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Evaluating Motorcyclists' Safe Riding Competencies: Integrating Hazard Perception, Theory, and Road Tests

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ABSTRACT – *This study presents a novel approach to evaluating motorcyclists' safe riding competence through a comprehensive assessment framework. Participants were 31 consented courier riders aged 19 to 46 years (M=29.9, SD=7.43, 99% male) recruited through a road safety awareness program. A 100-cc motorcycle was fitted with a data acquisition system to record the motorcycle speeds and location, braking and turn signals data, and video images. The participants were asked to ride the instrumented motorcycle on a 6.5 km predefined route, which included riding in commercial areas, residential areas, town areas, and a section of a multi-lane highway. The participants also answered 32 safe riding theoretical questions and sat for a video-based hazard perception test. Results indicate that the developed instrumentation and scoring methodology are both suitable and replicable for evaluating motorcyclists' safe riding competencies in real-world conditions. Notably, the assessment framework successfully differentiated various skill levels among participants, highlighting its discriminative power. Findings emphasize the necessity for targeted interventions to enhance higher-order riding skills, particularly in areas such as hazard perception and response. Given the high incidence of motorcycle fatalities and persistent road safety challenges, the research proposes a paradigm shift in approach: integration of more robust and comprehensive competency training and assessments in both licensing processes and post-license safety programs.*

KEYWORDS: Safe motorcycle riding competencies, on-road assessment, higher-order skills, instrumented motorcycle, rider training

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1. INTRODUCTION

Driving a vehicle on a road is a series of signal processing and decision-making activities, which, before the advent of autonomous driving technologies, were fully conducted by the operator (i.e., the driver) of the vehicle. Operating a vehicle is a complex and cognitively challenging activity due to multiple interactions between the operators and their environment (Bolstad et al., 2010; Boot et al., 2014). A safe driving performance – in essence – is an ability to attend to the most important information, process this information, and then react accordingly (Bolstad et al., 2010). The critical role of humans in operating a vehicle can be traced in the road traffic crash causation analyses. Research has long established that human factors are the most dominant factor in a road crash. A landmark study by Treat et al. (1979) found that human errors were a primary factor in over 90% of the crashes investigated, emphasizing the significant role of human factors in road crashes, especially the operators of the vehicle.

Motorcycle safety is a critically important road safety issue in Malaysia and many parts of the world, with an alarming number of crashes and fatalities. Between 2010 and 2021, data from the Royal Malaysia Police (PDRM) recorded 48,209 deaths involving motorcyclists in road crashes throughout the country (PDRM, 2021). On average, at least 310 motorcycles were involved in road crashes every day, with 11 fatalities recorded daily over the course of these years. Alarmingly, the fatality rate among motorcycle users has exhibited a significant upward trend during this period, with 70 motorcycle fatalities recorded for every 100 deaths resulting from road crashes in 2021.

Motorcyclists face greater risks on the roads than car drivers due to the lack of physical protection, reduced visibility, and increased vulnerability to road hazards. The absence of both active and passive safety systems in motorcycle designs, particularly in low-capacity engine models (below 250cc) is also a disadvantage for motorcycle safety (Abdul Khalid et al., 2021). Motorcycles require active balance and are inherently less stable than cars, especially at low speeds or during maneuvers like cornering or sudden braking. This increased instability requires constant rider attention and skill to maintain balance and control. While motorcycles can accelerate quickly and are more maneuverable in tight spaces, this also means that inexperienced and unskilled riders may overestimate their ability to control speed, increasing the risk of a crash.

As such, a nuanced and comprehensive rider training and assessment approach is needed to improve a rider's ability to handle these unique challenges. This approach needs to accommodate rider-centered training and provide a more accurate assessment of rider competencies, addressing the specific demands and risks inherent in motorcycle riding. For instance, a training and assessment method that involves exposure to real-world traffic conditions will allow assessment of riders' ability to handle various challenges, such as interacting with other vehicles, navigating intersections, and adjusting to varying weather and road conditions.

The present study utilized the Goals for Driver Education (GDE) Matrix, an established driver education framework developed by Hatakka et al. (2002) to create a comprehensive and nuanced approach for assessing a motorcycle rider's competencies. The GDE highlights that enhancing road safety requires vehicle operators to possess not only technical driving knowledge and skills, including handling the vehicle (Level 1) and navigating traffic (Level 2), but more importantly, the ability to self-assess personal risks associated with their journeys (Level 3) and recognize the personal values and goals influencing their behaviour on the road (Level 4). Drivers also need to comprehend factors that increase risk and develop self-evaluation skills to understand how their beliefs and behaviors can elevate their crash risk.

This study aims to explore the feasibility of integrating theory tests, video-based hazard perception tests, and on-the-road riding assessments to measure motorcyclists' safe riding competencies. The modular test format aims to enable the assessment of all levels of skill enhancement highlighted in GDE framework. By enabling targeted evaluation, it ensures precise assessment of individual competencies, helping to identify strengths and areas for improvement. Furthermore, its adaptability allows for the selection of modules based on the context or audience, making it a versatile solution for diverse testing needs. The findings of this study are expected to enhance motorcycle license testing approaches and methodologies, while also providing an effective framework for training and retraining riders after licensing.

2. METHODOLOGY

2.1 Instrument

Three test tools were developed for the purpose of this study: a safe riding knowledge test, a video-based hazard perception test, and the MIROS Motorcycle Riding Road Test (MRRT), which involves riding on actual roads.

2.1.1 MIROS Safe Riding Knowledge Test

The knowledge test consisted of 30 theoretical questions on defensive riding skills (10 questions), road signs (10 questions) and general knowledge on road safety (10 questions). Participants were asked to select a correct answer from a list of multiple answer options. The test was administered using an online form.

2.1.2 MIROS Hazard Perception Test

This assessment method measures the competency to perceive and identify hazards on the roads. The MIROS Hazard Perception Test software (PERCEIVE) used in this study was developed by MIROS and utilized the reaction time paradigm for the competency measurement, similar to other studies (McKenna et al., 2006; Wetton et al., 2011). The test included 31 hazards for motorcyclists presented in 12 short clips, accumulating to 396s short video. These clips were recorded in high-definition mode from the perspective of a motorcycle rider riding a small-displacement motorcycle in the local vicinity, mostly during the daytime. Participants were asked to view the video clips on a computer and to use the mouse to click on the screen where the hazards were located. The software captured the frame and superimposed the position of the mouse and time on top of it. The captured image, along with the clicking time and mouse position, was stored for analysis (see Ab Rashid and Ibrahim, 2017).

2.1.3 MIROS Motorcycle Riding Road Test (MRRT)

The MIROS Motorcycle Riding Road Test (MRRT) was developed to assess the competencies for safe motorcycle riding on the actual roads. The test consists of two main assessment criteria, which are pre-riding safe routine (30% of the total score), and critical on-road riding maneuvers (70% of the total score) utilizing MIROS Instrumented Motorcycles (INSMO). The scoring method includes both demerit and merit points with a specific scoring weightage assigned to each category of on-road safe riding competency (refer to Table 1).

2.1.3.1 MRRT Route Design

Route design is one of the most critical components of on-road assessment for fitness to drive and safe driving competencies. Variations in route design reported in the previous studies include options of open or closed route, standardization of route (i.e., fixed-route for all participants versus non-standardized route), distance and/or duration, and level of difficulties (Bellagamba et al., 2020). The finalized test route in the present study was designed for an open route motorcycle riding performance assessment. The participants were expected to have sufficient route navigation skills to ride along the standardized test route on their own. The 6.5 km test route includes riding on two-lane single carriageways, four-lane single carriageways, a ramp, and a section of six-lane highways. Figure 1 displays the flow diagram of the MRRT route design and finalization process.

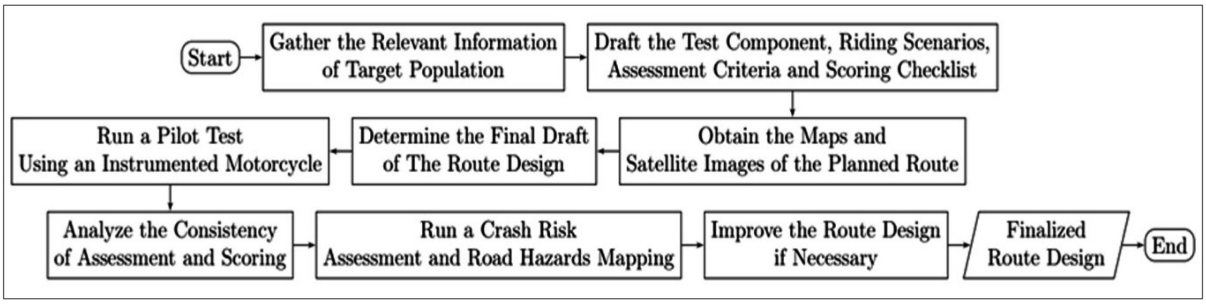
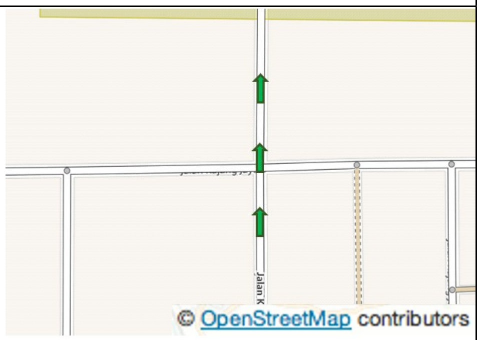
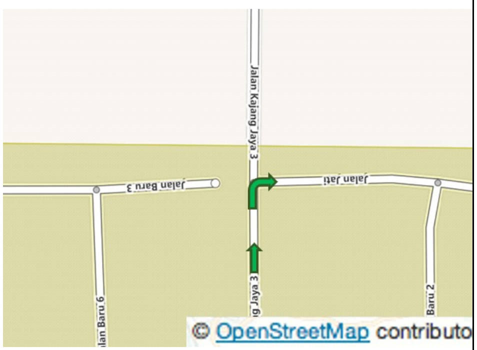


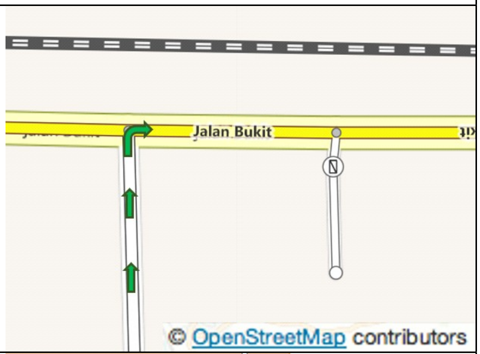
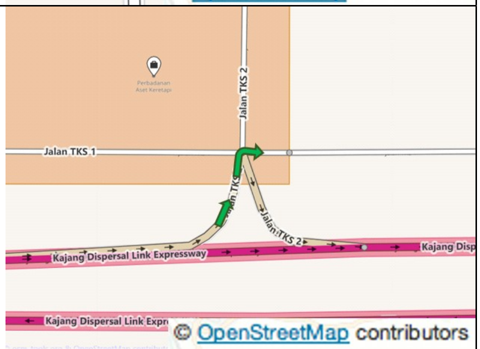
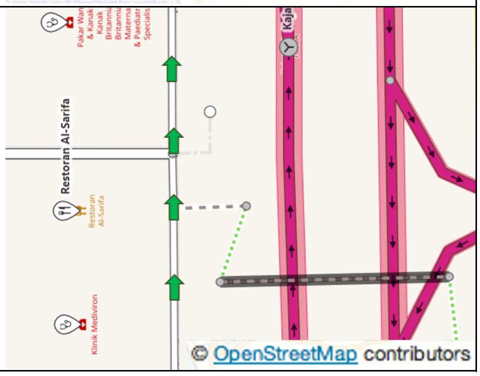
FIGURE 1: Process flow diagram of the MRRT route design and finalization

2.1.3.2 MRRT Road Sections and Elements

MRRT road sections and elements were carefully selected for inclusion to ensure that specific competencies for safe motorcycle riding can be assessed on the actual roads. One of the key criteria of inclusion was the availability of certain traffic scenarios that presented the opportunity to assess the participants in critical riding situations. Table 1 listed seven intersections (i.e., critical conflict points) included in the version of MRRT used in the present study, along with the still images of the intersections captured from the forward view recording of MIROS Instrumented Motorcycle (INSMO) and the street maps.

TABLE 1: Intersections included in the MRRT as the points of riding competencies assessment

Intersection	INSMO's image	Street maps
J1-3L Right turn at a three-legged intersection		
J2-3L Through movement at a three-legged intersection		
J3-4L Through movement at a four-legged intersection		
J4-3L Right turn at a three-legged intersection		

Intersection	INSMO's image	Street maps
J5-3L Right turn at a three-legged intersection		
J6-4L Right turn at a four-legged intersection		
J7-3L Through movement at a three-legged intersection		

2.1.3.3 MRRT Assessment Criteria and Scoring Methods

MRRT assesses seven criteria for riding competency across its two main assessment components. The seven criteria are pre-riding safe routine inspection, safe maneuvering at intersections, effective hazard anticipation, effective signaling, safe merging and lane changing, safe and effective braking, and safe speed management. Table 2 presents the details of MRRT assessment criteria, scoring methods, and the source of data used to assess each riding competency in the present study. A higher weightage was assigned to certain riding competencies that could influence a higher risk of a crash. For example, effective signaling is crucial for motorcycle safety in a mixed-traffic environment in Malaysia; thus was given higher weightage.

TABLE 2: MRRT assessment criteria, weightage, scoring method, and source of data for analysis

MRRT Assessment Components	Demerit	Merit	Data Source
C0 Pre-riding safe routine inspection (30% of MRRT) ***General competency indicator:*** Participants were rated for competencies to inspect the motorcycle physically including checking the functionality of the motorcycle's brake, brake light, turn signal lights, tire pressure, motorcycle chains and other items. Participants were also rated for the choice of helmets and the use of safety vests.			

MRRT Assessment Components		Demerit	Merit	Data Source
C0.1	Missing an item or failing to conduct any of the inspections listed in the 11-item pre-riding safe routine checklist	-1 point (each item)		Checklist form filled by trained observers
C1 Safe maneuvering at intersections (20%) ***General competency indicator:*** Full stopping (0 km/h) before crossing or turning at unsignalized intersections or when the red light is on at signalized intersections.				
C1.1	Not stopping fully (0 km/h) when crossing/turning at any of the seven intersections.	-2.9 points (each time)		GPS speed recording Camera footages
C1.2	Accelerates through J7-3L without checking for hazards.	-5 points		
C1.3	Full stopping (0 km/h) at a minimum of four (4) intersections.		+10 points	
C1.4	Full stopping (0 km/h) at J6-4L		+10 points	
C2 Effective hazard anticipation (20%)				
C2.1	Checking for potential hazards at all intersections or at any relevant traffic scenarios using head movement.		+20 points	Camera footages
C2.2	Not checking for potential hazards using head movement at any intersections or at any relevant traffic scenarios.	Mandatory zero score for C2		
C3 Effective signaling (40%) ***General competency indicator:*** Turning the signal lights on at least 3 s before turning, merging, or committing any lane-changing maneuvers.				
C3.1	Turning the signal lights on less than 3 s before turning, merging, or committing any lane-changing maneuvers.	-5 points (each time)		Instrumentation / recording of turn signal use Camera footages
C3.2	Taking more than 6s to turn the signal lights off.	-5 points (each time)		
C3.3	Not turning the signal lights on at all before committing any lane-changing maneuvers.	Mandatory zero score for C3		
C4 Safe merging and lane changing (20%)				
C4.1	Effective hazard anticipation (C2)	(Refer C2)		GPS speed recording

MRRT Assessment Components		Demerit	Merit	Data Source
C4.2	Effective signaling (C3)	(Refer to C3)		Instrumentation / recording of turn signal use Camera footages
C4.3	Sudden swerving across lanes	-5 points (each time)		
C4.4	Obstructing the traffic due to incorrect lane positioning or insufficient speed	-5 points (each time)		
C4.5	Exceeding the speed limit	-5 points (each time)		
C4.6	Checking the blind spot for hazards by looking over the right shoulder		+10 points	
C5 Safe and effective braking (Demerit only) ***General competency indicator:*** Safe and effective braking competencies measure the ability to anticipate the situation and brake gradually at intersections without having to bring the motorcycle to a sudden stop. A sudden stopping refers to the average braking deceleration value of 6.2 m/s2 (Ecker et al., 2001) or a braking force of 0.6 g (Lenkeit et al., 2011).				
C5.1	Stopping or slowing down at intersections with an average braking deceleration value of 6.2 m/s2 or higher	-5 points		GPS speed recording Camera footages
C6 Safe speed management (Demerit only) ***General competency indicator:*** Maintaining safe riding speeds by not exceeding the designated speed limit (both advisory and mandatory).				
C6.1	Exceed a posted speed limit once	-5 points		GPS speed recording Camera footages
C6.2	Exceed a posted speed limit more than once	-15 points		
General criteria: Any conflict with other road users in which the participants were deemed at fault will result in 10-point deductions (each time).				

2.2 Equipment

The list of equipment used in this study includes computers for the hazard perception test, participants' smartphones for the knowledge test, and the fleet of MIROS Instrumented Motorcycle (INSMO) for the MRRT safe riding assessment. INSMO is an instrumented motorcycle developed by the Malaysian Institute of Road Safety Research (MIROS) based on small-displacement motorcycles. For the present study, a 100 cc Honda Wave (as it is locally known) was used as the instrumented motorcycle. The motorcycle was equipped with a front disc brake and an expanding rear brake (drum brake). The transmission system was a 4-speed semi-automatic system with both an electric and kick starter. The Honda Wave weighs around 90.7 kg with a seat height of 804 mm (see Figure 2).

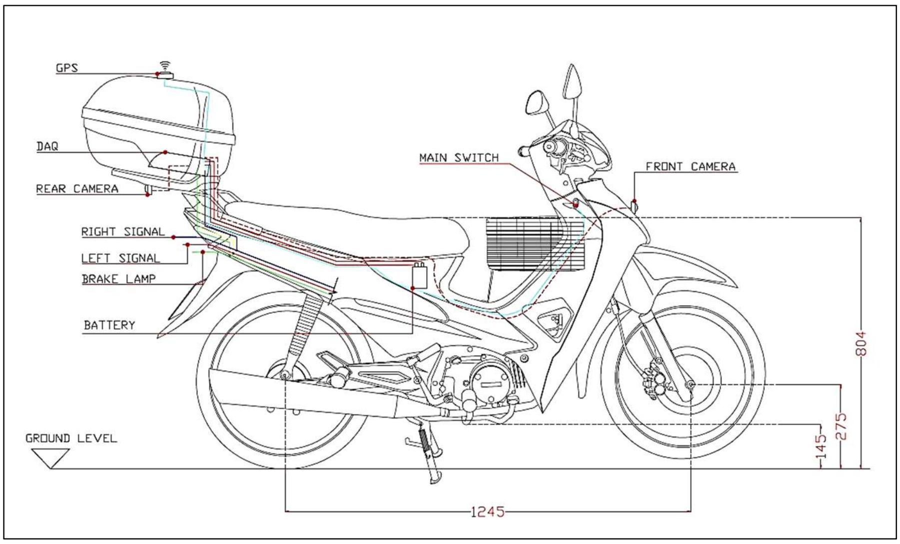


FIGURE 2: INSMO instrumentation details (Ibrahim, 2017, p. 35)

2.2.1 INSMO Instrumentation and Data Acquisition

An off-the-shelf DR-9100 data logger manufactured by Horiba Ltd, Japan was fitted inside a helmet storage box mounted at the rear of the motorcycle. The data logger weighed around 135 g with a dimension of 111.8 mm (W) x 91.4 mm (D) x 25.4 mm (H). The data logger used the 12 V direct voltage generated from motorcycle battery as its power source. Real-time video images of the forward view and the face of participants were captured using two high-resolution, weatherproof miniature cameras with 30 frames per second (fps) video recording covering 117° horizontal and 84° vertical angle of view. For the purpose of MRRT assessment, the cameras were mounted on the motorcycle front panel (forward view) and on the instrument panel (face view). The use of brakes and turn signals were recorded by capturing the electrical analog inputs from the electrical circuits of the rear brake light and both sides of the signal lights. A Global Positioning System (GPS) device (update rate: 5 Hz) was used to record the riding speeds during the test. All data was stored in a memory card and transferred to a laptop for processing. Sensors and video data were accessed and viewed using a data management software developed by the system manufacturer. More details on the motorcycle instrumentation can be found in Ibrahim (2017) and Ibrahim, Hamid, Law, and Wong (2018).

2.2.2 Verification of INSMO's Video Footage and GPS Speed Measurement

Each footage included in the dataset should represent the actual time and the site of recordings; thus, the authentication of the representativeness of instances of the recorded footage was paramount. The relative timing of the video, GPS, and riding behavior data was inspected for synchronization errors to verify the representativeness of the video footage. The inspections were conducted using a playback function embedded in data management software. A verification was also conducted to ascertain the accuracy of the locations of the recorded footage. Verification of the instrumented motorcycle's GPS-based speed measurement was reported extensively in a study conducted by Ibrahim (2017). The study reported that the GPS speeds were strongly correlated with speeds measured by a PR1000 Doppler-based speed radar ($r = 0.982$, $p < 0.001$).

2.3 Participants and Procedure

Participants were 31 consented courier riders aged 19 to 46 years (M=29.9, SD=7.43, 99% male). The participants were recruited during a road safety program for a group of courier workers, which MIROS was involved in. During the data collection day, all participants were gathered at MIROS's office in Kajang, Malaysia. A briefing session was held involving all participants to explain the necessary details of the assessment process. The test procedures, MRRT test route, and the equipment they will be using were explained in detail in a classroom setting. Participants were assigned turns for each assessment in a convenient, non-random manner. For the MRRT, an emergency contact number was provided to the participants for them to call in case of emergency. A specific instruction was given to the participants not to use their phones while riding. Prior to the actual on-road assessment, each participant completed a route familiarization trip led by a member of the research team, with each individual riding a different motorcycle.

All participants began their MRRT assessment from a room that had an exit leading to a nearby parking space where the instrumented motorcycle was parked on a double center stand with a key in the ignition. A table was prepared inside the room to place different types of motorcycle helmets, including non-compliant helmets and safety vests. Once all preparations were completed, the participant received clearance to begin riding the instrumented motorcycle. A trained observer then started to observe and rate the participant on his or her pre-riding safe routine. A standardized pre-riding safe routine checklist with 11 items was developed for this purpose. The scoring only involved merit points for correct selections and correct practices, with no demerit points. The participants who chose a non-compliant helmet or did not wear the safety vest will be stopped and instructed to change the helmet and wear the vest before riding. Each participant completed the on-road riding on their own without way-finding devices or any printed maps.

2.4 Data Analysis

A database containing classification variables based on all assessment criteria was prepared using a spreadsheet program to facilitate the data collection, reduction, and analysis process from the three assessment methods. Sensors and video data recorded by INSMO were viewed using a data management software developed by the system manufacturer. Figure 3 shows a sample display of the data management software. The software displays synchronized sensors, video, and GPS data simultaneously, making the analysis of specific riding events possible. In the present study, a trained data reductionist and analyst was responsible for the reduction and analysis process. Statistical analysis was conducted using R software (R Core Team, 2023).

FIGURE 3: Sample display of data management software

3. RESULTS AND DISCUSSION

3.1 Replicability of the MIROS Motorcycle Riding Road Test (MRRT)

Replicability of the MRRT method was determined by examining the quality of the recorded data, reliability of the data acquisition system, the participants' route completion and way-finding success rate, the complexity of data analysis, and the safety of participants. Throughout the assessment sessions, we observed no significant instrumentation and data acquisition issues, suggesting the reliability of the vehicle instrumentation methods. In addition, only nine instances where a participant missed a junction (involving 6/31 participants) and two instances of conflict with other road users (2/31 participants) were recorded. This study concluded that the motorcycle instrumentation and the overall assessment and scoring method were suitable and can be replicated to assess a motorcyclist's safe riding competencies on actual roads.

3.2 Descriptive Statistics

Table 3 summarizes participants' scores and other descriptive statistics across the three competency tests.

TABLE 3: Descriptive statistics for MRRT, HPT, and knowledge test

Competency test	N	M	SD	Mdn	Min	Max	Skewness	Kurtosis
On-road Riding (MRRT)	31	68.1%	21.7%	68.0%	29.0%	117.5%	0.2	2.54
Hazard Perception Test	31	49.3%	13.3%	49.1%	14.5%	72.3%	-0.28	2.95
Knowledge Test	31	54.5%	14.2%	56.7%	26.7%	80.0%	0.05	2.22

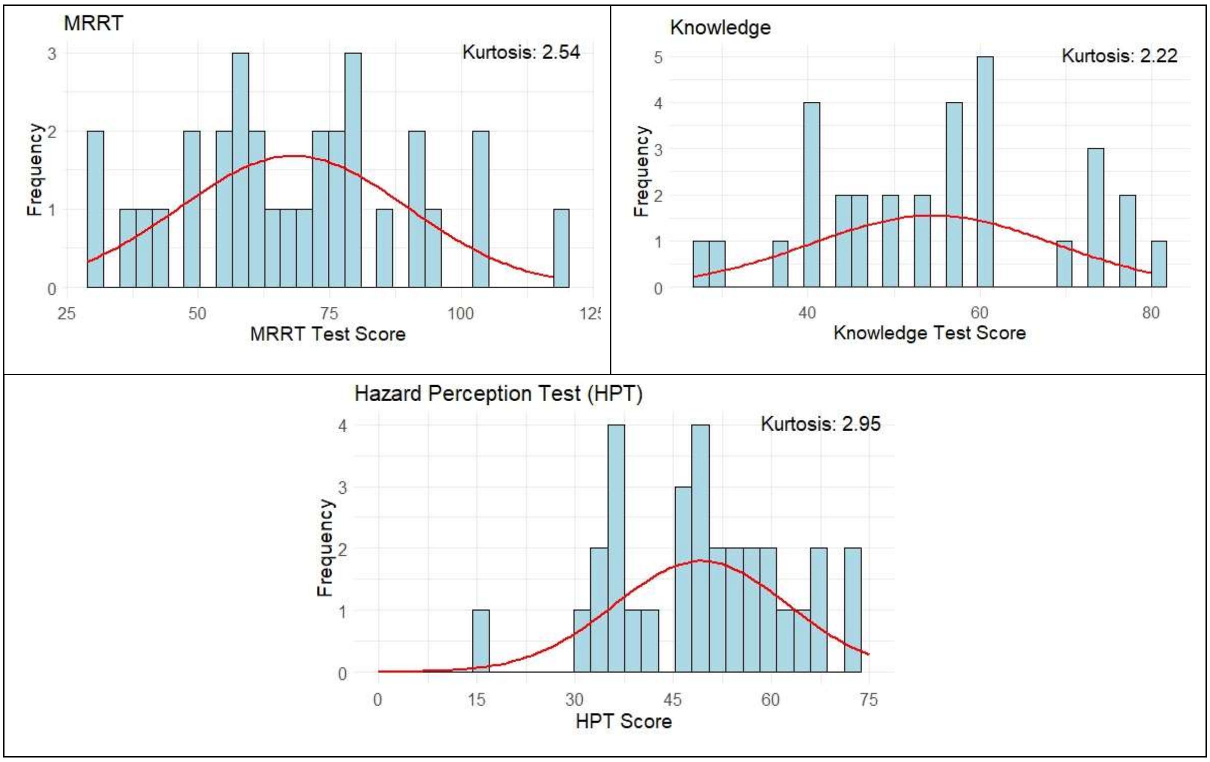


FIGURE 4: Histogram of competency test scores

3.2.1 Participants' On-road Safe Riding Performances

The MRRT scores had the highest mean (68.13) among the three assessments. This suggests that participants, on average, performed better in the practical, real-world assessment of their riding abilities. However, the standard deviation (21.71) is also the highest, indicating more variability in performance, which could reflect the diverse real-world riding experiences and skills of the participants. The slight positive skewness (0.20) suggests a few higher scores, while the positive kurtosis (2.54) indicates a more peaked distribution with fatter tails, suggesting the presence of more extreme values in the data. Table 4 presents the detailed scores across seven MRRT assessment components (refer to Table 2).

TABLE 4: Descriptive statistics for MRRT assessment components (C0-C6)

Competency (Weightage)	N	M	SD	Mdn	Min	Max
C0 (30%)	29	19.3%	5.8%	19.3%	8.2%	30.0%
C1 (20%)	31	9.7%	12.9%	2.9%	-2.1%	40.0%
C2 (20%)	31	20.0%	0.0%	20.0%	20.0%	20.0%
C3 (40%)	31	24.8%	12.8%	30%	0.0%	40.0%
C4 (20%)	31	15.2%	10.7%	15.0%	-10.0%	30.0%
C5	31			0 demerit point		
C6	31			0 demerit point		
On-road riding [C1-C6 (70%)]	31	50.7%	19.4%	49.0%	12.6%	87.5%
MRRT (100%)	31	68.1%	21.7%	68.0%	29.0%	117.5%

Note: negative percentage indicates loss (demerit), percentage more than the weightage indicates bonus points

The MRRT assessment criteria with the highest mean score recorded was C2 (Effective hazard anticipation), with a mean score matching its 20.0% weightage. The standard deviation of 0.0% shows perfect consistency in this competency. This suggests that checking for potential hazards using head movement is a universally applied skill among the participants. A box plot analysis revealed that C1 (Safe maneuvering at intersections) has the lowest median score, with most riders performing poorly, though a few outliers demonstrate high discipline among a few participants. Most participants demonstrated a critical lapse in safe riding by accelerating through J7-3L without adequately checking for hazards and failing to stop fully at most of the junctions, resulting in demerit points. Figure 5 shows the box plot of weighted scores for the five MRRT main competencies measures. No scores (no demerit points) were recorded for C5 (Safe and effective braking) and C6 (Safe speed management).

Overall, the finding implies that while most riders are clustered around the mean score, some riders demonstrate significantly higher riding competencies, reflecting a wider range of practical skills. The score distribution suggests that the assessment method is sensitive enough to detect both the typical performance and the exceptional skills of top riders, making it a useful tool for motorcycle licensing tests and training needs analysis for licensed riders.

3.2.2 Participants' Hazard Perception Skill

The HPT scores show the lowest mean (49.26) among the three assessments, indicating that participants found this test more challenging compared to both the practical riding test and the theoretical test. The standard deviation (13.29) is the lowest of the three, suggesting less variability in the hazard perception scores. The negative skewness (-0.28) reflects a slight skew towards lower scores, indicating that more participants scored below the mean. The kurtosis (2.95) suggests a distribution with heavier tails and a higher peak compared to a normal distribution. Given that hazard perception is crucial for road safety, the test's ability to reveal deficiencies in this area is particularly valuable. It effectively reveals the spectrum of hazard perception abilities among riders, from those who struggle significantly to those who excel. This information is crucial for tailoring training programs and potentially for informing licensing decisions, ultimately contributing to improved road safety for motorcyclists.

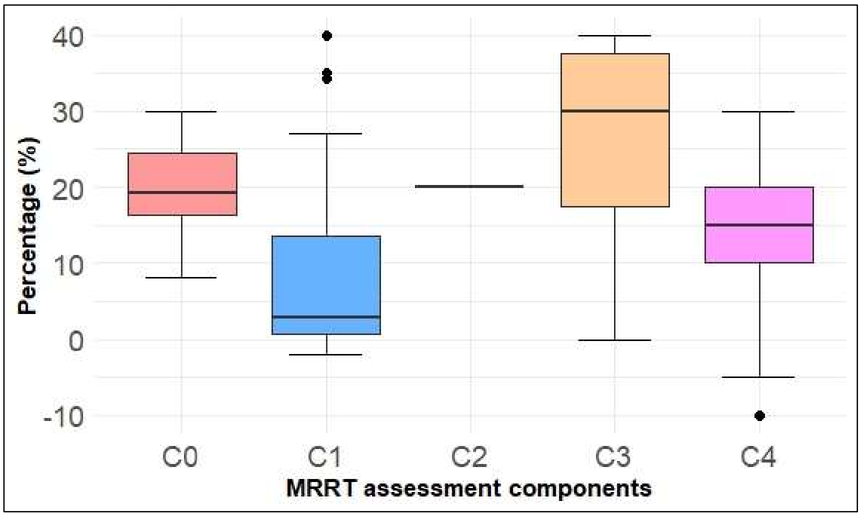


FIGURE 5: Box plot of scores from MRRT main assessment components

3.2.3 Participants' Safe Riding Knowledge

The scores from the knowledge test have a lower mean (54.52) compared to the MRRT scores, suggesting that participants generally scored lower on theoretical knowledge of safe riding, road safety rules, and regulations than on their practical riding skills. The standard deviation (14.21) indicates moderate variability, which is lower than that for MRRT scores. The nearly zero skewness (0.05) reflects a symmetric distribution of scores around the mean. However, the positive kurtosis (2.22) indicates the presence of both very high and very low values in the theoretical knowledge scores. This result implies that while the riders' theoretical knowledge is generally evenly distributed, there are some notable exceptions or inconsistencies in their performance.

3.3 ANOVA: Comparing Participants' Safe Riding, Knowledge, and Hazard Perception Competence

This study used a repeated measures ANOVA to compare the safe riding competencies of each participant across three different assessment methods. The computation of the repeated measures ANOVA was achieved using the anova_test() function in the rstatix package (Kassambara, 2021) of the R software. The data was checked using the box plot method for potential extreme outliers. The assumption of normality was checked using the Shapiro-Wilk test for each assessment method. The riding competency scores from each method were found to be normally distributed ($p > 0.05$), as assessed by Shapiro-Wilk's test [Riding ($p = 0.961$), Knowledge ($p = 0.369$), HPT ($p = 0.654$)]. The normality of data was also checked using a QQ plot, which draws the correlation between a given dataset and the normal distribution. Figure 6 shows that all the points fall approximately along the reference line for each method, thus confirming the assumption of normality. The assumption of sphericity was automatically checked during the computation of the ANOVA test using the R function anova_test() with the use of Mauchly's test to assess the sphericity assumption and the Greenhouse-Geisser sphericity correction for automatic correction of factors violating the sphericity assumption.

The ANOVA results indicate a significant overall effect ($F(1.66, 49.71) = 14.74$, $p < 0.0001$), with a partial eta-squared (η^2) of 0.19, suggesting a moderate effect size. Table 5 summarizes the ANOVA results.

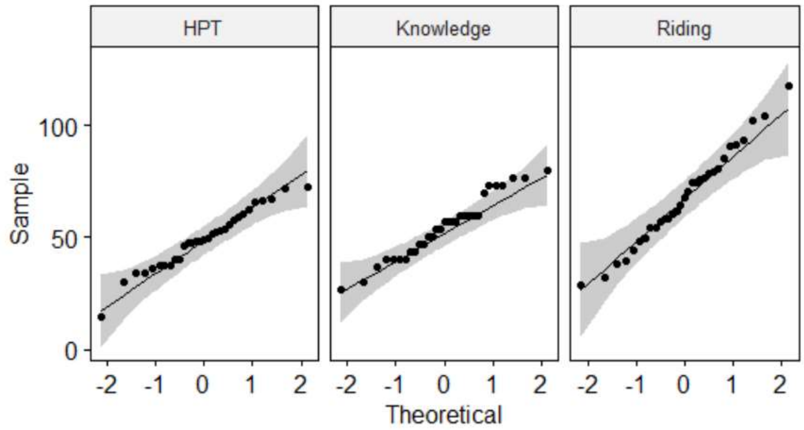


FIGURE 6: QQ plots for assessing normality of scores across assessment methods

TABLE 5: ANOVA results of participants' scores by assessment method

Predictor	df_{Num}	df_{Den}	*Epsilon*	SS_{Num}	SS_{Den}	*F*	*p*	η^2_g
(Intercept)	1.00	30.00		305357.43	13536.89	676.72	.000	.92
Methods	1.66	49.71	0.83	5877.69	11958.45	14.75	.000	.19

Note. df_{Num} indicates degrees of freedom numerator. df_{Den} indicates degrees of freedom denominator. Epsilon indicates Greenhouse-Geisser multiplier for degrees of freedom, *p*-values and degrees of freedom in the table incorporate this correction. SS_{Num} indicates sum of squares numerator. SS_{Den} indicates sum of squares denominator. η^2_g indicates generalized eta-squared.

Post-hoc Bonferroni-adjusted comparisons show significant differences between Riding (MRRT) and HPT scores, and between Knowledge and HPT scores, but no significant difference between Riding and Knowledge scores. These findings suggest that while the Riding and Knowledge assessment may share some similarities in performance, the HPT scores represent higher-order skills that differ significantly and may require specific experience, training, or sets of preparation to achieve a certain level of competency. This underscores the need for tailored interventions to improve hazard perception skills among participants and highlights the importance of including HPT in the assessment framework for competencies, especially for licensing purposes. Figure 7 illustrates a comparison of scores across assessment methods with a box plot and ANOVA results.

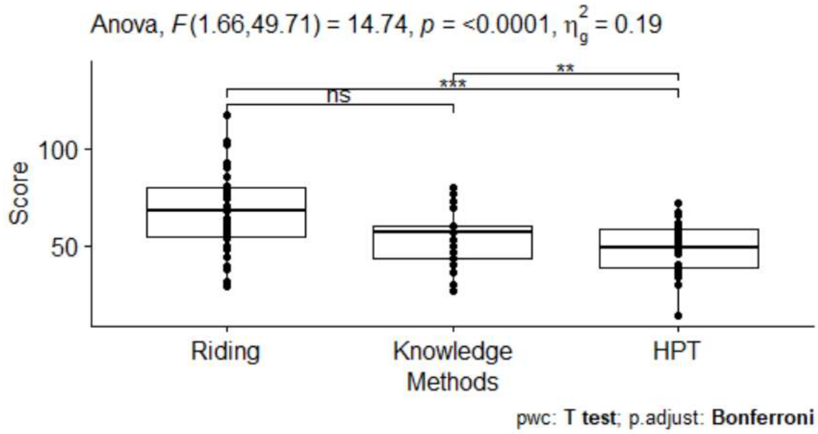


FIGURE 7: Box plot of scores by assessment method and ANOVA results

4. DISCUSSION

The present research demonstrates that a comprehensive assessment framework combining multiple key competency measures was effective in evaluating a motorcyclist's abilities to ride safely on the road. Such an approach facilitates a more accurate measurement of rider competencies, specifically addressing the demands and inherent risks associated with this mode of transport. One of the purposes of this study was to explore the feasibility of conducting an on-road assessment of safe riding through instrumentation of small-displacement motorcycles. This study concluded that the motorcycle instrumentation and the overall assessment and scoring method were suitable and can be replicated to assess a motorcyclist’s safe riding competencies on actual roads. The comprehensive assessment method was also effective in detecting different skill levels among the participants. The findings underscore the need for tailored interventions to improve higher-order riding skills such as hazard perception and responding among the participants.

Research supports the importance of exposing motorcyclists to real-world scenarios during training, as it helps develop critical skills like hazard perception and emergency braking in realistic contexts. Studies have found that realistic training methods can better prepare riders to manage complex traffic environments and emergencies. For example, training that integrates real-world perceptual and action tasks, such as emergency braking in controlled, realistic scenarios, has been shown to improve rider response without the risks associated with on-road training involving other traffic (Huertas-Leyva et al., 2017; Wallace et al., 2005).

However, directly exposing trainees to high-risk on-road scenarios can lead to safety concerns, such as potential collisions. In mitigating these risks, controlled on-road testing, utilization of advanced motorcycle simulators, Augmented Reality (AR) training tools, and progressive licensing systems are several alternatives that should be considered. These methods combine safety and efficacy, ensuring trainees develop necessary competencies while minimizing the risks associated with early exposure to live traffic. Figure 8 presents the key details of this study summarized in a graphical abstract.

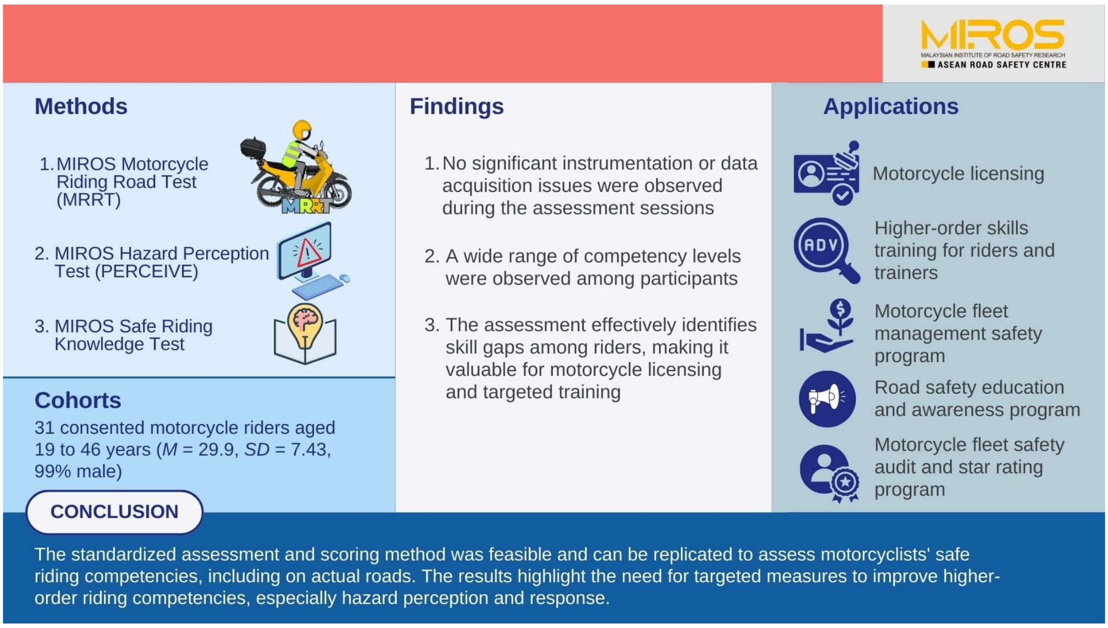


FIGURE 8: Graphical abstract of the present study

5. RECOMMENDATIONS

Given the statistics of motorcycle fatalities and the persistent road safety challenges, prioritizing motorcycle riders as the focal point of a solution model could be groundbreaking. The introduction of more robust and comprehensive training and competency assessments – both in the licensing process and in post-license road safety programs – could significantly enhance rider skills and safety behavior. By implementing these improved evaluation methods, countries with high motorcycle ridership can better equip motorcyclists with the critical skills needed to navigate complex road environments, while also fostering safer interactions between motorcyclists and other road users.

This approach not only addresses the vulnerabilities specific to motorcyclists but also offers a scalable model for improving road safety across all vehicle types. Prioritizing motorcyclists in safety policies and education initiatives has the potential to reduce fatality rates and set new standards in road safety management, ultimately leading to safer roads for all. Therefore, it is strongly recommended that competency assessment reforms and continuous safety training become cornerstones of Malaysia's national road safety strategy.

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