PERCEPTION OF CYCLING RISKS AND NEEDS ASSOCIATED WITH SKILL LEVEL, GENDER, AND AGE

Fadi ALHOMAIDAT[1], Tamer ELJUFOUT[2]

[1] *Department of Civil Engineering, Al-Hussein Bin Talal University, Ma'an, Jordan*

[2] *Department of Civil and Environment Engineering, American University of Madaba , Madaba, Jordan*

Abstract:

Over the last decade, there has been a growing number of individuals using cycling for transport. However, a fraction of workers in the United States of America (USA) are riding bicycles for commuting due to different risk and need factors. Cycling still has serious obstacles to be utilized as alternative transportation. Therefore, there is a need to have a better understanding of the perceived risk/need factors among cyclists. This survey study clarifies the awareness among cyclists of different categories of Risk/Need Factors (RNF) and it contributes to a better understanding of the differences in perceived risks/needs within age groups, genders, and skill levels. An online survey was conducted that included three main categories of Risk/Need Factors (RNF) related to cycling: infrastructure-related, traffic-related, and facility-related. Mean Score Analysis and Ordered Probit Model were used to examine the differences in risk/need perception among cyclists of different ages, genders, and skill levels. According to the study outcomes, older cyclists are influenced more than young cyclists with the infrastructure-related RNF's. Moreover, gender was not statistically significant when related to perceived RNF. Also, it was found that there are significant differences in the RNF's among cyclists' skill levels, infrastructure-related, and facility-related. The study findings emphasize the importance of improving cyclists' safety and promoting cycling for transportation. Meanwhile, beginner-skilled cyclists are more likely to be influenced by infrastructure-related RNF when compared to other skill levels. The findings of this study give clarifications for potential issues that contribute to a better understanding of the differences in perceived risks/needs among age groups, genders, and skill levels. This reflects among the efforts to promote cycling safety and support cycling for transportation. Therefore, policymakers and city planners should consider the differences in RNF's in developing cycling infrastructures and traffic management. This allows the urban street system to operate more efficiently, safely, and reliably for all users. Which will enhance the safety awareness of cyclists, reduce the risk factors in the long run, and play a leading role in increasing the number of cyclists.

Keywords: cyclist's skill level, perceived risk, cycling safety, survey questionnaire, urban cycling

Contact:
1) fadi.a.alhmedat@ahu.edu.jo [https://orcid.org/0000-0001-6876-4945] - corresponding author;
2) t.eljufout@aum.edu.jo [https://orcid.org/0000-0003-1834-3047]

1.   Introduction

Transportation networks should meet society and people's needs to provide safe and environmental-friendly systems. It became obvious by the end of the 20th century that an effort had to be made to create cities clean places to live on with a reliable transport network (Berglund, 2015; Gonzalez et al., 2020; Sheikh Mohammad Zadeh & Rajabi, 2013; Southworth, 2005). According to the global sustainable development report in 2019, the development in different fields must meet the needs of the present without compromising the ability of future generations to meet their own needs (Messerli et al., 2019). A key role in sustainable development is played by the transport systems. Transportation networks provide access to economic and social communities all over the world. This makes the engineering society worldwide under an essential need to increase the role of cycling as active mobility for developing urban transportation networks.

Cycling is an alternative and sustainable mode of transportation that has social, economic, and environmental benefits (Götschi et al., 2016; Rizk Hegazy, 2020). It reduces relevant disease risk factors, such as cardiovascular problems, cancer, and obesity for middle-aged and senior individuals (Bassett et al., 2008; Mueller et al., 2018; Oja et al., 2011; Pucher et al., 2010; Riiser et al., 2018; Sharara et al., 2018). Both walking and cycling minimize the costs associated with traffic crashes and congestion (Jarrett et al., 2012; Litman, 2016; Okraszewska et al., 2017; Sælensminde, 2004). Cycling also reduces carbon emissions resulting from the use of fossil fuels (Buekers et al., 2015; Chapman et al., 2018; Coley, 2002; Maibach et al., 2009; Mueller et al., 2018). It was found that cycling was grown by around 300% in different cities in the USA, such as San Francisco, New Orleans, Chicago, Portland, and Philadelphia, while in other cities, such as Boston, Denver, St Louis, and Louisville, it has grown by about 100% (The League of American Bicyclists, 2014). Even with these increases, cycling still faces significant obstacles to be utilized as alternative transportation. In 2008-2012, American Community Survey reports showed that the percentage of cycling among other means of transportation was only 1.0% for the 50 largest cities in the U.S.A (McKenzie, 2014). Several studies have emphasized the need of simple access to destinations and a variety of transportation modes, as well as the availability of infrastructure to encourage the use of active transportation, such as walking and cycling (Sandt, Combs, & Jesse, 2016; Thrun, Perks, & Chriqui, 2016).

2.   Literature review

Risk/need factors (RNF) of cyclizing are consistently receiving attention from researchers all over the world. In the last two decades, different studies were conducted on cyclists' perceived risk factors and how they are discouraging the use of cycling. For example, the presence and quality of cycling infrastructure, facility, and traffic operation are significant factors for individuals' decision to use the bicycle as a mode of commuting regularly (Lawson et al., 2013; Panter et al., 2016; Pooley et al., 2011; Sanders, 2015; Song et al., 2017; Winters et al., 2012). Different perceived RNF among age groups, gender, and skill levels were investigated. Researchers found that cyclists' risk perception and safety concerns varied when they were asked to rank the behaviour of drivers overtaking (Parkin & Meyers, 2010; Pazdan, 2020; Useche et al., 2019). Moreover, it was found that safety and comfort regarding cycling for transportation are more important for women than men (Heesch et al., 2012). A recent study on risk perception was conducted by Bill et al. (Bill et al., 2015). They studied the influence of age, gender, and skill level on the involvement in a crash. The study investigated the likelihood of encountering thirteen cycling hazard risk factors utilizing survey data of cyclists commuting to work. The obtained results showed significant differences among the age and gender groups reacting to several risk factors.

Studies that do not account for the differences among cyclists remain useful, but the obtained data are limited in their interpretive conclusions. It was found that the presence or absence of bike lanes and other facilities with respect to heavy traffic routes, intersections, and roundabouts do not influence the perceived risk factors (Møller & Hels, 2008; Parkin et al., 2007). This inconsistency in the outcomes might be due to the fact that such studies did not account for the skill level or age group. Other studies showed that the level of confidence coincides with the skill level (Alhomaidat et al., 2017; Lawson et al., 2013). Besides, it was found that more than 30% of cyclists -involved in fatal crashes are within the age range of 50-64 years old (Michigan Office of Highway Safety Planning, 2017).

Although different studies in the literature focused on analysing the perception of risk factors, few studies were conducted on different categories of RNF together and attempted to evaluate the correlation of a cyclist's age, gender, and skill levels to the perceived RNF. Nevertheless, no research was found in the literature examining the relation of infrastructure, traffic, and facility RNF across the cyclists' age, gender, and skill levels altogether. This study contributes to a better understanding of perceived RNF among cyclists through (1) An examination of perceptions of different categories of RNF among cyclists, (2) an investigation into the relationships between perceived RNF with respect to age, gender, and skill level of cyclists. This helps to promote cycling safety and improve worldwide efforts to increase the percentage of cycling among the other transport means.

3. Methodology

The purpose of this study is to investigate the differences in perceived RNF across age, gender, and skill levels for different categories of RNF (infrastructure-related, traffic-related, and facility-related). The study is based on a larger research project investigating the cycling RNF using a mobile application that was developed to report the user's behaviour in the city of Kalamazoo. Kalamazoo city, with a 265,066 population, lies in the Midwest part of the United States and maintains 83 miles of major streets and 166 miles of local streets. As stated by the city code, roads have a sidewalk for pedestrian usage with a minimum width of 5 feet, whereas the lane width of vehicular traffic in major and local roads ranges between 10-12 feet and 9-12 feet, respectively. Kalamazoo has a decent public transportation system, fixed-route Metro buses serve throughout the Kalamazoo with a system size of 36 buses.

In May 2015, an online survey was disseminated, after it was approved for research protocol by the Human Subject Institutional Review Board at Western Michigan University. The sample size was determined based on several factors, that includes the number of bicycle commuters in the city of Kalamazoo (population size). In 2015 Kalamazoo bicycle commuter was estimated to be 758, considerably smaller than 1% of bicycle commuters per capita (Joe, 2019; McKenzie, 2014); the error was established to be 5% as recommended by (Bartlett et al.,

2001); the level of confidence was set to be 95% as suggested by (Adam, 2020; Bartlett et al., 2001). Therefore, based on the aforementioned information and Equation (1) of the minimum sample size:

$$x = \frac{t^2 * p * q}{d^2} \qquad (1)$$

where:
$t = 1.96$ – normal value corresponding to 95% confidence interval;
p – sample proportion which is response distribution and usually is assumed to be (0.5);
$q = (1 - p)$ – remaining sample proportion;
d – the maximum allowable error.
Sample size adjusted to response rate is presented by Equation (2):

$$S = \frac{x}{(1 + \frac{x}{N})} \qquad (2)$$

where:
S – sample size adjusted for response rate;
x – the minimum sample size;
N – Kalamazoo bicycle commuter population.
According to the results the minimum survey sample size adjusted for response rate is 255 participants (Adam, 2020; Bartlett et al., 2001).

The survey sample size was a total of 256 participants, at which 182 participants (71.09% of the total) completed the whole survey. Twenty-four participants were eliminated from the sample as they do not how to ride a bicycle. A more complete description of the survey can be found in Al-Fuqaha et al. (Al-Fuqaha et al., 2017). Among the 182 respondents, 61% were males, and 39% were females. The data indicated that the largest age group was 50 to 64 years old. Of all participants who considered themselves experienced cyclists, 80% were males, and 20% were females. The survey population based on the sample group is presented in Table 1. It is worth mentioning that the analysis was conducted based on the 256 participants, yet some surveys were not sufficient enough to be considered.

RNF's were classified into three categories: infrastructure-related, traffic-related, and facility-related. Mean Score and Ordered Probit Model were used for analysing the survey responses. Mean scores were used to rank the RNF and determine how the per-

ceived RNF varies for cyclists of different skill levels. The Ordered Probit Model was utilized to examine the perceived RNF among different age groups, gender, and skill levels.

The survey focused on potentially hazardous cycling conditions identified from previous studies and based on a discussion with several members of the cycling group in Kalamazoo city, Michigan, such as bike lanes, bike paths, shared lane arrows, street lighting, bicycle-specific signage, lack of bike lane continuity, high traffic volume, aggressive driver behaviours, unsafe riding habits of bicyclists, and lack of bicycle route maps. Moreover, the uneven pavement surface and low-angled grades were considered, as they affect the risk of crashes. The bicycle facilities include different factors that enhance the cycling comfortability, such as bike racks, curbside auto parking, sufficient lighting, signage devoted to bike traffic, manage work zone, and maps devoted to bike infrastructure (Demers et al., 1995; Gaca, 2002; Hamann & Peek-Asa, 2013; Hamilton & Stott, 2004; Li et al., 2016; Mateu & Sanz, 2021; Sheik Mohammed Ali et al., 2012; Winters et al., 2012),.

The survey contained three main questions that addressed the RNF related to cycling. The first question investigated the impact of twenty infrastructure-related RNF's. The second question probed the impact of seven traffic-related RNF's, while the third question focused on the impact of twelve facility-related RNF's. Participants were also asked different questions related to the socio-demographic information and skill level. The Likert scale was adopted for this survey and included five levels to allow the participants to express how much they agree or disagree with each RNF, one being the least impact and five being the most impact. The five-level scale was used because near-misses and collisions were found to influence cyclist's perception of traffic risks in varying degrees (Sanders, 2015). Cronbach's alpha was calculated to test the internal consistency (Cronbach, 1951) of the whole survey questionnaire. The questionnaire shows satisfactory validity and an excellent internal consistency with Cronbach's alpha value of 0.95.

Mean Score Analysis and an Ordered Probit Model were used to analyse the survey responses. The survey outcomes were mean scores that were ranked based on the impact level chosen by cyclists. The Mean Score Analysis can demonstrate the influence of each RNF. The mean score is the sum of impact levels for each given empirical distribution (e.g., minor impact =1 and very strong impact =5) divided by a total number of responses for each group. The mean score ranges between one and five. The data were used to rank the most influential RNF among age, gender, and skill level. The weighted average mean scores were calculated for each RNF for each subgroup (age, gender, and skill level).

This study utilized also the Ordered Probit Modelling structure. Explicitly, this study considered this interaction by developing a unique Ordered Probit Model for each of the factors describing the level of perceived risk/need. Significant levels of 90% (α=0.1) and 95% (α=0.05) were used in this study and state whether the estimated coefficient is different from zero. Although the most common significant level is 95% (α=0.05) as it gives a smaller chance of being wrong, 90% (α=0.1) also makes it valid to conclude that the coefficient is different from zero (Hair et al., 2010).

The primary benefit of the Ordered Probit Model is to incorporate a continuous latent measure underlying each perceived risk/need choice among age groups, gender, and skill levels. Perceived risks/needs are determined from the five ordered alternatives based on the survey, where the responses fall among the set values of thresholds. Therefore, as the respondents choose a higher impact, the likelihood of bicyclists perceiving RNF will increase. As the project considered the real relationships between risk factors and their cycling habits, the subjects' views are immaterial.

The structure for each Ordered Probit Model took a similar form. For example, in each type of RNF modeling, each respondent n ($n = 1, 2\ldots., N$) chose to rate that RNF in the level of impact m ($m = 1,2\ldots.,5$) As such, the relationship between age groups, gender, and skill-levels, x_n, and each perceived risk/need factor, Z_{-n}, can be written as (3):

$$z_{-n}^* = \beta x_n + \varepsilon_n \qquad (3)$$

where:
β – the corresponding coefficient vectors
x_n – a vector of variables;
ε – the random error terms;
ε_n – parameter explanation needed.

These factors are assumed to be independent and identically normally distributed across individual *n*. Respondents' choice to rate the level of RNF, Z_{-n},

is determined by the stepwise function of the latent measure z_{-n}^*, as defined in Equation (4):

$$z = \begin{bmatrix} 1 & if & -\infty < z^* < \mu_1 (Outcome\ 1) \\ 2 & if & \mu_1 < z^* < \mu_2 (Outcome\ 2) \\ 3 & if & \mu_2 < z^* < \mu_3 (Outcome\ 3) \\ 4 & if & \mu_3 < z^* < \mu_4 (Outcome\ 4) \\ 5 & if & \mu_4 < z^* < \infty (Outcome\ 5) \end{bmatrix} \quad (4)$$

where:
1,2,3,4,5 – the level of impact of RNF;
μ – the threshold value to be estimated for each level;
$z*$ – unobserved variables of the latent measure.

The Ordered Probit Model, as shown in Equation (5) provides the probabilities of Z_{-n} taking on each of values $n = 1, 2,..,5$:
Observed ordinal data z_n for each observation is (5):

$$P(z_{-1}) = \phi(\mu_1 - \beta x)$$
$$P(z_{-2}) = \phi(\mu_2 - \beta x) - \phi(\mu_1 - \beta x)$$
$$P(z_{-3}) = \cdots \quad (4)$$
$$P(z_{-4}) = \cdots$$
$$P(z_{-5}) = 1 - \phi(\mu_4 - \beta x)$$

where:
ϕ - the cumulative probability function of the normal distribution formula;
z_i – an impact level of each RNF (five categories of the impact level).

4. Survey characterization and results
The obtained data also showed a relationship between the skill level and cycling frequency. It was observed that the skill level of cycling indicates a higher frequency of bicycle use. Moreover, it was noticed that (24%) of experienced cyclists ride a bicycle every day, while 39 participants cycle at least once a week. As might be expected; intuitively, experienced cyclists tend to bicycle more than beginner cyclists.

The data show a relationship between cyclists' primary purpose and skill levels as shown in Figure 1. The cycling groups also varied with respect to races and ethnicities. White respondents were the highest percentage among the three types of skill levels. This agrees with the conducted research on cycling in North America, which consistently includes that a high percentage of white respondents have a high

skill level of cycling (Sanders, 2015). Therefore, the obtained results of the study should not be applied to other races and/or ethnicities without further research.

5. Discussion
5.1. Mean score analysis
The highest-ranked impact levels are shown in Table 2, overall and divided by age group, gender, and skill level. These impact levels are based on the mean scores for three RNF categories. The three highest perceived RNF are highlighted in bold for overall and subgroup.

There is a definite difference in the mean scores for different skill levels with respect to the infrastructure-related factors. Where the intermediate and experienced perceived potholes as the most impact risk factor. Beginner did not perceive it among the top three RNF's. In addition, respondents in the age group 35 to 49 years old perceive potholes and lack of grade-separated bike lanes differently than the other age groups. No significant difference was found between the genders.

Traffic-related RNF's, in comparison to other factors, are less likely to reveal differences in the way of perceiving RNF's, across age, gender, and skill level. The exception to this trend for traffic-related factors was the mean scores for the age groups 50 to 65 and 16 to 24 years old; their mean scores were lower than the other age groups. The traffic-related overall most perceived RNF's were aggressive driver behavior, high-speed traffic, and high-volume traffic. As for the facility-related RNF intermediate cyclists more often perceived these as influences across the three skill levels. In addition, respondents in the age group 50 to 64 years old perceived RNF as less significant than the other age groups.

As shown in Figure 2, the various interactions exerted a stronger influence on beginner cyclists than on intermediate and experienced cyclists, suggesting that the skills attained from more cycling may alleviate concerns about infrastructure-related RNF's. It is also possible that those are experienced and intermediate cyclists, who bicycle more frequently, are willing to bicycle on a roadway with traffic without having a bike lane. In facility-related RNF's, there is a definite difference in the mean score between beginners, intermediate and experienced cyclists; while in traffic-related factors, the difference between skill levels is negligible.

Table 1. Survey population characteristics

Skill level	Total	Beginner	Intermediate	Expert	Not specified
	182 (100%)	15 (8%)	73 (40%)	69 (38%)	24 (13%)
Age					
16-24	29 (18%)	2 (13%)	19 (26%)	8 (12%)	--
25-34	30 (19%)	4 (27%)	20 (27%)	6 (9%)	--
35-49	35 (22%)	6 (40%)	16 (22%)	13 (19%)	--
50-64	48 (30%)	3 (20%)	15 (20%)	30 (43%)	--
65+	16 (10%)		4 (5%)	12 (17%)	--
Gender					
male	110 (61%)	4 (27%)	38 (52%)	55 (80%)	13 (54%)
female	71 (39%)	11 (73%)	35 (48%)	14 (20%)	11 (46%)
Race/ ethnicity					
White	144 (92%)	14 (93%)	67 (91%)	63 (91%)	--
Hispanic/ Latino	4 (3%)	1 (7%)	1 (1%)	2 (3%)	--
Black/ African American		--	--	1 (1%)	--
Native American/ American Indian	3 (2%)	--	3 (4%)	--	--
Asian/ Pacific Islander	3 (2%)	--	2 (3%)	1 (1%)	--
Other races	3 (2%)	--	1 (1%)	2 (3%)	--
Cycling frequency					
Every day	20 (13%)	--	3 (4%)	17 (25%)	--
Several times per week	77 (49%)	4 (27%)	34 (46%)	39 (57%)	--
Several times per month	33 (21%)	2 (13%)	22 (30%)	9 (13%)	--
Several times per year	28 (18%)	9 (60%)	15 (20%)	4 (6%)	--
Primary purpose					
Exercise and health	119 (36%)	6 (27%)	56 (38%)	57 (34%)	--
Recreation	113 (34%)	13 (59%)	53 (36%)	47 (28%)	--
Commuting	62 (19%)	2 (9%)	24 (16%)	36 (22%)	--
Shopping	41 (12%)	1 (5%)	14 (10%)	26 (16%)	--
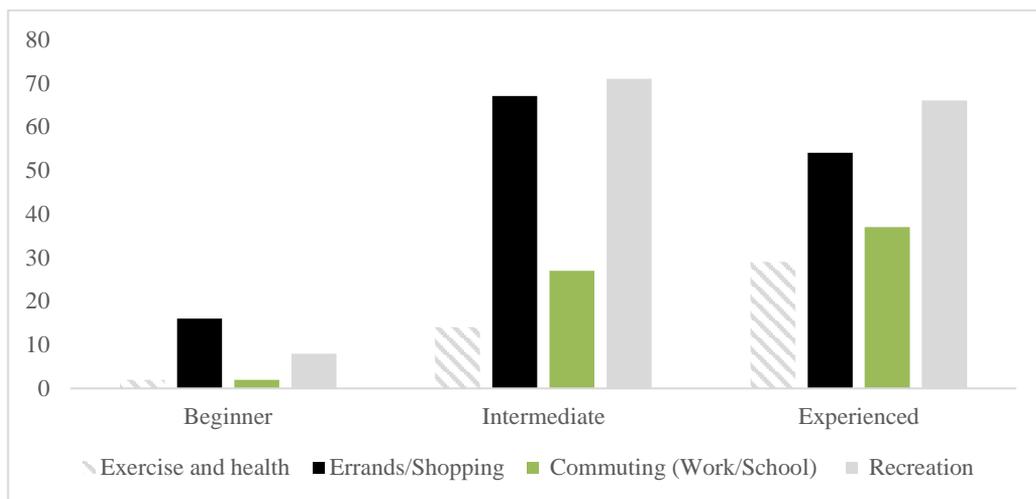
Fig. 1. Skills level and the primary purpose of cycling

Experienced and intermediate bicyclists (represented by the light-dark and light bars, respectively) were asked about the impact of curbside auto parking contiguous to bike lanes. Their responses indicated a clear difference between their perceptions of the risk of curbside auto parking; perception of risk/need is lower for the beginners than for the experienced and intermediate cyclists. These findings suggest that experienced cyclists may bicycle on roads without bike lanes, in distinction to beginner cyclists, who would prefer to ride in a bike lane.

The risk/need perception with the highest mean scores of all skill level cyclists to traffic-related risks are the same ones. The findings suggest that all cyclists with different skill levels may believe that traffic-related risks are the riskiest versus other types of RNF's. These findings also suggest that the role of skill levels in different perceived categories of traffic RNF is more complicated than expected.

Table 2. The overall and disaggregated mean scores ranking of different skill levels, age groups, and gender for the three risks and need perception categories. The three risks/needs that received the highest mean score are highlighted in bold

Factor Categories	Risk/need Factor	Overall Ranking	16-24	25-34	35-49	50-64	65+	beginner	Intermediate	Experienced	Male	female
Infrastructure-Related	Potholes	3.90 (1)	4.07 (1)	4.03 (1)	3.35 (3)	3.98 (1)	4.06 (1)	3.29	3.92 (1)	3.96 (1)	3.88 (1)	3.85 (1)
	Lack of dedicated bike lane	3.58 (2)	3.57 (3)	3.90 (2)	3.44 (2)	3.63 (2)	3.38	3.79 (1)	3.73 (2)	3.44	3.51 (2)	3.76 (2)
	Pavement rutting	3.32	3.23	3.66 (3)	3.18	3.54 (3)	4.00 (2)	3.77 (2)	3.38	3.52 (2)	3.41 (3)	3.57
	Pavement cracking	3.52 (3)	3.61 (2)	3.31	2.82	3.42	3.88 (3)	3.08	3.29	3.46 (3)	3.25	3.53
	Drop offs at overlay	3.33	3.11	3.53	3.06	3.31	3.63	3.43 (3)	3.42	3.15	3.25	3.34
	Lack of grade separated	3.41	3.22	3.43	3.49 (1)	2.98	3.50	2.99	3.47 (3)	2.99	2.99	3.74 (3)
	Narrow bicycle lane	3.21	3.07	3.62	3.16	3.06	3.13	3.17	3.43	2.96	3.03	3.49
Traffic-Related	Aggressive driver behavior	3.70 (1)	2.96 (3)	4.20 (1)	4.06 (1)	3.48 (3)	3.81 (1)	3.93 (1)	3.64 (2)	3.68 (1)	3.65 (1)	3.74 (2)
	High speed traffic	3.64 (2)	3.29 (1)	4.20 (1)	3.62 (2)	3.54 (1)	3.56 (3)	3.79 (2)	3.68 (1)	3.58 (2)	3.56 (2)	3.79 (1)
	High volume traffic	3.56 (3)	3.15 (2)	4.03 (3)	3.44 (3)	3.54 (1)	3.63 (2)	3.43 (3)	3.64 (3)	3.49 (3)	3.47 (3)	3.67 (3)
	Lack of bicycle signals/detectors	2.85	2.75	3.19	2.78	2.71	2.81	2.75	2.94	2.72	2.79	2.88
	Waiting time at signalized intersection	2.63	2.78	2.67	2.70	2.70	2.75	2.82	2.59	2.82	2.77	2.61
	Invisibility of traffic light	2.48	2.24	2.65	2.52	2.12	2.86	2.27	2.46	2.38	2.45	2.35
	Lack of space to pass slow bicyclists	2.39	2.36	2.76	2.47	2.17	2.19	3.00	2.33	2.32	2.32	2.47
Facility-Related	Unpruned trees and overgrowing vegetation (blocking bike lane)	2.91 (1)	3.07 (2)	3.03	2.82 (1)	2.64 (3)	3.00 (2)	2.71 (3)	3.13 (1)	2.65	2.84 (2)	2.93 (3)
	Curbside auto parking	2.89 (2)	2.71	2.97	2.70 (2)	2.64	3.44 (1)	2.09	2.90	2.83 (2)	2.83 (3)	2.79
	Lack of signage devoted to bike traffic	2.86 (3)	2.86	3.29 (2)	2.44	2.85 (1)	2.88 (3)	2.23	2.97	2.83 (2)	2.78	2.96 (1)
	Lack of bike racks	2.86	3.21 (1)	3.31 (1)	2.45	2.76 (2)	2.56	2.09	2.97	2.87 (1)	2.92 (1)	2.76
	Blind corners (poor sight distance)	2.83	3.04 (3)	3.21 (3)	2.52 (3)	2.57	2.81	2.73 (2)	2.99 (3)	2.59	2.70	2.95 (2)
	Lack of information about existing facilities (i.e. maps)	2.63	2.88	2.89	2.38	2.38	2.63	3.60 (1)	2.73	2.41	2.58	2.59
	Poorly managed work zones	2.48	2.65	2.54	2.48	2.41	2.31	2.18	2.45	2.57	2.53	2.42
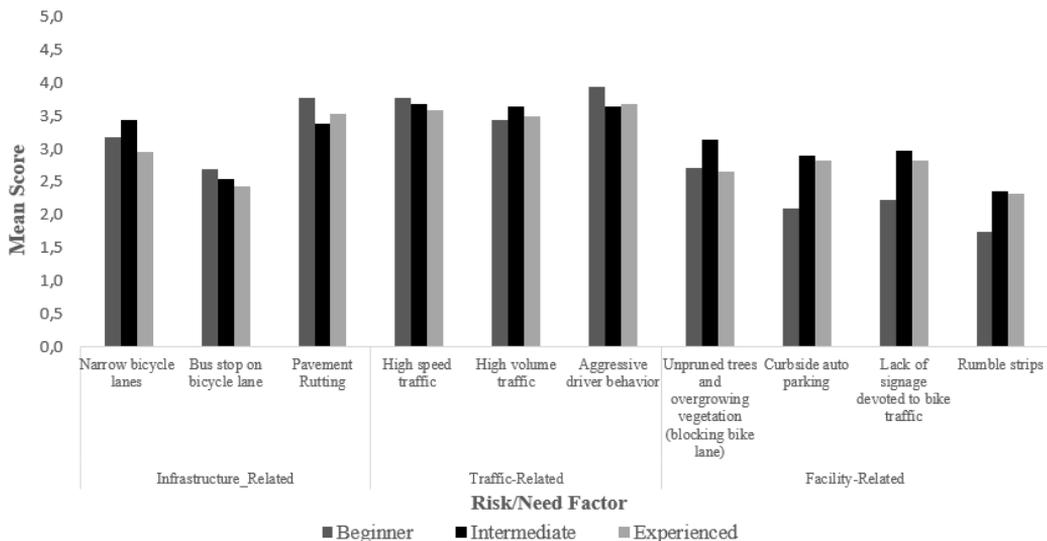
Fig. 2. Skills level and the primary purpose of cycling

5.2. Ordered Probit Model analysis

The Ordered Probit Model is a powerful tool for estimating probabilities related to ordinal dependent variables. In this study, the Probit Model was utilized to develop a separate model for each RNF in the survey. In the case of impact level, the model provided four thresholds as five levels of perceived impact level were considered. The lower sample size of age groups requires combining the age groups to increase the same size of the subgroups; the age groups 24 to 35 years old and 35 to 49 years old were combined, as well as the age groups 50-64 and 65+. A positive sign of the estimated parameters indicates the increased perceived RNF by different cyclist groups. The significance level (P-value) for each RNF was listed. The coefficient estimates describe the increase or decrease in the impact of each RNF for each age and skill level group. For categorical variables, the coefficient estimates reflect the change of impact compared to the reference group as all other groups remain the same. The comparison results for age groups and skill levels were provided after the analysis of individual model results for each RNF.

As summarized in Table 3, significant statistical differences were observed between different groups' skill levels and the twelve RNF's. Age groups' perceptions were significantly different for the four RNF's, which consisted of a narrow bicycle lane,

unsmooth patches, wide pavements joints, and aggressive drivers. However, gender was not significantly different for any types of RNF's.

Influence of age on risk/need perception

RNF for the 50+ years age group were significantly ($p=0.005$) related to concerns about riding on wide pavement joints more often than for young cyclists (16-24) by a coefficient estimate of 0.515. The age group 25-49 perceived RNF significantly ($p=0.079$) related to riding on a narrow bicycle lane by a coefficient estimate of 0.309 more than young cyclists (16-24). These findings support the research conducted by Lawson et al (Lawson et al., 2013) about the influence of age groups on the perceived safety of cycling.

The relationship between age and RNF appears stronger for the middle age group (25-49) than for young bicyclists (16-24) when they perceived traffic-related RNF's. This may indicate a systematic difference between the two populations. For the age group 25 to 49 years old, aggressive driver behaviours have more ($p=0.04$) influence for the 16 to 24 years old age group by a coefficient estimate of 0.363.

Facility-related RNF's were more clearly perceived by older cyclists (50+) than by young cyclists (16-24), reflecting the significant ($p=0.038$) and coefficient estimate of 0.367 correlation between older cyclists and unsmooth patches.

Table 3. OPM (age groups and skill levels) significant findings of perceived RNF at different levels. Significance indicated by the following: *p $\leq$ 0.10; ** p $\leq$ 0.05; and (-) base group

Risk/need Factor Categories	Significant Perceived Risk/Need Factors	Age Group			Skill Level		
		16-24 (n=41)	25-49 (n=74)	50+ (n=67)	Beginner (n=15)	Intermediate (n=74)	Experienced (n=69)
Infrastructure-Related	Narrow bicycle lanes	-	0.309 (0.079)*		0.850 (0.010)**		-
	Wide pavement joints	-		0.515 (0.005)**			-
	Bus stop on the bicycle lane	-			0.779 (0.018)**		-
	Pavement friction	-				0.324 (0.063)*	-
	Unsmooth patches	-		0.367 (0.038)**		0.366 (0.041)**	-
	Standing water	-				0.548 (0.002)**	-
Traffic-Related	Aggressive driver behavior	-	0.363 (0.040)**				-
Facility-Related	Rumble Strips	-			-0.806 (0.022)**		-
	Speed bumps	-			-0.632 (0.046)**		-
	Poorly managed work zones	-				0.372 (0.041)**	-
	Curbside auto parking	-				0.300 (0.085)*	-
	Lack of information (maps)	-				0.407 (0.032)**	-
	Signs too close to the roadway	-				0.353 (0.061)*	-
	Unpruned trees and overgrowing vegetation	-				0.395 (0.029)**	-

5.3. Influence of skill level on risk/need perception

To help filling the knowledge gap for different RNF categories and how they correlate with skill level, the survey respondents were asked to rank RNF among the three list categories. The survey responses indicate that the distribution of participants as follows: 43% were cycling frequently and described themselves to have experienced skills, 46% had intermediate experience skills, and 11% had beginner experience skills. The percentage was high for both intermediate and experienced because most cyclists in this sample who responded to the survey were from a Kalamazoo bicycle group and were bicyclist advocates. When compared to beginner cyclists, the likelihood that experienced cyclists would perceive rumble strips and speed bumps as impact levels increased by a coefficient estimate of (0.806) (p=0.022) and (0.632) (p=0.046). This because experienced cyclists tend to travel at higher speeds than beginners. These findings are supported by a study conducted by Lawson et al (Lawson et al., 2013), as they found that high skilled cyclists travel at higher speeds.

It seems intuitive that perceived infrastructure and facility-related RNF's are more often affect cyclists who describe themselves at an intermediate skill

level than experienced skill level, as shown in Table 3. Intermediate cyclists' perceived facility-related RNF's —poorly managed work zones, lack of information, overgrowing vegetation, unpruned trees, and unsmooth patches—were around the coefficient estimate of 0.30, significantly (p=0.029) more than experienced cyclists. The influence of the RNF is less for the experienced cyclists since they

are exposed to these RNF's on a daily or weekly basis.

The perceived RNF's data were also examined via an Ordered Probit Model to identify the influences of gender. Gender was not statistically significant when related to perceived RNF's. These results indicate that there is no clear pattern between the perception of risk/need for both males and females as shown in Figure 3.
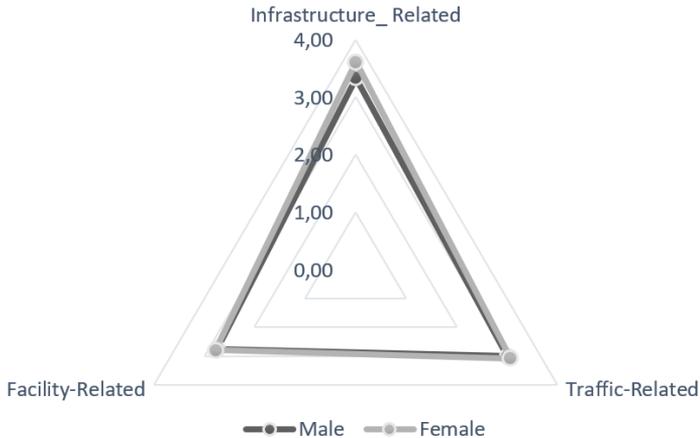
Fig. 3. Cycling gender variates among the influence of perceived risk/need factor categories

6. Conclusions

This study examines the differences in cyclists' perceived Risk/Need Factor (RNF) with respect to their age, gender, and skill levels. A survey was conducted to determine the RNF's as perceived by a sample of cyclists. Mean Score Analysis and Ordered Probit Modelling were used to identify the most influential RNF's and to determine differences of the RNF's among each group of cyclists. The obtained outcomes help to clarify potential issues contributing to a better understanding of the differences of risk/need perception among the studied groups. This reflects on the efforts to promote cycling safety and increase cycling as sustainable transportation mean. Based on the outcomes of the Mean Scores Analysis, the following conclusions can be drawn:

- Potholes, lack of a dedicated bicycle lane, and pavement rutting were the severest infrastructure-related RNF's. With respect to the traffic-related facilities, aggressive driving behaviour, high-speed traffic, and high traffic volume were the highest three perceived RNF's.

Whereas debris, curbside auto parking, and lack of signage devoted to bicycle traffic were the highest-ranked facility-related RNF's.

- For beginner cyclists, the skill level was associated with a decrease in the influence of perceived infrastructure-related RNF's. It was found that experienced cyclists may bicycle on roads without bike lanes, in distinction to beginner cyclists who would prefer to ride in a designed bike lane.

- Experienced and intermediate cyclists reported more concerns about facility-related RNF's more than beginner cyclists. Skill levels seemed not to be affected by the traffic-related RNF's. All cyclists with different skill levels believe that traffic-related risks are more severe than the other types of RNF's.

Based on the outcomes of the Ordered Probit Model, the following conclusions can be drawn:

- Significant differences were observed in the total impact of beginners, intermediate, and experienced cyclists.

– Middle age group and older cyclists are more influenced by infrastructure and traffic-related RNF's than the young age group, which supports the impact of cyclists' age on the RNF's perception.

– Cycling skills are associated with the number of rides cyclists have frequently. Better cycling skills reduce the concerns about RNF's. The skill level was found statically significant for twelve risks/needs, distributed between facility and infrastructure-related. Intermediate cyclists were more influenced by facility and infrastructure RNF's than the experienced skill level.

– Experienced cyclists ride their bicycles at a higher speed when compared to beginner cyclists. Therefore, experienced cyclists perceived risks are related to the speed reduction factors, such as speed bumps and rumble strips, more than beginner cyclists.

– Gender was not statistically significant when related to perceived RNF's. No clear pattern was found between the perception of risk/need for both males and females.

– Combining the skill level, age group, and gender differences in perceptions of bicycling safety with the effect of bicycle infrastructure and facility-related RNF's could explain the difference in cycling rates for different cities and places.

– Infrastructure and facility-related RNF's influence individuals' decisions (beginner cyclists) to cycle. Enhancing cycling infrastructures and facilities for a wide range of trip purposes improve cyclist safety and promote cycling as an active and sustainable mode of transportation.

Further research is needed to expand a better understanding of the causes of perceived RNF. Authors are suggesting the following for future research:

– The perceived risk/need of cycling can be expanded by exploring the behavioural responses to certain RNF's.

– Different risk/need scenarios can be studied using a bicycling simulator or by interviewing cyclists.

– This study was conducted among a sample that represents North American cyclists. Although there are evidences that the obtained outcomes may hold in different countries (Hamilton & Stott, 2004; Lawson et al., 2013; Okraszewska

et al., 2017). Further research should be performed on a larger international sample.

– It is important to study the RNF for different countries, as the type and relevance of the RNF vary, such as weather and topological conditions. This study excluded the weather conditions to prevent the underestimation of infrastructure-related, traffic-related, and facility-related RNF's. The exclusion may have biased the reporting toward more consistent RNF's, rather than contingent RNF that may occasionally occur, such as snow or wind. Future research is required to explore this possible bias.

– Further investigation should be conducted from different countries all over the world, where the type and relevance of risk and need factors are quite different from the presented context in this study.

– The sample size was relatively small especially the beginner group, with unequal age, gender, and skill level groups. A larger sample is required to include findings related to gender differences in cycling trips.

– Self-selection of participants might have affected the validity of the study outcomes. Future survey studies based on non-randomized cyclist groups and collecting information on key variables, such as skill level and age groups might improve the study validity.

– There was a little lack of reference to the coexistence of cycling and pedestrian traffic. It is worth taking up this topic in future research.

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