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The Relationships Between iRAP Star Rating Score and Various Safety Performance Indicators

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Abstract. The iRAP Star Rating assessment has gained global recognition as an effective strategy for reducing fatalities caused by road crashes. As part of its road safety initiatives, Indonesia has also adopted the iRAP Star Rating methodology with the goal of achieving a 3-Star Rating or higher for over 75% of its road network, with a focus on prioritizing toll roads. However, it remains crucial to ascertain the effectiveness of the iRAP Star Rating methodology with regards to safety performance indicators such as crash and fatality rates and the number of crashes and fatalities. Unfortunately, there have been limited studies examining the relationship between safety performance indicators and iRAP Star Rating, with only a few conducted in Indonesia. Most of these studies only focused on iRAP Star Rating results and used a limited dataset without examining correlations to safety performance indicators. Thus, this study aims to estimate the relationship between the iRAP Star Rating Score (SRS) and safety performance indicators. The results indicate a positive correlation between SRS and safety performance indicators, with a higher SRS indicating a higher level of hazard and correspondingly higher safety performance indicators values. However, it is important to note that the R^2 value was not particularly high (ranging from 0.2-0.7), suggesting that this relationship may not be accurately reflected, possibly due to factors unique to the Indonesian environment and human factors not specifically accounted for in the iRAP methodology.

Keywords: Crash rate; Fatality rate; iRAP star rating; Star Rating Score (SRS); Toll road

1. Introduction

Road safety assessment based on the International Road Assessment Programme (iRAP) Star Rating has become a global standard for achieving the Sustainable Development Goal (SDG), which aims to reduce fatalities due to road crashes (United Nations, 2022; WHO, 2021). Achieving a 3-star or better standard through this method can improve road safety and help to halve road deaths and injuries by 2030 as part of the United Nations' SDGs targets (iRAP, 2022; Mclnerney and Smith, 2009).

The iRAP Star Rating is an internationally recognized standard for conducting road safety assessments, and it has been widely adopted in many countries, including in Europe, the United Kingdom, Central and South America, Australia, New Zealand, Thailand, China, Brazil, Malaysia, Pakistan, and Indonesia. Several studies regarding the iRAP Star Rating assessment have been conducted (Li, Bradford, and Bachani, 2024; Daidone *et al.,* 2023;

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García-Ramírez, 2023; Setyarini *et al,* 2023; Kumar and Sharma, 2022; Murozi *et al,* 2022; Joshua and Setyarini, 2021; Ryandi and Setyarini, 2021; Ambros, Borsos, and Sipos, 2017; Charlton and Starkey, 2018; Jurewicz and Excel, 2016; Hadi, 2015; Waibl, Tate, and Brodie, 2012).

Li *et al.* (2024) reviewed the estimation of fatalities and serious injuries (FSI) saved by iRAP protocols in 74 countries. The study suggested more extensive applications of iRAP protocols to improve road safety as it could significantly reduce FSI through its countermeasures. Through before and after studies using crash data and iRAP protocols and its countermeasures, there were evidence on reduction of crashes in UK (iRAP, 2011), and reduction of FSI by 50% in Sweden (EuroRap, 2020; Vadeby, 2016; Carlsson, 2009).

EuroRAP (2011) conducted a study on the relationship between average crash rates and the iRAP Star Rating/Road Protection Score (RPS) in multiple European countries using various models. The findings from these studies showed variations, but overall, they suggested that higher Star Ratings were associated with a decrease in average crash rates or crash cost and vice versa. Jurewicz and Excel (2016) utilized AusRAP protocols (Austroad, 2024; Metcalfe and Smith, 2005) to calculate the relative risk of different types of severe crashes and used these results to predict the frequency of severe crashes in the Australian National Risk Assessment Model (ANRAM) (ARRB, 2015). A validation study conducted by Ambros, Borsos, and Sipos (2017) on rural roads in Hungary using a state-of-the-art empirical Bayes approach (Hauer *et al.,* 2002; Hauer, 2001) confirmed the relationship between increasing Star Rating and decreasing crash frequencies. However, the study also found that the Star Rating had a minor influence and an unexpected positive relationship with crash frequency.

There were only limited studies regarding the relationship between iRAP Star Rating and crash rate/frequency in Indonesia. Hadi (2015) conducted a study on a 28-km length of a national road segment in Central Java, Indonesia, and found that segments with higher Star Ratings were associated with lower crash rates. However, the study only considered Star Ratings between 1 to 3, as no segments with Star Ratings 4 or 5 were included in the study. Another study by Rahmita and Malkamah (2020) examined the relationship between crash rate, number of crashes, Star Rating Score (SRS), and Star Rating band for a 10.6 km segment of National Road in Java Island. The study showed a weak correlation (R^2 less than 0.07) between the SRS and Star Rating band with crash rate and number of crashes. Nevertheless, none of the studies explored the relationship between iRAP Star Rating and crash severity, despite the fact that iRAP aims to evaluate road infrastructure features that impact crash likelihood and severity.

In compliance with United Nations Sustainable Development Goals (UN SDGs), one of the road safety targets stated in the Indonesian National Road Safety Plan 2021-2040 is to achieve a minimum 3-Star Rating, using iRAP, for more than 75% of Indonesia’s road network (Central Government of Indonesia, 2022). The primary focus is on enhancing road safety on toll roads, given their higher crash rates compared to other road types in the country. To achieve this goal, it is crucial to understand the relationship between crash data (such as the number of crashes, severity, crash rates, and fatality rates) and the iRAP Star Rating Score (SRS). This understanding will help determine the effectiveness of the iRAP assessment in Indonesia, which has distinct driving behavior compared to other countries. The purpose of this study is to assess toll road safety using iRAP, and estimate the relationship between iRAP Star Rating, crashes, and their severity levels in Indonesia toll road case study.

2. Methods

The iRAP methodology assesses the road safety in a proactive manner and identify road infrastructure deficiencies towards providing some countermeasures to improve road safety by eliminating highrisk roads (Uddin and Raihan, 2023; iRAP, 2021; Hoque *et al.*, 2010).

iRAP Star Rating is generated using ViDA online platform for every 100-meter road segment (iRAP, 2020). Road attributes required in ViDA to calculate the SRS include roadside severity (distance and type of side object), vehicle flow, speed limit, operation speed, sight distance, intersection, pave shoulder, access point, number of lanes and lane width, grade, road condition, delineation, and the existence of shoulder rumble strip, curvature, traffic calming, service road, street lighting (iRAP, 2022). Only vehicle Star Rating was calculated in this research, as pedestrians, motorcyclists, and cyclists are not permitted to use the toll road. In addition to road attributes, the number of fatalities for each crash type is also an input in Vida for fatality estimation.

The study was conducted on four toll roads in Java Island, Indonesia (Figure 1), namely Padaleunyi (Padalarang-Cileunyi) toll road (71.5km), Cipularang (Cikampek-Purwakarta-Padalarang) toll road (112.9km), Cipali (Cikopo-Palimanan) toll road (237km), and Palikanci (Palimanan-Kanci) toll road (52.5km). In total, the four toll roads cover a length of 473.90km. The crash and fatality data for Padaleunyi and Cipularang were obtained from 2019, while for Cipali and Palikanci, the data were from 2020. The road attributes assessed in iRAP were based on the same year as the crash data for each of the toll road segments. A total of 385 crashes and 90 fatalities were recorded on the studied toll roads.

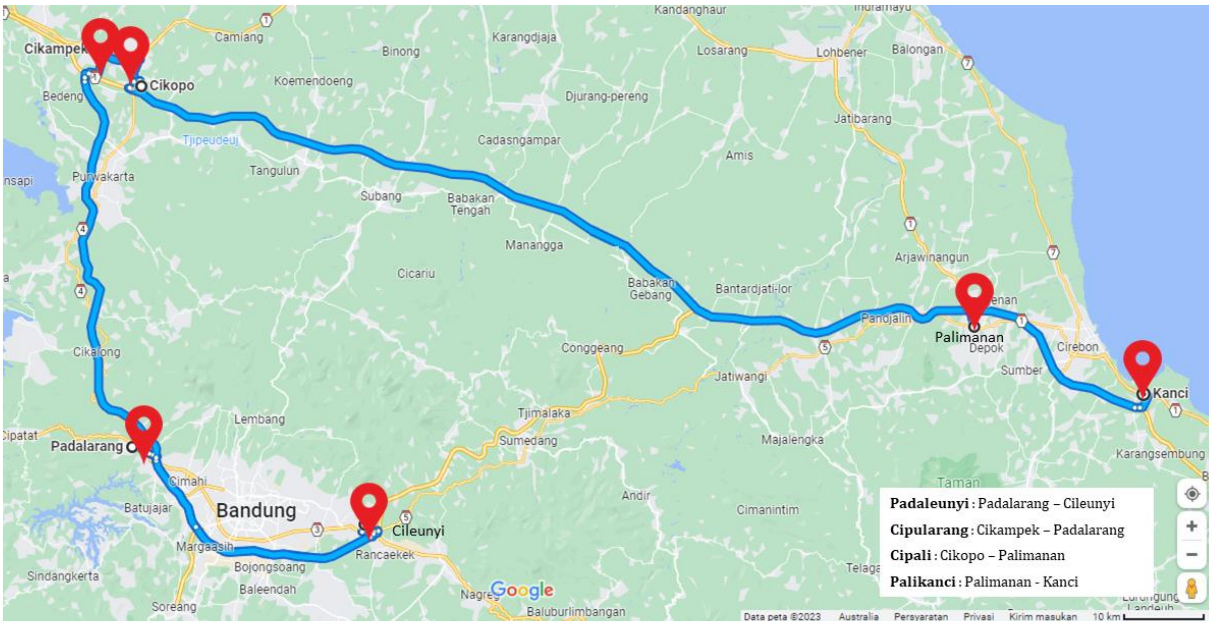


Figure 1 Study Locations

ViDA calculated the SRS and Star Rating based on the coded road attributes. The Star Rating Score (SRS) is calculated for each 100m segment of road for each road user (iRAP, 2014). The SRS is a summary of Crash Type Scores and represents the relative risk of serious injury and fatality for an individual road user. Crash type score is calculated by multiplying road attribute risk factors that account for several circumstances, including the chance that a crash will be triggered (*Likelihood*), the severity level of a crash (*Severity*), operating speed (*Speed*), the risk of being involved in a crash as a function of other person's use of the road (external flow influence-*Flow*), and potential that errant vehicle will cross the median (median traversability-*Medtraverse*). The equation for calculating the crash type score can be seen below:

$$Crash\ type\ score = Likelihood\ x\ Severity\ x\ Speed\ x\ Flow\ x\ Medtraverse \quad (1)$$

The roadside hazards in ViDA were coded according to the type of roadside object which is part of "*Severity*" in formulation (1), along with its distance from the edge line to the object per 100m road segment. If there were variations in road attributes within a coding segment for the length of 100m, the attribute with the highest risk would be coded for the segment. In the case of choosing the roadside object with the highest risk, iRAP has compiled a list of 62 roadside hazards, ranked according to their relative risk, to assist in identifying the objects with the highest risk. This list can be found in iRAP (2022). The top-ranked hazard on the list is the cliff, regardless of its distance from the edge line. In contrast, wire rope barriers located more than 10m from the edge line are considered to have the lowest risk. However, it is important to note that these rankings were based on research from around the world and may not necessarily reflect the specific environment of Indonesia.

Formulation (1) highlights the importance of operating speed as a factor influencing the crash type scores. This formulation considers operating speed as a combined risk factor without separating the effects of speed on the likelihood of a crash occurring and the severity of a crash. Higher operating speeds lead to higher crash-type scores, indicating a higher relative risk of serious injury and fatality for road users. The likelihood component of the formulation (1) takes into account several road attributes, including lane width, number of lanes, curvature and its quality, delineation, shoulder rumble strip, road condition, grade, skid resistance, intersection type, and its quality, the presence of street lighting, sight distance, and traffic calming. On the other hand, the severity component considers the roadside object and its distance, paved shoulder width, median type, intersection type, and access points to properties. The relationship between each attribute is based on previous studies collected by iRAP in each iRAP methodology factsheet (iRAP, 2014). Figure 2 illustrates the formulation (1) and its attributes in more detail.

SRS is apportioned to Star Rating bands to determine the Star Rating for every 100 meters of the road as in Table 1 based on iRAP. Star Rating Bands are not equally distributed. Thus, the lower the Star Rating, the greater the variance between SRS. A higher SRS indicates a more hazardous road. On the opposite, the lower the Star Rating band, the more dangerous the road. Star rating band 1 is the most dangerous, while 5 is the safest. A star rating band is commonly used to describe the star rating on the map or table because it is simpler and easier to understand (iRAP, 2024). On the other hand, SRS is the calculation for the relative risk of death and serious injury without any simplification. The distribution of SRS into Star Rating bands for vehicle occupants is as shown in Table 1:

Table 1 iRAP Star Rating Variables (iRAP, 2022)

Star Rating Band	Star Rating Score (SRS)	Notes
★	22.5+	The most dangerous road
★★	12.5 - < 22.5	
★★★	5.0 - < 12.5	
★★★★	2.5 - < 5.0	
★★★★★	< 2.5	The safest road

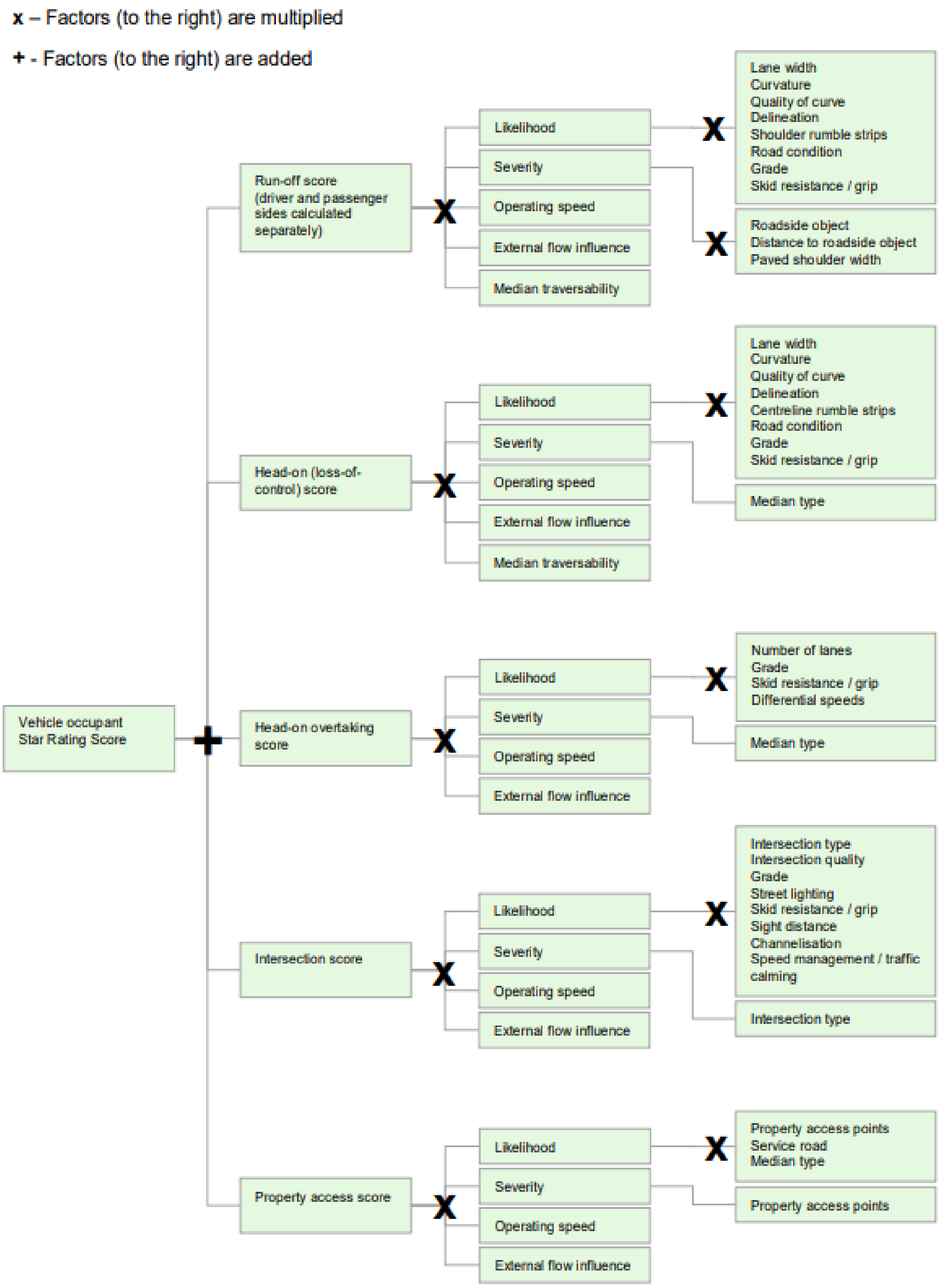


Figure 2 SRS equation in more detail (formulation 1) (iRAP, 2014)

3. Results and Discussion

3.1. Star Rating Bands on Indonesia Toll Road

The star rating band was calculated using Vida based on the formulation (1), which consider the risk factor based on inputting variable for iRAP (road attributes and fatality estimation). It describes the level of road safety from 1 (highest risk) to 5 (safest road). The Star Rating bands for Indonesia Toll Roads in the case study can be seen in Table 2 and Figure 3.

Table 2 iRAP Star Rating Result

Star rating	Length (km)	Percent (%)
3 star or better	318.3	67.25%
5 Stars (lowest risk)	0.9	0.19%
4 Stars	92.3	19.50%
3 Stars	225.1	47.56%
2 Stars	143	30.21%
1 Stars (highest risk)	12	2.54%
Totals	473.90	100%

The results indicate that 67.25% of the toll road network achieved a 3-star or better rating. Among the network, only 0.19% achieved a 5-star rating, indicating the lowest risk, while 2.54% of the network received a 1-star rating, representing the highest risk. The majority of the network achieved a 2-star or 3-star rating, with 30.21% and 47.56% of the network falling into these categories, respectively. In order to improve road safety, it is important to focus on the specific areas with lower star ratings, particularly Star Ratings 1 and 2. A detailed observation of these areas can help identify the best countermeasures to address the safety issues. The Safer Roads Investment Plan (SRIP) in iRAP recommends a number of road safety measures for these segments, including adding a central median barrier, and roadside barrier, improving delineation, and adding shoulder rumble strips in several segments.

Figure 3 depicts that the Cipali toll road has a lower star rating band, indicating a higher level of risk compared to the Padaleunyi, Cipularang, and Palikanci toll roads. This could be attributed to the wide median with wire rope barriers present on only one side or with no barrier on some segments of the Cipali Toll Road (Figure 4). This condition increases the probability of an errant vehicle crossing the median into the opposite lane, which can lead to severe head-on collisions and result in fatalities.

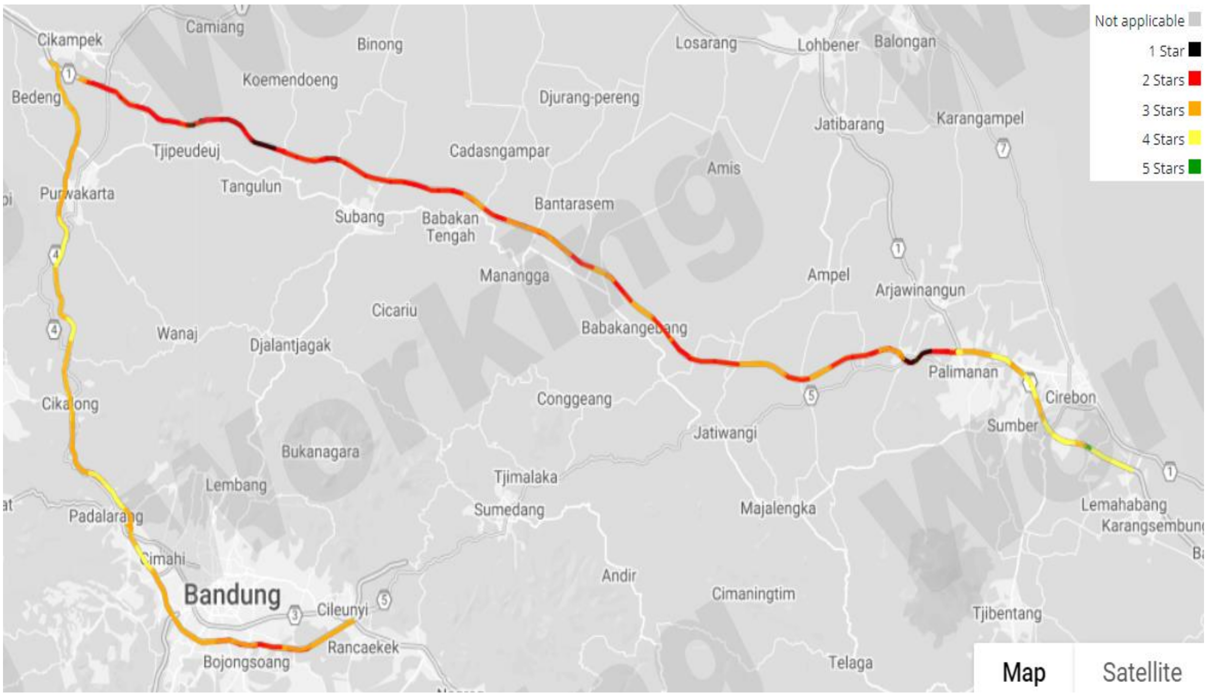
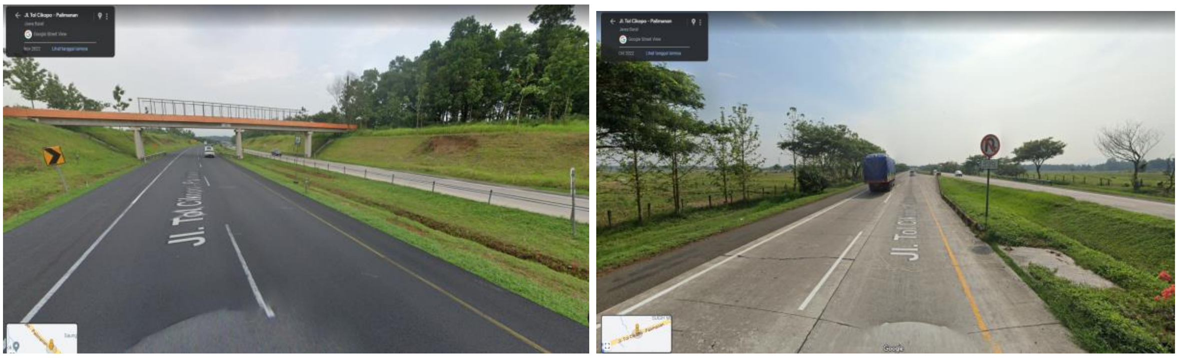


Figure 3 iRAP Star Rating results on maps



(a) (b)

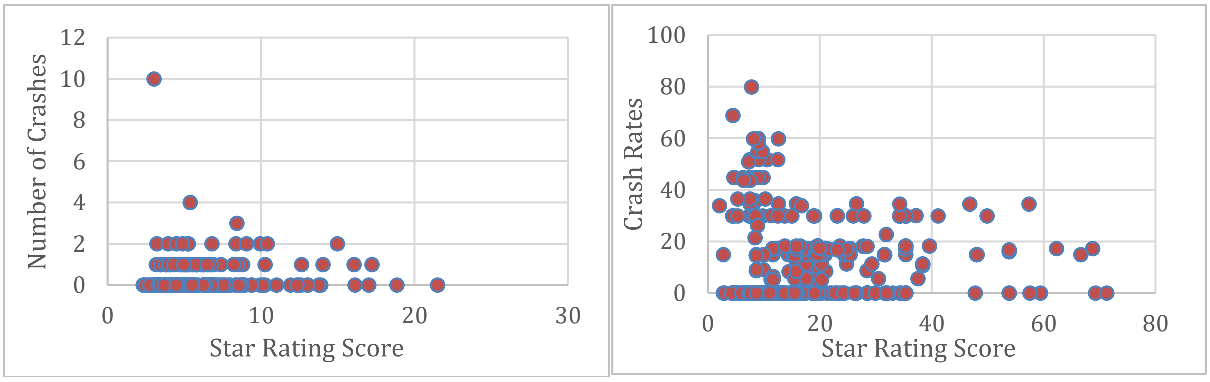
Figure 4 Wirerope barrier median (a) and wide median (b) in Cipali toll road

3.2. Number of Crashes, Crash Rates, Fatalities, Fatality Rates, and Star Rating Score

Analysis of the number of crashes per 100m segment shows that most segments had no crashes, with some having one crash and only a few with two or three crashes due to the consideration of only one year of crash data. The data were then combined into a 1km segment to allow for more variation in the number of crashes. The SRS for the 1km segment was the average SRS for the ten-100m segment.

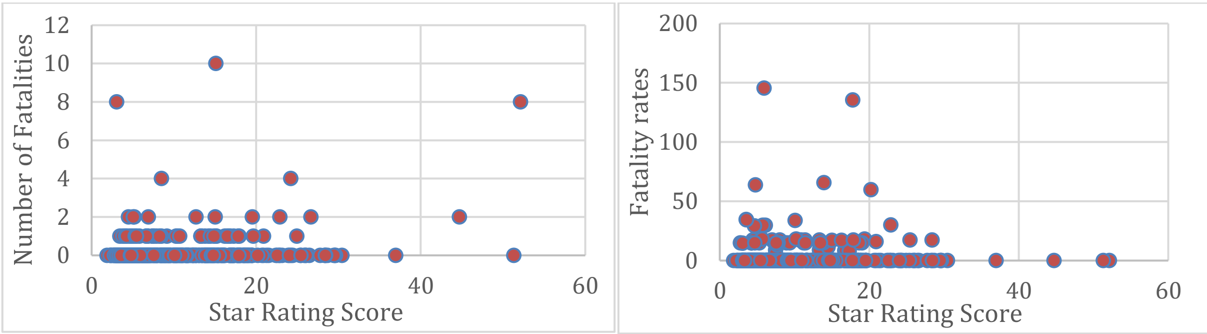
The number of crashes was in the range between zero to four, except for one segment, which had ten crashes. The segment was KM 91-92B of the Cipularang toll road, which is one of the blackspot locations in the Indonesian toll road network. The corresponding crash rate for this segment was 79.8 crashes per 100 million vehicle-km. Figure 5 presents the distribution of the number of crashes and the crash rate for each of the SRS.

Figure 6 presents the distribution of the number of fatalities and the fatality rates for each of the SRS. The charts reveal that most segments do not have any fatalities, either because no crashes have occurred, or even if crashes did occur, they did not result in any fatalities. However, the highest number of fatalities, which is ten, was recorded on the Cipali toll road at KM 78-79B. In contrast, the highest fatality rate, which amounted to 145.5 fatalities per 100 million vehicle-km, was observed on the Palikanci toll road at KM 190-191B.



(a) (b)

Figure 5 Distribution of the Number of Crashes Vs SRS (a) and Crash Rate Vs SRS (b)



(a) (b)

Figure 6 Distribution of the number of fatalities vs SRS (a) and fatality rate vs SRS (b)

3.3. Relationship Between SRS and Number of Crashes, Number of Fatalities, Crash Rate, and Fatality Rate

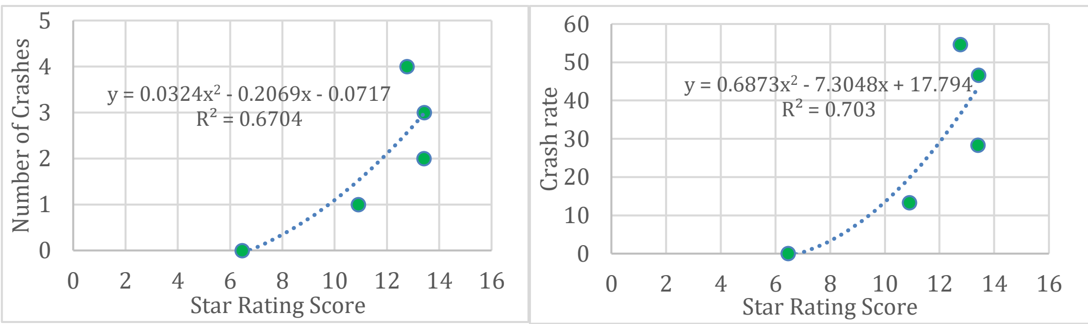
To establish the relationship between SRS and the number of crashes, fatalities, crash rates, and fatality rates, the data in Figure 5 and Figure 6 were grouped according to the number of crashes. For each number of crashes, the number of fatalities for all segments with a certain number of crashes was summed up, and the SRSs were averaged. Therefore, for example, road segments with only one crash had a cumulative fatality of 39 and an average SRS of 10.912.

Grouping the data based on the number of crashes allowed for a more accurate analysis of the data distribution. Nonetheless, the data point representing ten crashes on the Cipularang Toll Road was excluded from the analysis due to its outlier status. The resulting groups of data are thus presented in Table 4.

Table 4 Crash Data in Groups

Number of Crashes	Crash Rates	Number of Fatalities	Fatality Rates	Average SRS
0	0	0	0	6.468
1	13.33	39	3.41	10.912
2	28.30	23	5.54	13.416
3	46.66	14	10.51	13.430
4	54.68	14	34.98	12.770

Figures 7 and 8 illustrate the relationship between SRS and the number of crashes and fatalities, as well as the crash and fatality rates, respectively. Each graph was estimated using linear, logarithmic, exponential, polynomial, and power trendlines, and the one with the highest coefficient of determination (R^2) was selected. The selected relationships for the number of crashes and crash rate VS SRS are polynomial trendlines, while the number of fatalities and fatality rates VS SRS are logarithmic trendlines.



(a) (b)

Figure 7 Relationship between the number of crashes vs SRS (a) and crash rate vs SRS (b)

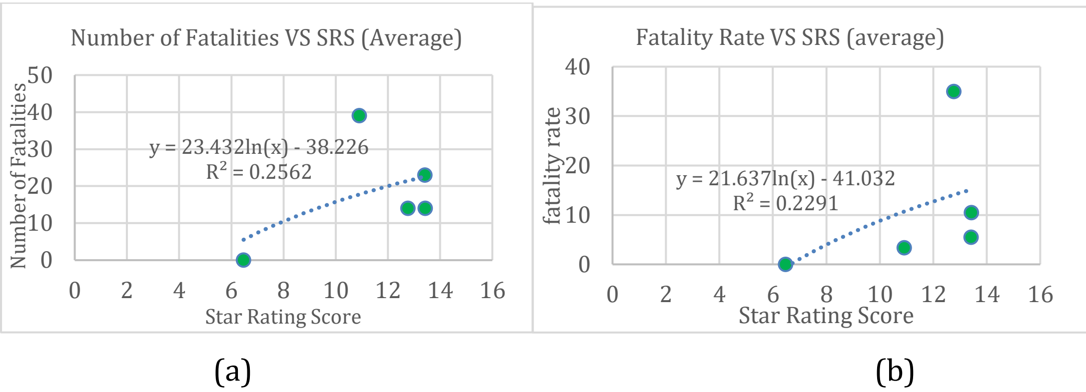


Figure 8 Relationship between number of fatalities vs SRS (a) and fatality rates vs SRS (b)

The charts show that number of crashes, crash rates, number of fatalities, crash rate (in a crash per 100 million vehicle-km), and fatality rate (in fatality per 100 million vehicle-km) have a positive relationship with SRS, with the following relationships:

$$Number\ of\ crashes\ =\ 0.0324(SRS)^2 - 0.2069(SRS) - 0.0717 \quad (2)$$

$$Crash\ Rate = 0.6873(SRS)^2 - 7.3048(SRS) + 17.794 \quad (3)$$

$$Number\ of\ Fatalities = 23.432\ln(SRS) - 38.226 \quad (4)$$

$$Fatality\ rate\ = 21.637\ln(SRS) - 41.032 \quad (5)$$

This study has revealed that the SRS has positive relationship with the number of crashes, number of fatalities, crash rate, and fatality rate. These findings are in accordance with the theory that a higher SRS value implies a more hazardous road segment. Therefore, SRS can be used as a proxy to measure the hazard level of a segment relative to the other segments. Reducing the SRS or improving the iRAP Star Rating band can lead to a decrease in the likelihood of road crashes and fatalities.

Nonetheless, it should be noted that the R^2 values obtained from the graphs were not high, specifically for the relationships between the SRS and the number of crash rates as well as the number of fatalities. As a result, the obtained results may not fully and accurately represent the existing relationships. It is possible that the unique environment and driver behavior in Indonesia differ from those of other countries used as the basis for establishing the iRAP methodology. Additionally, there may be other factors related to crashes that were not considered in the methodology, particularly those related to human factors. These factors could have contributed to the lower R^2 values observed in this study.

4. Conclusions

Road safety assessment using iRAP Star Rating in Indonesia toll roads show that approximately 67.25% of toll road in the case study had a 3-star rating band or better and met the international standard set by the UN SDGs target. This study has revealed that the SRS has positive relationship with the number of crashes, number of fatalities, crash rate, and fatality rate. These findings are in accordance with the theory that a higher SRS value implies a more hazardous road segment. However, it should be noted that the R^2 values for each relationship were not high, suggesting that the existing relationships may not be accurately reflected. This may be attributed to the Indonesian road environment and driver behavior, which were not specifically considered in the iRAP methodology. Further research is required to investigate these potential factors and their impact on the relationship between the SRS and various safety performance indicators in Indonesia. It is highly recommended that the iRAP methodology be adapted to the Indonesian environment to achieve more accurate results. Additionally, the findings of this research indicate that iRAP Star Rating can serve as a suitable proxy for assessing road safety conditions, in this case, safety improvements should be prioritized for segments with a star rating less than 3.

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References

Ambros, J., Borsos, A., Sipos, T., 2017. Exploring an Alternative Approach to iRAP Star Rating Validation. *In:* 96th Annual Meeting of the Transportation Research Board, Washington DC, 8-12 January, United States

ARRB, 2015, ANRAM Hub, ARRB Group Ltd, Vermont South, Victoria. Available online at: www.arrb.com.au/anram. Accessed on July 17, 2024

Austroad, 2024. Australian Road Assessment Program (AusRAP). Available online at: https://austroads.com.au/safety-and-design/road-safety/ausrap, Accessed on September 4, 2024

Carlsson, A., 2009. Evaluation of 2+1-roads with cable barrier. VTI report 636A. Available online at www.vti.se/publications, Accessed on September 1, 2024

Central Government of Indonesia, 2022. Peraturan Presiden (Perpres) Nomor 1 Tahun 2022 tentang Rencana Umum Nasional Keselamatan Lalu Lintas dan Angkutan Jalan. *(Presidential Regulation No 1, 2022. Indonesian National Road Safety Plan).* Indonesia

Charlton, S.G., Starkey, N.J., 2018. Transitions Within a Safe Road System. *Accident Analysis and Prevention*, Volume 121, pp. 250–257

Daidone, L., Pagliari, E., Pennisi, L., Caporali, E., Mazzia, E., Tiberi, P., 2023. Road Infrastructure Inspections to Assess Road Network According to the iRAP/EuroRAP Methodology. *Transportation Research Procedia,* Volume 69, pp. 743–750

EuroRap, 2011. Crash Rate- Star Rating Comparisons: Review of Available Evidence. Available online at: https://www.eurorap.org/wp-content/uploads/2015/04/iRAP-EuroRAP-Crash-rate-Star-Rating-comparison-504.2-20110420.pdf, Accessed on June 20, 2022

EuroRap, 2020. Case Study RAP Partnerships Saving Lives. The Swedish 2+1 with Wire Rope Median. Available online at: https://toolkit.irap.org/case-studies/, Accessed on July 20, 2024

García-Ramírez, Y., 2023. Proposal of New Star Rating Bands for iRAP on Two-lane Rural Roads in Ecuador. *International Conference on Civil, Structural and Transportation Engineering ICCSTE 2023 Ottawa*

Hadi, S., 2015. *Analysis on The Relationship Between Crash and Star Rating on Road Safety Performance (Case Study: National Road Segment Klampok - Banjarnegara city border, Central Java, Indonesia).* Unpublished Thesis, Magister Program of Highway Engineering and Develeopment, Institut Teknologi Bandung

Hauer, E., 2001. Overdispersion in modelling accidents on road sections and in Empirical Bayes estimation. *Accident Analysis and Prevention, Vol. 33, 2001, pp. 799–808*

Hauer, E., Harwood, D.W., Council, F.M., Griffith, M.S., 2002. Estimating Safety by the Empirical Bayes Method – A Tutorial. *Transportation Research Board,* Volume 1784(1), pp. 126–131

Hoque, M.M., Smith, G., Hossain, D.Z., Mahmud, S.M.S., 2010. Improving Highway Safety in Bangladesh: Road Improvement and the Potential Application of iRAP. *In:* 24th ARRB Conference, Melbourne, Volume 2010, p. 161

iRAP (International Road Assessment Programme), 2011. Before and after studies using crash data and iRAP protocols. Available online at: https://irap.org/research-and-technical-papers/, Accessed on July 23, 2024

iRAP (International Road Assessment Programme), 2014. iRAP Methodology Fact Sheets. Available online at: https://irap.org/methodology/, Accessed on March 23, 2023

iRAP (International Road Assessment Programme), 2020. *ViDA User Guide*. International Road Assessment Programme (iRAP) 2020

iRAP (International Road Assessment Programme), 2021. *iRAP Stories Behind our Journey for a World Free of High-Risk Roads*. Available online at https://irap.org/, Accessed on September 4, 2024

iRAP (International Road Assessment Programme), 2022. *iRAP Coding Manual, Drive on the left edition*. International Road Assessment Programme (iRAP) 2022.

iRAP (International Road Assessment Programme), 2024. *iRAP Crash Risk Mapping, Specification and Manual*. International Road Assessment Programme (iRAP) 2024.

Joshua, A., Setyarini, N.L.P.S.E., 2021. The Evaluation of 1km M.H Thamrin Street Using iRAP Star Rating to Achieve Star Rating 4. *Jurnal Mitra Teknik Sipil,* Volume 4(1), pp. 81–94

Jurewicz, C., Excel, R., 2016. Application of a Crash-Predictive Risk Assessment Model to Prioritise Road Safety Investment in Australia. *Transportation Research Procedia,* Volume 14, pp. 2101–2110

Kumar, S., Sharma, S., 2022. Measuring the Level of Road Safety through Road Safety Audit and Star Rating Method - A Case Study from Himalayan Expressway. *In:* IOP Conference Series: Earth and Environmental Science 2022, Volume 1084(1), p. 102044

Li, Q., Bradford, J., Bachani, A.M., 2024. Statistical Estimation of Fatal and Serious Injuries Saved by iRAP Protocols in 74 Countries. *PLoS ONE*, Volume 19(4), p. e0301993

McInerney, R., Smith, G., 2009. Saving Lives Through Investment In Safer Roads: The iRAP Partnership. *In:* Proceedings of the 13th Road Engineering Association of Asia and Australasia 2009, pp. 23–26

Metcalfe, J., Smith, G., 2005. The Australian Road Assessment Program (AusRAP). *2005 Australasian Road Safety Research Policing Education Conference*

Murozi, A.F. M., Ishak, S.Z., Nusa, F.N.M., Hoong, A.P.W., Sulistyono, S., 2022. The Application of International Road Assessment Programme (iRAP) as a Road Infrastructure Risk Assessment Tool. *In:* 2022 IEEE 13th Control and System Graduate Research Colloquium, ICSGRC 2022 - Conference Proceedings, pp. 14–16

Rahmita, D., Malkhamah, S., 2020. The Analysis of Road Safety Assessment with Crash Rates on Pantura Road in Tegal City. *Journal of Civil Engineering and Planning,* Volume 1(1), pp. 74–84

Ryandi, Y., Setyarini, N.L.P.S.E., 2021. The Evaluation of Gatot Subroto Street using iRAP Methods to Achieve Star Rating 4 & 5. *Jurnal Mitra Teknik Sipil,* Volume 4(3), pp. 777–782

Setyarini, N.L.P.S.E., Linggasari, D., Prihatiningsih, A., Arnando, R., 2023. Condition Evaluation of Length Jenderal Sudirman Road Jakarta Using IRAP Method to Achieve Star Rating 4. *In:* AIP Conference Proceedings, Volume 2680(1), p. 020002

Uddin, M.I., Raihan, M.A., 2023. Proactive Safety Assessment of a Road using iRAP Tool: A Case Study. *In:* AIP Conference Proceedings 2023, Volume 2713(1), p. 040012

United Nations, 2022. iRAP: Creating a World Free of High-Risk Roads. Available online at https://sdgs.un.org/partnerships/irap-creating-world-free-high-risk-roads#:~:text=

iRAP%20will%20work%20together%20with%20development%20bank%2C%20government%2C,injuries%20a%20year%20when%20achieved%20by%20all%20countries. Accessed on March 17, 2022

Vadeby, A., 2016. Traffic Safety Effects of Narrow 2+1 Roads with Median Barrier in Sweden. *In:* 17th International Conference, p. 12

Waibl, G., Tate, F., Brodie, C., 2012. Development of a Proactive Road Safety Assessment Tool - KiwiRAP Australasian Road Safety Research. *In:* Policing and Education Conference 2012, Wellington, 4-6 October, New Zealand

WHO, 2021. Global Plan. Decade of Action for Road Safety 2021-2030. Available online at https://www.who.int/teams/social-determinants-of-health/safety-and-mobility/decade-of-action-for-road-safety-2021-2030#:~:text=In%20September%202020%2C%20the%20UN,deaths%20and%20injuries%20by%202030. Accessed on March 17, 2022