IDENTIFICATION OF HIGH-RISK DRIVING BEHAVIORS USING THE HIRARC METHOD: A CASE STUDY ON BY PASS IR. SOEKARNO ROAD, TABANAN

Stefanus Sylvan Ryanto*, A.A. Bagus Oka Krisna Surya, Ni Ketut Nova Ariani
Road Transport Management, Politeknik Transportasi Darat Bali, Jl. Cempaka Putih, Sam-sam, Kerambitan, Tabanan, Bali 82111, Indonesia
*sylvan@poltradabali.ac.id

ABSTRACT

Traffic accidents on Bypass Ir. Soekarno Tabanan, pose a significant risk due to its role as a major transportation corridor connecting Java and Bali. This study aims to assess hazardous driving behaviors and propose effective mitigation strategies using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method. The research follows three stages: hazard identification, risk assessment, and risk control. A total of 14 hazardous driving behaviors were identified and classified into high-risk (4 behaviors), medium-risk (8 behaviors), and low-risk (2 behaviors). The most critical factors contributing to severe accidents include distracted driving (risk score: 25), drowsy driving (16), unsafe overtaking (16), and dangerous maneuvering (15), which exhibit high occurrence rates and significant accident severity. Medium-risk behaviors, such as tailgating (12) and brake checking (9), present moderate risks, whereas low-risk behaviors, including blocking other drivers (4) and swerving (1), have minimal consequences but require monitoring. The study suggests a comprehensive risk mitigation approach integrating technology, enforcement, and education. Recommended measures include driver monitoring systems, speed cameras, and real-time enforcement to deter risky driving behaviors. Additionally, public awareness campaigns and stricter law enforcement policies are essential for promoting safer driving practices. These findings provide valuable insights for policy development, urban traffic planning, and road safety improvements, contributing to evidence-based decision-making in accident-prone transportation networks.

Keywords: accident mitigation; driving behavior; HIRARC method; risk assessment; road safety

INTRODUCTION

Traffic safety has become a critical issue in Indonesia, particularly in regions that serve as primary transportation corridors connecting major islands. Among these, Tabanan Regency holds strategic importance as it lies at the heart of Bali and functions as a key transit hub for vehicles traveling between Java and Bali. Due to this geographical significance, the area experiences high traffic volumes, accommodating not only local commuters but also logistics vehicles and tourists who contribute to the dynamic mobility within the region. The road network in Tabanan spans approximately 1,059.38 km, with 65.38 km classified as national roads, 13.78 km as provincial roads, and the remaining 863.22 km under the jurisdiction of the regency government (Badan Pusat Statistik, 2023). This extensive road infrastructure plays a crucial role in supporting the mobility needs of the region; however, it has also led to significant challenges in traffic management and safety.

One of the most vital road segments in Tabanan Regency is By Pass Ir. Soekarno Road, which serves as a national arterial road facilitating the movement of goods, people, and services. This road not only connects various regions within Bali but also acts as a major route for vehicles coming from and going to Java. Due to its function as a primary corridor, it experiences a high density of mixed vehicle types, including motorcycles, private cars, public transport, and heavy-duty trucks. Moreover, this road segment is located within a commercial and administrative area, further increasing traffic congestion and the likelihood of traffic conflicts. As a result, By Pass Ir. Soekarno Road has been identified as one of the high-risk accident locations in Tabanan, with a high frequency and severity of traffic crashes.

Recent statistical reports indicate a worrying trend in traffic accidents in Tabanan Regency. According to data from the Tabanan Traffic Police Unit, the number of road traffic accidents has been rising significantly. By mid-2023, a total of 523 accidents had been recorded, out of which 38 incidents resulted in fatalities, two cases involved serious injuries, while the remaining 483 cases caused minor injuries (Simabur, 2023). By early December 2023, the number of traffic accidents had reached 827 cases, with 68 people losing their lives. By the end of the year, the total number of recorded accidents stood at 850 cases, resulting in material losses amounting to IDR 833.85 million (Ismayana, 2023). These alarming statistics underscore the pressing need for a more comprehensive traffic safety assessment to mitigate accident risks and enhance road safety measures in the region.

The nature of traffic accidents occurring in Tabanan, particularly along By Pass Ir. Soekarno Road, reveals a pattern in which motorcycles are disproportionately involved in crashes. The dominance of motorcycles in accident statistics reflects behavioral tendencies among riders, which are influenced by various factors, including driving habits, attitudes toward safety, and awareness of traffic regulations. Many motorcyclists fail to comply with essential safety measures such as wearing helmets and following traffic signals. Additionally, risky driving behaviors, including exceeding speed limits, making abrupt lane changes without signaling, and disregarding pedestrian crossings, are frequently observed. These behaviors not only increase the likelihood of crashes but also elevate the severity of accidents when they occur. Moreover, external factors such as adverse weather conditions, road surface irregularities, and inadequate traffic management further exacerbate safety concerns. These risk factors collectively highlight the urgent need for systematic hazard identification and risk assessment to develop more effective accident prevention strategies.

Several studies have examined risk factors associated with traffic accidents, emphasizing the role of infrastructure conditions, driver behavior, and law enforcement policies in shaping road safety outcomes. Previous research by Wicaksono et al. (2014) and Marwoto et al. (2013) has provided valuable insights into general traffic accident trends in Indonesia, highlighting key determinants such as vehicle types, road geometry, and traffic control measures. However, despite these contributions, there remains a gap in studies that specifically analyze high-risk driving behaviors using structured risk assessment methodologies. This research aims to address this gap by employing the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method, which has been extensively applied in occupational safety management but remains underutilized in traffic risk analysis (Pembuaian et al., 2024). The application of HIRARC in this study seeks to provide a systematic and data-driven approach to identifying hazards, evaluating associated risks, and formulating risk mitigation strategies tailored to local traffic conditions.

The HIRARC framework consists of three fundamental stages: hazard identification, risk assessment, and risk control. The first stage, hazard identification, involves recognizing potential hazards that could lead to traffic accidents, including both human and environmental factors. The second stage, risk assessment, evaluates the probability and severity of identified hazards to determine their impact on overall road safety. The final stage, risk control, focuses on implementing effective countermeasures to eliminate or minimize risks through a combination of engineering solutions, educational programs, and enforcement mechanisms. This structured approach enables a comprehensive analysis of accident risks and facilitates the development of targeted interventions that align with international best practices in traffic safety management.

Understanding traffic accident risks requires a multidimensional approach that considers both behavioral and infrastructural factors. In the context of Tabanan Regency, the identification of hazardous driving behaviors serves as a crucial step in improving road safety. The presence of aggressive driving patterns, such as excessive speeding, failure to yield, and reckless overtaking, has been consistently associated with an increased likelihood of severe accidents. Research conducted by Wicaksono et al. (2014) emphasizes the need for enhanced enforcement of traffic regulations, as weak law enforcement often leads to higher rates of traffic violations. Moreover, Pembuain et al. (2024) highlight the significance of proactive road safety audits and risk assessments in reducing crash rates and improving traffic management policies. The integration of such measures into local traffic safety frameworks can lead to more sustainable improvements in road safety outcomes.

This study aims to achieve three key objectives. First, it seeks to assess the existing road conditions and traffic characteristics of Bypass Ir. Soekarno Road, providing an empirical basis for understanding accident risks. Second, it aims to identify hazardous driving behaviors that contribute to traffic accidents, particularly those involving motorcycles. Finally, it intends to conduct a risk assessment of these behaviors and propose effective countermeasures to mitigate accident risks. By systematically analyzing traffic accident risks using the HIRARC framework, this research aspires to contribute to data-driven policymaking in road safety, supporting the development of evidence-based strategies for accident prevention.

The significance of this study extends beyond academic contributions, as it provides practical insights for policymakers, traffic authorities, and urban planners seeking to enhance road safety. The findings are expected to inform the design and implementation of targeted interventions, including stricter law enforcement, educational campaigns to raise public awareness, and technological innovations such as driver monitoring systems and automated speed enforcement. These measures, when combined with improved infrastructure planning, can help create a safer and more efficient transportation environment in Tabanan Regency.

In summary, the increasing trend of traffic accidents in Tabanan, particularly along Bypass Ir. Soekarno Road, necessitates a comprehensive safety assessment to identify and mitigate accident risks. This study leverages the HIRARC method to systematically analyze hazardous driving behaviors, assess risk levels, and propose countermeasures. By integrating insights from previous research and aligning with global traffic safety standards, the findings of this study are expected to contribute significantly to ongoing efforts in improving road safety in Indonesia. Future research directions may focus on expanding the scope of risk assessment methodologies, incorporating real-time traffic monitoring systems, and evaluating the long-term effectiveness of implemented safety interventions.

METHOD

This study employs a quantitative descriptive research approach, aiming to systematically describe the hazards and risks identified along By Pass Ir. Soekarno Road in Tabanan. The research framework serves as a guiding structure for implementing all study activities, ensuring that the research objectives are systematically achieved. The study was conducted from April 2024 to December 2024 at Bypass Ir. Soekarno Road, Tabanan Regency. This road segment was selected due to its high frequency of traffic accidents and its significance as a major transportation corridor linking Java and Bali. Data collection is a critical component of this research to ensure the acquisition of high-quality, reliable information. This study relies on two primary types of data: primary data and secondary data. Primary data include driving behavior observations, road inventory data, road safety inspections, instant speed measurements, and

traffic condition assessments. This data were gathered through on-site surveys and direct field observations. Secondary data consist of accident reports and road network information obtained from law enforcement agencies, particularly the Tabanan Traffic Police Unit.

The research employs the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method to analyze the collected data. The HIRARC framework consists of three sequential stages: hazard identification, risk assessment, and risk control. The hazard identification phase involves analyzing factors that contribute to potential road hazards, focusing on human behavior, vehicle conditions, and environmental influences. Specifically, this study assesses hazardous behaviors among motorcycle riders, identifying potential dangers based on likelihood and severity levels. The risk assessment stage consists of two key steps: risk evaluation and risk rating classification. Risk evaluation is conducted based on an extensive literature review and direct observational data. This framework is consistent with the guidelines provided by the Department of Occupational Safety and Health (DOSH), Malaysia, which emphasizes a structured approach to identifying workplace hazards and systematically controlling associated risks (DOSH, 2008).

Hazardous driving behaviors are classified according to their characteristics and prevalence in the study location. The study identifies 14 hazardous driving behaviors. The types of driving behavior observed as hazard identification in this study can be defined as follows: Sudden Lane Changes Without Signaling (Martinez, 1997), Intimidating Other Drivers (Ellison, 2017), Swerving (Ellison, 2017), Brake Checking (Wu et al. 2022), Blocking Other Drivers (Parker, 2001), Flashing Lights Excessively (Martinez, 1997), Tailgating (Eby, 1998), Dangerous Maneuvering (Mekonnen, Tesfaye, Moges, & Gashaw, 2017), Unsafe Vehicle Condition (Mannering, 2014), Driving While Using Earphones or Headphones (Harbluk, 2007), Unsafe Overtaking (Clarke, 1998), Speeding (Fuller, 2005), Overtaking Vehicles in Unsafe Places (Shinar, 1998), and Disregarding Traffic Signs and Road Markings (Nezamoddini & Eluru, 2017). Each behavior is assigned a risk rating based on observed patterns and traffic conditions.

The likelihood assessment is based on empirical data, historical accident trends, and observed driving behaviors. Likelihood classification follows the ISO 31000 risk management guidelines, which define likelihood levels based on proportional data distribution. According to ISO 31000: Risk Management, likelihood categorization is structured as follows:

Table 1.
Likelihood Classification

Likelihood	Relative Frequency	Rating
Inconceivable	<1% of total data	1
Remote	1-5% of total data	2
Conceivable	5-10% of total data	3
Possible	10-25% of total data	4
Most Likely	>25% of total data	5

This classification ensures an objective evaluation of accident probability. Several studies, including those by Covello & Merkhofer (1993), emphasize the use of frequency-based risk assessment in traffic safety research. This study calculates relative frequency by dividing the number of occurrences of a specific hazardous behavior by the total number of recorded incidents, providing a quantified likelihood percentage. The relative frequency is determined using the following formula:

Relative Frequency = (Number of Accidents Based on Driving Behavior) / (Total Accidents) × 100

Severity assessment is conducted by evaluating the crash severity index, based on historical accident records and the types of injuries sustained. The severity index is computed using the *Pedoman Penanganan Lokasi Rawan Kecelakaan Lalu Lintas* (2004), assigning a weighted score for fatalities, serious injuries, and minor injuries. This approach aligns with ISO 31010:2019, which advocates for the application of quantitative severity scales in risk assessment. The severity score calculation follows the equation:

Severity Total = (N Fatalities × 12) + (N Serious Injuries × 3) + (N Minor Injuries × 3)

where N represents the number of cases for each injury category. Based on computed severity scores, accident risks are classified into five categories:

Table 2.
Severity Classification

Likelihood	Severity Index	Rating
Negligible	Index < 10 (minimal impact, minor material loss)	1
Minor	10 ≤ Index < 30 (low impact with minor injuries or damages)	2
Serious	30 ≤ Index < 70 (moderate impact with significant injuries)	3
Fatal	70 ≤ Index < 150 (severe impact with fatalities or multiple serious injuries)	4
Catastrophic	Index ≥ 150 (extreme impact with multiple fatalities)	5

These categories provide an empirical basis for assessing accident impact and prioritizing risk mitigation measures. The final stage, risk control, involves determining appropriate intervention strategies to mitigate identified risks. Control measures are prioritized based on risk severity and frequency, aligning with global traffic safety best practices. Risk mitigation strategies include technological interventions such as speed monitoring systems, educational programs like driver awareness campaigns, and stricter law enforcement measures including enhanced penalties for traffic violations. By systematically analyzing accident risks using the HIRARC framework, this study contributes to evidence-based policymaking in traffic safety. The findings serve as a foundation for developing targeted interventions to enhance road safety along By Pass Ir. Soekarno Road and similar high-risk corridors in Indonesia. The final risk evaluation stage involves using a risk matrix to determine overall risk levels, incorporating both likelihood and severity assessments. The risk matrix allows for a systematic visualization of accident risks and their corresponding levels of concern.

Table 3.
Risk Matrix

	Saverity				
Likehood	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

The integration of the risk matrix provides a comprehensive framework for assessing and managing road accident risks effectively. The structured methodology in this study ensures that findings contribute to traffic safety improvements and inform targeted policy interventions.

RESULT AND DISCUSSION

Hazard Identification

The first step in identifying the danger of accidents is the analysis of the types of driving behavior that cause accidents based on the chronological data of accidents found on the Ir Soekarno bypass road section. Risk identification is carried out by analyzing traffic accident data in 2023 on the following types of driving behavior:

Table 4.
Data on Types of Dangerous Driving Behavior

No.	Type of Driving Behavior	Number of Incidents	Death	Serious Injury	Minor Injury
1	Distracted Driving	81	12	1	89
2	Unsafe Overtaking	28	2	0	35
3	Drowsy Driving	24	0	0	29
4	Dangerous Maneuvering	18	8	2	19
5	Tailgating	12	3	1	13
6	Brake Checking	11	0	0	13
7	Sudden Lane Changes Without Signaling	8	3	0	6
8	Speeding	8	1	0	10
9	Intimidating Other Drivers	7	2	0	6
10	Blocking Other Drivers	6	0	0	5
11	Overtaking Vehicles in Unsafe Places	6	1	0	7
12	Unsafe Vehicle Condition	5	1	0	6
13	Disregarding Traffic Signs and Road Markings	5	2	0	10
14	Swerving	2	0	0	2
	TOTAL	221	35	4	250

Risk Assessment

Based on the accident data in 2023 on the Ir Soekarno road section, a population data of 223 accidents was obtained. The relative frequency of driving behavior on the Ir Soekarno road section based on accident data from Tabanan Police can be used as a likelihood classification as follows:

Table 5.
Likehood Score

No.	Type of Driving Behavior	Number of Incidents	Relative Frequency	Likehood
1	Distracted Driving	81	37%	5
2	Unsafe Overtaking	28	13%	4
3	Drowsy Driving	24	11%	4
4	Dangerous Maneuvering	18	8%	3
5	Tailgating	12	5%	3
6	Brake Checking	11	5%	3
7	Sudden Lane Changes Without Signaling	8	4%	2
8	Speeding	8	4%	2
9	Intimidating Other Drivers	7	3%	2
10	Blocking Other Drivers	6	3%	2
11	Overtaking Vehicles in Unsafe Places	6	3%	2
12	Unsafe Vehicle Condition	5	2%	2
13	Disregarding Traffic Signs and Road Markings	5	2%	2
14	Swerving	2	1%	1

The severity values for each dangerous driving behavior are shown in table 6.

Table 6.
Severity Score

No	Type of Driving Behavior	Death (D)	Serious Injury (S)	Minor Injury (M)	D Score (Dx12)	S Score (Sx3)	M Score (Mx3)	Total Score	Severity
1	Distracted Driving	12	1	89	144	3	267	414	5
2	Dangerous Maneuvering	8	2	19	96	6	57	159	5
3	Unsafe Overtaking	2	0	35	24	0	105	129	4
4	Drowsy Driving	0	0	29	0	0	87	87	4
5	Tailgating	3	1	13	36	3	39	78	4
6	Sudden Lane Changes Without Signalling	3	0	6	36	0	18	54	3
7	Disregarding Traffic Signs and Road Markings	2	0	10	24	0	30	54	3
8	Speeding	1	0	10	12	0	30	42	3
9	Intimidating Other Drivers	2	0	6	24	0	18	42	3
10	Brake Checking	0	0	13	0	0	39	39	3
11	Overtaking Vehicles in Unsafe Places	1	0	7	12	0	21	33	3
12	Unsafe Vehicle Condition	1	0	6	12	0	18	30	3
13	Blocking Other Drivers	0	0	5	0	0	15	15	2
14	Swerving	0	0	2	0	0	6	6	1

Based on the results of the assessment of the probability of an accident and the severity of the accident caused by dangerous driving behavior, the results of the risk assessment are obtained by comparing the probability value and the severity value of the accident of each type of dangerous driving behavior. The risk value based on the calculation with the risk matrix can be seen in table 7.

Table 7.
Risk Matrix

No.	Type of Driving Behavior	Likehood	Severity	Risk	Risk Category
1	Distracted Driving	5	5	25	High
2	Drowsy Driving	4	4	16	High
3	Unsafe Overtaking	4	4	16	High
4	Dangerous Maneuvering	3	5	15	High
5	Tailgating	3	4	12	Medium
6	Brake Checking	3	3	9	Medium
7	Intimidating Other Drivers	2	3	6	Medium
8	Speeding	2	3	6	Medium
9	Unsafe Vehicle Condition	2	3	6	Medium
10	Disregarding Traffic Signs and Road Markings	2	3	6	Medium
11	Overtaking Vehicles in Unsafe Places	2	3	6	Medium
12	Sudden Lane Changes Without Signaling	2	3	6	Medium
13	Blocking Other Drivers	2	2	4	Low
14	Swerving	1	1	1	Low

The risk matrix analysis of driving behaviors leading to traffic accidents on Bypass Ir. Soekarno Road categorizes hazards into three levels: high, medium, and low risk. This classification provides a structured understanding of how specific driving behaviors contribute to accident occurrences and their severity. Among the high-risk behaviors, four were identified as particularly dangerous due to their high likelihood and severe consequences. Driving behaviors classified as high risk have a risk score of ≥15, indicating both frequent occurrences and serious impacts on road safety.

Distracted driving presents the highest risk (25), as it is both highly prevalent and has severe consequences. This behavior is primarily caused by mobile phone usage, eating or drinking while driving, and general inattentiveness, all of which significantly increase the likelihood of fatal collisions. Drowsy driving and unsafe overtaking each hold a risk score of 16. Drowsy driving is particularly concerning due to its impact on reaction time and vehicle control, making it a critical factor in head-on collisions, especially on long-distance routes such as those connecting Java, Bali, and Nusa Tenggara. Unsafe overtaking, on the other hand, often involves excessive speed and occurs in areas with limited visibility, increasing the risk of frontal crashes. Dangerous maneuvering, with a risk score of 15, is also a notable hazard due to the road's width, which encourages erratic driving patterns that can escalate into severe incidents.

The medium-risk category includes eight driving behaviors with risk scores ranging from 5 to 12. These behaviors, while less critical than high-risk behaviors, still contribute to significant accident occurrences. Tailgating (risk score 12) and brake checking (risk score 9), for instance, increase the likelihood of multi-vehicle collisions, particularly in emergency braking situations. Speeding, with a risk score of 6, is another significant contributor, as higher speeds reduce braking distances and reaction times, thereby increasing accident severity. The likelihood rating (2) and severity score (3) highlight that while these behaviors occur less frequently, they have the potential to result in severe accidents. Other behaviors, such as flashing lights excessively or misleading other drivers, are categorized as intimidation tactics that, although infrequent (likelihood score 2), still pose psychological stress on other road users (severity score 3). Driving with an unsafe vehicle condition, such as worn-out brakes or bald tires, increases accident risk due to mechanical failures. This behavior, with a likelihood score of 2 and severity score of 3, is moderate in occurrence but severe in impact. Low-risk driving behaviors, with risk scores below 5, are less likely to cause severe accidents. These include blocking other drivers (risk score 4) and swerving (risk score 1). While these actions have a minimal impact on overall road safety, they can still disrupt traffic flow and contribute to hazardous conditions if left unchecked. Swerving, despite its low classification, necessitates monitoring as it can create unpredictable movements that affect surrounding drivers.

Risk Control

Effective risk control measures must be implemented based on the assigned risk categories. High-risk behaviors require proactive interventions to mitigate their occurrence and consequences. Strategies such as driver monitoring systems, real-time traffic surveillance, and stricter law enforcement have been shown to be effective in reducing distracted driving and drowsy driving incidents. Additionally, automated speed enforcement systems, adaptive cruise control, and behavioral AI tracking can help manage unsafe overtaking and dangerous maneuvering. Educational campaigns emphasizing the dangers of high-risk behaviors must also be prioritized, aligning with ISO 31010:2019 risk management principles, which emphasize hazard elimination and behavioral modification as key strategies for risk mitigation.

Medium-risk behaviors, while not as critical as high-risk behaviors, still necessitate control measures to prevent escalating into severe accidents. These interventions include administrative controls such as clearer traffic signage, adaptive speed limits, and stricter vehicle inspections. Technologies like adaptive cruise control can aid in maintaining safe following distances, thus reducing tailgating-related collisions. Driver training programs focusing on defensive driving techniques can also be instrumental in curbing medium-risk behaviors. Low-risk behaviors, although not directly life-threatening, require preventive measures to ensure overall road discipline. Public awareness campaigns promoting courteous driving behavior can help mitigate issues such as blocking other drivers or swerving. Additionally, mild administrative sanctions,

such as small fines or warning notices, can deter repeat offenses. Implementing lane departure warning systems can further reduce swerving incidents by assisting drivers in maintaining lane discipline.

In general, this control approach involves technology, regulation and education as the main pillars. An explanation of risk control for each type of driving behavior is as follows:

Table 8.
Risk Control

No.	Type of Driving Behavior	Risk Control
1	Distracted Driving	Law enforcement for cell phone use violations. Educational campaigns on the dangers of distraction. Implementation of distraction detection technology in vehicles.
2	Drowsy Driving	Installation of rest areas on toll roads. Camera or sensor-based drowsiness detection system. Rest schedule and sleep time awareness campaigns.
3	Unsafe Overtaking	Law enforcement against overtaking offenses in restricted areas. Installation of no overtaking signs. Frontal collision risk education.
4	Dangerous Maneuvering	Close surveillance through highway CCTV. Strict sanctions for aggressive drivers. Training on good driving manners.
5	Tailgating	Application of adaptive cruise control technology in vehicles. Education on maintaining a safe distance. Campaign on the dangers of head-on collisions.
6	Brake Checking	Implementation of sudden braking behavior detection technology. Law enforcement for this behavior. Education on the impact on the safety of other road users.
7	Intimidating Other Drivers	Administrative sanctions for road intimidation offenses. Social awareness training in driving. Safe road behavior campaigns.
8	Speeding	Installation of speed cameras. Law enforcement for speed violations. Socialization of the dangers of high speed.
9	Unsafe Vehicle Condition	Periodic inspections by relevant agencies. Implementation of vehicle eligibility requirements before long trips. Fines for unfit vehicles.
10	Disregarding Traffic Signs and Road Markings	Surveillance in areas prone to sign violations. Education on the importance of obeying the rules of the road. Installation of interactive signs that attract more attention.
11	Overtaking Vehicles in Unsafe Places	Enforcement of overtaking restrictions on curves or dangerous areas. Additional signs on narrow roads. Education on the dangers of careless overtaking.
12	Sudden Lane Changes Without Signaling	Campaign on the importance of using vehicle signals. Implementation of light penalties for this offense. Lane departure warning technology.
13	Blocking Other Drivers	Warnings through loudspeakers or officers on the ground. Education on driving etiquette. Enforcement of rules at intersections or busy roads.
14	Swerving	Increased road patrols. Law enforcement for zigzagging violations. Education on the dangers to other road users.

CONCLUSION

This study provides a comprehensive analysis of traffic hazards and risk assessments on By Pass Ir. Soekarno Road, Tabanan, utilizing the HIRARC methodology. The findings highlight critical aspects of road safety, including the existing road conditions, hazardous driving behaviors, and the associated risk levels. The average daily traffic volume reaches 15,000 vehicles, with motorcycles comprising 60% of the total. Additionally, the road accommodates heavy vehicles, including trucks and buses, which contribute to pavement deterioration. Despite adequate road width, high traffic density and substantial load pressures increase the likelihood of accidents. Throughout 2023, a total of 223 accidents were recorded along this road segment, reinforcing the need for targeted road safety interventions.

Hazard identification reveals that 14 types of hazardous driving behaviors significantly contribute to accidents on this road. Among these, Distracted Driving emerges as the most

prevalent cause, accounting for 37% of total accidents. This behavior is primarily linked to mobile phone usage, eating or drinking while driving, and a general lack of road awareness. Additionally, Unsafe Overtaking represents 13% of crashes, particularly occurring in areas with limited visibility, such as curves and inclines, thereby increasing the risk of head-on collisions. Drowsy Driving is responsible for 11% of crashes, predominantly during nighttime or long-distance travel without sufficient rest. Furthermore, Dangerous Maneuvering and Tailgating contribute to multi-vehicle collisions, particularly in high-traffic conditions. The cumulative impact of these behaviors resulted in 35 fatalities and 254 injuries in 2023, emphasizing the role of non-compliant driving behaviors as a primary cause of accidents.

The risk assessment, based on the HIRARC methodology, evaluates each hazardous behavior by considering its Likelihood and Severity. The risk matrix analysis identifies four high-risk behaviors requiring immediate intervention: Distracted Driving (Risk Score: 25), Drowsy Driving (Risk Score: 16), Unsafe Overtaking (Risk Score: 16), and Dangerous Maneuvering (Risk Score: 15). These behaviors pose a severe risk due to their high occurrence rates and significant accident severity levels. Medium-risk behaviors, including Tailgating (Risk Score: 12), Brake Checking (Risk Score: 9), and Speeding (Risk Score: 6), display moderate severity but lower frequency. Lastly, low-risk behaviors, such as Blocking Other Drivers (Risk Score: 4) and Swerving (Risk Score: 1), occur infrequently with minimal consequences but still require monitoring to ensure smooth traffic operations.

Overall, the findings underscore the urgent need for integrated risk mitigation strategies, particularly targeting high-risk behaviors. Technology-driven solutions such as automated driver monitoring systems, speed cameras, and real-time enforcement mechanisms can significantly enhance traffic safety. Moreover, public education campaigns and stricter law enforcement policies should be implemented to raise awareness and reduce reckless driving behaviors. The structured risk assessment approach adopted in this study provides a clear framework for prioritizing safety interventions, offering valuable insights for policymakers, traffic authorities, and urban planners to enhance road safety management on high-risk corridors like ByPass Ir. Soekarno Road.

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