Determining of black spot location in Purbalingga Regency using road geometric approach

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Abstract. Traffic accidents are still one of the serious problems faced by the Indonesian Government. Based on traffic accident data from Traffic Corps Republic of Indonesia the number of traffic accidents in 2020 is 100,028 incidents and the number of deaths due to accidents is 23,529 people. Traffic accidents are caused by several factors such as vehicles, human error of road users, road conditions and the environment. Road geometry is one factor that contributes to the high value of the risk of accidents. One effort to reduce the number of traffic accidents is identification and handling the black spot location. The purpose of this research was to determine the black spot locations using road geometric facilities. Thus, the black spot location can be predicted before the incidence of a traffic accident occurs through the weighting parameter road geometric. Research was conducted on arterial and collector roads in Purbalingga. Six road geometric parameters are used to determine black spot locations, namely vehicle speed, road lane width, road shoulder width, road pavement width, road median width, and shoulder drop-off (difference in elevation between road shoulder and the pavement edge). Weighting intervals for road geometrics are 1 to 5 with interval 1. As a result of this study, there are differences in the ranking of black spot locations based on the equivalent accident number method and the road geometric parameter approach. The further research is conducted to determine the coefficient value of each road geometric parameter and combined with road equipment facilities.

1. Introduction

According to data released by the United Nations about 1.3 million people every year or about 3,000 people every day die due to traffic accidents. About 90% of deaths due to road accidents occur in developing countries between the ages of 5-44 years. If there are no effective efforts to reduce the number of accidents, deaths from traffic accidents will be the fifth leading cause of death in the world with an estimated number of around 2.4 million deaths every year. According to the Traffic Corps Republic of Indonesia in 2011-2018, the accident rate of 34.48% occurred in the morning and 24.14% in the afternoon. Based on the type of vehicle that had an accident, 52.5% were motorcycles; private cars 20%, trucks 17.5% and buses 10%. Accidents that occur can involve various ages who use the road as an area for activities. On average 20% of people who die in traffic accidents in developing countries are under the age of 15 [1]. The number of traffic accidents in Indonesia in 2020 as many as 100,028 incidents [1]. The same thing happened in Purbalingga Regency, Central Java, Indonesia where the number of traffic accidents increased from 2010 to 2019 [2].
Four factors that caused traffic accidents are vehicles, human error, road conditions and environment [3-4]. From the four factors, human error is a factor that often results in traffic accidents [5]. To minimize the road infrastructure deficiencies, there are three aspects, namely a forgiving road, a self-explaining road, and regulating road [6]. Mobility is one of the components that contribute to traffic accidents [7-9]. Therefore, the road safety model focuses mainly on risk factors [10]. The high number of traffic accidents indicates that there are various factors that cause accidents.

One of the factors that cause traffic accidents is the road, which includes the geometric conditions of the road [11]. Traffic accidents tend to be concentrated on certain roads. Several parameters used to analyze the causes of road accidents are road geometry, driving behavior, weather conditions, and speed limits [12]. This shows that in addition to driver error, road characteristics are also an important factor in the occurrence of traffic accidents. Road safety audit was introduced to handle the black spot location and reduce the severity of crashes, the accident cost [13-14], driving behavior [15], the generalized cost [16-17], and increased efficiency in transportation cost [18-21].

One of the efforts that can be done to reduce the traffic accidents number is by identification and handling the location of black spots. Black spot locations are areas that have a high accident rate, high risk and potential for accidents on a road section [22]. One of the methods to determine the black spot location is using the equivalent accident number and the upper control limit method. However, this method has a weakness, namely that traffic accident-prone locations can be determined after waiting for data on accidents and traffic accident victims [13, 23]. For this reason, a study using another approach is needed. Another method in determining the black sport locations without having to wait for accidents and victims is based on the road geometry facilities approach. The purpose of this research was to determine the black spot locations using road geometric facilities approach. Thus, the black spot location can be predicted before the incidence of a traffic accident occurs through the weighting of parameter road geometric facilities.

2. Method

2.1. Study location
The study was conducted on 10 (ten) arterial and collector roads in Purbalingga Regency, Central Java, Indonesia namely: Serang Village road, Selanegara Village road, Gembong Village road, Mangunegara Village road, Karanganyar Village road, Mayjend Sungkono Street Kalimanah Wetan, Bajong Village road, Bojongsari Village road, Padamara Village road and Tlahab Lor Village road.

2.2. Analysis approach

2.2.1 Equivalent accident number and upper control limit method
Accident data that has been grouped by fatality level then weighted using the equivalent accident number (EAN). The EAN weighting using a weighting formula from Road Research and Development Center Ministry of Public Work Republic of Indonesia [24]. The equivalent accident number with fatal: seriously injured: slightly injured: property damage only = 12:3:3:1 [24]. After being weighted for each level of victim fatality, then the accident equivalent number is total for each road segment.

After obtaining the EAN value for each road section, then calculate the upper control limit (UCL) value for each road section to determine which road sections are categorized as black spot locations. A road segment is declared a black spot location if the EAN value is greater than UCL (EAN > UCL).

2.2.2 Road geometric approach
There are six road geometric parameters used to determine the black spot locations, namely vehicle speed, road lane width, road shoulder width, road pavement width, road median width, and shoulder drop-off. Design speed is the speed chosen for planning purposes for each section of the highway such as horizontal alignment, road slopes, visibility, stopping sight distance and others [25]. The standards
for the six road geometric parameters used refers to Urban Road Geometric RSNI T-14-2004 [26], AASHTO [27], Government regulations Number 34, 2006 [28], and Law of the Republic of Indonesia Number 22 of 2009 concerning Road Traffic and Transportation [29].

Weighting intervals for road geometrics are 1 to 5 with interval 1. In this case, 1 is the best weight where the geometric conditions of the road exist and the size is in accordance with a predetermined standard. While the weight of 5 is the value with the worst condition where the geometric parameter of the road does not exist or the value exceeds the predetermined limit. For example, the vehicle speed, the higher the vehicle speed and the greater the difference with the design speed, the greater the effect on the rate of traffic accidents. This is related to the greater potential for traffic accidents for higher speeds. Mohammed in 2013 examined the effect of road geometric design characteristics on traffic accidents, mentioning several road geometric parameters that can affect traffic safety. The eight geometric parameters that influence the road are speed, lane width, number of lanes, shoulder width and type, median width and type, climbing lane length, access density, and median barrier. A reduction of 1.6 km/h from the average speed will reduce the incidence of injury by about 5%. Wider paths are theoretically associated with higher operating speeds and thus increased security. The more the number of lanes, the higher the traffic accident rate [30].

3. Result and discussion

3.1. Road geometric parameter weighting

The first road geometric parameter was vehicle speed. The vehicle speed used for weighting was based on the 85th percentile speed of all types of vehicles in the field. Five weighting intervals are set based on vehicle speed with a weighting number from 1 to 5, with interval 1. Vehicle speed weighting intervals for arterial and collector roads can be seen in Table 1.

| Interval of vehicle speed for arterial roads (km/h) | Weight | Interval of vehicle speed for collector roads (km/h) |
|--------------------------------------------------|--------|--------------------------------------------------|
| ≤ 60.9                                           | 1      | ≤ 50.9                                           |
| 61-66.9                                          | 2      | 51-55.9                                          |
| 67-72.9                                          | 3      | 56-60.9                                          |
| 73-78.9                                          | 4      | 61-65.9                                          |
| ≥ 79                                             | 5      | ≥ 66                                             |

The second road geometric parameter was the road lane width. The weighting interval was determined based on the difference in the width of the road lane in every 0.20 m multiple of the standard size. Weight 1 is the best weight where the road lane width is in accordance with the regulation standards. The road lane width weighting intervals for arterial and collector roads are presented in Table 2.

| Interval of road lane width for arterial roads (m) | Weight | Interval of road lane width for collector roads (m) |
|--------------------------------------------------|--------|--------------------------------------------------|
| ≥ 3.50                                           | 1      | ≥ 3.00                                           |
| 3.30-3.49                                        | 2      | 2.80-2.99                                        |
| 3.10-3.29                                        | 3      | 2.60-2.79                                        |
| 2.90-3.09                                        | 4      | 2.40-2.59                                        |
| ≤ 2.90                                           | 5      | ≤ 2.39                                           |

The third geometric parameter of the road was the shoulder width. The weighting interval was determined based on the difference in the width of the road shoulder compared to the standard shoulder width. Weight 1 is the best weight where the road shoulder width is in accordance with the
standard. The shoulder width weighting interval is divided into two conditions, namely for roads with sidewalks and roads without sidewalks for both arterial and collector roads as presented in Table 3.

| Interval of shoulder width weighting intervals for arterial and collector roads with sidewalks (m) | Weight | Interval of shoulder width weighting intervals for arterial and collector roads without sidewalks (m) |
|---|---|---|
| ≥ 0.25 | 1 | ≥ 2.00 |
| 0.15-0.249 | 2 | 1.20-1.999 |
| 0.10-0.149 | 3 | 0.80-1.199 |
| 0.05-0.099 | 4 | 0.40-0.799 |
| < 0.049 | 5 | < 0.399 |

The fourth road geometric parameter was the width of the sidewalk. The weighting interval was determined based on the difference between the width of the sidewalk and the width of the standard sidewalk. The weight of 1 is the best weight where the pavement condition is in accordance with the standard rules, while the weight that is worth 5 is the worst weight where the road segment does not have a sidewalk or sidewalk width is < 0.299 m. The weighting intervals for the sidewalk width for arterial and collector roads can be seen in Table 4.

| Interval of sidewalk width for arterial roads (m) | Weight | Interval of sidewalk width for collector roads (m) |
|---|---|---|
| ≥ 1.50 | 1 | ≥ 1.50 |
| 0.90-1.499 | 2 | 0.90-1.499 |
| 0.60-0.899 | 3 | 0.60-0.899 |
| 0.30-0.599 | 4 | 0.30-0.599 |
| < 0.299 | 5 | < 0.299 |

The fifth road geometric parameter was the median width. The weighting interval was determined based on the difference in the road median width compared to the standard median width. Weight 1 is the best weight where the median width of the road is in accordance with the standards. The median width weighting intervals for arterial and collector roads can be seen in Table 5.

| Interval of median width for arterial roads (m) | Weight | Interval of median width for collector roads (m) |
|---|---|---|
| ≥ 2.50 | 1 | ≥ 1.50 |
| 1.50-2.49 | 2 | 0.90-1.49 |
| 1.00-1.49 | 3 | 0.60-0.89 |
| 0.50-0.99 | 4 | 0.30-0.59 |
| < 0.499 | 5 | < 0.299 |

The sixth road geometric parameter was the shoulder drop-off (elevation difference between road shoulder and pavement edge). The weighting interval was determined based on the difference in elevation difference for each increment of 4 cm. Weight 1 is the best weight where the difference in elevation between the road shoulder and the edge of the pavement is < 1.99 cm. The elevation difference weighting intervals between the shoulder and the pavement edge for arterial and collector roads are presented in Table 6.
natural factors, for example when it rains, will also affect the amount of vehicle speed chosen by the driver and the vehicle speed limit [32]. Operating speed has a significant contribution to the total number of crashes [33]. Tarko in 2009 examined the impact of speed on driving behavior [15]. The effect of speed on travel time by Nilsson in 1991 [5] and the determination of the maximum speed value on urban roads [34]. The road pavement type affects the road roughness value [35]. Road safety strategies potentially are improved by applying the system theory and safety models [7].

| Name of road                        | Equivalent Accident Number | Upper Control Limit |
|-------------------------------------|-----------------------------|---------------------|
| Tlahab Lor Village Road, Karangreja| 168                         | 40.549              |
| Bojongsari Village Road, Bojongsari| 126                         | 37.813              |
| Serang Village Road, Karangreja     | 96                          | 34.806              |
| Mangunegara Village Road, Mrebet    | 87                          | 34.374              |
| Mayjend Sungkono Street Kalimanah Wetan | 75                  | 33.169              |
| Gembong Village Road, Bojongsari    | 75                          | 33.169              |
| Selanegara Village Road, Kaligondang| 75                          | 32.749              |
| Karanganyar Village Road, Karanganyar| 72                          | 32.853              |
| Padamara Village Road, Padamara     | 69                          | 32.531              |
| Bajong Village Road, Bukateja       | 63                          | 31.447              |

3.3. Black spot location based on road geometric approach

The results of the research, the ranking of black spot locations based on the weighting of the equivalent accident number-upper control limit method and the road geometric parameter method was different. It can be seen that the order of black spot locations tends to be not much different between two methods. For comparison, Tlahab Lor Village Road ranks first based on the EAN-UCL method with a total weight value of 168. Meanwhile, based on the road geometric parameter method, also the first ranks with a total weight value of 22. The maximum value for all parameters is 30. Meanwhile, Bajong Village Road which ranks 10th in the EAN-UCL method, changes to the 9th in the road geometric parameter.

There are several other factors that have a major influence on the occurrence of accidents on several roads which cause inconsistency of ranking results on several roads with both methods. The severity of traffic accident victims is also influenced by natural factors. The result of this study is relevant with the study of Shaheed et al that the driver's visibility, road surface conditions [31]. Natural factors, for example when it rains, will also affect the amount of vehicle speed chosen by the driver and the vehicle speed limit [32]. Operating speed has a significant contribution to the total number of crashes [33]. Tarko in 2009 examined the impact of speed on driving behavior [15]. The effect of speed on travel time by Nilsson in 1991 [5] and the determination of the maximum speed value on urban roads [34]. The road pavement type affects the road roughness value [35]. Road safety strategies potentially are improved by applying the system theory and safety models [7].

| Table 6. Shoulder drop-off weighting interval for arterial and collector roads |
|---------------------------------|-------------------|-------------------|
| Interval of drop-off (elevation difference between road shoulder and pavement edge) for arterial roads (cm) | Weight | Interval of drop-off (elevation difference between road shoulder and pavement edge) for collector roads (cm) |
| < 1.99                           | 1                 | < 1.99            |
| 2.0-5.99                         | 2                 | 2.0-5.99          |
| 6.0-9.99                         | 3                 | 6.0-9.99          |
| 10-13.0                          | 4                 | 10-13.0           |
| > 13.0                           | 5                 | > 13.0            |

3.2. Black spot location based on EAN-UCL

The analysis results of the equivalent accident number and upper control limit values for ten roads in Purbalingga Regency, Central Java which are as black spot locations are shown in Table 7.

Table 7. Equivalent accident number and upper control limit values for ten roads

| Name of road                        | Equivalent Accident Number | Upper Control Limit |
|-------------------------------------|-----------------------------|---------------------|
| Tlahab Lor Village Road, Karangreja| 168                         | 40.549              |
| Bojongsari Village Road, Bojongsari| 126                         | 37.813              |
| Serang Village Road, Karangreja     | 96                          | 34.806              |
| Mangunegara Village Road, Mrebet    | 87                          | 34.374              |
| Mayjend Sungkono Street Kalimanah Wetan | 75                  | 33.169              |
| Gembong Village Road, Bojongsari    | 75                          | 33.169              |
| Selanegara Village Road, Kaligondang| 75                          | 32.749              |
| Karanganyar Village Road, Karanganyar| 72                          | 32.853              |
| Padamara Village Road, Padamara     | 69                          | 32.531              |
| Bajong Village Road, Bukateja       | 63                          | 31.447              |
The result of the study is similar to Aljanahi et al. stated that road crashes are influenced by many factors such as road geometric design, traffic volume, vehicles speed, weather, driver's physical and mental conditions [36]. For two-lane rural highways, there is a relationship between geometric design consistency and road accidents in homogeneous traffic conditions [37]. The factors that affect the safety performance of the horizontal curve include: traffic volume, geometric features of the curves, cross section, roadside hazards, stopping sight distance, coordination between horizontal and vertical alignment, distance between curves, pavement friction and traffic control devices [38]. Super elevation, degree of curve, shoulder width and average daily traffic also contributes to road crashes [38-39]. Accident rate in horizontal curves increases monotonically and at an accelerating rate as curve radius is reduced [40]. According to AASHTO, factors that influence the safest speed depends on design features, conditions of road, traffic volumes, cross-traffic volumes, weather conditions, roadside development, spacing of intersecting roads and other factors [41-42].

In the other study, arterial roads with heavier traffic volumes and higher speed limits tended to have more severe crashes. Medians were helpful in reducing the severity of crashes [43] and reducing crash rate up to 15% [44-45]. The lower roadside hazard rate decreases the risk of more severe crashes.

| Name of road                          | Road function | Vehicle speed (km/h) | Lane width (m) | Shoulder width (m) | Sidewalk width (m) | Median width (m) | Drop-off (cm) | Total weight |
|---------------------------------------|---------------|----------------------|----------------|-------------------|-------------------|-----------------|--------------|-------------|
| Tlahab Lor Village Road, Karangreja   | Collector road| 46.00                | 3.40           | 0                 | 0                 | 0               | 44.00        |             |
| Weight                               |               | 1                    | 1              | 5                 | 5                 | 5               | 2            |             |
| Bojongsari Village Road, Bojongsari   | Collector road| 51.00                | 4.00           | 1.00              | 0                 | 0               | 13.00        |             |
| Weight                               |               | 2                    | 1              | 3                 | 5                 | 5               | 4            | 20          |
| Serang Village Road, Karangreja       | Collector road| 56.00                | 1.99           | 1.50              | 0                 | 0               | 0            |             |
| Weight                               |               | 3                    | 5              | 2                 | 5                 | 5               | 1            | 21          |
| Mangunegara Village Road, Mrebet      | Collector road| 52.00                | 4.00           | 1.00              | 0                 | 0               | 8.00         |             |
| Weight                               |               | 2                    | 1              | 3                 | 5                 | 5               | 3            | 19          |
| Mayjend Sungkono (to Purbalingga)     | Secondary arterial | 50.00             | 2.70           | 0.55              | 0                 | 1.50            | 6.00         |             |
| Weight                               |               | 1                    | 5              | 4                 | 5                 | 2               | 2            | 19          |
| Gembong Village Road, Bojongsari      | Collector road| 57.00                | 4.00           | 1.30              | 0                 | 0               | 11.00        |             |
| Weight                               |               | 3                    | 1              | 2                 | 5                 | 5               | 3            | 19          |
| Selanegara Village Road, Kaligondang  | Collector road| 53.00                | 3.30           | 0.85              | 0.91              | 0               | 1.00         |             |
| Weight                               |               | 2                    | 1              | 1                 | 2                 | 5               | 1            | 12          |
| Karanganyar Village Road, Karanganyar  | Collector road| 56.00                | 2.20           | 1.80              | 0                 | 0               | 0.00         |             |
| Weight                               |               | 3                    | 5              | 2                 | 5                 | 5               | 1            | 21          |
| Padamara Village Road, Padamara       | Collector road| 49.00                | 3.00           | 0.50              | 0                 | 0               | 7.00         |             |
| Weight                               |               | 1                    | 1              | 4                 | 5                 | 5               | 2            | 18          |
| Bajong Village Road, Bukateja         | Arterial road  | 58.00                | 3.50           | 2.00              | 0                 | 0               | 4.00         |             |
| Weight                               |               | 1                    | 1              | 1                 | 5                 | 5               | 2            | 15          |
The horizontal curve and its degree of curvature must be considered when predicting the total crash frequency on horizontal curves [47]. In the other study, the shoulder width had a significant effect on actual speed and on perceived safe driving speed, but only when a guardrail was present [48].

4. Conclusion and further research

Based on the results of study determining the black spot locations using road geometric facilities approach, the following conclusion can be drawn:

a. Six road geometric parameters are used to determine the black spot locations, namely vehicle speed, road lane width, road shoulder width, road pavement width, road median width, and shoulder drop-off (the difference in elevation between road shoulder and the pavement edge).

b. There are differences in the ranking of black spot locations based on the equivalent accident number method and the road geometric parameter approach.

In the further research is conducted to determine the coefficient value of each road geometric parameter and combined with road equipment facilities.

Acknowledgments

“The authors fully acknowledged the Ministry of Education, Culture, Research and Technology Republic of Indonesia for the approved fund the Basic Research in 2021 which makes this important research viable and effective”.

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