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Risk Assessment and Safety Perceptions on the Motorcycle Lane of Butterworth - Kulim Expressway: A Case Study

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Abstract

The motorcycle lane must have appropriate road safety measures installed to increase road safety, and these measures must be identified and proposed. Previous studies have highlighted the risk of crashes with exclusive motorcycle lanes. There are several factors that contribute to the accidents involving motorcyclist at dedicated motorcycle lanes in Butterworth - Kulim Expressway (BKE), Malaysia. Some of these factors include poor road design and inadequate roadside protection. This study aims to accomplish the following goals: assessing the risk level of the motorcycle lane. To achieve these objectives, the study was conducted field observations to examine the elements of existing road geometry and road facilities. To analyse the data, the study employed the Hazard Identification, Risk Analysis, and Risk Control (HIRARC) method. The study's findings underscore the need for targeted engineering interventions, emphasizing improvements in insufficient lane width, lighting, road surface conditions, and road markings in specific locations with identified risk levels. Addressing these concerns is vital for the effective enhancement of BKE motorcycle lane safety.

1. Introduction

Amidst the global increase in motorcycle usage, concerns about motorcycle safety have risen due to the escalating number of accidents and fatalities. The implementation of dedicated motorcycle lanes has been proposed as a potential solution. However, ongoing debates persist regarding the actual effectiveness of these lanes in enhancing road safety. While proponents argue that segregated lanes reduce collision risks, critics contend that this segregation might lead to a false sense of security and encourage risky behaviors. Therefore, this study primarily focuses on assessing risk and safety perceptions within the BKE motorcycle lane, aiming to discern their impact on overall safety for both motorcyclists and other road users. Such investigation is crucial, especially considering the substantial number of registered motorcycles in Malaysia, underscoring their extensive use and influence on traffic management and road safety.

According to data published by the Public Works Department, Malaysia (JKR) (2017), a growing country, had a sizable number of motorbikes registered in 2017. The numbers came to a substantial total of 13,173,030 registered motorcycles. These figures demonstrate the wide use and significance of motorcycles among Malaysians as a preferred mode of transportation. Such information provides a useful understanding of the number of motorcycles in the country and their effect on traffic control and road safety. The rising number of motorcyclists on the Butterworth-Kulim Expressway (BKE) due to ongoing regional development (Rahim *et al*., 2016) highlights the necessity for increased safety measures. As infrastructure and economic opportunities expand, more people

opt for motorcycles as a mode of transportation, leading to a surge in demand for dedicated motorcycle lanes and safety protocols on the expressway. With motorcyclists accounting for a disproportionate 62% of road fatalities in Malaysia, despite comprising only 49% of the total vehicles (MIROS, 2016), urgent safety enhancements, including efficient motorcycle lanes, are imperative. Notably, despite the existence of dedicated lanes, the frequency of motorcycle accidents remains concerning, suggesting additional contributing factors.

Abdul Manan *et a*l. (2018) found that Malaysian expressways witness a higher number of fatal motorcycle accidents. In 2022, Universiti Putra Malaysia recorded 545,588 accidents, including 5,671 fatal cases resulting in 6,080 deaths, with 4,101 involving motorcyclists. These alarming figures highlight the pressing need for focused interventions to improve motorcycle safety and reduce fatal crashes on Malaysian expressway lanes. Such data underscores the hazards faced by motorcycle riders. Consequently, targeted interventions are crucial to enhance motorcycle safety and reduce fatal crashes on Malaysian expressways (Transport Ministry Road Accidents Statistics Book, 2022). Table 1 provides a breakdown of crash cases involving motorcycles, categorized by expressway section and severity levels.

Table 1 *Number of crash cases by expressway section and severity involving motorcycle* (Abdul Manan *et al.,* 2018)

Expressway Sections	Fatal		Severe		Light		Damage Only	
Slow lane	204	34.1%	807	29.0%	425	15.1%	107	14.9%
Emergency lane	178	29.7%	1409	40.0%	1392	49.5%	324	45.0%
Fast lane	106	17.7%	655	18.6%	463	16.5%	140	19.4%
Middle lane	87	14.5%	349	9.9%	164	5.8%	73	10.1%
Exclusive motorcycle lane	14	2.3%	219	6.2%	320	11.4%	41	5.7%
Road medians	5	0.8%	40	1.1%	25	0.9%	22	3.1%
Overall road section	4	0.7%	28	0.8%	20	0.7%	11	1.5%
On the opposite lane	1	0.2%	4	0.1%	2	0.1%	1	0.1%
On lane closure	-	-	9	0.3%	3	0.1%	1	0.1%
Total (n = 7653)	599		3520		2814		720	

The primary objective of this study is to assess the risk level associated with the motorcycle lane route by employing the HIRARC method. This involves a comprehensive evaluation of potential hazards, risks, and control measures to ensure a thorough understanding of the safety dynamics within the motorcycle lane. Assessing risk the BKE motorcycle lane aims to enhance overall safety for riders and road users. Through observations and data collection on incidents and feedback, recommendations were made to improve safety standards.

2. Literature Review

Implementing dedicated motorcycle lanes to segregate traffic stands as a strategy aimed at curbing the increasing occurrences of motorcyclist-related incidents. The effective isolation of bikes from other motor vehicles through this measure can effectively mitigate such risks (Saini, Chouhan & Kathuria, 2022). Malaysia currently utilizes two distinct infrastructural facilities, namely the Exclusive Motorcycle Lane (EMCL) and Non-Exclusive Motorcycle Lane (NEMCL), designed specifically to segregate motorcycle traffic (Khaidir, Abdul Manan & Megat, 2015). Incorporating a designated lane for motorcyclists can diminish the risk of traffic exposure, consequently contributing to a decline in the overall accident count (Idris, Hamid & Hua, 2019). Table 2 shows studies relevant to the motorcycle lane discussed in this research study.

Table 2 *Selected previous research examining factors influencing motorcycle crashes*

Author	Objective	Methodology	Result/Finding
Khaidir, Abdul Manan, & Megat, (2015)	To identify various types of access design available on EMCL and suggest the safe one.	Videography data was collected at 10 locations (5 at egress and 5 at ingress), followed by using Swedish traffic conflict technique for data analysis.	The study found that auxiliary lane and give way lengths over 15m are safe for egress, while giving way over 15m is safe for ingress, with Y-type access causing the most serious conflicts.

Table 2 *Selected previous research examining factors influencing motorcycle crashes (continued)*

Saini, Chouhan, & Kathuria, (2022)	To identify the necessity for specific geometric design standards for EMCL and evaluate the safety implications of segregating motorcyclists from other mixed traffic.	This paper conducted a systematic review of studies related to EMCL, selecting relevant ones using the PRISMA approach.	The EMCL should have a 3-4 meter lane width, considering motorcyclists' eye height. access design, including a guardrail, is crucial for reducing accidents and ensuring safety.
Abdul Manan, Zulkiffli,, & Jamil, (2020)	To determine the most common cause and contributing factors of motorcycle crash along Malaysian expressways.	The study uses mixed-effects logistic regression (MELR) to analyze crash data and identify three key variables: critical event, critical reason, and associated factors.	The top three factors contributing to fatal motorcycle crashes are loss of control, poor visibility (due to lack of lighting), and incompetence (poor driving skills).
Alvin Poi, W. H. *et al*. (2019*)*	To evaluate the efficacy of NEMCL by estimating the potential saved lives from the facility's provision.	Crash statistics and several key road attributes were analyzed for road segments with and without NEMCL using statistical regression.	The study's negative binomial model reveals NEMCL effectively reduces motorcyclist crash risk, with area type, traffic proportion, and NEMCL presence significantly influencing crash rates.

3. Methodology

This research study utilized a Hazard Identification, Risk Assessment and Risk Control (HIRARC) method and field observations to identify potentially hazardous areas and components at a site. Data was collected through systematic on-site observations and accident data spanning the period from 2019 to 2022, sourced from Projek Lebuhraya Usahama Berhad (PLUS). The study covers the Butterworth-Kulim Expressway, connecting Butterworth in Penang to Kulim in Kedah. Study were conducted in both directions, covering the KM6.0 to KM21.1 section, which has a designated motorcycle lane. Serving as a crucial conduit between Butterworth and Kulim, the expressway handles substantial daily traffic, predominantly comprising motorcyclists reliant on it for their daily commute.

The study focused on identifying hazardous areas within the BKE motorcycle lane by analyzing accident rates and crash frequencies over four years (2019 to 2022). Using data from reputable sources from PLUS, areas with higher accident occurrences were pinpointed. On-site assessments were conducted to understand the causes of these accidents, aiming to uncover underlying reasons contributing to hazards on the BKE motorcycle lane. These insights provide a foundation for targeted plans to improve traffic safety and decrease collisions in these high-risk zones.

3.1 Data collection

This study employed observation to gather comprehensive and trustworthy data aligned with its objective. By combining both methods, it ensured a holistic approach, blending objective observations with subjective experiences. This approach enriched the datasets, offering a more comprehensive understanding and enabling more precise analysis and interpretation of the results. The study utilized observation and analysis to gather information on road safety. It focused on observing road pavement condition, road geometry, and existing road furniture. Real-time data was collected, enabling the researchers to identify patterns and potential issues. The research combined observation and analysis to analyze vulnerabilities and lacks in road infrastructure, providing unbiased data for the study area.

The study assesses the BKE motorcycle lane, including interchanges, rest areas, and service zones, using field observations and specific standards. It aims to assess the current condition of road facilities against guideline standards from Public Works Department, Malaysia (JKR), Malaysia Highway Authority (LLM) and Road Engineering Association of Malaysia (REM) to evaluate infrastructure effectiveness and safety. The study identifies areas needing improvements or modifications, analyzing observed conditions against criteria like lane width, signage, pavement, markings, barriers, and lighting, to enhance road safety.

3.2 HIRARC Method

The study employed primary methods for data analysis: the risk matrix and Hazard Identification, Risk Assessment, and Risk Control (HIRARC). The risk matrix HIRARC approach facilitated an in-depth examination of physical risks through on-site observation to assess the current road safety conditions of the motorcycle lane. A thorough analysis of physical risks through on-site observation was carried out using the risk matrix of the HIRARC method. This systematic approach allowed for a thorough evaluation of the current road safety conditions. The HIRARC method facilitated a systematic assessment of the study area's safety conditions, determining whether they met satisfactory safety standards, as indicated in Table 3. By employing the HIRARC method, a comprehensive understanding of the road safety situation in the selected area was achieved.

Table 3 *Risk matrix of HIRARC (Guideline for HIRARC by DOSH, 2008)*

RISK	DESCRIPTION	ACTION
15 - 25	High	A HIGH risk requires immediate action to control the hazard as detailed in the hierarchy of control. Actions taken must be documented on the risk assessment form including date for completion.
5 - 12	Medium	A MEDIUM risk requires a planned approach to controlling the hazard and applies temporary measures if required. Actions taken must be documented on the risk assessment form including date for completion.
1 - 4	Low	A risk identified as LOW may be considered as acceptable and further reduction may not be necessary. However, if the risk can be resolved quickly and efficiently, control measures should be implemented and recorded.

The process involves identifying potential hazards, assessing their associated risks, and implementing control measures to mitigate or eliminate those risks. The HIRARC method for evaluating road safety follows these steps:

- **Identification of potential hazards**: The initial phase involves recognizing potential dangers that may pose risks to road users, such as road furniture condition, road design flaws, driving behavior, weather conditions, and vehicle issues.

- **Risk assessment**: After spotting hazards, the next phase involves assessing the risk level of each. This includes gauging the likelihood and potential severity of harm from each danger. Risk can be calculated using the following formula:

$$\text{Risk (R)} = \text{Likelihood (L)} \times \text{Severity (S)}$$

The following table depicts the criteria and ratings for frequency (Table 4) and severity (Table 5) based on the Department of Occupational Safety and Health, Malaysia (DOSH) standards. These tables served as reference guidelines to categorize risk levels as low, medium, or high.

Table 4 *Criteria and rating of frequency (Guideline for HIRARC by DOSH, 2008)*

RISK	DESCRIPTION	ACTION
Most likely	The most likely result of the hazard / event being realized.	5
Possible	Has a good chance of occurring and is not unusual.	4
Conceivable	Might be occur at some time in future.	3
Remote	Has not been known to occur after many years.	2
Inconceivable	Is practically impossible and has never occurred.	1

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Table 5 *Criteria and rating of frequency (Guideline for HIRARC by DOSH, 2008)*

RISK	DESCRIPTION	ACTION
Catastrophic	Numerous fatalities, irrecoverable property damage and productivity.	5
Fatal	Approximately one single fatality major property damage if hazard is realized.	4
Serious	Non-fatal injury, permanent disability.	3
Minor	Disabling but not permanent injury.	2
Negligible	Minor abrasions, bruise, cuts, first aid type injury.	**1**

- **Risk control**: Controls like engineering, administrative measures (e.g., signage, speed limits), road design changes, and personal protective gear (helmets, safety gear) are implemented to manage or eliminate identified hazards.

Table 6 summarizes the hazard identification and risk analysis of road safety conditions, offering valuable insights for detecting hazards, analyzing risks, and implementing effective control measures to enhance road safety and reduce accidents in the motorcycle lane. analysis aimed to draw conclusions about motorcyclists' safety perceptions, guiding the identification and recommendation of appropriate road safety measures for the motorcycle lane.

Table 6: *Risk matrix (Guideline for HIRARC by DOSH, 2008)*

	Severity (S)				
Likelihood (L)	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

4. Result and Discussion

The investigation examines motorcycle traffic on the Butterworth-Kulim Expressway (BKE) using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) form. It analyzes collision records and closed observations from 2019 to 2022 to identify potential hazards along the motorcycle lane. The structured assessment provides a comprehensive understanding of potential hazards, categorizing them based on known criteria and frameworks.

4.1 Accident data

The study shows a significant decrease in accidents in the West between 2019 to 2021 as illustrated in Fig. 1, possibly due to improved road safety measures or shifts in driving behavior. However, the East experienced a sharp increase in 2022, contrasting the West's significant decline from 47 to zero. This highlights the need for immediate investigations, targeted interventions, and improved safety measures for motorists using the Eastbound route.

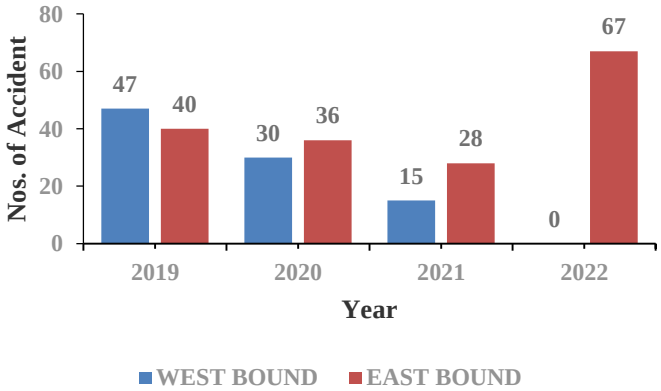

Fig. 1 *Road accident frequency at BKE's motorcycle lane from 2019 to 2022*

Table 7 shows that road users in the motorcycle lane at BKE, both west and eastbound, are involved in accidents. Out of control collisions are the most common, followed by rear collisions. Hitting objects nad hitting animal incidents are less common, suggesting a lower occurrence of accidents due to stationary objects. The data suggests that improving road safety measures in both directions of the motorcycle lane is crucial.

Table 7 *Distribution of type of collision-involved accidents in 2019 to 2022*

Direction	Type of Collision	Year				Total
		2019	2020	2021	2022	
WEST	Hitting Animal	0	1	0	0	1
	Hitting Object	0	0	0	0	0
	Out of Control	24	18	7	0	49
	Rear Collision	13	7	3	0	23
	Side Swipe	10	4	5	0	19
	TOTAL	47	30	15	0	92
EAST	Hitting Animal	2	2	2	1	7
	Hitting Object	1	1	0	5	7
	Out of Control	21	16	18	28	83
	Rear Collision	7	11	3	23	44
	Side Swipe	9	6	5	10	30
	TOTAL	40	36	28	67	171

Fig. 2 shows data from 2019 to 2022 in westbound direction, a BKE accident analysis revealed that out-of-control collisions caused the most serious injuries, while rear collision and side swipe incidents also resulted in fatalities and injuries. However, collisions involving hitting animals and objects caused minimal harm, highlighting the need for targeted safety measures.

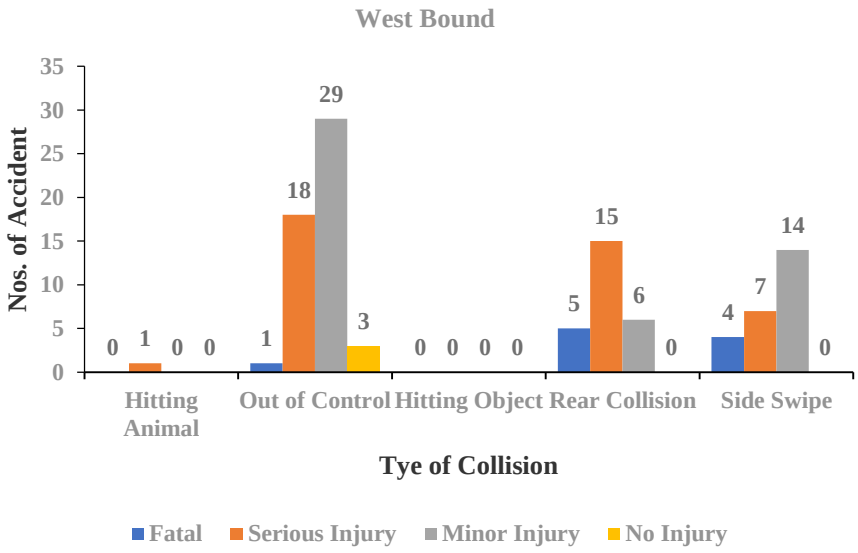

Fig. 2 *Graph type of collision against accident severity in westbound*

From 2019 to 2022, the severity of eastbound road accidents showed distinct trends as presented in Fig. 3. Out of control incidents led to the highest fatalities and injuries, while rear collisions and side swipes contributed less. Hitting animals and hitting object collisions resulted in lower fatalities but still caused injuries. The study emphasizes the need for targeted safety measures to address high-severity collisions and minimize risks, ultimately improving road safety in the eastbound direction.

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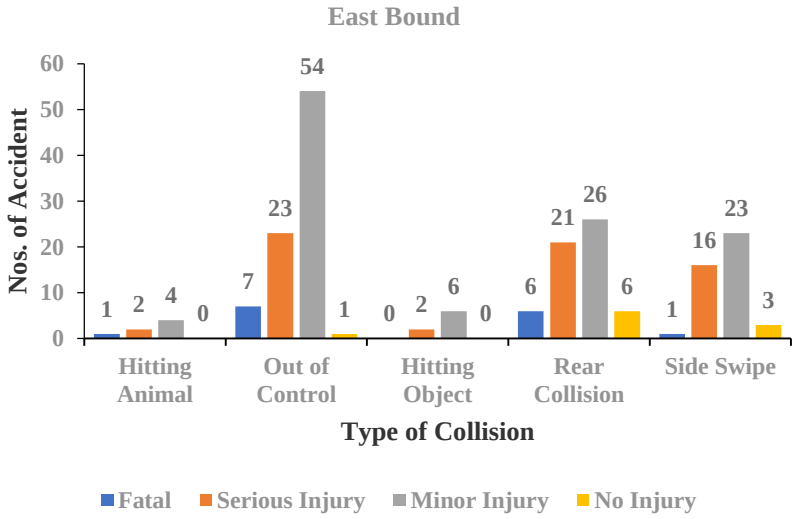

Fig. 3 *Graph type of collision against accident severity in westbound*

Table 8 shows accident severity in west and east directions, with out of control incidents, rear collisions, and side sweeps being more common in the West. In contrast, hitting animals and hitting object incidents were less common. The East reported higher numbers of out of control incidents, rear collisions, and side sweeps, emphasizing the need for targeted safety measures.

Table 8 *The type of collision occurs according to the severity of the accident*

Direction	Type of Collision	Type of Severity				Total
		Fatal	Serious Injury	Minor Injury	No Injury	
WEST	Hitting Animal	0	1	0	0	1
	Out of Control	1	18	29	3	51
	Hitting Object	0	0	0	0	0
	Rear Collision	5	15	6	0	26
	Side Swipe	4	7	14	0	25
	TOTAL	10	41	49	3	103
EAST	Hitting Animal	1	2	4	0	7
	Out of Control	7	23	54	1	85
	Hitting Object	0	2	6	0	8
	Rear Collision	6	21	26	6	59
	Side Swipe	1	16	23	3	43
	TOTAL	15	64	113	10	202

4.2 Assessing risk levels

Tables 4.3 and 4.4 provide a comprehensive risk classification for westbound and eastbound directions, focusing on location and collision types. They prioritize risks by severity and type, aiding in identifying high-risk areas and collision types. The tables summarize identified hazards and their associated risk levels for each location and collision type.

i. West Bound

Table 9 categorizes risks in the westbound direction based on location and collision type. The data set provides risk assessment data categorized into "LOW" risk levels (Risk 1-4) based on specific locations and collision types. The data shows that side swipe collisions were assessed as a risk level of 4, while out of control or side swipe collisions were assigned a risk level of 4, indicating a low-risk classification for these specific collision types and locations along the designated route. The data set provides a comprehensive overview of potential collision hazards along the designated route.

The data categorizes risks as "MEDIUM" (5-12) based on specific locations and collision types. Medium-risk incidents are documented across various kilometers ranges, such as out of control, rear collision, and side swipe. Other collision types are rated as medium risk, such as out of control, rear collision, side swipe, and hitting animal. These findings highlight specific collision types and locations with medium-risk

classifications along the designated route. The risk assessment data for the westbound direction of the motorcycle lane shows no identified high-risk category "HIGH" (Risk 15-25) accidents or significant hazards within the kilometer range of KM6.0 - KM21.0, indicating no high-risk incidents.

Table 9 *Classification level of risk priority based on location and type of collision in westbound*

WEST BOUND			
Risk Description	**Location (Km)**	**Type of Collision**	**Risk Level Obtained**
1 – 4 (LOW)	9.0 – 10.0	Side Swipe	4
	10.0 – 11.0	Out of Control	4
	12.0 – 13.0	Side Swipe	4
	17. 0 - 18.0	Side Swipe	4
	18.0 – 19.0	Out of Control	4
5 – 12 (MEDIUM)	6.0 – 7.0	Out of Control	6
		Rear Collision	6
		Side Swipe	6
	7.0 – 8.0	Out of Control	6
		Side Swipe	6
	8.0 – 9.0	Out of Control	6
		Rear Collision	8
		Side Swipe	8
	9.0 – 10.0	Out of Control	6
	10.0 – 11.0	Rear Collision	8
		Side Swipe	8
	11.0 – 12.0	Out of Control	6
		Rear Collision	8
	12.0 – 13.0	Out of Control	6
		Rear Collision	8
	13.0 – 14.0	Out of Control	6
		Rear Collision	6
	14.0 – 15.0	Out of Control	6
	15.0 – 16.0	Out of Control	8
		Rear Collision	6
		Side Swipe	8
	16.0 – 17.0	Out of Control	6
		Side Swipe	6
	17.0 – 18.0	Hitting Animal	6
		Out of Control	6
	18.0 – 19.0	Rear Collision	6
	20.0 – 21.0	Rear Collision	6
15 – 25 (HIGH)	-	-	0

ii. East Bound

Table 4.4 categorizes risk priority levels in the eastbound direction based on location and collision types. The motorcycle lane segment's risk assessment data shows "LOW" risk incidents (Risk 1-4) based on specific locations and collision types. Collisions like side swipe, hitting object, hitting animal, out of control, and rear collision have a low-risk classification of 4. These locations and collision types in the motorcycle lane have a lower potential for severe accidents or safety hazards. The risk assessment data categorized "MEDIUM" (Risk 5-12) and identified specific locations and collision types. It highlighted incidents involving out of control, rear collision, side swipe, and incidents involving hitting animal or hitting object.

Several locations spanning KM14.0 - KM21.0 had higher risk levels, particularly involving out of control and rear collision, with risk levels ranging from 8 to 12. The risk evaluation for the motorcycle lane's westbound direction does not reveal any recorded incidents or significant hazards falling within the "HIGH" risk category (Risk 15-25) between Km 6.0 and Km 21.0 in the eastbound lane. This indicates the absence of any high-risk occurrences or notable hazards within this kilometer range.

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Table 10 *Classification level of risk priority based on location and type of collision in eastbound*

EAST BOUND			
Risk Description	**Location (Km)**	**Type of Collision**	**Risk Level Obtained**
1 – 4 (LOW)	7.0 – 8.0	Side Swipe	4
		Hitting Object	4
	8.0 – 9.0	Hitting Animal	4
	11. 0 -12.0	Out of Control	4
		Hitting Object	4
		Hitting Animal	4
		Side Swipe	4
	12.0 – 13.0	Out of Control	4
	13.0 – 14.0	Rear Collision	4
	15.0 – 16.0	Side Swipe	4
		Hitting Animal	4
	18.0 – 19.0	Rear Collision	4
	20.0 – 21.0	Hitting Object	4
5 – 12 (MEDIUM)	6.0 – 7.0	Out of Control	9
		Rear Collision	9
		Side Swipe	9
	7.0 – 8.0	Out of Control	6
		Rear Collision	8
	8.0 – 9.0	Out of Control	6
		Rear Collision	6
		Side Swipe	6
	9.0 – 10.0	Out of Control	8
		Rear Collision	6
	10.0 – 11.0	Out of Control	6
		Rear Collision	6
		Side Swipe	6
	11.0 – 12.0	Rear Collision	8
	12.0 – 13.0	Rear Collision	8
		Side Swipe	6
		Hitting Animal	6
		Hitting Object	6
	14.0 – 15.0	Out of Control	12
		Rear Collision	8
		Side Swipe	8
		Hitting Object	6
	15.0 – 16.0	Out of Control	8
		Rear Collision	6
	16.0 – 17.0	Out of Control	8
		Rear Collision	6
		Side Swipe	6
	17.0 – 18.0	Hitting Animal	8
		Out of Control	9
		Rear Collision	6
		Side Swipe	6
	18.0 – 19.0	Out of Control	12
	20.0 – 21.0	Out of Control	12
		Side Swipe	6
15 – 25 (HIGH)	-	-	0

5. Discussion

The study on the BKE's motorcycle lane used the HIRARC method to identify critical risk areas and collision types, providing a detailed risk profile for prioritizing safety measures. The HIRARC analysis identified varied risk levels in both westbound and eastbound directions along the road. Recommendations include interventions in low and medium-risk segments, addressing issues such as lane width, lighting, and road surface conditions. Surprisingly,

high-risk segments reported no incidents. Both directions emphasize targeted improvements in specific location ranges, focusing on infrastructure, visibility, and collision types. Allocating resources effectively for sustained road safety enhancements is crucial. Critical measures like infrastructure enhancements, improved lighting, pavement maintenance, and addressing road furniture deficiencies are imperative for creating a safer environment for motorcyclists on the BKE motorcycle lane.

The study provides a holistic understanding of the motorcycle lane's safety landscape on the BKE. It emphasizes the need for interventions such as infrastructure improvements, awareness initiatives, and targeted measures to mitigate risks identified through systematic analysis. The findings provide a comprehensive understanding of the motorcycle lane's safety landscape, emphasizing the need for interventions like infrastructure improvements, awareness initiatives, and targeted measures to mitigate risks. The propose of safety control measures aim to create a safer environment within the motorcycle lane, providing a foundation for implementing strategic interventions to improve road safety and enhance the riding experience for motorcyclists.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Mat Saad and Ab Ghani;* ***data collection:*** *Mat Saad;* ***analysis and interpretation of results:*** *Mat Saad and Ab Ghani;* ***draft manuscript preparation:*** *Mat Saad and Ab Ghani. All authors reviewed the results and approved the final version of the manuscript.*

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