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Motorcyclist Hazard Perception and Situational Awareness Deficits: Evidence for Motorcycle Collision Warning Technologies and Policy Reform in Malaysia

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ABSTRACT

Motorcyclists in Malaysia face disproportionately high fatality risks, reflecting cognitive and behavioral gaps not adequately addressed by conventional training or enforcement. This study examined hazard perception and situational awareness (SA) as critical contributors to crash risk through two controlled experiments. Experiment 1 assessed 31 courier motorcyclists using a Motorcycle Riding Road Test (MRRT), a hazard perception test (HPT), and a theory test. Results revealed systemic weaknesses in hazard appraisal, with HPT scores significantly lower than MRRT and theory performance ($F(1.66, 49.71) = 14.74$, $p < .0001$, $\eta^2 = 0.19$). Riders frequently accelerated through intersections without sufficient hazard checks, underscoring lapses in risk recognition that elevate crash likelihood. Experiment 2 evaluated 264 riders using the Motorcycle Riding Situation Awareness Assessment (MRSAA), a video-based instrument anchored in Endsley's three-level SA model: Level 1 (perception), Level 2 (comprehension) and Level 3 (projection). Results showed striking deficits, with mean total scores at 23.2% and Level 1 perception at just 27.5%. Older riders scored 17.4% higher than younger riders ($t_{111.12} = 5.93$, $p < .001$), and monthly riding exposure correlated positively with total SA and Level 3 performance. Age was consistently associated with better outcomes across all SA levels. Together, these findings confirm that hazard perception and situational awareness are distinct, higher-order competencies with foundational deficits among Malaysian motorcyclists. The evidence provides a data-driven justification for adoption of collision warning technologies in motorcycle design to assist riders in hazard detection and collision avoidance. In parallel, the study proposes the Integrated Motorcycle Safety Empowerment Framework for Malaysia (IMSEF-MY) as a long-term strategy.

Keywords: Motorcycle safety; hazard perception, situational awareness; collision warning technologies; policy

INTRODUCTION

Motorcycle safety remains a pressing concern in Malaysia, given the high proportion of fatalities and injuries involving this mode of transport. Between 2013 and 2023, a total of 44,699 motorcyclists and pillion riders were killed in road traffic crashes, while another 128,722 sustained injuries (Royal Malaysia Police (PDRM), 2023). Motorcycle fatalities accounts for 65.4% or nearly two-third of 68,364 recorded road traffic fatalities during the same period. On average, approximately 4,063 motorcyclist fatalities occurred annually, equivalent to at least 11 deaths each day. Motorcycle casualties in Malaysia surged from 31,923 in 2018–2020 to 80,431 in 2021–2023, representing an alarming 2.5-fold increase within just three years.

A closer examination of crash data from 2017 to 2021 indicates that over one-third of all motorcycle fatalities and injuries involved riders between the ages of 16 and 25. Notably, more than half of the combined fatalities and

injuries within the 16–25 age brackets each year were concentrated within the 16 to 20 age group. The statistic is illustrated in Figure 1 and Figure 2. Considering that 16 is the minimum legal age for obtaining a motorcycle license in Malaysia, these figures point to a disproportionately high collision involvement rate among newly licensed riders. The sustained contribution of motorcycle casualties to national road crash statistics highlights the vulnerability of this group and reinforces the need for systematic interventions, particularly those addressing rider competency and exposure-related risk factors.

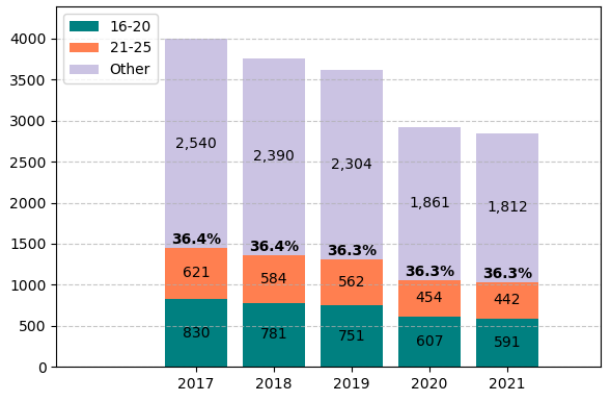

FIGURE 1. Motorcycle fatalities by rider age group (2017–2021).
Source: Authors' analysis of Royal Malaysia Police (PDRM) data.

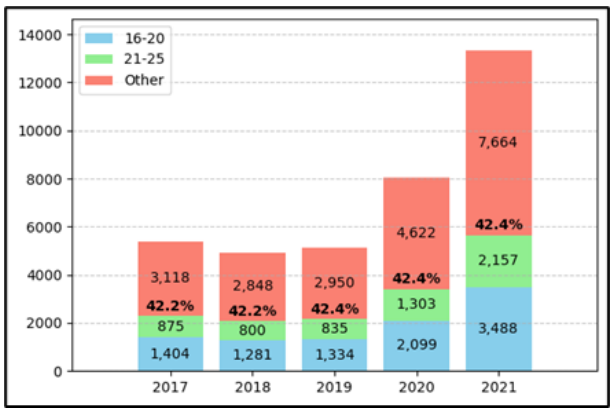

FIGURE 2. Motorcycle injuries by rider age group (2017–2021).
Source: Authors' analysis of Royal Malaysia Police (PDRM) data.

Several studies shown that newly licensed motorcyclists often begin their on-road experience without sufficient development of higher-order cognitive skills such as hazard perception and responsive decision-making (Clarke et al. 2006; Ibrahim & Ab. Rashid, 2016). In the Malaysian context, the issue is compounded by structural limitations within the current training system, which relies heavily on standardized closed-circuit environments. These circuits primarily aim to develop basic maneuvering skills such as slalom and obstacle avoidance but are limited in their ability to expose learners to the range of complex situations commonly encountered on public roads. Ibrahim and Mohd Yusoff (2011) demonstrated through an instrumented motorcycle study that newly trained Malaysian riders displayed inconsistent and sometimes inadequate responses to real-world hazards at unsignalized junctions.

Further investigation by Ibrahim et al. (2016) on the impact of the revised driver education curriculum introduced in 2014, indicated some improvement in hazard perception skills among newly trained motorcyclists. However, response times remained significantly slower for motorcycle riders compared to car drivers, suggesting that motorcyclists may require longer or more targeted exposure before attaining a similar level of hazard anticipation. The current motorcycle licensing system in Malaysia lacks structured risk exposure control for learner and provisional license holders. Given these persistent challenges in hazard perception development, early cognitive readiness, and exposure-based licensing progression, there remains a critical need to better understand the specific competency gaps contributing to crash risk among Malaysian motorcyclists.

The high-risk nature of motorcycling is compounded by the complex mechanical dynamics required for rapid evasive action, such as a lane change manoeuvre, which often precedes a collision. Response mechanisms for motorcyclists are correspondingly more immediate and demanding, necessitating heightened scanning techniques, anticipatory skills, and quick reflexes. Cossalter and Sadauckas (2006) provide a rigorous quantitative framework for assessing the complex motorcycle dynamic. Through instrumented experiments on diverse vehicles (a 125-cc scooter, 750 cc street motorcycle, and 1350 cc touring model), they demonstrated how motorcycle mass, wheelbase, and caster angle influence roll and yaw dynamics, with heavier touring bikes exhibiting larger gyroscopic moments that demand greater rider torque to overcome, especially at higher speeds. This work not only corroborates the trade-off between manoeuvrability and stability but also emphasizes the rider's reliance on intuitive control actions, such as momentary counter-steering, to achieve safe evasion actions that, if impaired by low situational awareness, amplify crash risks in real-world scenarios like obstacle avoidance.

Considering the issues related to motorcycle crashes on Malaysian roads, it is evident that there are almost zero margins for errors for a motorcyclist in terms of hazard detection and vehicle control. On a high-speed road, a

failure to detect and respond sufficiently to an obstacle along the riding path could be fatal for a motorcyclist. It is evident that crashes involving motorcycles striking a stationary or slow-moving vehicle on highways are not uncommon in Malaysia. Some of these crashes occurred along emergency lanes or in the proximity of work zones. In the case of work zones on high-speed roads and highways, the risk of road crashes and other safety issues has been documented in previous studies (Che Ahmad et al. 2016; Gannapathy et al. 2008; Gundy, 1998; Harb et al. 2008). From a road user's perspective, the work zones on high-speed roads are a form of hazard that can increase the load to cognitive resources related to vehicle control and lane-keeping. Given these persistent challenges in hazard perception development, early cognitive readiness, and the inherent risk of motorcycle riding, there remains a critical need to better understand the specific competency gaps contributing to crash risk among Malaysian motorcyclists. The present study aims to address this need by analyzing empirical data from two experimental assessments. The findings are intended to inform both long-term safety system reforms and the justification for deploying real-time collision warning technologies as a complementary and immediate intervention to reduce motorcycle crash risk.

METHODOLOGY

EXPERIMENT DESIGN AND PROCEDURE

The present study analyzed data from two experiments designed to measure real-world competency across key safe riding domains. Experiment 1 involved a comprehensive assessment of courier riders using three assessment tools: a knowledge test, a hazard perception test (HPT), and the MIROS Motorcycle Riding Road Test (MRRT). The assessments were designed to reflect real-world risk and measure higher-order riding skills objectively. The knowledge test included 30 multiple-choice questions covering defensive riding, road signs, and general safety knowledge. The HPT consisted of 12 video clips displaying 31 real-road motorcycle hazards. Participants viewed the clips and responded by clicking on perceived hazards, allowing the system to capture reaction time and accuracy.

The MRRT assessed practical riding competency using an instrumented 100 cc Honda Wave motorcycle (Figure 3). 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.

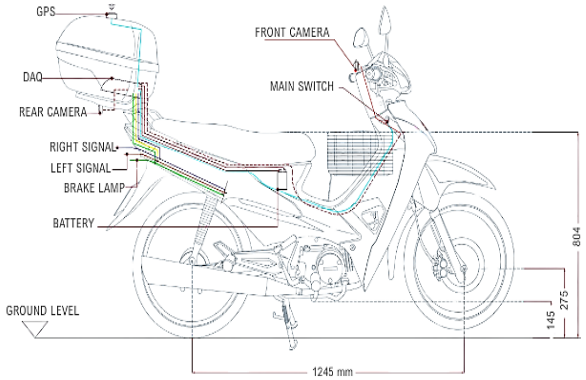

FIGURE 3. MRRT Motorcycle instrumentation details

Data were collected through video cameras, GPS, and sensor-based logging, and then analyzed using custom-built data management software. The MRRT measures seven key competencies across two components: pre-riding

safety checks and on-road riding performance. These include intersection maneuvering, hazard anticipation, signaling, merging and lane changing, braking, and speed management. Higher scoring weightage was assigned to competencies with greater crash risk implication, for example, effective signaling was assigned higher weightage due to its relevance in Malaysia's mixed-traffic environments. Statistical analysis was conducted using R software. Details of the scoring methods are available in Ibrahim et al. (2024).

Experiment 2 utilized a video-based Motorcycle Riding Situation Awareness Assessment (MRSAA) tool. The MRSAA applied the Situation Awareness Global Assessment Technique (SAGAT) framework to measure three levels of situational awareness (SA): perception (Level 1), comprehension (Level 2), and projection (Level 3). Participants viewed real-world riding clips recorded from a motorcyclist's perspective and responded to multiple-choice questions prompted during freeze-frame moments. The motorcycle riding speed (km/h) was displayed on each clip (Figure 4). Each query was designed to assess participants' awareness at a specific level across the three levels of SA defined by Endsley (1995). Demographic and riding exposure data were also collected using a structured questionnaire. Sample SA queries at each level are listed in Table 1. Detailed SA queries are available in Ibrahim et al. (2021). Situational awareness scores were calculated as the percentage of correct responses across all SA levels, with a maximum score of 100%. Data analysis was conducted using SPSS to evaluate overall SA performance and its relationship with rider characteristics and exposure.

FIGURE 4. Screenshot of a sample video clip included in the MRSAA

TABLE 1. SA queries and the level of riding situational awareness

Level of SA	Queries
Level 1 (*Perception*)	• Did you see a taxi before the video ends? • What was the last road sign you saw before the video ends?
Level 2 (*Comprehension*)	• From the first time you saw the taxi until just before the clip ended, the speed of the taxi was… • At your last position (before the video ends), how long have you passed a bicyclist who was riding against the traffic?
Level 3 (*Projection*)	• If you make that U-turn, how much time there is before a collision could happen with the oncoming motorcycle? • If the taxi changes lane onto your travelling direction at the point of the clip ended, how much time is available before a collision could happen between you and the taxi?

PARTICIPANTS

Experiment 1 involved 31 consented courier riders aged 19 to 46 years (M=29.9, SD=7.43, 99% male). The data collection was conducted during a road safety program for a group of courier workers. Experiment 2 involved a total of 264 motorcyclists (95.1% male), with ages ranging from 16 to 57 years (M = 24.4, SD = 8.2).

RESULTS AND DISCUSSION

RIDING PERFORMANCE, HAZARD PERCEPTION AND THEORETICAL KNOWLEDGE

Table 2 summarizes participants' scores and other descriptive statistics across the three competency tests in Experiment 1. The MRRT produced the highest mean score among the three assessments (M = 68.1%, SD = 21.7%), indicating that participants generally performed better in the real-world riding test. However, the high variability suggests a wide range of practical skill levels. Of the seven assessed competencies, effective hazard anticipation had a perfect mean score with no variation, reflecting consistent head-checking behavior. In contrast, intersection maneuvering had the lowest median score, with many participants failing to fully stop or adequately assess for hazards, especially at critical junctions resulting in repeated demerits. The HPT yielded the lowest mean score (M = 49.3%, SD = 13.3%), indicating that participants found the test more challenging than both the MRRT and knowledge assessments. The distribution was negatively skewed with elevated kurtosis, suggesting a concentration of low-performing riders and limited variability.

These findings suggest widespread deficiencies in hazard detection and reinforce the role of HPT in revealing cognitive skill gaps that may not be captured through conventional tests. Participants scored a mean of 54.5% (SD = 14.2%) on the safe riding knowledge test. The distribution was symmetric but exhibited moderate kurtosis, suggesting that while scores were generally even, some riders demonstrated very high or very low knowledge levels. Compared to MRRT, theoretical scores were lower and more concentrated, pointing to inconsistencies in

participants' understanding of defensive riding and road rules. A repeated measure ANOVA 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 (see Figure 5).

Post-hoc Bonferroni-adjusted comparisons showed that HPT scores were significantly lower than both MRRT and knowledge scores, while no significant difference was observed between MRRT and knowledge. These findings suggest that hazard perception reflects a distinct, higher-order cognitive competency requiring specialized training and assessment. The inclusion of HPT in licensing evaluation and training frameworks may enhance riders' readiness to ride on actual roads.

TABLE 2. Descriptive statistics for MRRT, HPT and knowledge test

Competency test	N	M	SD	Mdn	Skewness	Kurtosis
On-road riding (MRRT)	31	68.1%	21.7%	68.0%	0.2	2.54
Hazard perception test	31	49.3%	13.3%	49.1%	-0.28	2.95
Knowledge test	31	54.5%	14.2%	56.7%	0.05	2.22

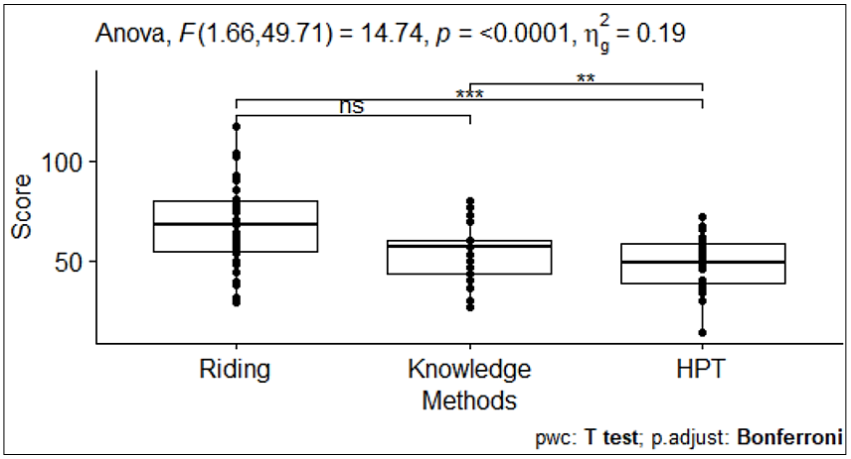

FIGURE 5. Scores across assessment methods (MRRT, Knowledge, HPT)

SITUATIONAL AWARENESS PERFORMANCE

Findings from Experiment 2 revealed that participants demonstrated generally low situational awareness (SA), with an average total SA score of 23.2% (*SD* = 20.5%). Level 1 SA (*Perception*) recorded an average of just 27.5%. Nearly 30% of participants scored zero across all SA queries, while only a few achieved scores above 80%, indicating that situational awareness among riders is severely underdeveloped. A comparison between younger (16–25 years) and older (26+ years) motorcyclists revealed significant differences in SA performance. Older riders outperformed younger ones across all three SA levels, with total SA scores averaging 17.4% higher ($t = 5.93$, $p < .001$). Specifically, Level 1 SA was 21.8% higher, Level 2 SA (*Comprehension*) was 14.5% higher, and Level 3 SA (*Projection*) was 16.3% higher in the older group. This indicates a substantial cognitive gap in younger riders, particularly in their ability to perceive, comprehend, and project potential road hazards. Table 3 summarizes the results.

TABLE 3. Descriptive statistics and comparison between younger and older riders

Variable	Younger (16-25 years)			Older (> 26years)			*t*-test
	N	M	SD	N	M	SD	
Total SA score (%)	184	17.9	16.4	79	35.3	23.8	5.93**
Level 1 SA score (%)	185	20.0	31.8	79	41.8	36.2	4.64**
Level 2 SA score (%)	185	19.7	29.5	79	34.2	28.6	3.67**
Level 3 SA score (%)	184	13.8	23.6	79	30.1	27.3	4.62**

**$p < 0.01$

Pearson correlation analysis revealed that age showed a moderate, positive correlation with total SA ($r = 0.40$, $p < .001$), and this relationship remained significant after controlling for riding exposure (partial $r = 0.39$, $p < .001$). While riding exposure had a weaker correlation with SA ($r = 0.13$, $p = 0.036$), it was notably associated with Level 3 SA, suggesting that experience modestly enhances riders' anticipatory judgment. These findings reinforce the role of cognitive maturity and accumulated exposure in developing situational awareness which is critical for safe riding decisions.

The empirical findings of this study consistently reveal substantial deficits in hazard perception and situational awareness among Malaysian motorcyclists, particularly among younger, less experienced riders. These cognitive gaps, evidenced through low MRSAA scores and delayed hazard detection in the HPT test, were further reinforced by unsafe on-road behavior observed during the MRRT assessments. Riders frequently failed to check for potential threats at intersections, performed incomplete stops, and neglected safe routine, all contributing factors to crash risk in mixed-traffic environments.

Motorcycle safety in Malaysia remains an enduring challenge, with national statistics consistently revealing a disproportionate burden of road fatalities involving motorcyclists. Despite decades of licensing, enforcement, and awareness campaigns, the high incidence of fatal and severe motorcycle crashes persists. A naturalistic study by Ibrahim et al. (2018) recorded over 360 hazardous events and 66 near misses within just 12 hours of real-world courier delivery rides. On average, each rider encountered 30 hazardous events and 5 near crashes per hour. Importantly, 29% of these near crashes were caused by the riders themselves, largely due to lane filtering, risk taking and unsafe turning. The road safety status quo suggests that current interventions, though well-intentioned, may not sufficiently address the cognitive and behavioral gaps that contribute to motorcycle crash risk.

MOTORCYCLE SAFETY TECHNOLOGIES AND SAFETY SYSTEM REFORM

To address the documented delays in hazard perception and unsafe response behaviors among Malaysian riders, this study proposes the incorporation of safety technologies as a layered, assistive safety strategy. These technologies operate independently of rider motivation or training progress and offer real-time crash avoidance or mitigation benefits. Foremost among them is the pre-collision warning technologies. Utilization of LiDAR, radar or image processing technologies for object detection and the provision of automatic speed-sensitive alerts before a crash becomes imminent is particularly valuable. The findings from Ibrahim et al. (2018) further justify the need for pre-collision warning technologies in motorcycle design. Their study shows that a significant portion of near crashes occurred due to visual obstructions and lane-change-related conflicts, which had odds ratios of 4.6 and 7.8 respectively for resulting in near crashes. These are precisely the scenarios where a LiDAR- or GPS-enabled collision warning system could intervene by alerting the rider in time to respond appropriately.

To move toward a more impactful, evidence-based solution, this study proposes an Integrated Motorcycle Safety Empowerment Framework for Malaysia (IMSEF-MY). Figure 6 shows the IMSEF-MY framework in detail. This multi-theoretical framework is anchored on six key pillars: safe system approach, mode shift, shared accountability among stakeholders, strengthened enforcement, and motorcycle segregation. The framework advances five domains of action namely pre-licensing, licensing, technology, exposure control, and retraining, through which its principles are translated into targeted interventions.

This framework is designed to systematically improve rider safety by embedding hazard perception and situational awareness training into the earliest stages of rider development and deploying advanced technologies such as collision warning system and Anti-lock Braking System (ABS) to compensate for real-time cognitive gaps and enhance riders' capabilities. Exposure control strategies target high-risk rider groups such as young or commercial riders through adaptive training and policy measures, while retraining programs ensure continued risk awareness and skill reinforcement throughout a rider's lifecycle.

Together, these pillars form a cohesive and scalable blueprint to shift Malaysia's motorcycle safety paradigm from reactive enforcement to proactive empowerment. The framework provides a basis to guide future interventions that are contextually grounded in the realities of Malaysian road safety.

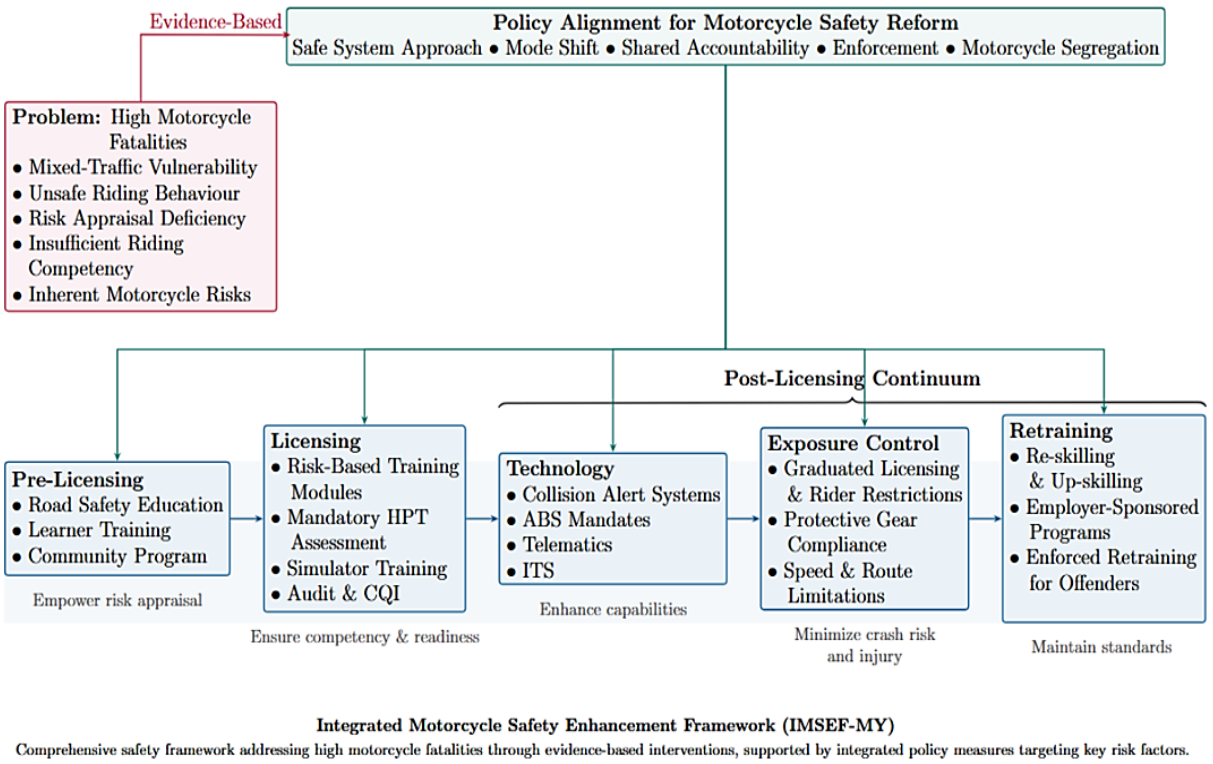

FIGURE 6. Integrated Motorcycle Safety Empowerment Framework for Malaysia (IMSEF-MY)

CONCLUSION

While Malaysia continues to rely on proven road safety strategies through education, enforcement, and engineering, the time lag between policy implementation and its tangible outcomes remains a critical vulnerability. In contrast, motorcycle safety technologies offer an immediate layer of protection, particularly for high-risk and high-exposure rider groups. By offering real-time alerts for instance, this technology has the potential to interrupt unsafe riding trajectories before a crash occurs. Beyond the adoption of these safety technologies, and to sustain its long-term impact, a broader safety framework is needed. The IMSEF-MY framework proposed in this study considers the unique challenges of the Malaysian context and offers a forward-looking solution capable of delivering meaningful reductions in motorcycle crashes over the next five to ten years.

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DECLARATION OF COMPETING INTEREST

None.

REFERENCES

Che Ahmad, A., Mohd Zin, I. N., Rosli, M. N., Ab Wahid, A. M. & Mohd Kamar, I. F. 2016. Hazard and risk of highway maintenance works: Case study of PLUS Expressways. *MATEC Web of Conferences* 66: 00106. https://doi.org/10.1051/matecconf/20166600106

Clarke, D. D., Ward, P., Bartle, C. & Truman, W. 2006. Young driver accidents in the UK: The influence of age, experience, and time of day. *Accident Analysis and Prevention* 38(5): 871–878. https://doi.org/10.1016/j.aap.2006.02.013

Cossalter, V. & Sadauckas, J. 2006. Elaboration and quantitative assessment of manoeuvrability for motorcycle lane change. *Vehicle System Dynamics* 44(12): 903–920. https://doi.org/10.1080/00423110600742072

Endsley, M. R. 1995. Measurement of situation awareness in dynamic systems. *Human Factors* 37(1): 65–84. https://doi.org/10.1518/001872095779049499

Gannapathy, V. R., Subramaniam, S. K., Mohamad Diah, A. B., Suaidi, M. K. & Hamidon, A. H. 2008. Risk

factors in a road construction site. *World Academy of Science, Engineering and Technology* 46: 640–643.

Gundy, C. M. 1998. *Road Work Zone Accident Studies—ARROWS Task 2.2 Internal Report 4J*.

Harb, R., Radwan, E., Yan, X., Pande, A. & Abdel-Aty, M. 2008. Freeway work-zone crash analysis and risk identification using multiple and conditional logistic regression. *Journal of Transportation Engineering* 134(5): 203–214. https://doi.org/10.1061/(ASCE)0733-947X(2008)134:5(203)

Ibrahim, M. K. A. & Ab Rashid, A. A. 2016. Performances of inexperienced motorcycle riders in PC-based hazard perception test. In *Proceedings: Putrajaya International Built Environment, Technology and Engineering Conference*, 24–25 September 2016, pp. 543–548.

Ibrahim, M. K. A., Ab Rashid, A. A., Hamzah, A., Awang, A. & Ishak, S. Z. 2025. Evaluating motorcyclists' safe riding competencies: Integrating hazard perception, theory, and road tests. *Journal of the Society of Automotive Engineers Malaysia* 8(3): 124–139.

Ibrahim, M. K. A., Ab Rashid, A. A. & Low, S. F. 2016. *Effects of New Driver Training Curriculum (KPP) on Novice Drivers' Hazard Perception Skills*. Kajang: Malaysian Institute of Road Safety Research (MIROS).

Ibrahim, M. K. A., Ab Rashid, A. A., Mohd Jawi, Z. & Mohamed Jamil, H. 2018. Riding hazards and crash risks facing Malaysian courier riders in the last mile delivery. *Journal of the Society of Automotive Engineers Malaysia* 2(2): 126–135.

Ibrahim, M. K. A., Hamzah, A. & Abu Kassim, K. A. 2021. Measurement of riding situation awareness among Malaysian motorcyclists using a video-based assessment approach. *International Journal of Road Safety* 2(1): 4–9.

Ibrahim, M. K. A. & Mohd Yusoff, M. F. 2011. Use of instrumented motorcycle to measure the effectiveness of Malaysian rider training: A pilot study. *Proceedings of the Sixth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, pp. 489–495.

Royal Malaysia Police (PDRM). 2023. *Laporan Perangkaan Kemalangan Jalan Raya Malaysia Polis Diraja Malaysia*. Kuala Lumpur: PDRM.