



Situational Awareness as a Human Factor in Near Miss and Crash Incidents Among Student Motorcyclists

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ABSTRACT: The high vulnerability of motorcyclists stems from their direct exposure to continuously changing and unpredictable traffic conditions, while many traffic crashes are preceded by near miss incidents that provide valuable opportunities for proactive safety evaluation. The research assessed the influence of Situational Awareness (SA) on near miss and crash incidents among university student motorcyclists and to evaluate the contributions of the three dimensions through the Situation Awareness Rating Technique (SART): demand, supply, and understanding. This study addressed a gap in the literature by conceptualizing SA as a human factor and examining its relationship with two distinct safety outcomes near miss and crash incidents within the same student motorcyclist population. It also examined the individual contributions of the demand, supply, and understanding dimensions of SART to identify which dimensions were most strongly associated with each safety outcome. A quantitative cross-sectional design was employed, involving 96 students from Universitas Malikussaleh. The participants were recruited through purposive sampling, and data were obtained using a structured questionnaire adapted from the Situation Awareness Rating Technique (SART) and analyzed using simple and multiple linear regression. The results revealed that higher levels of SA were found to have a statistically significant relationship with fewer near miss events ($\beta = -0.614$, $p < 0.001$) and crash incidents ($\beta = -0.370$, $p < 0.001$), explaining 48.7% and 42.3% of the variance, respectively. Furthermore, the Understanding dimension consistently showed the strongest association with both safety outcomes, whereas the Supply dimension was not significantly associated with crash incidents. These findings indicate that improving riders' cognitive ability to recognize, interpret, and anticipate hazardous traffic situations may contribute to reducing near miss incidents and crash risk. The results provide practical implications for motorcycle safety education and hazard perception training among university students.

KEYWORDS: Crash; motorcycle safety; near-miss; situation awareness rating technique (SART); situational awareness

1. Introduction

Motorcyclists face substantial safety risks due to their limited physical protection and continuous interaction with rapidly changing traffic conditions, highlighting the importance of human factors in preventing motorcycle related injuries and crashes [1, 2]. Large scale crash studies have shown that motorcyclists experience a disproportionate burden of traffic related injuries and fatalities compared with occupants of other vehicles, with rider characteristics such as age, riding experience, and behavioral tendencies frequently associated with crash involvement [2–4]. Evidence from South America [5], Southeast Asia [6, 7], and studies applying deep learning and explainable machine learning approaches [3, 8, 9] further indicates that motorcycle crashes result from complex interactions among rider cognition, behavior, and the surrounding traffic environment rather than from vehicle or infrastructure factors alone. Within the Indonesian transportation context, motorcycles are widely used for commuting, education, everyday mobility, riders are frequently exposed to complex and unpredictable traffic conditions [6, 7]. Consequently, improving motorcycle safety requires not only engineering and infrastructure interventions but also greater attention to the cognitive and behavioral factors influencing rider performance and decision-making [7, 10].

From a human factor's perspective, motorcycle safety depends on continuous interaction among the rider, motorcycle, and traffic environment. Riders must simultaneously detect multiple environmental stimuli, allocate limited attentional resources, interpret the movements and intentions of other road users, make rapid decisions, and execute appropriate responses. Unsafe outcomes may therefore result not only from deliberate risky behavior but also from failures in perception, attention, comprehension, anticipation, and decision making [7]. These cognitive processes are particularly important for motorcyclists because the time available to recognize and respond to emerging hazards is often limited.

Traffic crashes are also frequently preceded by near miss events, in which a collision is narrowly avoided through emergency braking, evasive maneuvering, or other last moment corrective actions [11, 12]. Given that near miss events are more commonly observed than actual crashes, they provide valuable information for identifying hazardous conditions and unsafe behavior before more serious outcomes occur [11]. This principle has encouraged the use of near miss and traffic conflict data as surrogate safety indicators, including sensor based detection [12] and statistical, Bayesian, and machine learning approaches for estimating crash risk [13]. Studies involving different driver and rider populations have demonstrated that near-miss characteristics can provide meaningful information about crash mechanisms [14–17]. Importantly, the factors associated with near miss incidents may not be identical to those associated with actual crashes [15, 16]. Therefore, near miss and crash incidents should be examined as distinct safety outcomes rather than assumed to represent the same underlying process.

Among the cognitive human factors relevant to road safety, Situational Awareness (SA) has received increasing attention. Situational awareness (SA) is the ability to recognize important environmental cues, understand their implications, and anticipate potential changes in a situation to guide effective decisions [18]. Endsley's framework conceptualizes SA through three hierarchical levels: Perception (Level 1), involving the detection of relevant environmental information; Comprehension (Level 2), involving the interpretation and integration of that information; and Projection (Level 3), involving anticipation of how the situation may develop [18, 19]. Because these levels are interdependent, inadequate perception

can impair comprehension, while inaccurate comprehension can subsequently reduce the ability to anticipate future hazards [19, 20].

In motorcycle riding, effective SA enables riders to identify hazards, interpret rapidly changing traffic situations, and anticipate potential conflicts before they develop into dangerous events [21, 22]. Conversely, inadequate SA may impair hazard perception, delay corrective responses, and increase the likelihood of unsafe behavior or crash involvement [23–25]. A rider may detect another vehicle but fail to recognize its immediate significance, or may understand the current traffic situation but fail to anticipate how it will develop over the following seconds. Such cognitive deficiencies can contribute to inappropriate maneuvers, delayed braking, unsafe gap acceptance, or failure to anticipate conflicts [18, 19, 21, 23, 24]. SA can therefore be regarded as an important cognitive mechanism linking environmental demands, rider responses, and safety outcomes.

Taylor developed the SART, which has been widely applied to evaluate an individual's level of situational awareness [26]. SART assesses SA through three complementary dimensions: Demand on Attentional Resources (Demand), representing the attentional workload imposed by the environment; Supply of Attentional Resources (Supply), representing the cognitive resources available to process information; and Understanding of the Situation (Understanding), representing the ability to integrate, interpret, and anticipate environmental conditions [26, 27]. Because SART is administered as a subjective post-task assessment rather than an intrusive concurrent measure, it has been applied across transportation and other high risk operational settings without directly disrupting task performance [27, 28]. Recent research has supported the demand supply understanding structure in cognitively demanding human machine tasks [28] and demonstrated that analyzing individual SART dimensions can reveal relationships with operator behavior and performance that may be obscured when SA is represented only by a composite score [29].

Previous studies provide substantial evidence that cognitive and behavioral factors contribute to motorcycle safety. Research involving Indonesian motorcyclists has demonstrated associations between rider characteristics and risky riding behavior [6], while naturalistic observations have highlighted continuous interactions between riders and unpredictable traffic conditions [7]. Similar evidence from Vietnamese motorcyclists has linked risk perception and rider attitudes to unsafe riding behavior [30]. Research among university students in Yogyakarta has also demonstrated substantial motorcycle related safety risks within student populations [31]. More specifically, video-based studies of Indonesian motorcyclists have reported relatively low SA among younger and less experienced riders [32], while simulation-based research involving university riders has shown that SA can be improved through structured training [33]. Eye-tracking studies further indicate that cognitive workload influences gaze behavior and hazard related attention [34–36], while attention related errors have been associated with motorcycle safety risk [25]. Research on motorcycle conspicuity [37, 38] and driver distraction, including mobile-phone use [39], further demonstrates the importance of perceptual and attentional processes in road safety.

At the crash outcome level, studies employing behavioral and economic prediction models [40], safety performance functions [5], machine learning models [3, 8], and explainable artificial intelligence [9] have demonstrated the multifactorial nature of motorcycle crashes. In depth crash investigations have further identified comprehension-related failures, including “looked but failed to see” events, as important contributors to crash occurrence [23]. Such

findings are particularly relevant to SART because they suggest that merely having attentional resources available may not be sufficient; riders must also correctly interpret and understand the traffic situation. Table 1 summarizes representative studies on SA, SART, near-miss incidents, and motorcycle safety, and highlights the methodological and empirical gaps addressed by the present study.

Table 1. Summary of representative previous studies on Situational Awareness, SART, and motorcycle safety outcomes.

Focus/variables	Method/sample	Key finding	Research gap	Ref.
SA, video-based assessment	Indonesian motorcycle riders	SA was relatively low, particularly among younger riders	Did not directly link SA with near-miss and crash outcomes	[32]
SA, driving simulation	University students, Indonesia	SA improved following structured training	Intervention study rather than predictor–outcome analysis	[33]
SA, video-based assessment	Malaysian motorcyclists	Low perception, comprehension, and projection among young riders	Did not examine SART dimensions separately	[22]
SA, SART, eye tracking	Professional forklift operators	Individual SA dimensions showed different relationships with performance	Occupational context rather than motorcyclists	[29]
SART vs. NASA-TLX	Complex human–machine tasks	Demand–Supply–Understanding structure was supported	Not transportation-specific	[28]
Near-miss risk factors	Thai motorcyclists	Identified predictors of near-miss incidents	Did not simultaneously examine crashes	[15]
Near-miss and crash	Long-distance bus drivers, Ghana	Predictors of near-miss and crash outcomes partly differed	No SA/SART dimensional analysis	[16]
Near-miss, self-report	Younger and older motorcyclists	Near-miss patterns differed between rider groups	Did not incorporate SA/SART	[41]
Risky riding behavior	Vietnamese motorcyclists	Risk perception influenced risky riding	Focused on behavior rather than SA	[30]
Motorcycle safety risk	University students, Yogyakarta	Substantial safety risk was identified among student riders	Did not measure SA/SART	[31]
Crash causation	In-depth crash investigation	Comprehension-related failures contributed to crashes	Did not quantitatively model SA and safety outcomes	[23]
SA and three SART dimensions	University motorcyclists, Universitas Malikussaleh (n = 96)	Examines Demand, Supply, and Understanding against both outcomes	Present study	Present study

Despite these advances, three key gaps in the existing literature can still be identified. The first issue concerns motorcycle safety studies have commonly investigated risky riding, distraction, or crash prediction separately from SA, with limited research directly examining SA as a predictor of both near miss and crash incidents within the same rider population [6, 30, 40]. Second, although SART has been used to assess SA, its application has largely involved professional operators or complex human machine systems [28, 29]. Moreover, SA is often analyzed as a composite construct, leaving the individual contributions of Demand, Supply, and Understanding to motorcycle safety outcomes insufficiently understood. Third, university students represent a highly exposed motorcycle riding population in Indonesia [31, 33], yet few studies have simultaneously examined SA in relation to both near miss and crash incidents. This distinction is important because evidence indicates that the determinants of near miss events and actual crashes may differ [15, 16].

Therefore, present study examined the effect of Situational Awareness on near miss and crash incidents among university student motorcyclists at Universitas Malikussaleh.

Specifically, the study examined (1) the effect of overall SA on near miss incidents, (2) the effect of overall SA on crash incidents, and (3) the individual contributions of the SART dimensions Demand, Supply, and Understanding to each safety outcome. By simultaneously examining two safety outcomes and decomposing SA into its constituent dimensions within the same population, this study extends previous research that has predominantly treated SA as a composite measure [32], applied SART to occupational settings [28, 29], or examined near miss and crash outcomes separately [22, 41].

2. Research Methodology

2.1. Research Design.

This study utilized a quantitative cross-sectional design to investigate the association between situational awareness on near miss and crash incidents among student motorcyclist and two motorcycle safety outcomes: near miss and crash incidents among university student riders. The non-experimental design allowed SA and safety experiences to be assessed under actual riding conditions without experimental manipulation, consistent with previous motorcycle safety studies [7, 30, 31, 33]. The analysis considered both the overall SA score and the individual contributions of the three SART dimensions. A simple linear regression model was applied to examine the association between overall SA with near miss and crash incidents, while multiple linear regression evaluated the contribution of each SART dimension [27]. Figure 1 illustrates the associations among the variables examined in this study.

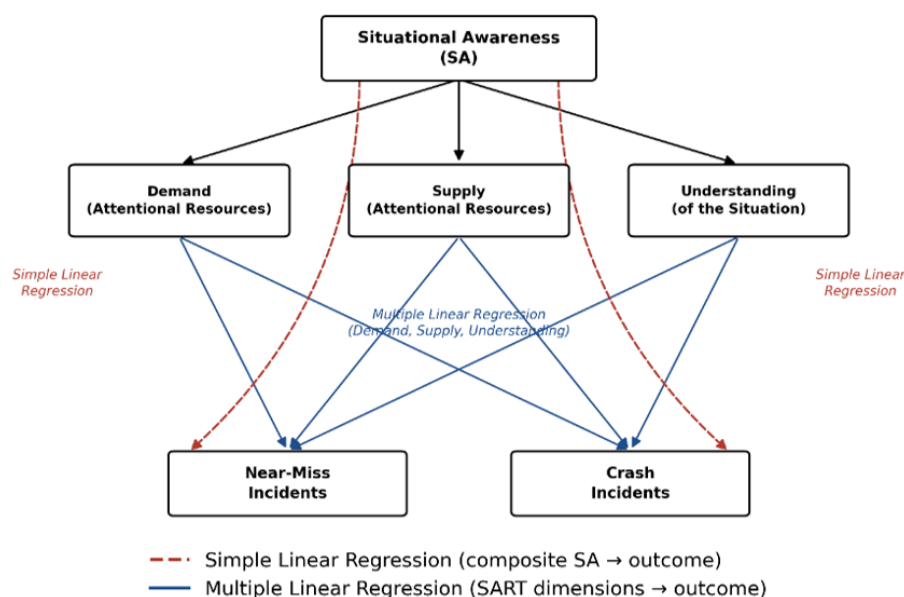


Figure 1. A simple linear regression model was utilized to assess the relationship between Situational Awareness Dimensions and Motorcycle Safety Outcomes.

2.2. Study Site and Data Collection Procedures.

Data collection took place at the Bukit Indah Campus of Universitas Malikussaleh, Indonesia, and along the surrounding commuting route between Bathuphat Barat and Paloh villages. This area represents a typical daily commuting environment for university students, where motorcycles are a major mode of transportation and riders encounter dynamic traffic conditions [31, 33]. Data collection began in February 2026 and continued until the required sample size

was achieved. Participants reported their SA and near miss and crash experiences during the preceding one-month period. This recall period was selected to capture recent safety events while limiting potential recall bias. Eligible participants were active Universitas Malikussaleh students who used motorcycles as their primary mode of transportation, regularly rode within the study area, held a valid Class C driving license (SIM C), and had at least one year of riding experience [41].

2.3. Population, Sample, and Sampling Methods.

The target population consisted of active Universitas Malikussaleh students at Bukit Indah Campus who regularly used motorcycles. As the population size could not be precisely determined, the minimum required sample size was calculated using the Lemeshow formula.

$$n = \frac{Z^2 p(1-p)}{d^2} \quad (1)$$

In the formula, n denotes the minimum required sample size, Z represents the standard normal value at a 95% confidence level (1.96). The calculation resulted in 96 respondents. A purposive sampling technique was employed to identify participants who met the established eligibility requirements [31, 33]. A total of 96 eligible student motorcyclists completed the survey and were included in the statistical analysis.

2.4. Variables and Measurement.

This study examined Situational Awareness (SA) as the independent variable and near miss and crash incidents as the dependent variables. Taylor's situation awareness technique served as the instrument for measuring participants' situational awareness [26]. These dimensions represent the interaction between environmental demands, available attentional resources, and the rider's ability to understand the surrounding traffic situation.

Previous studies have supported the multidimensional structure of SART. The Demand, Supply, and Understanding dimensions have been shown to represent distinct and interpretable constructs [27], capture cognitive information beyond conventional workload measures [28], and demonstrate different relationships with operator behavior and task performance [29, 42]. These findings supported the use of both the individual SART dimensions and the composite SA score in the present study.

The original SART instrument was adapted to motorcycle riding conditions. The items were translated and contextualized to address changing traffic conditions, interactions with other road users, road conditions, attention management, and hazard recognition. The adapted items were reviewed for contextual relevance and pilot tested before full data collection. The final SA instrument contained 10 items, comprising three Demand items, four Supply items, and three Understanding items. Table 2 summarizes the measurement structure.

Table 2. Measurement Structure of the Research Variables.

Variable	Dimension	Indicators	Items	Measurement scale
Situational Awareness (X)	Demand (D)	Instability, complexity, variability	3	Likert scale (1–5)
	Supply (S)	Arousal, concentration, division of attention, spare mental capacity	4	Likert scale (1–5)
	Understanding (U)	Information quantity, information quality, familiarity	3	Likert scale (1–5)
Near-Miss (Y ₁)	–	Near-collision, hard braking, evasive swerving, intersection conflict	4	Frequency scale (1–5)
Crash (Y ₂)	–	Single-vehicle crash, multi-vehicle crash, collision with object	3	Frequency scale (1–5)

The obtained mean score of the corresponding items was calculated for each SART dimension, allowing direct comparison despite differences in the number of items. The overall SA score was calculated using Taylor's original SART equation [26]:

$$SA = U - (D - S) \quad (2)$$

where *U* represents Understanding, *D* represents Demand, and *S* represents Supply. A higher SA score indicates greater perceived Situational Awareness, reflecting stronger understanding and sufficient attentional resources relative to environmental demands.

A near miss was defined as an event in which a rider nearly experienced a collision but successfully avoided it [11, 12]. It was measured using four indicators: near collision, hard braking, evasive swerving, and intersection conflict. A crash was defined as an actual motorcycle accident involving a single vehicle crash, collision with another vehicle, or collision with an object. These indicators were adapted from previous motorcycle safety studies [15, 41]. Both outcomes were measured based on respondents' self-reported frequency of events during the preceding month. Near miss incidents were rated from 1 (Never) to 5 (Very Often), whereas crash incidents were rated from 1 (Never) to 5 (More than Three Times). Higher scores therefore represented more frequent safety related incidents.

2.5. Data Analysis.

Statistical analyses were performed using IBM SPSS Statistics. Pearson's correlation was applied to evaluate validity, with $\alpha \geq 0.70$ regarded as an acceptable reliability threshold [27, 41]. Regression assumptions, including normality, linearity, multicollinearity, and heteroscedasticity, were tested beforehand using the Kolmogorov Smirnov test, Deviation from Linearity test, Tolerance and Variance Inflation Factor (VIF), and Glejser test, respectively. These assumptions were examined separately for the composite SA and dimensional SART models. Multiple linear regression was then applied to determine the individual contributions of Demand, Supply, and Understanding to each safety outcome [27, 29]. Significance criterion was established at $p < 0.05$. The direction and strength of the relationships were evaluated using standardized coefficients (β) and R^2 .

3. Results and Discussion

3.1. Respondent Characteristics.

A total of 96 undergraduate students from Universitas Malikussaleh participated in the study. All respondents were active motorcycle riders who regularly traveled within the Bukit Indah Campus area and along the surrounding routes between Bathuphat Barat and Paloh villages. Table 3 summarizes the participants' demographic and riding characteristics.

Table 3. Participant Characteristics (n = 96).

Characteristic	Category	n	%
Semester	Semester 2	24	25.0
	Semester 4	47	49.0
	Semester 6	18	18.7
	Semester 8	7	7.3
Gender	Male	21	21.9
	Female	75	78.1
Riding experience	1–3 years	20	20.8
	4–6 years	38	39.6
	>6 years	38	39.6
Riding frequency	3–4 times/week	16	16.7
	5–6 times/week	31	32.3
	7–10 times/week	18	18.7
	>10 times/week	31	32.3
Daily riding duration	<30 min	33	34.4
	30–60 min	45	46.9
	61–120 min	9	9.4
	>120 min	9	9.4

As shown in Table 3, almost half of the respondents were fourth semester students (49.0%), followed by second semester (25.0%), sixth-semester (18.7%), and eighth semester students (7.3%). Female students constituted the majority of the sample (78.1%), whereas male students accounted for 21.9%. The respondents generally had substantial motorcycle riding experience. A total of 79.2% had ridden motorcycles for at least four years, including 39.6% with more than six years of experience. Motorcycle use was also frequent, with 83.3% of respondents riding at least five times per week. Regarding daily exposure, 46.9% reported riding for 30–60 minutes per day, while 18.8% rode for more than one hour per day. These characteristics indicate that the participants were predominantly regular and experienced motorcycle users with frequent exposure to everyday traffic conditions. Consequently, the sample was appropriate for examining associations between Situational Awareness (SA), near miss and crash incidents.

3.2. Instrument and Regression Assumption Tests.

Before hypothesis testing, the instruments were tested for validity and reliability. Item validity was examined using Pearson's correlation, with $r > 0.2006$ considered valid for $n = 96$. Reliability was assessed using Cronbach's alpha. The results are presented in Table 4.

Table 4. Instrument Validity and Reliability Results.

Variable	Number of items	Item validity (<i>r</i>)	Cronbach's α	Conclusion
Situational Awareness	10	0.638–0.842	0.916	Valid and reliable
Near-Miss	4	0.741–0.840	0.811	Valid and reliable
Crash	3	0.775–0.832	0.741	Valid and reliable

As presented in Table 4, all item total correlation coefficients exceeded the minimum criterion of 0.2006. The coefficients ranged from 0.638 to 0.842 for SA, 0.741 to 0.840 for Near Miss, and 0.775 to 0.832 for Crash, indicating satisfactory item validity. The three instruments demonstrated acceptable to high internal consistency. These results confirmed that the questionnaire provided sufficiently reliable measurements for subsequent regression analyses.

The assumptions underlying linear regression were subsequently examined using tests for normality, linearity, multicollinearity, and heteroscedasticity. Table 5 shows a Kolmogorov Smirnov *p* value of 0.200, indicating no significant departure from normality. The Deviation from Linearity tests were also non-significant for both Near Miss (*p* = 0.761) and Crash (*p* = 0.895), supporting the assumption of linearity. Tolerance values ranged from 0.242 to 0.264 and remained above the minimum criterion of 0.10, while VIF values ranged from 3.792 to 4.127 and remained below 10. These results indicated no problematic multicollinearity among the predictor variables. Finally, the Glejser test produced *p* values ranging from 0.144 to 0.881, providing no evidence of heteroscedasticity.

Table 5. Regression Assumption Tests.

Assumption test	Criterion	Result	Conclusion
Normality	Kolmogorov–Smirnov ($p > 0.05$)	$p = 0.200$	Residuals normally distributed
Linearity: Near-Miss	Deviation from Linearity ($p > 0.05$)	$p = 0.761$	Linear relationship
Linearity: Crash	Deviation from Linearity ($p > 0.05$)	$p = 0.895$	Linear relationship
Multicollinearity	Tolerance > 0.10	0.242–0.264	No problematic multicollinearity
	VIF < 10	3.792–4.127	
Heteroscedasticity	Glejser test ($p > 0.05$)	$p = 0.144–0.881$	No evidence of heteroscedasticity

Overall, the instruments demonstrated satisfactory validity and internal consistency, and the regression diagnostics indicated that the data met the specified assumptions for linear regression analysis. The dataset was therefore considered suitable for subsequent analyses examining the relationships between SA, its SART dimensions, and near-miss and crash incidents.

Before proceeding to regression analysis, the bivariate relationships among the research variables were examined using Pearson correlation analysis. The correlation matrix, presented in Figure 2 provides a summary of the strength and direction of association among Demand, Supply, Understanding, overall Situational Awareness, Near Miss, and Crash prior to regression modeling.

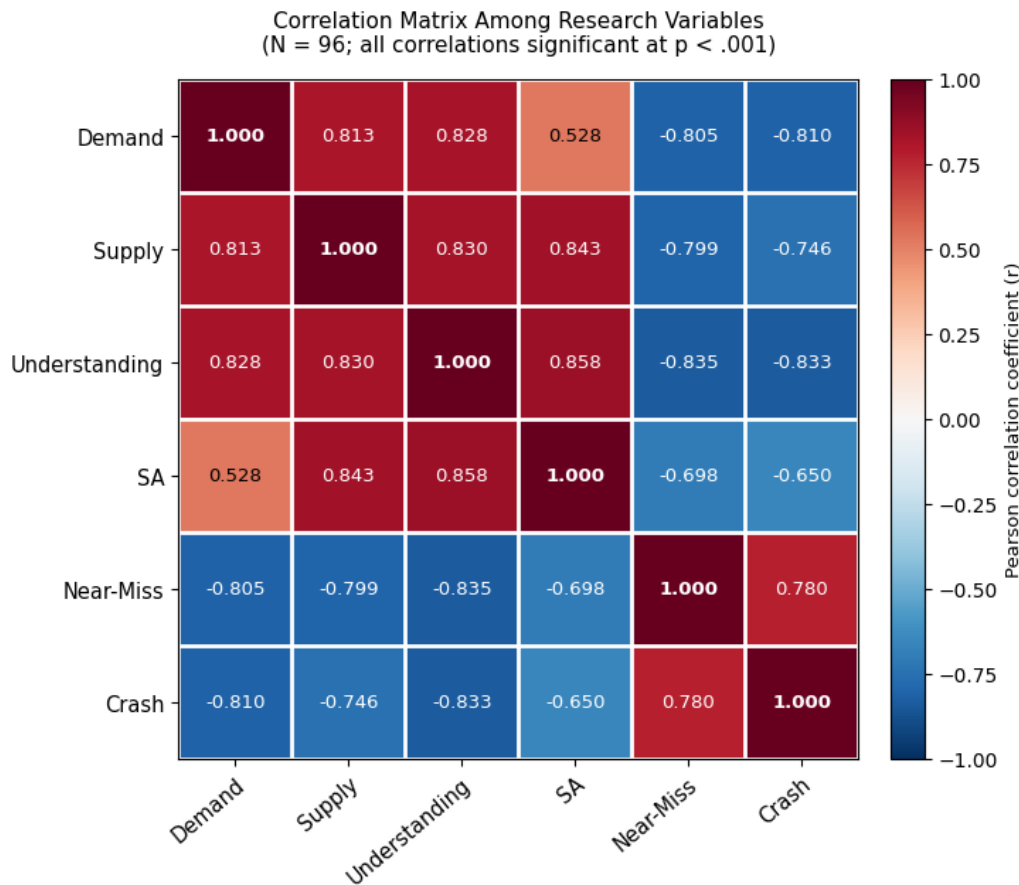


Figure 2. Correlation Matrix.

As shown in Figure 2, all variables were significantly correlated with one another ($p < 0.001$, $n = 96$). The three SART dimensions were strongly and positively intercorrelated ($r = 0.813$ – 0.830), and each dimension showed a positive correlation with the composite Situational Awareness (SA) score, ranging from $r = 0.528$ for Demand to $r = 0.858$ for Understanding. These results indicated that Understanding had the strongest association with the composite SA score among the three dimensions. All three SART dimensions and the composite SA score were negatively correlated with both near miss and crash incidents, consistent with the expected protective role of Situational Awareness. Notably, Understanding exhibited the strongest bivariate association with both near-miss ($r = -0.835$) and crash incidents ($r = -0.833$) among the three dimensions, suggesting its potentially dominant role in the subsequent regression analyses. Near miss and crash incidents were also strongly and positively correlated with each other ($r = 0.780$), indicating that riders who reported more frequent near miss experiences also tended to report more frequent crash involvement. However, the correlation was not sufficiently high to suggest that the two outcomes were interchangeable, supporting their separate modeling in the subsequent analyses.

3.3. Effect of Situational Awareness on Near Miss and Crash.

A simple linear regression model was employed to investigate the association between overall situational awareness (SA) and the two motorcycle safety outcomes, Near-Miss and Crash

incidents. Separate regression models were developed for each outcome. The regression coefficients, model significance, and explanatory power are presented in Table 6.

Table 6. Simple Linear Regression Analysis of the Effect of Situational Awareness on Near Miss and Crash.

Dependent Variable	B	SE	β	t	F	p-value	R ²	Adjusted R ²
Near-Miss	-0.614	0.065	-0.614	-9.441	89.136	<0.001	0.487	0.481
Crash	-0.370	0.045	-0.370	-8.299	68.866	<0.001	0.423	0.417

Note: B=unstandardized regression coefficient, SE=standard error, β =standardized regression coefficient and R²=coefficient of determination.

The resulting regression model for Near Miss incidents reached statistical significance ($F = 89.136$, $p < 0.001$), with SA accounting for 48.7% of the observed variance ($R^2 = 0.487$; adjusted $R^2 = 0.481$). A significant negative relationship was identified between SA and Near miss incidents ($B = -0.614$, $SE = 0.065$, $\beta = -0.698$, $t = -9.441$, $p < 0.001$). The regression equation was:

$$\text{Near-Miss} = 4.674 - 0.614(\text{SA})$$

The negative coefficient indicates that higher SA was associated with fewer Near Miss incidents. The predicted Near Miss score decreased by 0.614 units. Although SA explained a substantial proportion of the variation, 51.3% remained unexplained, suggesting that other individual, environmental, traffic, or behavioural factors may also contribute to Near Miss incidents.

A similar relationship was observed for Crash incidents. The model was statistically significant ($F = 68.866$, $p < 0.001$) and explained 42.3% of the variance in Crash scores ($R^2 = 0.423$; $R^2 = 0.417$). The regression equation was:

$$\text{Crash} = 3.122 - 0.370(\text{SA})$$

Accordingly, for every one unit increase in SA, the predicted Crash score decreased by 0.370 units. Overall, the results indicate a consistent inverse relationship between SA and both safety outcomes. Based on the standardized coefficients, the relationship was somewhat stronger for Near-Miss incidents ($\beta = -0.698$) than for Crash incidents ($\beta = -0.650$). Thus, respondents with higher overall SA tended to report fewer Near Miss and Crash incidents.

3.4. Effects of Demand, Supply, and Understanding on Near Miss and Crash.

The three SART dimensions demand on attentional resources, supply of attentional Resources and understanding of the Situation, were simultaneously examined using multiple linear regression to determine their contributions to Near Miss and Crash incidents. As shown in Table 7, the multiple regression model for Near Miss incidents achieved statistical significance ($F = 92.946$, $p < 0.001$), with the three SART dimensions jointly explaining 75.2% of the variability observed in Near Miss scores ($R^2 = 0.752$, adjusted $R^2 = 0.744$). All three SART dimensions were significantly and negatively associated with Near Miss incidents. Understanding showed the largest standardized coefficient ($\beta = -0.420$, $t = -3.980$, $p < 0.001$), followed by Demand ($\beta = -0.267$, $t = -2.645$, $p = 0.010$) and Supply ($\beta = -0.233$, $t = -2.294$, $p = 0.024$). These results suggest that, after accounting for the other SART dimensions, Understanding had the strongest unique statistical relationship with Near Miss incidents.

Table 7. Multiple Linear Regression Analysis of SART Dimensions on Near-Miss and Crash Incidents.

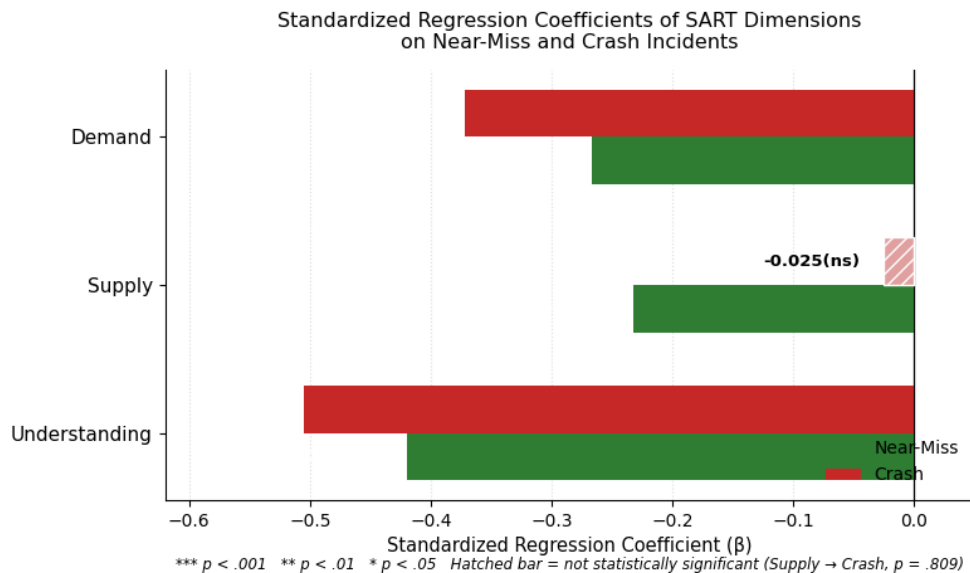
Predictor	Near-Miss β	t	p-value	Crash β	t	p-value
Demand	-0.267	-2.645	0.010	-0.372	-3.592	0.001
Supply	-0.233	-2.294	0.024	-0.025	-0.242	0.809
Understanding	-0.420	-3.980	<0.001	-0.505	-4.673	<0.001
R ²	0.752			0.740		
Adjusted R ²	0.744			0.732		
F-statistic	92.946		<0.001	87.356		<0.001

Note: β = standardized regression coefficient. $p < 0.05$ indicates statistical significance

The statistical analysis confirmed that the model predicting Crash incidents was significant ($F = 87.356$, $p < 0.001$), explaining 74.0% of the variance in Crash scores $R^2 = 0.740$, adjusted $R^2 = 0.732$. Understanding again showed the largest standardized coefficient ($\beta = -0.505$, $t = -4.673$, $p < 0.001$), followed by Demand ($\beta = -0.372$, $t = -3.592$, $p = 0.001$). In contrast, Supply was not significantly associated with Crash incidents after controlling for Demand and Understanding ($\beta = -0.025$, $t = -0.242$, $p = 0.809$).

Taken together, the findings indicate that the three SART dimensions did not contribute equally to the two safety outcomes. Understanding emerged as the strongest statistical predictor in both models, while Demand also showed significant negative associations with both Near Miss and Crash incidents. Supply was significantly associated with Near Miss incidents but not with Crash incidents. This difference suggests that the attentional resources represented by Supply may be more relevant to avoiding potentially hazardous situations before they develop into Near Miss events, whereas its independent contribution to reported Crash incidents was not supported by the present model.

To provide a clearer visual comparison of the relative contributions of the three SART dimensions, the standardized regression coefficients from Table 7 are presented in Figure 3.

**Figure 3.** Coefficient Plot.

Understanding had the largest absolute standardized coefficient for both Near Miss and Crash incidents, followed by Demand. Supply had a smaller coefficient for Near Miss and an almost negligible coefficient for Crash. The non-significant Supply Crash relationship should be visually distinguished from the statistically significant coefficients. Overall, the figure complements Table 7 by showing that Understanding was the most prominent SART

dimension associated with both safety outcomes, whereas the contribution of Supply differed substantially between Near Miss and Crash incidents.

3.5. Discussion.

The findings demonstrated a significant negative association between Situational Awareness (SA) and both near miss and crash incidents among motorcycle riders at Universitas Malikussaleh. Overall SA explained 48.7% of the variation in near miss occurrences and 42.3% of the variation in crash occurrences, indicating that SA was an important factor associated with motorcycle safety outcomes in this sample. Nevertheless, the relatively substantial explanatory power of the models suggests that SA should be considered alongside behavioural, environmental, and traffic related factors when examining motorcycle safety among university students. The present findings support previous evidence suggesting that the occurrence of near-miss events is linked to riders' cognitive readiness and their ability to detect and appropriately respond to potential hazards [11, 14]. Studies of Indonesian riders have similarly reported lower SA among younger and less experienced riders and linked these deficits with riskier riding behaviour [32, 33]. The present study extends these findings by quantifying the statistical relationship between SA and two motorcycle safety outcomes using regression analysis.

At the dimensional level, Demand, Supply, and Understanding jointly explained 75.2% of the variance in near miss incidents and 74.0% of the variance in crash incidents. These values were considerably higher than those obtained using the overall SA score (48.7% and 42.3%, respectively). This difference suggests that examining the SART dimensions separately provided additional information that may have been obscured when SA was represented by a single composite score. However, the higher R^2 values should be interpreted cautiously because multiple predictor models generally explain more variance than single predictor models. The findings nevertheless support Taylor's multidimensional conceptualisation of SA, in which Demand, Supply, and Understanding represent distinct but related components [26, 27]. All three dimensions were significantly associated with near miss incidents, indicating that attentional demand, availability of attentional resources, and understanding of traffic situations were independently related to near miss outcomes after accounting for the other dimensions. This interpretation is supported by previous research showing that allocating attentional resources alone may be inadequate for enabling riders to fully comprehend complex traffic situations and anticipate potential hazards as they develop [21, 24].

Among the three dimensions, Understanding showed the largest absolute standardized regression coefficient for both near miss ($\beta = -0.420$) and crash incidents ($\beta = -0.505$). For crash incidents, higher Understanding scores were associated with lower predicted crash scores, with a one standard deviation increase in Understanding corresponding to an estimated 0.505 standard deviation decrease, after controlling for Demand and Supply. This finding suggests that the ability to interpret the meaning of available traffic information may be particularly important for motorcycle safety. Previous research has similarly highlighted situations in which riders detected or observed hazards but failed to interpret their significance appropriately [23]. Attention related riding errors have also been linked to failures in interpreting traffic situations rather than distraction alone [25]. These findings are broadly consistent with theoretical models of SA that emphasise the importance of progressing beyond the perception of environmental information toward comprehension and anticipation of its

implications [18–20]. However, the present findings should not be interpreted as demonstrating that Understanding *causes* fewer crashes; rather, Understanding showed the strongest independent statistical association among the three SART dimensions examined.

The Supply dimension demonstrated a significant association with near miss incidents ($\beta = -0.233$, $p = 0.024$), whereas no statistically significant relationship was found for crash incidents ($\beta = -0.025$, $p = 0.809$). The near zero coefficient for crash incidents indicates that Supply provided little independent statistical contribution to crash scores after Demand and Understanding were controlled. One possible explanation is that the availability of attentional resources may be more relevant during the earlier stages of hazard detection and avoidance, whereas the interpretation of the situation may become increasingly important as a traffic conflict develops. Previous studies have similarly reported differences between factors associated with near-miss events and those associated with actual crashes [15, 16]. Nevertheless, the present cross sectional data cannot establish that Supply functions specifically as an “early warning” mechanism.

The evidence suggests that motorcycle safety interventions for university students should address not only attentional readiness but also riders' ability to interpret developing traffic situations. Scenario based exercises, video based hazard identification, and hazard prediction training could therefore be considered as components of motorcycle safety education, particularly because similar approaches have been used to improve SA among young riders [33]. Environmental measures, including appropriate signage, visibility improvements, speed management, and identification of locations with frequent near-miss events, could complement rider-focused interventions [12, 14]. However, the present results do not provide sufficient evidence to determine which intervention would be most effective or cost effective. Intervention priorities should therefore be established through further evaluation rather than solely from the relative magnitude of the regression coefficients.

Although the dimensional models explained 75.2% and 74.0% of the variance in near miss and crash scores, respectively, 24.8% and 26.0% remained unexplained. Other factors that were not included in the models may therefore contribute to motorcycle safety outcomes, including risky riding behaviour and traffic violations [6, 30, 31], traffic density and time of day exposure [9, 17], fatigue and mental workload [35, 36], and weather and road surface conditions [5, 40]. A key limitation is the cross-sectional design, which prevents causal conclusions because situational awareness and safety outcomes were measured concurrently. It is therefore not possible to establish whether higher SA reduced unsafe events or whether previous experiences with near-misses or crashes influenced respondents' perceptions of their SA. The use of self reported measures may have resulted in recall bias and social desirability effects, particularly in reporting previous crash involvement [41]. Generalisability may be limited by the single university sample. Future research should use multi site longitudinal designs and objective riding measures to examine SA alongside behavioural and environmental risk factors [7].

4. Conclusions

This study explored the link between situational awareness (SA) and near miss and crash incidents among motorcycle riders at Universitas Malikussaleh. Higher SA was significantly associated with reduced near miss and crash occurrence, indicating an important relationship between riders' cognitive awareness and motorcycle safety. At the dimensional level, demand, supply, and understanding were significantly associated with near miss incidents, whereas only

Demand and Understanding were significantly associated with crash incidents. Among the three SART dimensions, Understanding showed the strongest association with both safety outcomes, highlighting the importance of accurately interpreting traffic conditions and recognising developing hazards. These findings support the relevance of SA in motorcycle safety and suggest that safety interventions should extend beyond compliance with traffic regulations. Training programs could incorporate hazard perception exercises, scenario based learning, and defensive riding education to strengthen riders' ability to recognise, interpret, and anticipate hazardous traffic situations. Future studies should incorporate additional factors, including riding experience, risk taking behaviour, distraction, fatigue, traffic conditions, and environmental factors, and should involve larger and more diverse populations across different geographical settings.

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Author Contributions

Diana Khairani Sofyan: Conceptualization, methodology, supervision, writing, and review. Defi Irwansyah: Methodology, data analysis, supervision, writing, and review. Alfian Mahendra: Research design, methodological development, data gathering, analysis, manuscript writing, and visualization. Anwar: Methodology, writing, review, and supervision.

Competing Interests

The authors affirm that they have no financial, personal, or professional interests that could have influenced the conduct or presentation of this research.

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