Journal of Engineering and Technological Sciences

Research Paper

How do Road Users in Mixed Traffic Perceive Risk Towards Each Other? A Comparative Study from a Developing Country

Khalisha Zahra & Nur Sabahiah Abdul Sukor*

School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, Jalan Transkrian - Bukit Panchor, 14300, Nibong Tebal, Pulau Pinang , Malaysia

*Corresponding author: cesabahiah@usm.my

Abstract

Many developing countries have high traffic accident rates due to the mixed traffic environment in which bicycles and motor vehicles travel in the same lanes. This paper examines the perceived risk among road users in mixed traffic. A questionnaire survey was used to obtain demographic information and self-reported risk perception among cyclists, motorcyclists, and drivers. Statistical analyses, including the T-test and ANOVA, were used to examine the relevant differences in risk assessment among the groups. The results demonstrate that the groups differ significantly in sociodemographic characteristics, driving experience, and travel characteristics. For self-reported perceived risk, the respondents' perceptions of road surface conditions, the potential of daydreaming while operating a vehicle, and distraction from passengers or riding companions exhibited significant differences between the groups. The research findings could be beneficial as a guide for policymakers in planning road safety awareness to reduce risk in mixed traffic environments.

Keywords: *cyclists; drivers; motorcyclists; perceived risk; road accident.*

Introduction

In developing countries, the complexities of mixed traffic environments create significant challenges to road safety. Mixed traffic environments exist not only in cities but also in suburban and rural areas. A previous study stated that mixed traffic causes high risk of road accidents [1]. The higher the traffic volume, the higher the number of accidents, especially on weekends. In mixed-traffic situations, vehicles with less protection and a smaller size (such as bicycles and motorcycles) are at a higher risk of injury or fatality in a collision with larger vehicles [2].

In contrast to more developed countries, where dedicated lanes, cyclist-friendly spaces, and pedestrian-friendly spaces are provided, road users in developing nations share space, thus raising the risk of being involved in a road accident [3,4]. Sharing space designated for cars and heavy vehicles limits the safety of vulnerable road users such as cyclists, pedestrians, and motorcyclists.

Thus, many studies have suggested to provide dedicated lanes to overcome the risk of accidents in mixed traffic in developing countries [5,6]. However, providing segregated lanes requires high-cost construction projects. For example, Malaysia was the first country to have fully segregated lanes for motorcycles. Although such segregated lanes have been reported to reduce accidents involving motorcycles and other motor vehicles, the cost of building one segregated motorcycle lane is RM 2 million for 1 kilometer, which equals USD 427,213.60/km (at the time of writing) [7]. Hull and O'Holleran [8] reported that providing the construction of a cycling network in Cambridge, England, reached 15 million US dollars. This huge financial requirement makes it difficult for developing countries to build segregated infrastructure on roads, where money allocation to develop infrastructure for health, housing, and education has higher priority [9].

Moreover, the unpredictability of road users' attitudes and behaviors, such as fatigue or recklessness, increases the likelihood of road accidents in mixed traffic [10,11]. Useche *et al.* [12] have suggested that it is essential to explore the viewpoints of different road users regarding safety behaviors to enhance road safety policies, especially in mixed traffic.

ISSN: 2337-5779
J. Eng. Technol. Sci. Vol. 56, No. 5, 2024, 559-570
DOI: 10.5614/j.eng.technol.sci.2024.56.5.1

Previous studies used the self-perceived risk survey method among road users to understand their perceptions of themselves and other road users [13-16].

The self-perceived risk survey approach is essential for comprehending road users' viewpoints and behaviors [17]. This strategy examines individuals' experiences and perceptions to provide insight into their decision-making processes as they negotiate complex mixed traffic. An in-depth comprehension of how road users perceive risks allows policymakers to customize actions that align with the community's needs and concerns [18, 19].

There remains a notable gap in the literature regarding the perceptions and attitudes of road users towards each other in developing countries. This research sought to fill this gap by examining the perceived risk among cyclists, motorcyclists, and drivers in mixed traffic settings. Using Malaysia as a case study provides empirical insight into a pressing concern that directly impacts public safety and well-being.

Car usage is dominant in Malaysia. However, motorcycles play a significant role as a transportation mode, especially for commuting to work, which have more chance of being involved in fatal accidents [20]. Motorcycles are popular because they have greater fuel efficiency and are smaller, making them easier to park and maneuver in congested areas [21]. The coexistence of motorcycles and cars on roadways creates conflicts and poses significant risks to accidents. These conflicts are exacerbated by the increasing popularity of recreational cycling on Malaysian roads [22]. Recreational cyclists tend to cycle in suburban or rural areas but have to share space with motorcycles and cars.

This paper consists of five sections. After the introduction, the second section explains the literature review related to perceived risk. The third section discusses the methodology framework, including the respondent profiles, the survey design, and analyses. The fourth section presents the main results. This paper ends with discussion, study limitations, and conclusion sections.

Literature Review

Risk Perception of Road Users

Risk perception is influenced by sociodemographic factors and experiences [23, 24]. How a person perceives risk may also vary depending on social status and personal conditions. Pajković and Grdinić-Rakonjac [25] reported that gender and driving experiences affect drivers' risk perception. Their study found that younger participants perceived driving above the speed limit as the most perilous behavior. Meanwhile, older participants emphasized enhancing road infrastructure safety to reduce the risk of road accidents. In addition, older drivers also exhibited a heightened awareness of the risky behaviors of younger drivers, including alcohol-impaired driving as the most significant risk factor.

The perceived traffic risk may differ substantially based on road users' points of view and their modes of transport. Based on the literature review, studies comparing self-reported and proxied data on road safety-related behaviors [12] suggest that individuals tend to have a more favorable perception of their own road behavior than that of others. Furthermore, road users' perspectives may differ depending on the roles they adopt; for instance, they may perceive the actions of third parties as more hazardous, whereas the evaluations of their own actions are generally more favorable. Consequently, personal road-risk assumptions and misbehaviors are undervalued, while crash-related risks are overestimated [26]. However, previous studies emphasize that by understanding self-risk perception, one can understand the diversities of the perception and risks [27]. Even though it may come with some biased perceptions towards other road users, self-perceived risk still significantly affects driving behavior on the road.

For example, Ram and Chand [13] examined the impact of drivers' perceptions of risk and their driving tasks while driving. The study showed that increasing drivers' awareness will also increase their perception of driving tasks, which leads to the prevention of accidents. The study predominantly evaluated the behavioral causes of road crashes. Stülpnagel and Rintelen [14] studied subjectively perceived safety in shared road conditions and discovered disparities in the risk assessments among drivers, bicyclists, and pedestrians. The level of subjective safety is mainly influenced by the interaction between bicyclists and other vehicles using the road. Drivers would likely perceive cycling lanes as secure for cyclists, but cyclists would likely perceive cycling lanes as risky, especially narrow lanes alongside parked vehicles. The inverse was also found concerning sidewalks, where bicyclists felt more comfortable sharing them with pedestrians while pedestrians did not.

DOI: 10.5614/j.eng.technol.sci.2024.56.5.1

Another research study comparing the perspectives of various road users was done by Chaurand and Delhomme [15]. They examined regular cyclists' and drivers' perceived accident risk in mixed traffic scenarios. Additionally, drivers tend to perceive that being involved in a road accident will have high consequences for their material and physical well-being. Meanwhile, cyclists underestimated the impact of road accidents because they assumed that other road users are not able to speed in mixed traffic.

Differences in perceived risk among road users, encompassing pedestrians, cyclists, motorcyclists, drivers, and public transport users, were studied across different countries [16]. They evaluated road users' perceptions in Turkey, Russia, Kosovo, Estonia, and Greece, focusing on trip characteristics, road infrastructure, and everyday travel experiences. Drivers and motorcyclists in Turkey and Kosovo perceived their driving environments as less safe. Conversely, pedestrians and cyclists in Russia and Estonia viewed their environment as more conducive to pedestrian and cyclist safety, while public transport users in Russia perceived the system as commuter-friendly. The scholars concluded that structural differences between the location and population of a country determine the level of road safety. For this reason, separate regulations should be implemented for each road user group within a single country.

Method

This research was undertaken using an internet-based survey questionnaire focusing on the population in the small town of Nibong Tebal, Pulau Pinang. The questionnaire was distributed via online platforms, including WhatsApp and Facebook. We targeted specific communities' social networking platforms and used a face-to-face approach to reach more participants. This study's total number of respondents was 600, with 200 participants for each group of road users. Based on Czaja and Blair [28], the sample size for this study was adequate.

Questionnaire Design

The initial part of the survey asked about the participants' sociodemographic characteristics, consisting of gender, ethnicity, age, marital status, monthly income, highest education level, and employment status. The initial part was the same for all questionnaire sets.

The next section of the questionnaire focused on the participants' self-reported perceived risk. The items used to develop the questionnaire were obtained from the literature [15]. However, several new items were added and sorted into new sets of questions, creating three different versions of the questionnaire: the first was adapted for drivers, the second for motorcyclists, and the third for cyclists. They were asked to answer the questions using a Likert scale of 1-5 (1 = 'totally disagree', 5 = 'totally agree') to examine their risk perceptions and behaviors in mixed traffic. The participants were asked to complete the form according to their primary transportation mode and were not allowed to fill in more than one set.

In addition to testing the reliability of the self-reported questions, Cronbach's alpha was used to test the internal consistency and reliability of the items within each version of the questionnaire. According to Bujang *et al.* [29], Cronbach's alpha is essential to ensure that all items measure the same construct. Cronbach's alpha was 0.77 for the drivers, 0.83 for the motorcyclists, and 0.80 for the cyclists. Based on factor analysis, the questions regarding perceived risk and behaviors were identified and divided into three groups: perceived control (10 items, αdriver = 0.77, αmotorcyclist = 0.70, αcyclist = 0.69), perceived incompetence (6 items, αdriver = 0.73, αmotorcyclist = 0.80, αcyclist = 0.81), and perceived risk (6 items, αdriver = 0.81, αmotorcyclist = 0.83, αcyclist = 0.63) (see Appendix A).

Participants

Table 1 shows the sociodemographic profiles of the respondents in this study. A total of 600 respondents completed the final survey, consisting of 200 participants in each group (drivers, motorcyclists, and cyclists). The results show that more than half of the total respondents were men. There were 61% male and 39% female driver respondents, 68% male and 32% female motorcyclist respondents, and 88% male and 12% female cyclist respondents.

In terms of ethnicity, Chinese respondents made up more than half of the total number of cyclists (54%), while Malay respondents made up more than half of the total number of motorcyclists (71%) and drivers (76%). The distribution represents the population in Penang, where the proportion of Chinese and Malays is almost the same. The recruited drivers in the study spanned an age range of 18 to 67 years, exhibiting an average age of 32 years (SD = 10.077). The motorcyclists spanned an age range of 18 to 55, with an average age of 28 years (SD = 7.123). As for the cyclists who

participated, their ages varied from 19 to 62, with an average age of 35 (SD = 8.762). For marriage status, the results show that the majority of the drivers (59%) and motorcyclists (71%) were single, while the majority of cyclist respondents were married (67%).

In general, the majority of respondents in this study had low incomes, with 76% of drivers, 84% of motorcyclists, and 44% of cyclists earning less than RM 4,850 (USD 1,070) per month. Only 5% of drivers and 7% of motorcyclists had a high income, that is, more than RM 10,971 (USD 2,400), while cyclists had the highest percentage of high income, at 18%. The results indicate that low-income road users can only afford a motorcycle as their primary mode of transportation, whereas high-income road users are more likely to engage in recreational cycling.

The highest level of education was a bachelor's degree, held by 54% of drivers, 52% of motorcyclists, and 48% of cyclists. The percentage of respondents with a PhD was 1% of motorcyclists and 2% of cyclists. Regarding the variable employment status, most respondents were full-time employees, i.e., 54% of drivers, 47% of motorcyclists, and 75% of cyclists.

Table 1 Sociodemographic profiles of 200 drivers, 200 motorcyclists, and 200 cyclists.

Variable		Drivers = 200		Motorcyclists = 200		Cyclists = 200	
		(%)	Mean/ Standard deviation	(%)	Mean/ Standard deviation	(%)	Mean/ Standard deviation
Gender	1 = Male	61	1.26/ 0.440	68	1.12/ 0.452	88	1.02/ 0.427
	2 = Female	39		32		12	
Race	1 = Malay	76	1.82/ 0.530	71	1.39/ 0.695	39	1.92/ 0.652
	2 = Chinese	21		21		54	
	3 = India	2		6		4	
	4 = Other	1		2		4	
Age			31.59/ 10.077		27.80/ 7.123		35.22/ 8.762
Marriage Status	1 = Single	59	1.23/ 0.567	71	1.27/ 0.431	29	1.79/ 0.450
	2 = Married	49		28		67	
	3 = Other	1		1		1	
Monthly income	1 = Below RM 4850	76	1.29/ 0.556	84	1.23/ 0.566	44	1.64/ 0.634
	2 = RM 4851 – RM 10970	19		9		38	
	3 = Above RM 10971	5		7		18	
Highest Education Level	1 = SPM/SKM	31	2.85/ 1.925	15	2.56/ 0.912	19	2.91/ 1.012
	2 = STPM/Diploma	15		18		17	
	3 = Bachelor's degree	54		52		48	
	4 = Master's degree	2		4		14	
	5 = PhD	-		1		2	
Employment Status	1 = Full time	54	2.13/ 1.641	47	2.02/ 1.014	75	1.95/ 1.666
	2 = Part-time	2		5		3	
	3 = Student	34		45		12	
	4 = Unemployed	8		3		4	
	5 = Self-employed	1		-		3	
	6 = Retired	1		-		2	

Statistical Analysis

This study used descriptive statistics to understand the sociodemographic characteristics of cyclists, motorcyclists, and drivers. A one-way Analysis of Variance (ANOVA) test was conducted to determine significant differences in perceived risks among the three groups of respondents: drivers, motorcyclists, and cyclists. This test allows to discover the relationship between more than two groups by simultaneous comparison. The F statistic, or F-ratio, is generated by the ANOVA formula and enables several data sets to analyze the variability within and between samples. The F-ratio result for ANOVA will be close to 1 when no significant differences exist in the studied groups, which is the null hypothesis. The F distribution represents the probability distribution of all F statistic values [30].

This research also analyzed significant differences by using an independent t-test to determine the significant difference between:

1. Driver's and motorcyclists' perceptions toward cyclists
2. Motorcyclist's and cyclists' perceptions toward drivers
3. Driver's and cyclists' perceptions toward motorcyclists

DOI: 10.5614/j.eng.technol.sci.2024.56.5.1

Next, the t-test evaluates whether the means within each group with similar characteristics differ statistically. Three essential pieces of information must be available to perform a t-test: the mean value differences across data sets, the standard deviation, and the total count of data values in each group. The value derived from the T-Distribution Table, a crucial value table, is compared to the t-value obtained from the t-test. Using this comparison, the influence of pure chance on the difference can be assessed and determine whether it exceeds the range. The t-test evaluates if there is significant or random variation with no significance [31].

Results and Discussion

Self-Reported Perceived Risk

Self-perception among the groups was measured based on one-way ANOVA, as shown in Table 2. The results show a significant difference across groups regulating their riding, cycling, or driving against the conditions of the road surface ($F(2,597) = 3.385$, $p = 0.035$). Based on the Tukey post hoc test, the drivers (mean = 4.51, standard deviation = 2.052, $p = 0.048$) significantly more agreed that they had no trouble adjusting their driving to the road surface than motorcyclists (mean = 3.85, standard deviation = 1.866). There was no substantial difference between drivers/cyclists ($p = 0.088$) and motorcyclists/cyclists ($p = 0.966$), where the cyclists had mean = 3.92 and standard deviation = 1.988. These results indicate that motorcyclists and cyclists may face some difficulties with the road surface, especially potholes or debris, that could affect their riding and cycling.

Additionally, a statistically significant difference was identified among those groups reporting daydreaming when driving, riding, or cycling ($F(2,597) = 9.697$, $p = 0.000$). Following the Tukey post hoc analysis, motorcyclists (mean = 3.53, standard deviation = 1.930, $p = 0.000$) and drivers (mean = 3.52, standard deviation = 1.909, $p = 0.001$) significantly more agreed they may become lost in thoughts when driving or riding than cyclists (mean = 1.39, standard deviation = 0.695). In addition, there was no statistically significant difference between drivers and motorcyclists ($p = 0.999$). The findings show that cyclists focus more on the road due to their small physical appearance and high perception of easily getting involved in road accidents.

Next, the ANOVA test demonstrated a difference of statistical significance in the presence of other individuals in a car, on a motorcycle, or behind a bicycle across groups ($F(2,597) = 3.817$, $p = 0.023$). The Tukey post hoc analysis revealed that motorcyclists (mean = 3.41, standard deviation = 1.995, $p = 0.023$) significantly more agreed that the presence of another person on a motorcycle distracts them and deteriorates their riding than cyclists (mean = 2.71, standard deviation = 1.754). Between drivers and motorcyclists, as well as drivers and cyclists, there was no notable difference ($p = 0.113$ and $p = 0.796$, respectively), where the drivers had a mean = 2.88 and standard deviation = 1.849. The findings revealed that all groups were likely to report that they were most likely able to handle their vehicles in any condition except for the abovementioned conditions.

Table 2 Post hoc (Tukey-HSD) analysis per group.

Self–reported perceived risk	Drivers (D)	Motorcyclists (M)	Cyclists (C)	Sig.		
	Mean (SD)	Mean (SD)	Mean (SD)	P (D-M)	P (D-C)	P (M-C)
Perceived control I have **no trouble adjusting** my driving/riding/cycling to **the conditions of the road surface.**	4.51 (2.052)	3.58 (1.866)	3.92 (1.988)	0.048	0.088	0.966
Perceived incompetence I may become **lost in thoughts** when driving/riding/cycling.	3.52 (1.909)	3.53 (1.930)	1.39 (0.695)	0.999	0.001	0.000
I become **distracted** and deteriorate while driving/riding/cycling **when another person is around with me** in a car/on a motorcycle/on a bicycle behind me.	2.88 (1.849)	3.41 (1.995)	2.71 (1.754)	0.113	0.796	0.023

The significant differences between how drivers and motorcyclists perceive risks posed to cyclists, how motorcyclists and cyclists perceive risks posed to drivers, and how drivers and cyclists perceive risks posed to motorcyclists were determined using an independent T-test. With a 95% confidence level, the significance threshold set for this test was $p < 0.05$.

Table 3 compares the independent sample t-test scores of the three different groups. The results indicate no significant differences in risk perception for perceived risks among drivers and motorcyclists towards cyclists. However, based on the mean value, drivers are more likely to take high precautions when approaching cyclists.

Table 3 Comparison of the independent t-test scores of the three groups.

Variables		Mean	S.D	t	P
Independent t-test scores for drivers vs motorcyclists					
I sometimes fail to see bicycles on the road.	Drivers	3.40	2.010	0.765	0.536
	Motorcyclists	3.12	1.951		
I will decrease my speed whenever I notice bicycles on the road.	Drivers	5.27	1.858	0.827	1.903
	Motorcyclists	4.77	1.858		
I tend to be cautious when overtaking bicycles.	Drivers	5.62	1.830	0.447	1.652
	Motorcyclists	5.18	1.935		
Independent t-test scores for drivers vs cyclists					
I sometimes fail to see motorcycles on the road.	Drivers	3.42	2.006	0.708	1.327
	Cyclists	3.04	2.045		
I will decrease my speed whenever I notice motorcycles on the road.	Drivers	5.16	1.846	0.042	1.407
	Cyclists	4.77	2.069		
I tend to be cautious when overtaking motorcycles / Motorcyclists tend to be cautious when overtaking me.	Drivers	5.63	1.813	0.318	9.829
	Cyclists	3.05			
Independent t-test scores for motorcycles vs cyclists					
I sometimes fail to see cars on the road.	Motorcyclists	3.00	1.864	0.979	0.983
	Cyclists	2.74	1.878		
I will decrease my speed whenever I notice a car on the road.	Motorcyclists	4.77	1.890	0.145	0.036
	Cyclists	4.76	2.021		
Drivers tend to be cautious when overtaking me.	Motorcyclists	4.13	1.931	0.744	3.068
	Cyclists	3.29	1.940		

Meanwhile, the independent sample of the t-test results for risk perception towards motorcyclists showed a significant disparity between drivers' and cyclists' speeds. Between motorcyclists and cyclists, drivers tended to be more likely to slow down when noticing motorcyclists on the road. Even though there were no significant differences in noticing motorcycles and the level of precautions taken by both groups, the drivers showed slightly higher mean values for both variables. This finding indicates that in mixed traffic, drivers have a higher tendency to reduce their speed. This indirectly proves that drivers are concerned with two-wheeled road users' security.

Regarding perceived risks that motorcyclists and cyclists have towards drivers, the independent sample of the t-test showed no significant differences in their intention to speed while noticing cars. Their speeding attitude and perception towards drivers also showed no significant differences. However, based on the mean value, the cyclists were less likely to notice cars and perceived the drivers as taking fewer precautions while overtaking them.

Discussion

This study applied a quantitative approach to investigate self-perceived risk among Malaysian road users to understand the emotions and needs of different groups. Mixed traffic in Malaysia is complex since it involves diverse vehicles with varying speeds that travel on the same roads. During COVID-19, there was a surge in interest in recreational cycling. Many people in Malaysia were looking for alternative forms of recreation that do not require group participation, similar to other parts of the world [32, 33]. When the situation returned to normal, interest in leisure cycling persisted, causing many people to ride bicycles on the same roadways as motorcycles and cars, adding to traffic complexity and risk.

This study found that Malay males who were single, young, and low-income dominated motorcycle usage, which is similar to previous studies [34, 35]. Reports indicate that this group is prone to crashes and exhibits a low perception of risk. Regarding car ownership in Malaysia, the study demonstrated that many low-income respondents could also own a car. This is because of a national car policy that encourages affordable pricing for cars produced by Malaysia's own automotive industries [36]. Previous studies indicate that more men would like to be involved in cycling, especially recreational cycling, compared to women [37, 38], similar to this study's findings.

Different items of perceived accident risk significantly differed for the groups in this study, namely perception towards road surfaces, daydreaming, and the presence of other people while handling their vehicles. Regarding perceived

DOI: 10.5614/j.eng.technol.sci.2024.56.5.1

accident risk towards road surfaces, the drivers reported the ability to adapt to road surface conditions the most, since the vehicle structure and car tire technologies for drivers are more comfortable than for the other groups in this study. Meanwhile, the smaller tires of bicycles and motorcycles have a high potential to cause an accident, especially when the road surface is uneven, wet, and has debris and potholes that will increase the possibility of slipping and falling. Previous studies state that road surface is a contributor to motorcycle accidents [39,40]. Meanwhile, recreational cyclists are more likely to fall when cycling on a wet road surface, causing them to adjust their behavior and perceive higher risk in maneuvering their bicycle [41, 42].

This study highlights that being comfortable while driving leads to the possibility of daydreaming. This is supported by a previous study, which states that daydreaming or lost-in-thought drivers contribute to several road accident factors [43]. This is due to the degree of comfort of modern cars [44]. In addition, nowadays, many advanced technologies alert car drivers from distractions to reduce the risk of accidents [44, 45]. For motorcyclists, fatigue can cause daydreaming and become the cause of accidents [46, 47]. Recreational cyclists, such as drivers and motorcyclists, reported the lowest possibility of daydreaming because their activity is leisurely, in contrast to daily commuting. It is interesting to note that there is a significant difference regarding the presence of other individuals when handling a vehicle.

This study found that motorcyclists are more easily distracted by the presence of other people. This may be because the handling load while balancing and maneuvering is higher. Previous studies have reported that the presence of a pillion passenger can cause riders to be more cautious [48, 49]. In addition, the drivers and motorcyclists claimed that they are more cautious with the presence of cyclists on the road. Many self-reported studies have shown that drivers and motorcyclists claim they consider cyclists' safety [50, 51]. However, the finding shows that cyclists would likely claim that both groups are less considerate of their safety, especially while overtaking. Furthermore, as cyclists mostly share the same path as motorcyclists, they tend to reduce speed when a motorcyclist approaches.

Drivers perceive themselves as highly adaptable to road surface conditions, drive cautiously, maintain control of their car regardless of traffic volume, anticipate the actions of other road users, and have good reflexes. Drivers are more confident that they will be less involved in accidents than motorcyclists and cyclists and show less disruption when they are preoccupied and in a hurry. Previous studies have claimed that high performance and excellent safety features in automobiles lead to higher driving speeds [52]. However, this study found that night driving is difficult according to the drivers' respondents.

Meanwhile, motorcyclists perceived they could travel between other vehicles, ride efficiently, and ride well even when tired. When passing bicyclists, motorcyclists give more space than car drivers [53]. However, motorcyclists have difficulty adapting their riding to road surface conditions. They are perceived to ride carelessly and have less control under high traffic volumes and poor weather. They are less able to predict the actions of other road users, have less control over their riding regardless of speed, and can become lost in thoughts while riding. When they are in a hurry, the presence of a passenger on their motorcycle distracts them, impairs their riding, and causes them to become careless.

In addition, cyclists are able to control their bicycle regardless of speed, are not distracted by their thoughts when cycling, and have less difficulty cycling at night. The presence of someone behind them causes fewer distraction and a smaller decrease in their cycling performance. However, the cyclist respondents were less confident in traveling among other vehicles. Cylists' performance is less efficient when they are tired. They have slower reflexes, and their riding is impacted when they are preoccupied.

Notable differences in the affective experiences of participants also emerged; making ties with motorcycle users, our results underlined the rise in sentimentality associated with the usage of two-wheelers, most notably bicycles [54]. This has significant ramifications for policy and practice. Two-wheeled vehicle users need to establish a more sustainable transportation system. In order to encourage such a modal shift, it is crucial to create safety improvements and develop individual perception of safety. To achieve the expected benefits with higher motorbike and bicycle utilization [e.g. 55,56], we should make it more secure and pleasurable for those who already rely on those modes while also making it interesting for those who do not.

The study's findings highlight the critical need for targeted preventive measures to improve road safety in Malaysia's mixed traffic environments, where the complexities of multiple vehicles sharing the same road pose significant risks. According to the study, drivers are more adaptable to road surfaces due to modern car comfort and technology. In contrast, cyclists and motorcyclists face increased risks, especially on uneven, wet, and debris-laden roads. To begin,

addressing the issue of road surface conditions is identified as a critical area for intervention. Regular road surface maintenance, prompt pothole repair, and installing warning signs could reduce these risks and improve overall safety for all road users [57, 58].

In addition, this study emphasizes the importance of avoiding distractions, such as daydreaming, particularly among motorcyclists, which have been reported to a cause of road accidents. Interventions could include educational campaigns to raise awareness about distracted driving and support using technologies that alert riders to their concentration and fatigue [51, 59]. Furthermore, improving motorcycle handling skills and road conditions, for example, through training programs and safety campaigns, may help reduce motorcyclists' risks [60, 61]. Additionally, communication campaigns or road safety training programs for road users can be preventive measures to increase users' risk perception and improve their road behavior [62, 63]. Finally, a comprehensive approach that combines infrastructure improvements, educational efforts, and awareness campaigns is critical to promoting a safer and more harmonious coexistence of road users in Malaysia's mixed traffic settings.

Study Limitations

There was a specific limitation to the study. The data gathered in this research was obtained from Penang State due to the high number of recreational cyclists. Therefore, our suggestion for future research is to include a nationwide self-reported survey. In addition, utility cyclists could be included in measuring their perceived risk in mixed traffic, even though the percentage of this group in Malaysia is very small. Furthermore, future studies should explore the potential effects of targeted infrastructure enhancements, such as the introduction of dedicated cycling lanes or traffic calming strategies, on the perceived level of risk experienced by individuals using roadways in diverse traffic settings.

Conclusions

This study compared self-reported perceived risk among different road users under mixed traffic. This paper also highlighted how they perceived accident risks from other road users. It was expected that perceived risk would be significantly different among drivers, motorcyclists, and cyclists, but the results obtained from the ANOVA and t-tests showed a different outcome. Only 3 out of 16 self-reported perceptions exhibited significant differences, which included adaptation towards road surface conditions (perceived control), the potential of daydreaming while operating a vehicle, and distraction from passengers or riding companions (perceived incompetence). The drivers perceived high adaptation in their driving to road surface conditions. Meanwhile, the motorcyclists and the cyclists have difficulty adapting their riding to road surface conditions. The drivers and the motorcyclists agreed that they can get lost in thoughts while handling the vehicles, in contrast to cyclists. The drivers also showed less disruption when they are preoccupied. The presence of a passenger distracts motorcyclist and causes them to become careless. When cyclists are preoccupied, they have poorer reflexes and their riding is impacted.

Acknowledgements

This study was sponsored by a Fundamental Research Grant Scheme [FRGS/1/2022/TK02/USM/02/4] and Graduate Fellowship from Universiti Sains Malaysia. The authors thank Mr. Lim Kai Jet for his assistance during the collection of the data.

Compliance with ethics guidelines

The authors declare that they have no conflict of interest or financial conflicts to disclose.

This article does not contain any studies with human or animal subjects performed by any of the authors.

References

[1] Macioszek, E. & Kurek, A., *Road Traffic Distribution on Public Holidays and Workdays on Selected Road Transport Network Elements*, Transport Problems, **16**(1), pp. 127-138, 2021.

[2] Dupont, E., Martensen, H., Papadimitriou, E. & Yannis, G., *Risk and Protection Factors in Fatal Accidents*, Accident Analysis & Prevention, **42**(2), pp. 645-653, 2010.

DOI: 10.5614/j.eng.technol.sci.2024.56.5.1

[3] Mukherjee, D. & Mitra, S., *Development of a Systematic Methodology to Enhance the Safety of Vulnerable Road Users in Developing Countries*, Transportation in Developing Economies, **8**(2), 28, 2022.
[4] Macioszek, E., Granà, A. & Krawiec, S., *Identification of Factors Increasing the Risk of Pedestrian Death in Road Accidents Involving a Pedestrian with a Motor Vehicle*, Archives of Transport, **65**(1), pp. 7-25, 2023.
[5] Pulugurtha, S.S. & Thakur, V., *Evaluating the Effectiveness of On-Street Bicycle Lane and Assessing Risk to Bicyclists in Charlotte*, North Carolina, Accident Analysis & Prevention, **76**, pp. 34-41, 2015.
[6] Rad, S.R., Farah, H., Taale, H., van Arem, B. & Hoogendoorn, S.P., *The Impact of o Dedicated Lane for Connected and Automated Vehicles on the Behaviour of Drivers of Manual Vehicles*, Transportation Research Part F: Traffic Psychology and Behaviour, **82**, pp. 141-153, 2021.
[7] Sinar Harian, *KKR cadangan wajibkan bina lorong khas motosikal di setiap lebuh raya baharu*, https://mediamadani.com/2023/11/30/kkr-cadangan-wajibkan-bina-lorong-khas-motosikal-di-setiap-lebuh-raya-baharu, (10 March 2024).
[8] Hull, A. & O'holleran, C., *Bicycle Infrastructure: Can Good Design Encourage Cycling?*, Urban, Planning and Transport Research, **2**(1), pp. 369-406, 2014.
[9] Meijer, J.R., Huijbregts, M.A., Schotten, K.C. & Schipper, A.M., *Global Patterns of Current and Future Road Infrastructure*, Environmental Research Letters, **13**(6), 064006, 2018.
[10] Basu, S. & Saha, P., *Evaluation of Risk Factors for Road Accidents Under Mixed Traffic: Case Study on Indian Highways*, IATSS Research, **46**(4), pp. 559-573, 2022.
[11] Deme, D., *Review on Factors Causes Road Traffic Accident In Africa,* Journal of Civil Engineering Research & Technology, **1**(1), pp. 1-8, 2019.
[12] Useche, S.A., Faus, M. & Alonso, F., *Is Safety in the Eye of The Beholder? Discrepancies Between Self-Reported and Proxied Data on Road Safety Behaviors—a Systematic Review*, Frontiers in Psychology, **13**, 964387, 2022.
[13] Ram, T. & Chand, K., *Effect of Drivers' Risk Perception and Perception of Driving Tasks on Road Safety Attitude*, Transportation Research Part F: Traffic Psychology and Behaviour, **42**(1), pp. 162-176, 2016.
[14] von Stülpnagel, R. & Rintelen, H., *A Matter of Space and Perspective – Cyclists', Car Drivers', and Pedestrians' Assumptions about Subjective Safety in Shared Traffic Situations*, Transportation Research Part A, **179**, 103941, 2024.
[15] Chaurand, N. & Delhomme, P., *Cyclists and Drivers in Road Interactions: A Comparison of Perceived Crash Risk,* Accident Analysis & Prevention, **50**, pp. 1176-1184, 2013.
[16] Azık, D., Solmazer, G., Ersan, Ö., Kaçan, B., Fındık, G., Üzümcüoğlu, Y., Özkan, T., Lajunen, T., Öz, B., Pashkevich, A., Pashkevich, M., Danelli-Mylona, V., Georgogianni, D., Krasniqi, E. B., Krasniqi, M., Makris, E., Shubenkova, K. & Xheladini, G., *Road Users' Evaluations and Perceptions of Road Infrastructure, Trip Characteristics, and Daily Trip Experiences Across Countries*, Transportation Research Interdisciplinary Perspectives, **11**, 100412, 2021.
[17] Cristea, M. & Gheorghiu, A., *Attitude, Perceived Behavioral Control, and Intention to Adopt Risky Behaviors*, Transportation Research Part F: Traffic Psychology and Behaviour, **43**, pp. 157-165, 2016.
[18] Yu, H., Hu, X. & Gao, J., *Can Haze Warning Policy Reduce Traffic Accidents: Evidence from China*, Environmental Science and Pollution Research, **30**(2), pp. 2703-2720, 2023.
[19] Jahangiri, M., Karimi, A., Slamizad, S., Olyaei, M., MOOSAVI, S. & Amiri, F., *Occupational Risk Factors in Iranian Professional Drivers and their Impacts on Traffic Accidents*, International Journal of Occupational Hygiene, **5**(4), pp. 184-190, 2013.
[20] Sukor, N.S.A., Tarigan, A.K. & Fujii, S., *Analysis of Correlations between Psychological Factors and Self-Reported Behavior of Motorcyclists in Malaysia, Depending on Self-Reported Usage of Different Types of Motorcycle Facility*, Transportation Research Part F: Traffic Psychology and Behaviour, **46**, pp. 509-523, 2017.
[21] Chang, Z., Chen, J., Li, W. & Li, X., *Public Transportation and the Spatial Inequality of Urban Park Accessibility: New Evidence from Hong Kong*, Transportation Research Part D, **76**, pp. 111-122, 2019.
[22] Roslan, A., Jamaluddin, N., Harun, N.Z., Mohamed Rahim, S.A.S., Mohd. Zulkifli, N.S., Jamil, H.M., Sim, H.J., Hamidun, R., Mohd Yusof, A.S., Rahmat, N.F., Abu Kassim, K.A. & Kasim, K., *Malaysian Cyclist: How Visible They Are,* Journal of Advanced Vehicle System, **13**(1), pp. 1-7, 2022.
[23] Klauer, S.G., Guo, F., Simons-Morton, B.G., Ouimet, M.C., Lee, S.E. & Dingus, T.A., *Distracted Driving and Risk of Road Crashes Among Novice and Experienced Drivers, New England Journal of Medicine*, **370**(1), pp. 54-59, 2014.
[24] Choudhari, T. & Maji, A., *Socio-Demographic and Experience Factors Affecting Drivers' Runoff Risk Along Horizontal Curves of Two-Lane Rural Highway*, Journal of Safety Research, **71**, pp. 1-11, 2019.
[25] Pajković, V. & Grdinić-Rakonjac, M., *Road users'attitudes and Perception on Selected Road Safety Issues – Age-Related Comparison*, European Transport, **85**(7), 2021.
[26] Kaye, S. A., Lewis, I. & Freeman, J., *Comparison of Self-Report and Objective Measures of Driving Behavior and Road Safety: A Systematic Review*, Journal of Safety Research, **65**, pp. 141-151, 2018.

[27] Elliott, M.A. & Baughan, C.J., *Developing a Self-Report Method for Investigating Adolescent Road User Behaviour*, Transportation Research Part F: Traffic Psychology and Behaviour, **7**(6), pp. 373-393, 2004.
[28] Czaja, R. & Blair, J., *A Useful Resource for Factual-Style Surveys, Including Material on Interviews as Well As Mail Surveys*, Designing Surveys, 1996.
[29] Bujang, M.A., Omar, E.D. & Baharum, N.A., *A Review on Sample Size Determination for Cronbach's Alpha Test: A Simple Guide for Researchers*, The Malaysian Journal of Medical Sciences: MJMS, **25**(6), pp. 85-99, 2018.
[30] Kenton, W., *Analysis of Variance (ANOVA)*. www.investopedia.com/terms/a/anova, (6 October 2021).
[31] Hayes, A., *Descriptive Statistics*. www.investopedia.com/terms/d/descriptive_statistics, (03 August 2021).
[32] Costa, M., Félix, R., Marques, M. & Moura, F., *Impact of COVID-19 Lockdown on the Behavior Change of Cyclists in Lisbon, Using Multinomial Logit Regression Analysis*, Transportation Research Interdisciplinary Perspectives, **14**, 100609, 2022.
[33] Heesch, K.C., Sahlqvist, S.L. & Garrard, J., *Gender Differences in Recreational and Transport Cycling: A Cross-Sectional Mixed-Methods Comparison of Cycling Patterns, Motivators, and Constraints*, International Journal of Behavioral Nutrition and Physical Activity, **9**(1), pp. 1-12, 2012.
[34] Manan, M.M.A. & Varhelyi, A., *Motorcycle Fatalities in Malaysia*, IATSS research, **36**(1), pp. 30-39, 2012.
[35] Law, T.H., Hamid, H. & Goh, C.N., *The Motorcycle to Passenger Car Ownership Ratio and Economic Growth: A Cross-country Analysis*, Journal of Transport Geography, **46**, pp. 122-128, 2015.
[36] Champahom, T., Wisutwattanasak, P., Chanpariyavatevong, K., Laddawan, N., Jomnonkwao, S. & Ratanavaraha, V., *Factors Affecting Severity of Motorcycle Accidents on Thailand's Arterial Roads: Multiple Correspondence Analysis and Ordered Logistics Regression Approaches*, IATSS research, **46**(1), pp. 101-111, 2022.
[37] Shaw, C., Russell, M., Keall, M., MacBride-Stewart, S., Wild, K., Reeves, D., Bentley, R. & Woodward, A., *Beyond the Bicycle: Seeing the Context of the Gender Gap in Cycling*, Journal of Transport & Health, **18**, 100871, 2020.
[38] Tortosa, E.V., Lovelace, R., Heinen, E. & Mann, R.P., *Cycling Behaviour and Socioeconomic Disadvantage: An Investigation based on the English National Travel Survey*, Transportation Research Part A, **152**, pp. 173-185, 2021.
[39] Okalo, R.L., Khisa, G. & Kagendo, J., *Effects of Motorcycle Accidents on Household Livelihood in Vihiga County, Kenya*, European Journal of Sociology, **5**(1), pp. 45-56, 2022.
[40] Kashani, A.T., Jafari, M., Bondarabadi, M.A. & Dabirinejad, S., *Factors Affecting the Accident Size of Motorcycle-Involved Crashes: a Structural Equation Modeling Approach*, International Journal of Injury Control and Safety Promotion, **28**(1), 16-21, 2020.
[41] Ohlin, M., Algurén, B. & Lie, A., *Analysis of Bicycle Crashes in Sweden Involving Injuries with High Risk of Health Loss,* Traffic Injury Prevention, **20**(6), pp. 613-618, 2019.
[42] Qin, L., Li, Z.R., Chen, Z., Bill, M.A. & Noyce, D.A., *Understanding Driver Distractions in Fatal Crashes: An Exploratory Empirical Analysis*, Journal of Safety Research, **69**, pp. 23-31, 2019.
[43] Puthan, P., Lubbe, N. & Davidsson, J., *Characterizing Future Crashes on Indian Roads using Counterfactual Simulations of Pre-Crash Vehicle Safety Technologie*, IATSS Research, 2022.
[44] Biswal, A.K., Singh, D., Pattanayak, B.K., Samanta, D. & Yang, M.H., *Iot-Based Smart Alert System for Drowsy Driver Detection*, Wireless Communications and Mobile Computing, 2021.
[45] Yousif, M.T., Sadullah, A.F.M. & Kassim, K.A.A., *A Review of Behavioural Issues Contribution to Motorcycle Safety*, IATSS Research, **44**(2), pp. 142-154, 2020.
[46] Ospina-Mateus, H. & Jiménez, L.A.Q., *Understanding the Impact of Physical Fatigue and Postural Comfort Experienced During Motorcycling: A Systematic Review*, Journal of Transport & Health, **12**, pp. 290-318, 2019.
[47] Pervez, A., Lee, J. & Huang, H., *Identifying Factors Contributing to the Motorcycle Crash Severity in Pakistan*, Journal of Advanced Transportation, 2021.
[48] Ndagire, M., Kiwanuka, S., Paichadze, N. & Kobusingye, O., *Road Safety Compliance Among Motorcyclists In Kawempe Division, Kampala, Uganda: A Cross-Sectional Study,* International Journal of Injury Control and Safety Promotion, **26**(3), pp. 315-321, 2019.
[49] Salmon, P.M., Young, K.L. & Cornelissen, M., *Compatible Cognition Amongst Road Users: The Compatibility of Driver, Motorcyclist, and Cyclist Situation Awareness*, Safety Science, **56**, pp. 6-17, 2013.
[50] Walker, I., *Drivers Overtaking Bicyclists: Objective Data on the Effects of Riding Position, Helmet Use, Vehicle Type and Apparent Gender*, Accident Analysis & Prevention, **39**(2), pp. 417-425, 2007.
[51] Haworth, N., Heesch, K.C. & Schramm, A., *Drivers who don't Comply with a Minimum Passing Distance Rule When Passing Bicycle Riders*, Journal of Safety Research, **67**, pp. 183-188, 2018.
[52] Chuang, K.H., Hsu, C.-C., Lai, C.-H., Doong, J.-L. & Jeng, M.-C., *The Use of a Quasi-naturalistic Riding Method to Investigate Bicyclists' Behaviors when Motorists Pass*, Accident Analysis & Prevention, **56**, pp. 32-41, 2013.

DOI: 10.5614/j.eng.technol.sci.2024.56.5.1

[53] Samuel, O., Walker, G., Salmon, P., Filtness, A., Stevens, N., Mulvihill, C., Payne, S. & Stanton, N., *Riding the Emotional Roller-coaster: Using the Circumplex Model of Affect to Model Motorcycle Riders' Emotional State-changes at Intersections*, Transportation Research Part F, **66**, pp. 139-150, 2019.

[54] Cox, B.L. & Mutel, C.L., *The Environmental and Cost Performance of Current and Future Motorcycles*, Applied energy, **212**, pp. 1013-1024, 2018.

[55] Gössling, S., Choi, A., Dekker, K. & Metzler, D., *The Social Cost of Automobility Cycling and Walking in the European Union*, Ecological Economics, **158**, pp. 65-74, 2019.

[56] Hatfield, J. & Boufous, S., *The Effect of Non-Recreational Transport Cycling on Use of Other Transport Modes: A Cross-Sectional On-line Survey*, Transportation Research Part A, **92**, pp. 220-231, 2016.

[57] Sumit, K., Brijs, K., Ross, V., Wets, G. & Ruiter, R.A., *A Focus Group Study to Explore Risky Ridership among Young Motorcyclists in Manipal, India,* Safety, **8**(2), 40, 2022.

[58] Ismail, A., Razelan, I.S.M., Yusof, L.M., Zulkiple, A. & Masri, K.A., *An Overview of Pavement Maintenance Management Strategies in Malaysia,* In IOP Conference Series: Earth and Environmental Science, **682**(1), 012042, 2021.

[59] Chang, J.R., Hsu, H.M. & Chao, S.J., *Development of a Road Monitoring and Reporting System Based on Location-Based Services and Augmented-Reality Technologies*, Journal of Performance of Constructed Facilities, **26**(6), pp. 812-823, 2012.

[60] Sukor, N.A. & Sadullah, A.M., *Addressing the Road Safety Results Impasse through an Outcome-based Approach in the State of Penang, Malaysia*, Engineering Heritage Journal, **1**(1), 21-24, 2017.

[61] Davidović, J., Pešić, D., Lipovac, K. & Antić, B., *The Significance of the Development of Road Safety Performance Indicators Related to Driver Fatigue,* Transportation Research Procedia, **45**, pp. 333-342, 2020.

[62] Faus, M., Alonso, F., Esteban, C. & Useche, S.A., *Are Adult Driver Education Programs Effective? A Systematic Review of Evaluations of Accident Prevention Training Courses,* International Journal of Educational Psychology: IJEP, **12**(1), pp. 62-91, 2023.

[63] Faus, M., Alonso, F., Fernández, C. & Useche, S.A., *Are Traffic Announcements Really Effective? A Systematic Review of Evaluations of Crash-Prevention Communication Campaigns*, Saf. Now, **7**(4), 66, 2021.

Appendix

Appendix A. Items in self-reported survey

No	Questions
	Perceived control
1	I find no trouble regulating my driving/riding/cycling against the conditions of the road surface.
2	I am able to drive/ride/cycle cautiously.
3	I have control over how I drive/ride/cycle in heavy traffic.
4	I have control over how I drive/ride/cycle regardless of the environmental conditions.
5	I anticipate the actions of other users.
6	I have control over how I drive/ride/cycle regardless of my speed.
7	I am confident in myself when driving.
8	I manoeuvre between other vehicles with ease.
9	I drive/ride/cycle efficiently.
10	I can still drive/ride/cycle nicely although I'm exhausted.
	Perceived Incompetence
1	I have quick reactions.
2	I might become lost in personal thoughts when driving/riding/cycling.
3	I become distracted and deteriorate while driving/riding/cycling once another person is around with me in the car/on the motorcycle/other cyclists behind me.
4	I have a hard time driving/riding/cycling at night.
5	My driving/riding/cycling gets influenced when I am preoccupied.
6	I tend to act careless when I am in rush.
	Perceived risk
	Answered by drivers only
1	I sometimes fail to see motorcycles on the road.
2	I sometimes fail to see bicycle on the road.
3	I will decrease my speed whenever I notice motorcyclist on the road.
4	I will decrease my speed whenever I notice bicyclist on the road.
5	I intend to show precautions when overtaking the motorcycles.
6	I intend to show precautions when overtaking the bicycles.
	Answered by motorcyclists only
1	I sometimes fail to see cars on the road.
2	I sometimes fail to see bicycle on the road.
3	I will decrease my speed whenever I notice cars on the road.
4	I will decrease my speed whenever I notice bicyclist on the road.
5	The drivers intend to show precautions when overtaking me.
6	I intend to show precautions when overtaking the bicycles.
	Answered by cyclists only
1	I sometimes fail to see cars on the road.
2	I sometimes fail see motorcycles on the road.
3	I will decrease my speed whenever I notice cars on the road.
4	I will decrease my speed whenever I notice motorcyclist on the road.
5	The drivers intend to show precautions when overtaking me.
6	The motorcyclists intend to show precautions when overtaking me.

Manuscript Received: 9 November 2023
Revised Manuscript Received: 18 March 2024
Accepted Manuscript: 31 May 2024