Lecture Notes in Civil Engineering

Han Ay Lie · Monty Sutrisna ·
Joewono Prasetijo ·
Bonaventura H.W. Hadikusumo ·
Leksmono Suryo Putranto *Editors*

# Proceedings of the Second International Conference of Construction, Infrastructure, and Materials

## ICCIM 2021, 26 July 2021, Jakarta, Indonesia

Springer

# Lecture Notes in Civil Engineering

Volume 216

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ISSN 2366-2557 ISSN 2366-2565 (electronic)
Lecture Notes in Civil Engineering
ISBN 978-981-16-7948-3 ISBN 978-981-16-7949-0 (eBook)
https://doi.org/10.1007/978-981-16-7949-0



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# Preface

This new volume of Lecture Notes in Civil Engineering contains the proceedings of the Second International Conference of Construction, Infrastructure, and Materials (ICCIM 2021). This book presents the latest development in civil engineering on a global scale. It highlights the conference scopes, such as Structural Engineering, Construction Materials, Geotechnical Engineering, Transportation System and Engineering, Constructions Management, Water Resources Engineering, and Infrastructure Development. The 55 articles published in this book went through peer-review processes double-blindly and plagiarism check. Manuscript assessments by the expert reviewers were based on the organizer's technical criteria, including technical criteria, quality criteria, and presentation criteria.

The Second International Conference of Construction, Infrastructure, and Materials (ICCIM 2021) was hosted by the Civil Engineering Undergraduate Study Program of Universitas Tarumanagara, Indonesia, on 26 July 2021. The conference brought together national and international experts to share their researches, knowledge, and experiences. ICCIM 2021 carried the theme "Research and Technology in Civil Engineering to Enhance the Sustainability of the Built Environment".

Due to the global COVID-19 pandemic, which has impacted all activities globally, ICCIM 2021 was held as an online conference. ICCIM 2021 online conference aimed to capture a broader range of participants. The Conference was also expected to facilitate researchers, practitioners, and students in their respective fields of expertise to share information and exchange ideas about the current state of civil engineering development.

ICCIM 2021 was supported by Massey University, New Zealand; Universiti Tun Hussein Onn Malaysia, Malaysia; Nihon University, Japan; fib Indonesia; Diponegoro University, Indonesia; Soegijapranata Catholic University, Indonesia; Universitas Sebelas Maret, Indonesia; and Universitas Atma Jaya Yogyakarta, Indonesia.

ICCIM 2021 has received papers from various countries, such as Indonesia, Japan, Thailand, the United Kingdom, the United States of America, the

Philippines, India, Nigeria, and Bangladesh. More than 600 researchers, practitioners, and students from all over the world registered to attend the Conference.

We are likewise grateful to the keynote speakers for bringing the exciting topics to ICCIM 2021: Prof. Roesdiman Soegiarso (Universitas Tarumanagara, Indonesia); Prof. Monty Sutrisna (Massey University, New Zealand); Dr.-Ing. Joewono Prasetijo (Universiti Tun Hussein Onn Malaysia, Malaysia); and Dr. Tam Chat Tim (National University of Singapore, Singapore).

We would also like to extend our appreciation to the supporting institutions. Secondly, thank you to the sponsors for the utmost support and kind contribution: PT. Waskita Karya (Persero) Tbk, PT. Pamapersada Nusantara, and PT. Bank Negara Indonesia Tbk.

Many people have worked very hard for the organization of this Conference. Special thanks are needed to the Organizing Committee, Steering Committee, Editorial Board, and Scientific Committee. All of whom have generously worked to make this Conference rich in content and pleasant for the attendees. We would also like to thank all the authors who have contributed to the success of this Conference.

Semarang, Indonesia — Han Ay Lie
Auckland, New Zealand — Monty Sutrisna
Panchor, Malaysia — Joewono Prasetijo
Klong Luang, Thailand — Bonaventura H. W. Hadikusumo
Jakarta Barat, Indonesia — Leksmono Suryo Putranto

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# About the Editors

**Prof. Dr. Han Ay Lie** is working as Professor in the Department of Civil Engineering, Diponegoro University, Indonesia. At present, she is also Chairwoman of the International Federation of Structural Concrete Indonesia (fib-Indonesia). She has also taken the role of external examiner and is Advisor for many national and international universities. Her research interests include graded concrete, fibre-reinforced plastics for concrete, retrofitting and external reinforcing, modeling, and finite element analysis.

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# Dr. Saharjo Road Condition Audit Using IRAP Method to Achieve 3 Star Rating

**Ni Luh Putu Shinta Eka Setyarini and Garry Edison**

**Abstract** Traffic accidents are not just individual tragedies, but they also hinder economic growth, especially in developing countries. Traffic accidents continue to increase every year. One of the reasons is that there are still many roads that haven't applied the principle of safe roads to their design. The increase in traffic accidents shouldn't be underestimated because traffic accidents are predictable and prevented. To reduce the risk of accidents, it is necessary to carry out a strategy to improve road safety using existing methods. One of the methods is International Road Assessment Programme (IRAP) which was used in this study on Dr. Saharjo Road to achieving star ratings 3. From the observation, it was found the existing road conditions were very good for the vehicle occupant it had reached 4 stars, and it was functional for motorcycles and bicycles it had reached 3 stars, but for pedestrians on the road is still lacking in facilities because it only reaches 2 stars. So, it is necessary to do countermeasures through the existing treatment options to increase the star rating to 3 stars in all road users.

**Keywords** Accident · Road safety · IRAP · Dr. Saharjo road

## 1 Introduction

Based on the data received from the police and published by the Ministry of Transportation stated that across 2016 happened as many as 105,374 accident cases caused losses which are estimated to reach 2.9–3.1% of Indonesia's total Gross Domestic Product (GDP) [1]. There is a hypothetical statement that stated a positive relationship between GDP and the traffic accident number that caused death or injury [2]. Along with the increment of traffic accidents in Indonesia, it's harder to achieve good economic growth and development. Therefore, a country from both

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H. A. Lie et al. (eds.), *Proceedings of the Second International Conference of Construction, Infrastructure, and Materials*, Lecture Notes in Civil Engineering 216,
https://doi.org/10.1007/978-981-16-7949-0_24

government and society's point of view, especially in Indonesia, needs to pay more attention and become more responsive in doing preventive and treatment measures to the occurring accident [3].

Indonesia has also done a traffic accident preventive measure by assembling Presidential Instruction Number 4 of 2013 about a safety action program decade, and by forming Government Regulation Number 37 of 2017 about traffic and road transport safety. The inaction of Section 206 Government Regulation Number 37 of 2017, traffic and road transport safety can be done by using road safety improvement strategies approach with some conditions.

A road segment that has a high number of accidents and fatality rate should receive special attention to decrease both the road accident and fatality rate [4] because basically, road accidents are predictable and preventable [5]. To improve road safety, finding and fixing the existing problem is very important to prevent reoccurring accidents in the same spot [6].

To be able to do a preventive and treatment measure also to improve the road safety optimally, road condition assessment is needed for the existing and operational road [7]. It can be done by using the International Road Assessment Programme (IRAP) method to evaluate the accident-prone area in Dr. Saharjo Road, Menteng Atas Village, Setiabudi District, as shown in Fig. 1. IRAP method can give a measurement to the road safety performance from the road infrastructure point of view. IRAP method can also give the needed treatment recommendation based on the generated performance measurement [8].

Based on this description, this research is to conduct a study of road safety evaluation that has been carried out on the main road of Jakarta, namely Jenderal Sudirman Road, using the IRAP method to achieve Star Rating 4 by examining the existing along with road Star Rating. The examined roads and provide input on improving problematic roads. This research has the following objectives:

1. To find out the Safer Road Investment Plan (SRIP) and calculate the existing star rating of Dr. Saharjo Road using the IRAP method.
2. To find out how to reach Star Rating 3 for Dr. Saharjo Road using the IRAP method.
3. To determine the advantages of the IRAP method through the handling and calculation of the Benefit Cost Ratio (BCR).

The benefit of this research is to provide an evaluation of the IRAP method that was implemented in Indonesia, as well as to provide recommendations for how to repair Dr. Saharjo Road Jakarta that was carried out.

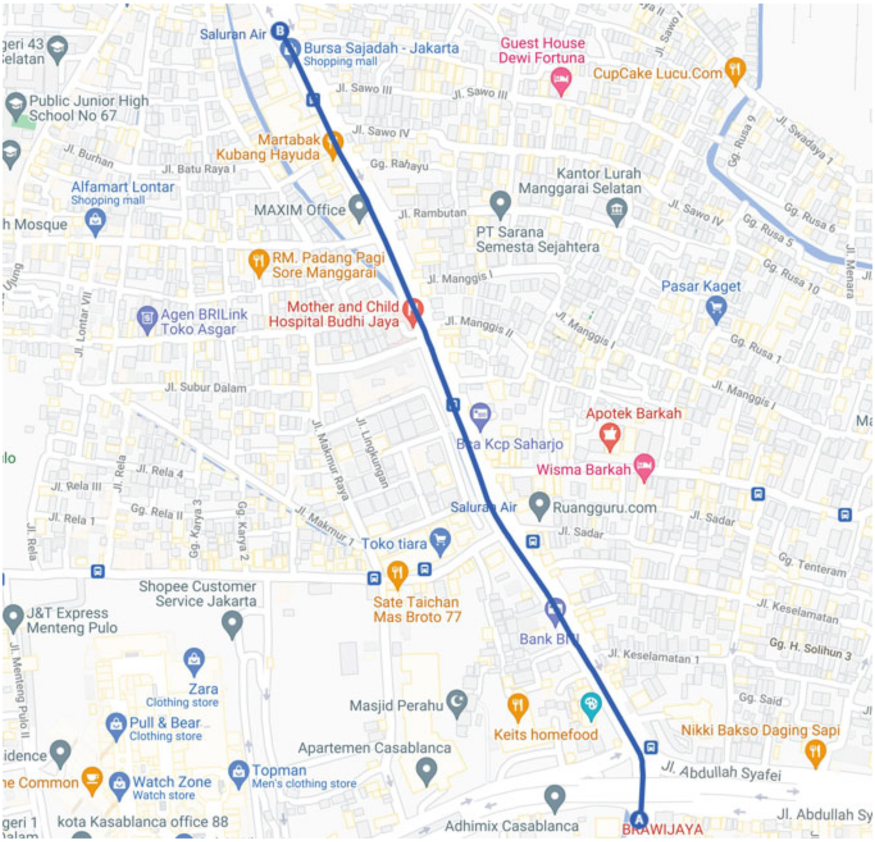


**Fig. 1** Dr. Saharjo road section. *Source* Google Maps

## 2 Literature Review

Traffic safety is a form of effort/method to prevent accidents in the form of security, comfort, and economy in moving cargo (people or goods/animals) by using certain means of transportation through certain media or routes from the location/place of origin to the location/place of destination, travel [9].

Traffic accidents are a negative event of road infrastructure and accidents also pose a risk to the safety of road users which also results in damage to vehicles and goods so that they become material losses [10].

The International Road Assessment Program (IRAP) is a road assessment program developed by an international organization in the field of road safety that has succeeded in developing ways of assessing road safety for road users through determining the value or risk score that may occur due to road infrastructure elements [11]. There are four protocols in IRAP:

1. Risk mappings, which is road risk mapping using detailed accident data to describe the actual number of deaths and injuries on a road segment.
2. Star Rating, which is the performance shown by a road segment to be classified. In a road segment, there are four modes that were assessed for its star rating, namely passenger vehicles, motorbikes, bicycles, and pedestrians. Increase the star rating on a road segment,
3. A safer road investment plan, which is the preparation of a star rating plan for a road segment. To increase the star rating on a road segment, eligible costs (affordable, eligible) were needed so that one alternative it's was chosen from the best planning.
4. Performance tracking, tracking of a road segment which is repeated continuously and re-evaluated.

Road Attribute is an element in a road segment such as markings, signs, geometric, road sections, complementary road buildings, road equipment.

Star Ratings are based on road inspection data and provide simple and objective measures of road elements installed for passenger vehicles, motorcyclists, cyclists, and pedestrians. Roads with a five-star rating are the safest, while roads with a one-star rating are the least secure. Coding the path attribute is at the heart of the IRAP method. The purpose of coding road attributes is to use images from the geometric reference of the road collected during the survey and record the road attributes of each 100 m segment. Risk factors or Crash Modification Factors (CMF) are used in the IRAP method to relate road attributes and accident rates. CMF is a multiplier factor to estimate the number of accidents after a countermeasure is applied to a certain place. A total of 94 precautions/countermeasures can be used in the IRAP method.

IRAP is a method for measuring the road safety rate based on the infrastructure condition and situation also plans a treatment measure to increase the road safety quality that is developed by a Non-Profit Organization. The purpose of having a partnership with a government and non-government organization was to:

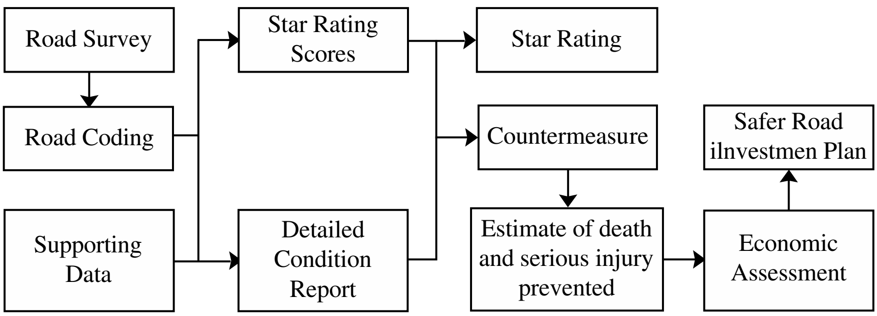


**Fig. 2** IRAP road inspection, star rating, and SRIP

1. Assessing the road with high risk and developing a star rating along with a safer road investment plan as shown in Fig. 2.
2. Giving training, technology, and support that can be built and maintain the national, regional, and local ability.
3. Tracking the road safety performance to ensure the investor can assess potential profit from their investment.
4. Has been implemented in many countries, e.g., Brazil, China, Malaysia, Australia, New Zealand, South Africa, India with a real achievement, including in Indonesia.
5. IRAP could evaluate the countermeasure result by calculating the BCR for it to be compared quantitatively (With currency value).
6. Could calculate the recommended implementation result by taking account of the quantitative decrease in the accident rate.

## 3 Research Methodology

The survey method is direct observation at the location to be reviewed. This method is the primary method of this research which covers many aspects, including geometric, road sections, road markings and signs, road complementary buildings, and road equipment, namely on Jenderal Sudirman Road. Researchers used Google Street View and Google Earth to get the results of the observations and analyze them by the IRAP method. The IRAP method was used to determine and analyze the star rating of the existing roads. In the initial stage, coding is carried out every 100 m road segment according to the Road Attribute form. The attributes reviewed were 78 elements, 66 technical and 12 non-technical. The crash type scores formula can be seen in Eq. 1.

$$\begin{aligned} \textit{Crash Type Scores} = & \textit{Likelihood} \times \textit{Severity} \times \textit{Operating speed} \times \\ & \textit{External flow influence} \times \textit{Median traversability} \end{aligned} \tag{1}$$

Likelihood refers to the risk factors for the road attribute, which take into account the possibility of accidents occurring. Severity refers to the road attribute risk factors that explain the severity of the accident. Operating Speed refers to the factors that describe the extent to which risk changes with speed. External flow influence factors explain the extent to which a person's risk is involved in an accident which is a function of road use. Median traversability factors take into account the potential for a wrong vehicle to cross the median (only applies to collisions of one vehicle and direct collisions of passenger vehicles and motorcyclists).

The SRS represents the relative risk of death and serious injury for individual road users and the value expressed in Eq. 2.

$$SRS = \sum Crash\ Type\ Scores \tag{2}$$

The SRS value was compared with the Star Rating Band table to obtain the Star Rating results, describe in Table 1

Each color represents a star rating as follows: black in sections represents Star Rating 1, red in sections represents Star Rating 2, orange in sections represents Star Rating 3, yellow in sections represents Star Rating 4, and green in sections represents Star Rating 5. Calibration of accident victims is carried out to relate the amount of traffic flow to the types of accidents that may occur on these roads within one year.

Used the formula of CF VO RO-D = calibration factor for vehicles with a single passenger accident (driver's side), n = number of segments per 100 m, SRS VO = Star Rating Score for passenger vehicles, a = AADT multiplier = 1, AADT = average daily traffic average, b = AADT power = 1, Fatality growth = 1. The CF VO RO-D = calibration factor for vehicles with a single passenger accident (driver's side) seen in Eq. 3.

$$CF\ VO{-}ROD = \frac{the\ real\ number\ of\ victims\ dying\ in\ a\ single\ accident\ on\ a\ road\ segment}{\sum_{t=1}^{n}\left(SRSvo \times a(AADT)^{b} \times AADT\ without\ MC \times Fatality\ growth\right)} \tag{3}$$

With Severity Index we can refers and accounted to the road attribute risk factors that explain the severity of the accident seen in Eq. 4.

$$SI = F \times \frac{the\ real\ number\ of\ victims\ who\ injured\ in\ the\ network/area}{the\ real\ number\ of\ victims\ who\ died\ in\ the\ network/area} \tag{4}$$

The next step is calculate FSI total = total number of deaths and serious injuries and calculation of BCR to see the treatment is feasible (BCR value > 1 = feasible), the formula of benefit of the countermeasure can be pictured in Eq. 5.

$$Benefit = FSI\ Saved \times GDP\ per\ capita \tag{5}$$

**Table 1** Star rating band [12]

| Star rating | Star rating score | | |
|---|---|---|---|
| | Vehicle occupants and motorcyclists | Bicyclists | Pedestrians |
| | | | Total |
| 5 | 0 to <2.5 | 0 to <5 | 0 to <5 |
| 4 | 2.5 to <5 | 5 to <10 | 5 to <15 |
| 3 | 5 to <12.5 | 10 to <30 | 15 to <40 |
| 2 | 12.5 to <22.5 | 30 to <60 | 40 to <90 |
| 1 | 22.5+ | 60+ | 90+ |

With FSI Saved = the number of victims who died and serious injuries were spared after treatment; GDP per capita = gross domestic product per capita.

# 4 Analysis and Discussion

## *4.1 Coding of Dr. Saharjo Existing Road Condition Survey Result*

The data that was obtained from the survey through Google Street View and Google Maps was used for coding to obtain Dr. Saharjo's existing road element risk factor. The coding process was done for every 100 m road segment. Table 2 is the coding example for five road attributes and risk factors from the first segment of the existing road.

## *4.2 Initial Score Rating*

To obtain the initial score rating on each road segment, the SRS equation was used. The SRS calculation was done to each road segment, or every 100 m was done based on each road user which is the car, motorcycle, bicycle, and pedestrian. SRS value was adjusted with the risk level, and if the SRS value is high, then the risk level was high, which caused the road to have a low star rating. SRS calculation for vehicle occupant on run-off accident on the Dr. Saharjo Road for every 1 km segment was described in Table 3.

The rating score from the SRS equation used to calculate vehicle occupant, motorcyclist, cyclist, and pedestrian was converted into the star rating range for each road user. The result compilation for all segments is described in Table 4. In segments 1–7 and segment 10, the star rating of the existing road for vehicle occupant, motorcyclist, cyclist, and pedestrian are 4, 3, 3, and 2. That means Dr. Saharjo's existing road safety condition for the vehicle occupant is high, for motorcyclists and cyclist is worthy of usage, and for the pedestrian, it is very bad.

**Table 2** Coding attribute example to obtain the vehicle occupant risk factor

| No. | Attributes | Category | Vehicle Occupant | |
|---|---|---|---|---|
| 1 | Lane width | Narrow ($\geq 0$ to 2.75 m) | 1.1 | 1.1 |
| 2 | Curvature | Straight or gently curving | 1 | 1 |
| 3 | Quality of curve | Adequate | 1 | 1 |
| 4 | Delineation | Poor | 1.2 | |
| 5 | Shoulder rumble strips | Not present | 1.2 | |

**Table 3** Example of the SRS equation for vehicle occupant on run-off accident (driver side)

| Type of risk factor | Category | Risk factor | Score |
|---|---|---|---|
| *Road attribute (likelihood)* | | | |
| Lane width | Narrow ( $\geq$ 0 to 2.75 m) | 1.1 | |
| Curvature | Straight or gently curving | 1 | |
| Quality of curve | Adequate | 1 | |
| Delineation | Poor | 1.2 | |
| Road condition | Medium | 1.2 | |
| Grade | 0 to <7.5% | 1 | |
| Skid resistance/grip | Sealed—medium | 1.4 | |
| Product of road attribute (likelihood) risk factors | | | 2.66112 |
| *Road attribute (severity)* | | | |
| Median type | Physical median width $\geq$ 1.0 m to <5.0 m | 80 | |
| External flow influence | 4221 vehicles/day | | 0.5 |
| Operating speed | 50 km/h | | 0.02 |
| Head-on (loss-of-control) star rating score | | | 2.128896 |

**Table 4** Dr. Saharjo road star rating compilation

| Star rating | | | | | | | | | | Road user |
|---|---|---|---|---|---|---|---|---|---|---|
| Seg. 1 | Seg. 2 | Seg. 3 | Seg. 4 | Seg. 5 | Seg. 6 | Seg. 7 | Seg. 8 | Seg. 9 | Seg. 10 | |
| 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | Vehicle occupant |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | Motorcyclist |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | Bicyclist |
| 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | Pedestrian |

### 4.3 Countermeasure

Countermeasure to improve the star rating to 3 through the existing treatment option. The treatments that were chosen are fences in the median, fences on sidewalks, and speed limit signs. Table 5 is the accident data for vehicle occupant that has been calibrated with star rating score, and Table 6 is the example for treatment on vehicle occupant that shows fatal and injury saved if the treatment was done.

**Table 5** Vehicle occupant FSI crash type

| Crash type | Fatality | Serious injury |
|---|---|---|
| Run-off driver side | 0.0208 | 0.2076 |
| Run-off passenger side | 0.0726 | 0.7265 |
| Head-on lost of control | 0.2767 | 2.7675 |
| Head-on overtaking | 0.0000 | 0.0000 |
| Intersection | 0.0737 | 0.7371 |
| Property accident | 0.0000 | 0.0000 |

**Table 6** Countermeasure for vehicle occupant

| Vehicle occupant | Risk factor | | Accident type | Effectivity (%) | FSI saved |
|---|---|---|---|---|---|
| Countermeasure | Before | After | | | |
| Median type | Median $\geq$ 0 m to < 1.0 m | Safety barier—metal | | | |
| | 90 | 0 | Head-on lost of control | 100 | 3.0442 |
| Road fence | Building | Road fence | | | |
| | 60 | 12 | Run-off passenger side | 80 | 0.6392 |
| Speed limitation signs | None | Exist | | | |
| | 1.25 | 1 | Intersection | 20 | 0.1621 |

## 4.4 *Economic Assessment*

The economic assessment was started with the alternative cost calculation for the road element changes that were done in Table 7.

The treatment cost also needs to be optimized with the budget constrain. BCR calculation was used to find out whether the cost for the treatment has already been optimized. Treatment benefits that can be obtained from the calculation are the reduction in FSI which has been calculated. Treatment cost is calculated based was obtained from data by the Center for National Road Implementation VI.

BCR calculation for treatment measures shows that all of the treatment that was done benefits in the next 20 years as the IRAP recommended. Table 8 shows the countermeasure needs a budget of IDR 8,840,597,002 for a 20-year period that generates a profit from the decrease of road accident rate that has been calculated at IDR 6,058,918,001 for the fence addition in the median along 700 m in the

**Table 7** Draft budget and treatment cost for 20-year period

| Needed treatment | | Unit price (IDR) | Total (IDR) | Cost (IDR) |
|---|---|---|---|---|
| Fence installation on sidewalks | 1000 m | 2,500,000 | 2,500,000,000 | 5,180,240,001 |
| Fence installation in median | 700 m | 2,500,000 | 1,750,000,000 | 3,626,168,001 |
| 40 km/h speed limitation signs | 4 unit | 2,750,000 | 11,000,000 | 22,793,000 |
| 40 km/h end of speed limitation signs | 2 unit | 2,750,000 | 5,500,000 | 11,396,001 |

**Table 8** Benefit of accident treatment on pedestrian for 20 years period

| Countermeasure | Cost (IDR) | Benefit (IDR) | BCR |
|---|---|---|---|
| Median type | 3,626,168,001 | 66,058,918,001 | 18.22 |
| Road fence | 5,180,240,001 | 63,892,866,001 | 12.33 |
| Speed limitation signs | 34,189,001 | 3,945,474,002 | 115.40 |
| Total | 8,840,597,002 | 133,897,258,004 | 15.15 |

20 years, then a profit of IDR 63,892,866,001 for the fence addition on the sidewalk, and a profit of IDR 3,945,474,002. BCR result of 15.15 was obtained for all treatments. With the benefit/cost result is above 1, then the treatment is considered worthy.

## 4.5 Final Score Rating

After the SRS value for each road user on each 100 m road segment was obtain, the SRS value was allocated to the star rating value to determine the star rating for each road segment. Data compilation of initial star rating is shown in Table 9. It can be seen that the road condition which has been countermeasure on each road segment has a star rating increment for the vehicle occupant and pedestrian. It happened because the road elements treatment measure has been rated based on the worthiness standard of the BCR method. With the addition of sidewalks fence, speed limit signs, and fence in road median gives a result which is the achieved star rating for all of the road users are 3 or more, and it made this road became a forgiving road.

**Table 9** Dr. Saharjo road final star rating compilation

| Star rating | | | | | | | | | | Road user |
|---|---|---|---|---|---|---|---|---|---|---|
| Seg. 1 | Seg. 2 | Seg. 3 | Seg. 4 | Seg. 5 | Seg. 6 | Seg. 7 | Seg. 8 | Seg. 9 | Seg. 10 | |
| 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | Vehicle occupant |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | Motorcyclist |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | Bicyclist |
| 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | Pedestrian |

# 5 Conclusion

Based on the data analysis done by using the IRAP method, the conclusion was:

1. From segment 1–6 and 10 in Dr. Saharjo Road Jakarta, star rating 4, 3, 3, and 2 was obtained for the car, motorcycle, bicycle, and pedestrian on the existing and also because of the fence in the median for segment 7–9, star rating for each road user was 5, 3, and 2.
2. Road existing condition for the car has already had a high safety condition, for the motorcycle and bicycle are categorized as worthy of usage, and for the pedestrian still very bad, which is proved by the star rating of 2.
3. For the pedestrian, crossing the road is being reevaluated for its possibility and severeness since it is the most troublesome one. Reevaluation was done in order to increase the star rating to 3 and 4 stars through the existing treatment measure. The pedestrian fence was chosen as the treatment measure because by adding the fence in the median and sidewalk. Hopefully, it decreases the accident possibility for pedestrians.
4. The final star rating in Dr. Saharjo Road after countermeasure was done to the car, motorcycle, bicycle, and the pedestrian is 5, 3, 3, and 4. It means that by the increment of star rating on this road, the accident possibility and fatality decrease.
5. The advantage of using the IRAP method is that issuing recommendations was done by a certain computerized algorithm based on the international applied empiric rules and faster analysis procedure. Also, besides give a treatment recommendation, it also gives a road attribute rating and the benefits after implementation.

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