Comparative Analysis Between the Star Rating iRAP Method and ULFJ With Star Rating Method

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ABSTRACT

Road traffic accidents remain a major problem within Indonesia's road transport system, resulting in significant social and economic impacts. One of the ways to enhance road safety is undertaken through infrastructure risk assessments using a star rating approach. Currently, these assessments are conducted via two methods: the International Road Assessment Programme (iRAP) Star Rating method, which is an international standard, and the Road Functional Feasibility Assessment (ULFJ) with Star Rating method, developed specifically for Indonesian conditions. This study aims to compare the road safety assessment results of these two methods, as well as to analyse their accuracy through ground truth validation and the sensitivity of infrastructure attributes to changes in risk values. The novelty of this research lies in the ground truth validation and attribute sensitivity testing of each method in assessing road safety risks. The analysis was conducted on the Pekutatan–Antosari national road section in Bali Province, using road segments as the units of analysis. Comparisons were made regarding the Star Rating Score (SRS) and star categories, with accuracy tested against actual accident data representing collective and personal risk. Furthermore, sensitivity testing was performed through attribute change scenarios to identify the factors most influential to road safety risk levels. The results indicate differences in risk values and star categories between the iRAP and ULFJ methods, influenced by variations in attribute structure, Crash Modification Factors (CMF), and approaches to traffic characteristics and road users. While the iRAP method excels in analytical depth and sensitivity to physical road attributes, the ULFJ with Star Rating method demonstrates a higher level of alignment with actual accident data and is more responsive to operational attributes. These findings suggest that the ULFJ with Star Rating method is more representative within the context of national technical standards for assessing road safety risks on the Pekutatan–Antosari section.

Keywords: road safety, Road Functional Feasibility Assessment (ULFJ), star rating, iRAP, crash risk.

INTRODUCTION

Road safety is an essential component of the land transport system as it directly impacts the safety of road users and results in significant social and economic losses [16], [27]. Road traffic accidents do not only cause fatalities and injuries but also impose a significant economic burden due to healthcare costs, infrastructure damage, and lost productivity [1], [4]. Although road safety has become a global concern, Indonesia still faces a relatively high rate of traffic accidents compared to several other developing nations [23], [28].

As an effort to reduce accident rates, the Government of Indonesia established the National Road Safety General Plan (RUNK LLAJ) through the Presidential Regulation of the Republic of Indonesia Number 1 of 2022. One of the primary targets of the RUNK is the improvement of road infrastructure safety, measured by achieving a minimum 3-star rating standard on road sections. In this context, road safety risk assessment has become an essential instrument for identifying the hazard levels of specific road stretches and establishing effective, evidence-based intervention priorities [12], [24].

Road safety assessments in Indonesia are currently conducted using two primary approaches: the International Road Assessment Programme (iRAP) Star Rating method and the Road Function

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Eligibility Test (ULFJ) with Star Rating method. The iRAP method has been implemented internationally, taking into account physical road characteristics and the risks posed to various road user groups, including vulnerable road users [7],[25]. Meanwhile, the ULFJ with Star Rating Method was developed based on national regulations and tailored to the traffic characteristics and road infrastructure conditions in Indonesia [3], [18].

Despite both methods sharing the same objective, differences in assessment attributes, Crash Modification Factors (CMFs), and road user approaches potentially lead to differing risk assessment outcomes [4], [11]. Furthermore, there is currently a lack of comprehensive studies comparing the accuracy of these two methods against actual accident data (ground truth) or testing the sensitivity of infrastructure attributes to changes in risk levels, particularly within the context of Indonesian national roads [17], [20]. Consequently, this study aims to analyse and compare the iRAP and ULFJ Star Rating methods in assessing road safety risks, evaluate the accuracy of both methods through ground truth validation, and identify the infrastructure attributes most sensitive in influencing risk assessment results.

RESEARCH METHODS

Research Methodology Stages

This study employs a quantitative approach with comparative analysis to evaluate and compare the road safety risk levels generated by the International Road Assessment Programme (iRAP) Star Rating method and the Road Function Eligibility Test (ULFJ) Star Rating method. The novelty of this research lies in the comparison of accuracy testing (ground truth validation) and attribute sensitivity analysis regarding the risk assessment outcomes of both methods. Figure 1 presents the research flowchart:

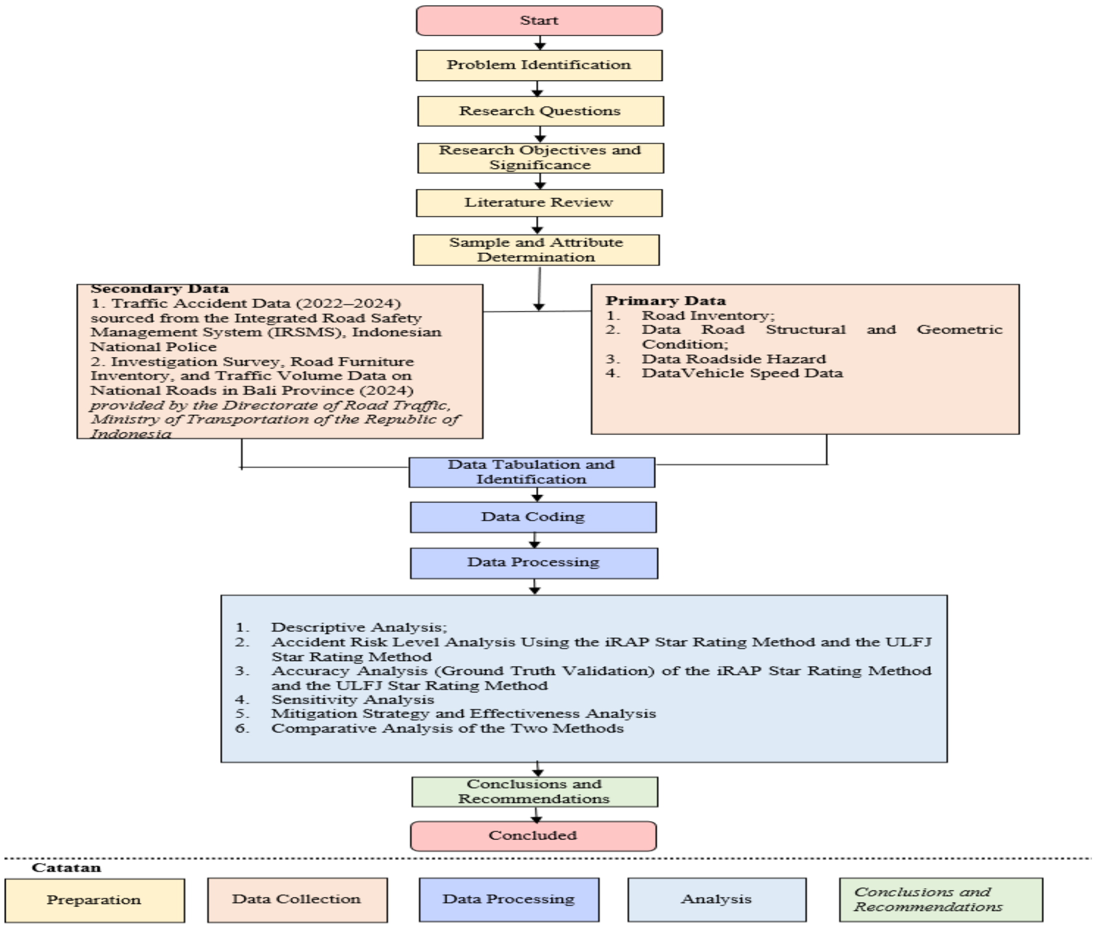

Figure 1. Research Flowchart

Methods

The analysis was conducted on the Pekutatan–Antosari national road section in Bali Province in 2025, using 100-metre segments as the unit of assessment. This aligns with the methodological requirements of both approaches to ensure an adequate spatial resolution for risk assessment [3], [7]. In this study, the dependent variables analysed are collective risk and personal road traffic accident risk. The independent variables comprise the risk assessment results obtained from the application of the iRAP method and the Road Function Eligibility Test (ULFJ) with Star Rating method. Meanwhile, the intervening variables influencing the relationship between the independent and dependent variables consist of road shoulder attributes, carriageway attributes, intersection attributes, and operational speed attributes. This approach facilitates a comprehensive analysis of the contribution of each infrastructure and operational attribute to accident risk levels, both individually and collectively, for every road segment under review. The following section details the methods utilised in this study.

a. Star Rating iRAP Method

The iRAP Star Rating method is an internationally developed road infrastructure safety assessment method designed to estimate accident risk levels based on physical conditions and road design elements [7], [12]. The assessment process is conducted by coding road attributes that influence the probability and severity of accidents, which are subsequently converted into a Star Rating Score (SRS). This conversion utilises Crash Modification Factors (CMFs) that have been empirically calibrated [4], [24]. The formula for calculating the Star Rating Score is presented below.

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$$SRS = \sum \text{Crash Type Score} \tag{1}$$

Where:

Crash Type Score = Likelihood x Severity x Operational Speed x External Flow Influence x Traversability Median (2)

The SRS values are then mapped into one-to-five-star categories as shown in Figure 2, where a higher star rating indicates a superior level of safety [11].

Star Rating	Star Rating Scores				
	Vehicle Occupants and Motorcyclist	Bycyclist	Pedestrian		
			Total	Along	Crossing
5	0 to < 2.5	0 to < 5	0 to < 5	0 to < 0.2	0 to < 4.8
4	2.5 to < 5	5 to < 10	5 to < 15	0.2 to < 1	4.8 to < 14
3	5 to < 12.5	10 to < 30	15 to < 40	1 to < 7.5	14 to < 32.5
2	12.5 to < 22.5	30 to < 60	40 to < 90	7.5 to < 15	32.5 to < 75
1	22.5 +	60+	90+	15+	75+

Figure 2. Star Rating Score Categories for iRAP Method

In its implementation, the iRAP method utilised 52 assessment attributes grouped into several primary categories, including road geometry and design attributes, medians and directional separators, road edges and shoulders, intersections and property access, traffic flows, operating speeds, and facilities for vulnerable road users. These attributes were designed to represent the main risk factors contributing to accident occurrence and severity for various types of road users, including motor vehicles, motorcyclists, pedestrians, and cyclists, thereby providing a comprehensive risk profile [2], [25]. The entire analysis process was conducted using ViDA (Virtual iRAP Drive Analysis), an online iRAP software, to ensure calculation consistency and uniformity of assessment results across road segments [8], [13].

b. The ULFJ with Star Rating Method

The Road Functional Feasibility Assessment (ULFJ) with Star Rating method was a road safety assessment approach developed based on national regulations and technical guidelines applicable in Indonesia [3]. This method utilised a set of road infrastructure attributes reflecting geometric conditions, traffic flow characteristics, operating speeds, the availability of road user facilities, as well as intersection and roadside conditions [9], [19].

Overall, the ULFJ Star Rating method utilised 38 assessment attributes grouped into several primary categories, including carriageway attributes, medians and directional separators, intersections, road edges and shoulders, traffic flows, and operating speeds. The risk assessment was conducted by calculating the Star Rating Score (SRS), which aggregated several potential accident types, such as run-off-road accidents, head-on collisions, intersection accidents, and traffic conflicts at property access points [15], [26].

Unlike the iRAP method, which evaluates various road user groups, the ULFJ with Star Rating approach was focused on motor vehicle users; consequently, its attribute structure and weighting were designed to represent the dominant risk characteristics of motor vehicle traffic on Indonesian national roads. The SRS values were obtained through data processing using Microsoft Excel and subsequently classified into star categories representing the safety level of each road segment. This approach was developed to align with the traffic characteristics and road infrastructure conditions in Indonesia, thereby providing more contextual and applicable risk assessment results [17], [22]. The calculation for the ULFJ with Star Rating risk values is presented below:

$$SRS = SRS\ \text{run-off} + SRS\ \text{Ho-Loc} + SRS\ \text{Ho-ot} + SRS\ \text{Int} + SRS\ \text{Pa} \quad (3)$$

SRS	:	Star Rating Score;
$SRS_{\textit{Run-off}}$	:	Run-Off Accident Score (Run-Off);
$SRS_{\textit{Ho-Loc}}$	:	Head-On Loss Control;
$SRS_{\textit{Ho-ot}}$	:	Head-On Overtaking;
$SRS_{\textit{Int}}$	:	Intersection Accident Score (Intersection);
SRS_{Pa}	:	Property Access Accident Score (Property Access).

The SRS values were subsequently classified into one-to-five-star categories, as shown in Figure 3, with the provision that a higher star rating indicated a superior level of road safety.

Star Rating Assessment	
Star Rating	**Score**
5	0.0 s.d.< 2.5
4	2.5 s.d. < 5.0
3	5.0 s.d. < 12.5
2	12.5 s.d. 22.5
1	≥ 22.5

Figure 3. Star Rating Score Categories for ULFJ Method

c. Ground Truth Validation

Ground Truth Validation is the process of testing the accuracy of a method, model, or analytical result by comparing it against reference data considered to be correct. This testing aims to evaluate the consistency between the risk assessment results obtained from the iRAP and ULFJ methods and actual field accident conditions (ground truth) [20]. Ground truth validation is conducted by analysing the correlation of the SRS values and star categories from both methods against historical road traffic accident data specifically collective and personal risk on the Pekutatan–Antosari road section [5], [10]. This correlation analysis is performed using a statistical approach through regression testing and correlation coefficients to assess the strength and direction of the relationship between the risk assessment results and actual accident occurrences. The interpretation of the correlation strength between variables is conducted with

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reference to Sugiyono's correlation coefficient guidelines, where the correlation coefficient value (R) is classified into categories ranging from very weak to very strong. This classification is used to objectively and systematically assess the level of consistency between the road safety risk modelling results and actual accident data [5], [10], [21].

R Value	Correlation coefficient (R)
0.00 s.d. 0.199	Very weak
0.220 s.d. 0.399	Weak
0.40 s.d, 0.599	Moderate
0.60 s.d. 0.799	Strong
0.80 s.d. 1.00	Very strong

Figure 4. Inter-variable Correlation Categories

d. Sensitivity Test

Sensitivity testing is conducted to identify the extent to which changes in road infrastructure attributes influence the Star Rating Score (SRS) generated by the iRAP method and the Road Function Eligibility Test (ULFJ) with Star Rating method. This test aims to determine the most dominant attributes affecting road safety risk levels and serves as a basis for prioritising road safety interventions [17], [26].

The sensitivity test is performed using a scenario-based approach through controlled changes to specific attributes, while other attributes are held constant. These changes cover operational and physical road aspects, such as roadside attributes, carriageway attributes, intersection attributes, and operating speeds. The impact of these changes is analysed through the difference and percentage change in SRS values before and after the scenarios are applied [15], [18]. In this study, attributes with a sensitivity value of less than 1 are categorised as less sensitive to risk changes, whereas attributes with a sensitivity value greater than 1 are classified as highly sensitive, as they exert a significant influence on SRS variations.

The sensitivity analysis is conducted separately for the iRAP and ULFJ methods to identify differences in how both methods respond to identical attribute changes. The results of the sensitivity test are used to identify priority attributes that are most effective in reducing SRS values and improving star rating categories, thereby supporting the development of more targeted and evidence-based road safety recommendations [17], [19].

Data Analysis

The data used in this study comprise secondary data, including accident records at the research location from 2022 to 2024 sourced from the Integrated Road Safety Management System (IRSMS) of the Indonesian National Police. Furthermore, the primary data utilised are obtained from field observations conducted in 2025, which include road inventory data, structural and geometric condition data, roadside hazard data, and speed data.

RESULT AND DISCUSSION

a. Crash Risk Assessment using the Star Rating iRAP Method

The accident risk assessment results using the iRAP Star Rating method for the Pekutatan–Antosari Bali Road are presented in Table 1 below:

Table 1. Risk Assessment for Star Rating iRAP Method

Star Rating	Rating Category	Risk Value	% Segments	Risk Value	% Segments
		Motor Vehicles		Motorcycles	
5	Very Low	0.0 s.d.< 2.5	0%	0.0 s.d.< 2.5	0%
4	Low	2.5 s.d. < 5.0	0%	2.5 s.d. < 5.0	0%
3	Moderate	5.0 s.d. < 12.5	51%	5.0 s.d. < 12.5	13%
2	High	12.5 s.d. 22.5	31%	12.5 s.d. 22.5	56%
1	Very High	≥ 22.5	18%	≥ 22.5	31%

Table 1 above shows that based on the iRAP Star Rating risk assessment for motor vehicle users, 51% of the Pekutatan–Antosari section achieves a 3-star rating with risk scores ranging from 5.0 to < 12.5. Meanwhile, 31% obtain a 2-star rating with risk scores between 12.5 and 22.5, and 18% of the section falls into the 1-star category with risk scores of ≥ 22.5. In contrast, the risk assessment for motorcyclists reveals that the majority of road segments do not meet the 3-star requirement. This condition indicates that the level of road safety on the Pekutatan–Antosari section remains uneven and is relatively low for motorcyclists; therefore, the road section requires targeted and sustainable safety interventions, particularly on segments with low star ratings (2 stars and 1 star), to enhance safety levels and reduce potential accident risks. Figure 5 illustrates the existing conditions of segments in the 3-star, 2-star, and 1-star categories under the iRAP Star Rating method:

Figure 5. Visualisation of Segments for Each iRAP Star Rating Category

b. Crash Risk Assessment using The ULFJ with Star Rating Method

The risk assessment results using the ULFJ Star Rating method on the Pekutatan–Antosari road section in Bali show that 49% of the section meets the RUNK (National Road Safety Master Plan) target by achieving a 3-star rating with risk scores between 5.0 and < 12.5. Meanwhile, 15% obtain a 2-star rating with risk scores ranging from 12.5 to 22.5, and 36% receive a 1-star rating with risk scores of ≥ 22.5. This indicates that 51% of the Pekutatan–Antosari road section still requires interventions in terms of geometry, road structure, and road equipment to reduce accident risk values and enhance road safety. Table 2 presents a summary of the star ratings for the ULFJ with Star Rating method on the Pekutatan–Antosari Bali road:

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Table 2. Risk Assessment using the ULFJ with Star Rating Method

Star Rating	Rating Category	Risk Value	% Segments
5	Very Low	0.0 s.d.< 2.5	0%
4	Low	2.5 s.d. < 5.0	0%
3	Moderate	5.0 s.d. < 12.5	49%
2	High	12.5 s.d. 22.5	15%
1	Very High	≥ 22.5	36%

Figure 6 illustrates the existing conditions of segments in the 3-star, 2-star, and 1-star categories according to the risk assessment of the ULFJ Star Rating method.

Figure 6. Segment Visualisation for Each ULFJ Star Rating Category

c. Ground Truth Validation

A comparison of the accuracy test results for the risk values of both methods against actual accident data comprising collective risk and personal risk on the Pekutatan–Antosari road section is presented in Table 4 and Table 5 below:

Table 3. Accuracy Testing Between the Risk Values of Both Methods and Collective Risk

Ground Truth Validation of Risk Values against Collective Risk			
The Star Rating iRAP Method		**ULFJ with Star Rating Method**	
Regression Statistics		Regression Statistics	
Multiple R	0.74	Multiple R	0.81
R Square	0.55	R Square	0.65
Adjusted R Square	0.52	Adjusted R Square	0.62
Standard Error	3.46	Standard Error	3.03
Observations	39	Observations	39

Table 4. Accuracy Testing Between the Risk Values of Both Methods and Personal Risk

Ground Truth Validation of Risk Values against Personal Risk	
The Star Rating iRAP Method	**ULFJ with Star Rating Method**

Regression Statistics		Regression Statistics	
Multiple R	0.70	Multiple R	0.74
R Square	0.49	R Square	0.55
Adjusted R Square	0.46	Adjusted R Square	0.52
Standard Error	0.42	Standard Error	0.39
Observations	39	Observations	39

The results of the Ground Truth Validation in Tables 4 and 5 show that both risk assessment methodologies the iRAP Star Rating method and the ULFJ Star Rating method possess an excellent ability to represent both collective and personal risk based on actual data. However, the regression results demonstrate that the ULFJ Star Rating method achieves a higher level of accuracy compared to the iRAP Star Rating method for the Pekutatan–Antosari road section.

d. Sensitivity Test

The comparison of sensitivity test results for the attributes of each method shows that both methods have relatively similar response patterns in several attribute categories, yet exhibit significant differences in certain attributes. In the roadside category, both the iRAP Star Rating method and the ULFJ Star Rating method produce sensitivity values of < 1, thus categorising them as less sensitive. This finding indicates that changes in roadside attributes do not exert a significant influence on variations in road safety risk scores. Meanwhile, the sensitivity values for other attributes show that the attributes in the ULFJ method possess higher sensitivity values compared to those in the iRAP Star Rating method.

Attribute Category Analysis	Sensitivity Test of the iRAP Star Rating Method								Sensitivity Test of the ULFJ Method with Star Rating							
	Total CMF (Before)	Total SRS (Before)	Total Modified CMF (After)	Total SRS (After)	ΔX	ΔY	S (Absolut)	Sensitivity Notes	Total CMF (Before)	Total SRS (Before)	Total Modified CMF (After)	Total SRS (After)	ΔX	ΔY	S (Absolut)	Sensitivity Notes
	X1	Y1	X2	Y2	(X2 - X1)	(Y2 - Y1)	ΔY / ΔX		X1	Y1	X2	Y2	(X2 - X1)	(Y2 - Y1)	ΔY / ΔX	
Roadside and Shoulder	53.9	31.10	25.54	23.7328	-28.36	-7.36	**0.26**	Low Sensitivity	53.90	59.26	25.54	51.78	-28.36	-7.49	**0.26**	Low Sensitivity
Carriageway and Median	5.00	31.10	4.00	15.47	-1.00	-15.63	15.63	High Sensitivity	5.00	59.26	4.00	33.63	-1.00	-25.64	25.64	High Sensitivity
Intersections	2.40	31.10	2.0	30.61	-0.40	-0.48	1.21	High Sensitivity	2.40	59.26	2.00	58.63	-0.40	-0.64	1.59	High Sensitivity
Speed	1.83	31.10	1.42	30.7799	-0.41	-0.32	0.77	Low Sensitivity	1.35	59.26	1.02	11.77	-0.33	-47.49	143.92	High Sensitivity

Figure 7. Results of Attribute Sensitivity Testing for the iRAP Star Rating and the ULFJ with Star Rating Methods

CONCLUSION

This study demonstrates that both the iRAP Star Rating method and the Road Function Eligibility Test (ULFJ) with Star Rating method are capable of identifying road safety risk levels on the Pekutatan–Antosari road section, yet they produce distinct characteristics and response levels. Risk assessment results from both methods show that several road segments do not yet meet the safety targets set in the National General Plan for Safety (RUNK); therefore, maintenance of geometric aspects, road structures, and road equipment is required to maintain safety performance and prevent an increase in accident risks from existing conditions. Furthermore, targeted road safety interventions are necessary, particularly for segments in the low star-rating categories. The ground

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truth validation results indicate that the ULFJ method possesses a higher level of consistency with actual accident data on national roads, especially in representing risks influenced by operational traffic characteristics. Conversely, the iRAP method shows superiority in identifying risks based on physical infrastructure characteristics and the risks faced by various road user groups, including vulnerable road users. Sensitivity testing reveals that differences in attribute structure and weighting lead to divergent responses in the two methods. The iRAP method is more sensitive to changes in physical road attributes, particularly the carriageway and median, while the ULFJ method is more responsive to operational attributes, especially speed. These findings suggest that the ULFJ method is more contextual to Indonesian traffic characteristics, whereas iRAP provides a more internationally comprehensive road safety approach. Consequently, within the context of applying national technical standards, the ULFJ with Star Rating method is considered more representative for assessing road safety risks on the Pekutatan–Antosari road section, particularly as a basis for the planning and evaluation of road safety interventions in Indonesia.

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