclists and other road users, particularly in the United States. This implies the need for a more comprehensive understanding of what happens when drivers and bicyclists interact.

Another group of studies investigated the reasons behind risky behaviors and addressed possible determinants among different people. Reyna and Farley tried to answer why adolescents may seek out risky situations [31]. They found that adolescents, despite conventional wisdom, generally overestimate risks. Indeed, after the age of 14, there might be no difference between teens and adults concerning the perception of risk [32]. Feenstra et al. conducted a survey-based study to investigate the risky cycling behaviors of adolescents from 13 to 18 years old before developing safety education programs [33]. They found that adolescents are capable of identifying themselves as risk-takers or not. They suggested shifting the focus of education programs from risk perception to decreasing risky attitudes in traffic and promoting a sense of responsibility. Shope and Bingham provided a list of possible determinants to explain why young drivers engage in more risky behavior than adult drivers; these include characteristics of the behavior, abilities, developmental factors, behavioral factors, and others [34].

Despite studies investigating the safety aspects of shared mobility schemes, there is little understanding of the perceived risk of reckless behavior from other road users' perspectives. For example, researchers and practitioners do not have much empirical knowledge about how certain aspects of risk rank when compared with others, nor do they know much about road users' fear of different types of reckless bike/scooter use. To address this gap, this study explores multiple aspects of perceived risk associated with reckless behaviors of bike and scooter riders. This paper aims to investigate the overall risk perception of the risky behaviors related to bicycle and scooter riders from a general perspective, including perceptions of users and non-users. We are also interested in examining the difference in the level of the risks associated with those using bicycles versus scooters. We can summarize our contributions in the following three areas:

- First, we address risky behaviors related to two popular sustainable modes of transportation in the United States: scooters and bicycles.

- Second, we develop a risk matrix to provide better insight into the magnitude and frequency of each risk. We use the ordered logistic regression to analyze the demographics and general cycling behaviors and ascertain if there are any significant underlying determinants.
- Finally, we focus on the risk perceived by the general audience (users and non-users) to determine the overall perception. We also provide feedback received from open-ended comments about real risks in individual experiences during interactions with scooters or bicycles.

The next two sections of this paper depict the methods, data, and findings, respectively, followed by the ordered logistics regression analysis section. Discussion of the variables in the statistical models and the limitations of this study are provided. Finally, the conclusion is provided.

METHODOLOGY

This study is composed of three parts. First, we explain the survey that was conducted in March 2019 to capture the risk perception of risky behaviors of riders. Then we build the risk matrix from the survey results for further analysis. Finally, we do a statistical analysis of the risk to identify significant factors associated with each level of risk.

Survey

We designed two separate cross-sectional online self-completed surveys for each vehicle type (bikes and scooters) to identify and assess reckless and risky behaviors of bike and scooter riders. Each survey has three sections:

1. Socio-demographics
2. Risky behavior characterization
3. General riding behavior

For risk analysis, the severity and frequency of each factor are asked using a Likert scale. Study respondents were first asked to complete a screening question to determine eligibility: respondents had to be 18 years old and U.S. residents. Eligible respondents then were asked to provide informed consent to complete the survey. Those who provided the informed consent then completed a 15-question survey about the significance and frequency of various types of risky behaviors associated with riders, overall cycling behaviors, and demographics. Participants who did not consent were not allowed to continue to the second part. The North Dakota State University Institutional Review Board (IRB) approved the questionnaires.

Sample Size and Recruitment

Respondents were recruited from March 1, 2019, to March 15, 2019, by a Qualtrics panel that consisted of the following criteria: U.S. residents in different geographic areas (rural, suburban, and urban areas) and ages 18-plus. The inclusion/exclusion criteria were the same for both surveys. We used the Qualtrics platform for participant recruitment because it is demographically and politically representative [35]. Qualtrics checks every IP address and uses a sophisticated digital fingerprinting technology to exclude duplication and ensure validity.

Participants completed the survey from their own devices. Upon survey completion, a unique code was used to redeem an incentive. Qualtrics was paid at a rate of $6 per subject, but the actual payment amount from Qualtrics to respondents is unknown to us. As is typical in web-based survey research, we employed multiple attention checks and quality screens in our surveys. Attention checks confirmed that web-based survey respondents were reading questions carefully and thoroughly. The Qualtrics panel suggested using the median time to complete the survey as the cutoff point to determine whether respondents rushed through the survey, so we applied this criterion to the survey as a part of the quality screening.

According to the 2010 U.S. Census, the United States has a population of 308,745,538; of which, 76% (234,646,609) are age 18 years and older [36]. For a very large population size, we can use the following formula to calculate the sample size for the surveys.

$$\text{Sample Size} = \frac{\text{Z-score}^2 \times \text{StdDev} \times (1 - \text{StdDev})}{\text{Margin of Error}^2}$$

Considering a 90% confidence level, a 5% margin of error, and a 0.5 standard of deviation, the expected sample size is 270.

Risk Matrix

We used a risk assessment matrix to conduct a subjective risk assessment in our model. The basis for the risk matrix is the definition of risk as a combination of the severity of the consequences occurring in a particular accident scenario and its frequency. To build the risk matrix, we first categorize and scale the severity and frequency as well as the output risk index. The categorization of the severity and frequency depends on the type of activity or the specifics of the processes involved. We categorized the frequency and the severity into five groups. This provided the basis for constructing the plane matrix with 25 cells, each representing a specific risk category. The relationships between all inputs and outputs for a standard risk matrix are suggested by the U.S. National Institute of Standards and Technology, as shown in Table 1 [37].

Table 1. Assessment scale

Likelihood	**Level of Severity (Impact)**				
	Very Low	**Low**	**Moderate**	**High**	**Very High**
Very High	Very Low	Low	Moderate	High	Very High
High	Very Low	Low	Moderate	High	Very High
Moderate	Very Low	Low	Moderate	Moderate	High
Low	Very Low	Low	Low	Low	Moderate
Very Low	Very Low	Very Low	Very Low	Low	Low

The application of the risk matrix is simple. After assessing the severity and frequency categories, the risk category as one out of five groups (very low, low, moderate, high, very high) is specified using the risk matrix. This is the basis for further risk control measures in the next section. We are interested in identifying any relationship between the level of risk (as represented in the risk matrix) of each risky behavior listed in Table 2 and explanatory variables such as sex, age, income, and others listed in Table 3.

Perceived Risk Model

Because the level of the risk, as a dependent variable, is ordinal (more than two categories and the value of each group has a meaningful sequential order), we use the ordered logistic regression method, also known as the proportional odds model, to investigate the determinants that influence ordinary road users' risk perceptions of the various risky behaviors in the United States, as listed in Table 2. Initially, eight explanatory variables were included as categorical variables in the perceived risk model, as described in Table 3.

Table 2. Dependent variables

Dependent Variables	**Description**
Y1	Ignoring traffic signals
Y2	Riding a scooter/bicycle while under the influence
Y3	Riding at night without lights on
Y4	Distracted riding, including, but not limited to, talking or texting on phones, eating or drinking, or other distracting activities
Y5	Ignoring stop signs
Y6	Not yielding to pedestrians
Y7	Speeding
Y8	Swerving (riding in a zigzag)
Y9	Riding on sidewalks
Y10	Riding against traffic on the roadway
Y11	Riding the wrong way on a one-way street
Y12	Stoppie – braking too quickly, resulting in a skid or the rear tire lifting up
Y13	Wheelie – riding a scooter/bicycle with the front wheel raised off the ground
Y14	Jumping off a curb
Y15	Passing too closely on either side of vehicles on the road
Y16	Tailgating – riding too closely behind another vehicle
Y17	Riding without helmets
Y18	Riding with under-inflated tires
Y19	Yelling, or making angry gestures at motorists, cyclists, scooter riders, or pedestrians
Y20	Riding with a passenger

width=0.75

Table 3. Independent variables

Independent Categorical Variables	**Description**	**Levels (reference case marked with asterisk)**
X1	Age	*18-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75 or older
X2	Sex	*Female, male
X3	Marital Status	*Divorced, married, separated, single, widowed
X4	Education	*Associate degree, bachelor's degree, graduate degree, high school diploma or equivalent, less than a high school diploma, some college, no degree
X5	Employment	*Disabled, employed full-time (40+ hours a week), employed part-time (less than 40 hours a week), retired, self-employed, unemployed (currently looking for work), unemployed (not currently looking for work)
x6	Income	*below $10k, $10k – $25k, $25k – $50k, $50k – $75k, $75k – $100k, $100k – $125k, $125k – $150k
X7	Race	*Asian American, Black or African American, Middle Eastern American (Middle East, North Africa, and the Arab world), Native American or Alaska native, Native Hawaiian or other Pacific islander, some other race, white American
X8	Region	*Rural, suburban, urban

RESULTS AND FINDINGS

Descriptive Analysis

Considering the initial estimate of 270, after 15 days of recruiting, 749 responses were collected, of which 659 (329 of scooters [S] and 330 of bicycles [B]) are valid responses and eligible for use in the analysis. A quantitative design allowed for information collected from a large number and enabled a comparison between groups, behaviors, and outcomes. Also, some qualitative analysis was possible as a result of one open-ended comment box within the questionnaire.

Data Description

The percentage of white respondents (72% S and 85% B) is approximately representative of the U.S. population (72% white). Black (15% S and 9% B) and Asian (4% S and 3% B) are the next two major groups of respondents. The respondents were more than twice as likely to hold a high school diploma, followed by some college.

Responses came from all over the United States with minimal to no responses from a couple of states, as seen in Figure 1, including Hawaii and Alaska (not pictured). Using Census regional designations, there were 145 responses from suburban areas (44%), 115 responses from urban areas (35%), and 69 responses from rural areas (21%) for the scooter survey. The bicycle survey generated 180, 79, and 71 responses from suburban, urban, and rural areas, respectively. Most respondents were in full-time employment (38% S, and 25% B). Interestingly, from the bicycle survey, the second major group with 25% of respondents is retired, while 15% of respondents in the scooter survey have a part-time job.

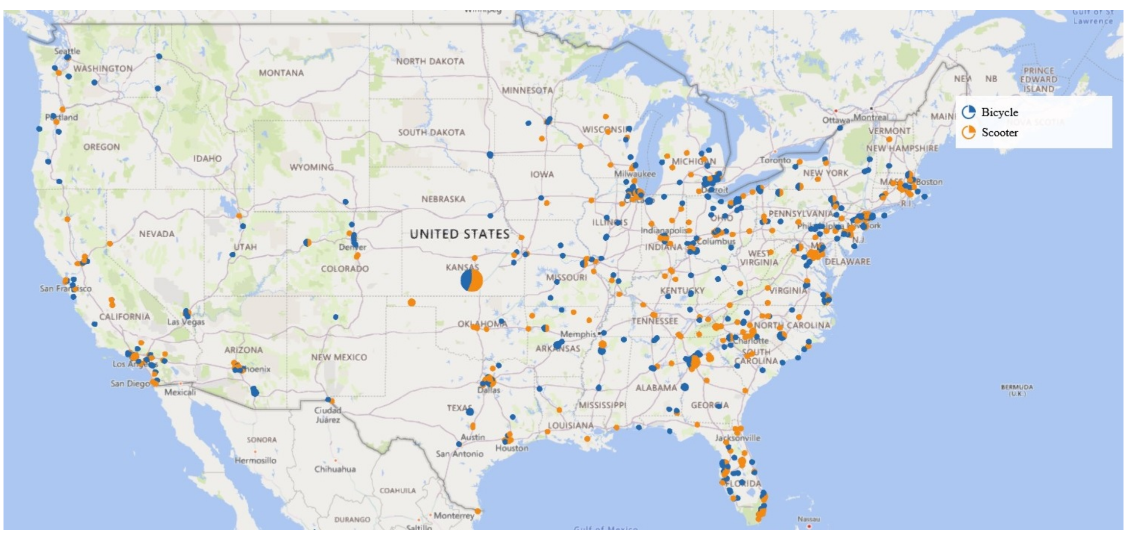

Figure 1. Distribution of respondents by vehicle type

Most respondents indicated they were married (47% S, 50% B). A total of 37% in the scooter survey and 30% in the bicycle survey indicated they were single. Most respondents earn $25k to $50k (over 23% in each survey) annually in both surveys. Respondents in the second major group in the scooter survey make $10k to $25k, while in the bicycle survey, most respondents make $50k to $75k annually.

Dill and McNeil adopted a topology developed by the City of Portland to describe the cycling behaviors of adults. It includes four categories: Strong and the Fearless," "Enthused and Confident," "Interested but Concerned," and "No Way No How" [38]. We also adopted the same approach but asked participants to describe their riding skills, as indicated in Table 4.

Table 4. Riders type by region

Region	Category	Scooter	Bicycle
No Way, No How: *unwilling to ride even if high-quality (bicycle/scooter) infrastructure is available*	Rural	22	28
	Suburban	32	51
	Urban	32	22
	Total	**86**	**101**
Interested but Concerned: *willing to ride if high-quality (bicycle/scooter) infrastructure is available*	Rural	32	29
	Suburban	68	87
	Urban	42	32
	Total	**142**	**148**
Enthusiastic and Confident: *willing to ride if some (bicycle/scooter) specific infrastructure is available*	Rural	10	8
	Suburban	29	33
	Urban	31	20
	Total	**70**	**61**
Strong and Fearless: *willing to use scooters with limited or no (bicycle/scooter) specific infrastructure*	Rural	5	6
	Suburban	16	9
	Urban	10	5
	Total	**31**	**20**

As described in Table 4, in all three distinct geographic areas there is a general trend: most respondents (more than 43%) characterize themselves as "interested but concerned," while the "strong and fearless" is the least selected option. This may mainly be due to the recent deployment of bike/scooter sharing programs across the United States. The weather might be another factor that needs to be included in future research. Interestingly, under the "strong and fearless" category, there were almost twice as many respondents who considered themselves as "strong and fearless" in riding scooters as there were for bicycles. This may be because of the greater ease of getting off a scooter versus a bicycle if there is an impending crash because scooters are usually lighter and more manageable than a bicycle. Surprisingly, the number of people who are not willing to ride a bicycle, even with high-quality infrastructure, is more than one-fourth of respondents in both cases (scooter and bicycle).

An analysis of respondents' bicycle and scooter riding frequency (includes both their own bikes/scooters and sharing systems) is illustrated in Figure 2, which shows that 36% of respondents never rode a scooter before, while only 3% never rode a bicycle. This might be because scooters are unavailable in some regions. Except for the categories "Never" and "More than five years ago," the riding profiles of respondents in both surveys follow the same pattern.

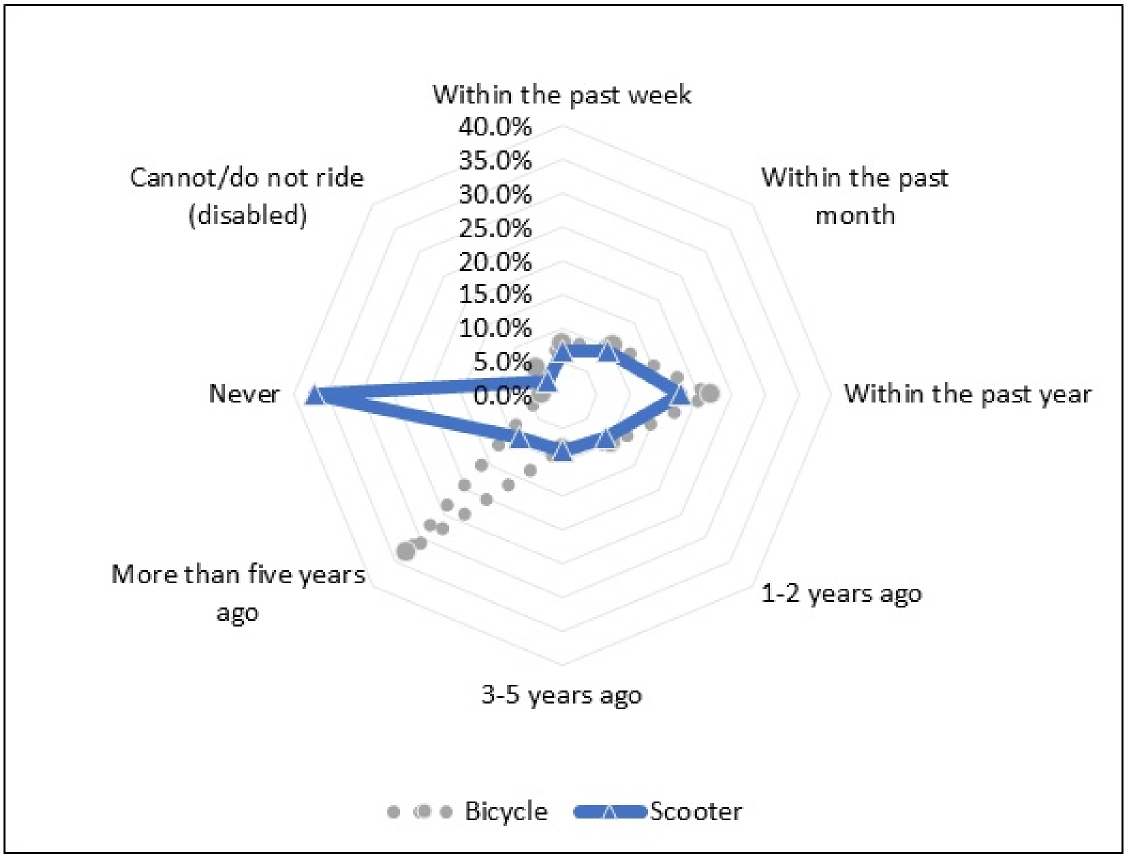

Figure 2. Bicycle/scooter riding profile

Based on miles traveled, people rode slightly longer distances with scooters than with bicycles. Other than that, scooter and bicycle survey responses follow the same pattern, as presented in Tables 5 and 6. These numbers also imply that most people prefer using scooters or bicycles for short trips between one and seven miles. Further data analysis was conducted to understand how far riders travel by either scooters or bicycles. On average, most trips made by either scooters or bicycles take 16 to 30 minutes. For travel times less than five minutes, the percentage of people using scooters is almost 5% higher than those who rode bicycles. The flexibility offered by dockless scooters might lead to improved accessibility and shorter trip times.

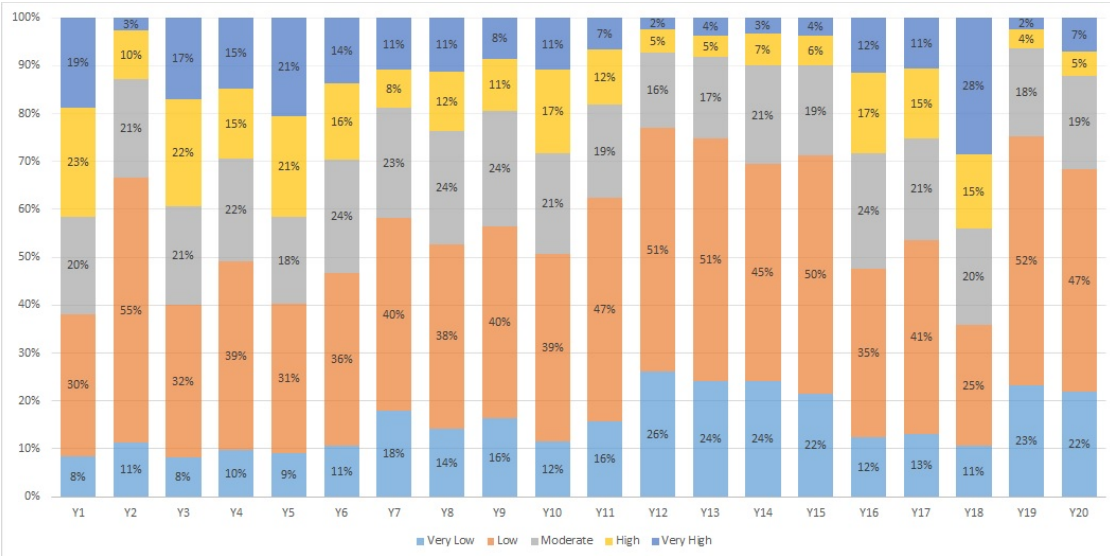

Figure 3. Distribution of responses by risky behaviors (bicycle)

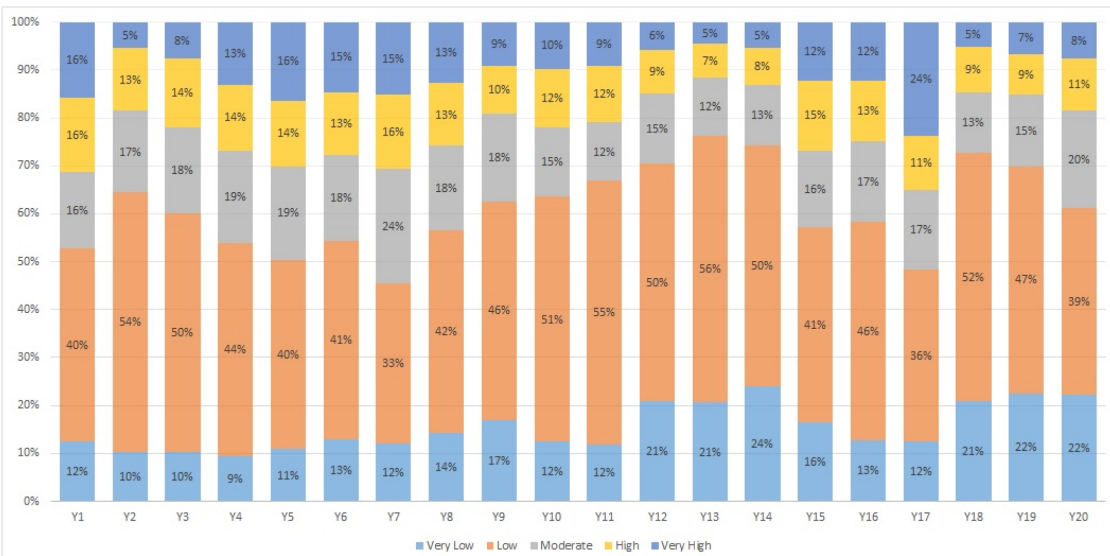

Figure 4. Distribution of responses by risky behaviors (scooter)

On average, many respondents perceive lower risk across all risky behaviors listed in the survey. However, the distribution of responses of risk is not the same across the two surveys (scooter vs. bicycle), as illustrated in Figures 3 and 4. Riding a bike with under-inflated tires and riding a scooter without a helmet are perceived as the highest risk activities than any other type of behavior. Surprisingly, "riding at night without lights on" and "distracted riding" are perceived as lower levels of risk in bicycle and scooter surveys, respectively, and are ranked as the top least-risky behaviors by respondents in the two surveys. This might imply that these behaviors are least physically possible to occur in the daily commute, which leads to a lower risk level.

Table 5. Traveled time/distance per trip (Bicycle)

		Time (minutes)							
		0–5	**6–15**	**16–30**	**31–50**	**51–75**	**75**	**N/A**	**Total**
	1	1.9%	7.7%	3.4%	2.4%	0.5%	0.0%	1.9%	17.8%
	1–3	0.5%	6.3%	17.3%	10.1%	1.9%	0.5%	0.0%	36.5%
	4–7	0.0%	1.9%	9.1%	8.7%	4.3%	1.4%	0.0%	25.5%
	8–12	0.5%	0.0%	0.5%	4.3%	3.4%	0.5%	0.5%	9.6%
	13	0.0%	0.0%	1%	2.4%	1.4%	1.9%	0.0%	6.7%
	N/A	1.0%	0.5%	1.0%	0.0%	1.0%	0.5%	0.0%	3.8%
	Total	3.8%	16.3%	32.2%	27.9%	12.5%	4.8%	2.4%	100.0%

Table 6. Traveled time/distance per trip (Scooter)

		Time (minutes)							
		0–5	**6–15**	**16–30**	**31–50**	**51–75**	**75**	**N/A**	**Total**
	1	5.9%	5.9%	3.2%	0.5%	0.5%	0.5%	0.0%	16.8%
	1–3	2.2%	8.6%	13.5%	4.3%	1.6%	0.5%	0.5%	31.4%
	4–7	0.0%	4.9%	10.3%	11.9%	3.2%	0.5%	0.5%	31.4%
	8–12	0.5%	0.5%	2.7%	2.7%	2.2%	1.6%	0.0%	10.3%
	13	0.0%	0.5%	1.6%	0.5%	1.6%	2.7%	0.5%	7.6%
	N/A	0.5%	0.5%	0.5%	0.0%	1.1%	0.0%	0.0%	2.7%
	Total	9.2%	21.1%	31.9%	20.0%	10.3%	5.9%	1.6%	100.0%

Because the interpretation of coefficients in an ordinal logistic regression is hard to generalize, we only focused on finding statistically significant variables as described in Tables 7, 8, 9, and 10. Income and age are the top two statistically significant variables (a significance level of 0.05) for at least 10 risky behaviors (dependent variables) in both surveys. Considering the age factor, the eight risky behaviors common between the two types of vehicles included Y1, Y5, Y6, Y9, Y10, Y11, Y15, and Y16. Interestingly, age is not a significant factor for explaining risky actions, including "Distracted riding," Wheelie, "Riding without helmets," "Yelling," and "Riding with a passenger." From an income perspective, Y1, Y2, Y3, Y5, Y6, Y7, Y8, and Y19 are the common significant factors for both surveys.

Considering other independent variables, being married is related to “speeding” in both surveys. Further research is needed to identify cognitive and emotional factors that influence risk-taking among people with different marital statuses. People living in urban areas have different risk perceptions associated with vehicle types. While “Speeding” with scooters is the only risky behavior explained by the factor, it is a critical factor for reckless cycling behaviors such as distracted cycling, ignoring stop signs, ignoring traffic signals, and others. Region is the least significant value across all 20 dependent variables, implying that how people perceive risk is not dependent on location.

Table 7. Significant factors by response variables (Y1–Y10) from bicycle survey (95% significance level)

Predictor	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**
Age										
25–34										
35–44										
45–54										*
55–64	*		*		*	*			*	*
65–74										
75 or older						*	*		*	
Gender										
Male										
Marital Status										
Married		*					*			
Separated										
Single		*								
Widowed										
Education										
Bachelor degree		*	*	*	*	*				
Graduate degree										
High school diploma or equivalent										
Less than a high school diploma										
Some college, no degree										

Employment Status										
Employed full-time										
Employed part-time										
Retired							*	*		
Self-employed										
Unemployed (currently looking for work)										
Unemployed (not currently looking for work)								*		
Income										
$10k - $25k		*	*				*	*		
$25k - $50k	*		*		*					
$50k - $75k	*	*	*		*	*	*	*		
$75k - $100k			*							
$100k - $125k			*		*					
$125k - $150k										
Over $150k	*									
Race										
Black or African-American										
Middle Eastern American										
Native American or Alaska Native		*						*	*	
Native Hawaiian or other Pacific islander										
White American		*	*							*
Other race	*	*							*	*
Region										
Suburban										
Urban	*		*							

Table 8. Significant factors by response variables (Y11–Y20) from bicycle survey (95% significance level)

Predictor	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Age										
25–34										
35–44										
45–54										
55–64	*				*	*		*		
65–74										
75 or older	*				*					
Gender										
Male										
Marital Status										
Married										
Separated										
Widowed										
Education										
Bachelor degree						*	*	*		
Graduate degree										
High school diploma or equivalent										
Less than a high school diploma										
Some college, no degree										
Employment Status										
Employed full-time										
Employed part-time							*			
Retired										
Self-employed										
Unemployed (currently looking for work)										

Unemployed (not currently looking for work)						*	*		*	
Income										
$10k - $25k								*		
$25k - $50k								*		
$50k - $75k								*	*	
$75k - $100k								*		
$100k - $125k		*						*		
$125k - $150k										
Over $150k										
Race										
Black or African-American										
Middle Eastern American										
Native American or Alaska Native			*							*
Native Hawaiian or other Pacific islander										
White American					*					*
Other race	*	*								
Region										
Suburban										
Urban										

Table 9. Significant factors by response variables (Y1–Y10) from scooter survey (95% significance level)

Predictor	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Age										
25–34		*								
35–44	*	*				*		*	*	*
45–54	*					*	*	*		
55–64										
65–74	*				*		*			
75 or older										
Gender										
Male						*				*
Marital Status										
Married							*			
Separated	*						*	*		
Single										
Widowed										
Education										
Bachelor degree										
Graduate degree										
High school diploma or equivalent										
Less than a high school diploma										
Some college, no degree										
Employment Status										
Employed full-time					*		*	*		
Employed part-time										
Retired										
Self-employed								*		

Unemployed (currently looking for work)					*					
Unemployed (not currently looking for work)										
Income										
$10k - $25k	*	*	*	*	*	*	*	*	*	*
$25k - $50k	*			*	*					
$50k - $75k	*		*	*	*	*	*	*	*	*
$75k - $100k										
$100k - $125k										
$125k - $150k					*	*				
Over $150k										
Race										
Black or African-American									*	
Middle Eastern American										
Native American or Alaska Native										
Native Hawaiian or other Pacific islander										
White American			*							
Other race			*							
Region										
Suburban										
Urban							*			

Table 10. Significant factors by response variables (Y11–Y20) from scooter survey (95% significance level)

Predictor	**Y11**	**Y12**	**Y13**	**Y14**	**Y15**	**Y16**	**Y17**	**Y18**	**Y19**	**Y20**
Age										
25–34					*					
35–44	*	*		*	*	*				
45–54		*		*	*	*				
55–64				*						
65–74										
75 or older										
Gender										
Male	*				*	*				
Marital Status										
Married										
Separated	*	*		*	*	*				
Single					*	*				
Widowed										
Education										
Bachelor degree										
Graduate degree										
High school diploma or equivalent										
Less than a high school diploma										
Some college, no degree										
Employment Status										
Employed full-time										
Employed part-time										
Retired					*					
Self-employed										

Unemployed (currently looking for work)										
Unemployed (not currently looking for work)										
Income										
$10k - $25k	*			*	*	*	*		*	
$25k - $50k					*		*		*	
$50k - $75k	*				*		*		*	
$75k - $100k										
$100k - $125k										
$125k - $150k							*		*	
Over $150k										
Race										
Black or African-American		*	*							
Middle Eastern American										
Native American or Alaska Native										
Native Hawaiian or other Pacific islander										
White American		*	*							
Other race										
Region										
Suburban										
Urban										

CONCLUSIONS AND IMPLICATIONS

The emergence of shared micromobility systems like bike- and scooter-sharing systems attracts many commuters to use these vehicles, but they are also an inconvenience to many residents because of their reckless use. Some riders show reckless behaviors, causing a backlash against these modes of transportation. Hence, the objective of this article was to evaluate how people perceive risk associated with a set of reckless behaviors among scooter/bicycle riders. The motivation to conduct this research was the increasing number of news articles about incidents related to bikes and scooters across the United States.

The results show that using scooters as a means of transportation (36 % never rode a scooter before) is at the early stage of development in the United States. Considering the percentage of enthusiastic and interested persons, there is much more room available for scooter sharing programs to be expanded. Also, the percentage of people not sure about their scooter/bicycle riding skills draws attention to more education programs in this respect. The short travel time either by scooter or bicycle (16 to 30 minutes) requires an enforcement approach that is agile and could track an individual's riding behavior while using the vehicle.

In this study, eight determinants, such as age, sex, income, and others, were identified to explain 20 risky behaviors. In general, in both surveys, participant risk perception of each identified behavior is relatively low. This may be because the frequency of the incidents is low in the region where participants are located and are not observed by many residents. From the perceived risk model, age and income play a critical role in explaining most of the risky behaviors in both surveys. Education levels differ between the two surveys and in explaining the risky behaviors. Noting a high school diploma or less in the scooter survey and a bachelor's degree in the bicycle survey were dominant factors that determined risky behaviors. One reason might be the availability of bike sharing programs on university campuses. However, this might change in the future as scooter sharing companies have been expanding across the United States over the past two years.

From the open-ended question, certain behaviors are not addressed in the surveys. Riding with no hands, holding onto vehicles, riding abreast instead of a single file are the respondents' major concerns. Also, respondents have observed many risky behaviors from kids, which is not within the scope of this study. Not wearing a helmet is another concern that is already on the list but frequently repeated in this section. The feedback could help future research have a comprehensive survey questionnaire or focus on a specific issue.

Limits of the Study

Though the sample size is small, the findings suggest there are great opportunities to understand the perceived risk of road users toward scooter and bike riders. Bigger sample size and a city-level survey would definitely help narrow down potential factors. The other avenue could be a longitudinal survey before and after micro-mobility services are available in a region. Second, since we wanted to make the survey feasible, the number of risky behaviors listed in the surveys is limited. At the beginning of this study, little was known about specific risky behaviors, so we tried to cover as many as possible. From the results of the open-ended question, more risky behaviors could be covered in future research. Third, this study did not systematically explore riding behaviors of an individual from current behavior models; therefore, an extra question on general riding behaviors might provide more detail about an individual's experience with bicycle or scooter use, as well as their interactions with different aspects of transportation systems, such as network geometry, rights of way, public safety, and others.

Practical Applications

Contribution to Research

First, we extend the literature on risk perception by doing two separate surveys to understand the magnitude and frequency of risk from road users' perspectives. We also developed the risk matrix and risk perception model to identify the significant factors explaining each risk. This work could be a starting point to identify other possible factors that cause any risky behaviors. The risk matrix is also used to build predictive models to characterize users' riskiness.

Contribution to Practice

Our findings offer several insights for practitioners. This work investigates the potential risks associated with scooters and bike riders and may help city planners and system operators to set policies or appropriate enforcement to reduce any harm from rogue riders. Second, the results of the risk matrix help to quantify the penalties related to each risky behavior. The results also help officials design educational programs to mitigate any reckless behaviors.

REFERENCES

[1] R. Godavarthy, J. Mattson, and A. R. Taleqani, "Evaluation Study of the Bike Share Program in Fargo, North Dakota," 2017.

[2] A. R. Taleqani, J. Hough, and K. E. Nygard, "Public Opinion on Dockless Bike Sharing: A Machine Learning Approach," *Transp. Res. Rec. J. Transp. Res. Board*, vol. 2673, no. 4, pp. 195–204, Apr. 2019.

[3] K. Kireyev, L. Palen, and K. Anderson, "Applications of topics models to analysis of disaster-related twitter data," in *NIPS workshop on applications for topic models: text and beyond*, 2009, vol. 1.

[4] K. Anderson-Hall, B. Bordenkircher, R. O'Neil, and S. C. Scott, "Governing micro-mobility: A nationwide assessment of electric scooter regulations," 2019.

[5] N. A. of City Transportation Officials, "NACTO Shared Micromobility in 2018." .

[6] M. Winters, K. Teschke, M. Grant, E. M. Setton, and M. Brauer, "How far out of the way will we travel? Built environment influences on route selection for bicycle and car travel," *Transp. Res. Rec.*, vol. 2190, no. 1, pp. 1–10, 2010.

[7] "E-scooters: a transport 'tsunami' flooding cities worldwide."

[8] G. Gardner, "Nashville Mayor Proposed E-Scooter Ban; Then Council Changed The Rules." Forbes Magazine.

[9] N. H. T. S. Administration, "Traffic Safety Facts 2017 A Compilation of Motor Vehicle Crash Data." .

[10] S. A. Shaheen, E. W. Martin, A. P. Cohen, N. D. Chan, and M. Pogodzinski, "Public Bikesharing in North America During a Period of Rapid Expansion: Understanding Business Models, Industry Trends & User Impacts, MTI Report 12-29," 2014.

[11] E. Martin, A. Cohen, J. L. Botha, and S. Shaheen, "Bikesharing and bicycle safety," 2016.

[12] K. C. Heesch, J. Garrard, and S. Sahlqvist, "Incidence, severity and correlates of bicycling injuries in a sample of cyclists in Queensland, Australia," *Accid. Anal. Prev.*, vol. 43, no. 6, pp. 2085–2092, Nov. 2011.

[13] J. Garrard, S. Greaves, and A. Ellison, "Cycling injuries in Australia: road safety's blind spot?," *J. Australas. Coll. Road Saf.*, vol. 21, no. 3, p. 37, 2010.

[14] S. O'Brien, "Curbing the road wars between motorists and cyclists." .

[15] Z. Williams, "Bikes vs Cars: why it's war between cyclists and drivers on city streets," *The Guardian*. .

[16] A. Tapp, S. Rundle-Thiele, R. Anibaldi, S. Warren, and A. Beardmore, "Road wars? The role of language in perceptions of bikes and cars sharing the road: Possible implications for social marketing interventions," in *Australia and New Zealand Marketing Academy*, 2014.

[17] P. M. Salmon, M. G. Lenné, G. H. Walker, and A. Filtness, “Investigating the factors influencing cyclist awareness and behaviour: an on-road study of cyclist situation awareness,” *J. Australas. Coll. Road Saf.*, vol. 24, no. 4, p. 7, 2013.

[18] A. Macmillan, A. Roberts, J. Woodcock, R. Aldred, and A. Goodman, “Trends in local newspaper reporting of London cyclist fatalities 1992-2012: the role of the media in shaping the systems dynamics of cycling,” *Accid. Anal. Prev.*, vol. 86, pp. 137–145, Jan. 2016.

[19] E. S. Chataway, S. Kaplan, T. A. S. Nielsen, and C. G. Prato, “Safety perceptions and reported behavior related to cycling in mixed traffic: A comparison between Brisbane and Copenhagen,” *Transp. Res. Part F Traffic Psychol. Behav.*, vol. 23, pp. 32–43, Mar. 2014.

[20] E. Fishman, S. Washington, and N. Haworth, “Barriers and facilitators to public bicycle scheme use: A qualitative approach,” *Transp. Res. Part F Traffic Psychol. Behav.*, vol. 15, no. 6, pp. 686–698, 2012.

[21] C. Rissel, C. Bonfiglioli, A. Emilsen, and B. J. Smith, “Representations of cycling in metropolitan newspapers - changes over time and differences between Sydney and Melbourne, Australia,” *{BMC} Public Heal.*, vol. 10, no. 1, Jun. 2010.

[22] T. Bogdanowicz, “Cycling and the Media,” *Intermedia-London*, vol. 32, pp. 21–22, 2004.

[23] D. Skinner and P. Rosen, “Hell is other cyclists: rethinking transport and identity,” in *Cycling and society*, Routledge, 2016, pp. 99–112.

[24] M. Møller and T. Hels, “Cyclists’ perception of risk in roundabouts,” *Accid. Anal. Prev.*, vol. 40, no. 3, pp. 1055–1062, May 2008.

[25] J. Parkin, M. Wardman, and M. Page, “Models of perceived cycling risk and route acceptability,” *Accid. Anal. Prev.*, vol. 39, no. 2, pp. 364–371, Mar. 2007.

[26] M. S. Klobucar and J. D. Fricker, “Network Evaluation Tool to Improve Real and Perceived Bicycle Safety,” *Transp. Res. Rec. J. Transp. Res. Board*, vol. 2031, no. 1, pp. 25–33, Jan. 2007.

[27] B. W. Landis, V. R. Vattikuti, R. M. Ottenberg, T. A. Petritsch, M. Guttenplan, and L. B. Crider, “Intersection level of service for the bicycle through movement,” *Pedestrians Bicycl. 2003 Saf. Hum. Perform.*, no. 1828, pp. 101–106, 2003.

[28] L. Leden, P. Gårder, and U. Pulkkinen, “An expert judgment model applied to estimating the safety effect of a bicycle facility,” *Accid. Anal. Prev.*, vol. 32, no. 4, pp. 589–599, Jul. 2000.

[29] R. G. Hughes and D. L. Harkey, “Cyclists’ perception of risk in a virtual environment: effects of lane conditions, traffic speed, and traffic volume,” in *Proceedings of the Conference on Traffic Congestion and Traffic Safety in the 21st Century*, 1997, pp. 132–138.

[30] R. B. Noland and H. Kunreuther, “Short-run and long-run policies for increasing bicycle transportation for daily commuter trips,” *Transp. Policy*, vol. 2, no. 1, pp. 67–79, Jan. 1995.

[31] V. F. Reyna and F. Farley, “Risk and Rationality in Adolescent Decision Making,” *Psychol. Sci. Public Interes.*, vol. 7, no. 1, pp. 1–44, Sep. 2006.

[32] R. E. DAHL, “Adolescent Brain Development: A Period of Vulnerabilities and Opportunities. Keynote Address,” *Ann. N. Y. Acad. Sci.*, vol. 1021, no. 1, pp. 1–22, Jun. 2004.

[33] H. Feenstra, R. A. C. Ruiter, and G. Kok, “Social-cognitive correlates of risky adolescent cycling behavior,” *{BMC} Public Heal.*, vol. 10, no. 1, Jul. 2010.

[34] J. T. Shope and C. R. Bingham, “Teen driving: motor-vehicle crashes and factors that contribute,” *Am. J. Prev. Med.*, vol. 35, no. 3, pp. S261--S271, 2008.

[35] T. C. Boas, D. P. Christenson, and D. M. Glick, “Recruiting large online samples in the United States and India: Facebook, mechanical turk, and qualtrics,” *Polit. Sci. Res. Methods*, pp. 1–19, 2018.

[36] D. L. Poston Jr. and L. F. Bouvier, “Age and Sex Composition,” in *Population and Society: An Introduction to Demography*, Cambridge University Press, 2010, pp. 228–264.

[37] R. S. Ross, “Guide for conducting risk assessments,” National Institute of Standards and Technology, 2012.

[38] J. Dill and N. McNeil, “Four types of cyclists? Examination of typology for better understanding of bicycling behavior and potential,” *Transp. Res. Rec.*, vol. 2387, no. 1, pp. 129–138, 2013.