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STRATEGIES FOR HANDLING BLACK SPOT AREA TO INCREASED ROAD SAFETY

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ABSTRACT

The deficiency of road infrastructure reduces or decreases its efficiency, thereby, resulting in inadequate functioning, capable of triggering traffic accidents. This is also one of the major causes of traffic accident on roads. Interaction between human errors and road infrastructure cause road traffic accident 34%. Road accidents are not only caused by the condition of vehicle and driver, but also due to many factors, including its design (horizontal and vertical alignments), preceding and stop sight distance, pavement conditions, and completeness of road equipment facilities. The aim of this research was analyzing road infrastructure deficiency at black spot area to increased road safety. The study location was in Brobot Street, Bojongsari, Purbalingga and Central Java, Indonesia. Three parameters that analyzed in road infrastructure deficiency i.e.: condition of road geometric, condition of road pavement, and harmonization of road equipment facilities. The result showed that some road infrastructures must be repaired to reduce traffic accidents. Road geometric aspect involves the shoulder width, (improve the shoulder to 1.5 m wide), while its pavement condition involve lane or shoulder drop off. To harmonize these inconsistencies equipment such as install maximum speed limit sign (40 km/h), warning sign along black spot location should be perfectly located along these roads and install traffic sign.

Keywords: infrastructure deficiency, traffic safety, black spot area, traffic accident, road safety audit.

INTRODUCTION

Road accidents are not only caused by the condition of vehicle and driver, but also due to many factors, including its design (horizontal and vertical alignments), preceding sight distance, stop sight distance, pavement conditions, and completeness of road equipment facilities. To minimize the deficiency of road infrastructure, there are three aspects namely forgiving road environment, self-explaining road, and self-regulating road [1].

More than 1.2 million people die worldwide as a result of road traffic crashes [2]. Traffic accidents occur due to several problems related to the management of road infrastructure, and deficiencies in safety. Therefore, it is important to develop a suitable road transport infrastructure as its [3-4]. Deficiency reduces or decreases its function thereby, making it potential accidents. Road Safety Audit (RSA) is based on accident data and direct measurements in the field of geometric and visibility deviations, conditions of pavement damage, and disharmony of equipment facilities for the proper functioning of these roads [5]. Road safety audit appears to be an ideal tool for improving the road safety [6].

Mobility is one of components that contribute to crashes [7-9], therefore, influential road safety models are focused mainly on risk [10]. Road safety strategies could be improved by applying system theory [11-12] and information from other safety models [13]. In addition, influential road safety visions are critical to its improvement [10]. The operational and management characteristics associated with reduced crash and injury risk include: safety training, management commitment, scheduling or journey planning, freight type, worker participation, incentives and safety policies [14].

Brobot Street, Bojongsari, Purbalingga, Central Java is the highest ranked road with traffic accidents in Purbalingga with 10 cases of accident leading to 17 deaths, a seriously-injured person, and 7 slightly-injured people. From 1 January 2014 to 31 December 2018 there are 2,609 traffic accident, 532 deaths, 7 seriously-injured people, and 3,672 slight-injured people, and IDR 1,782.05 million [15].

The aim of this research was analyzing road infrastructure deficiency at black spot area to increased road safety in Purbalingga District, Central Java, Indonesia.

To determine the existing conditions of roads based on type, and level of damage using the Pavement Condition Index (PCI) developed by the United States Army Corps of Engineers. PCI is a numerical index between 0 for failed and 100 for excellent pavement conditions [16]. When it is between 0-10, is categorized as failed, 11-25 serious, 26-40 very poor, 41-55 poor, 56-70 fair, 71-85 satisfactory, and 86-100 good or excellent pavement conditions. The Pavement Condition Index (PCI) rating range is shown in Figure-1.

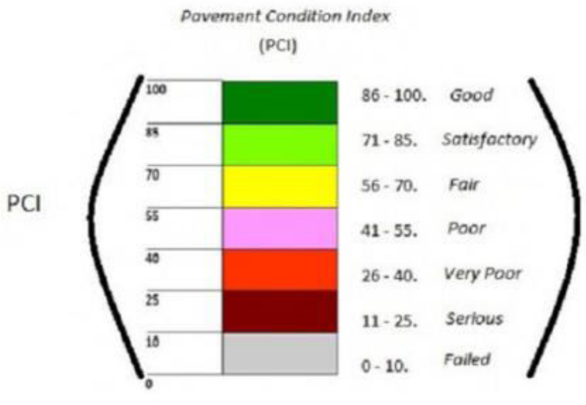

Figure-1. Scoring scale of pavement condition index [16].

Severity level and pavement condition index (PCI)

a) Density

Density is the percentage of the type of road damage to area of a unit segment measured in squared meters (m^2) or meters in length. With the damage type value distinguished based on its level. Density value equation is:

Density = (A_d/A_s) x 100% or
Density = (L_d/A_s) x 100% (1)

With A_d is total area of damage for each level of damage in (m^2), L_d is total length of damage for each level of damage in meter (m) and A_s is total unit area in squared meters (m^2).

b) Deduct value (DV)

Deduct value is the type of road damage obtained from the density and relationship curves. It is divided into the level and types of damages.

c) Total deduct value (TDV)

Total deduct value is value of the individual reduction for each type of road damage and the level present in a unit of the study sample.

d) Corrected deduct value (CDV)

Corrected deduct value is obtained from the curve of the relationship between TDV and CDV [16]. The curve selection according to the number of individual deducts is greater than 2. The CDV is seen in Figure-2. Assuming its value is known, and then each unit can be determined using Equation 2 and Equation 3 as follows:

$$PCI_{(s)} = 100 - CDV \quad (2)$$

With $PCI_{(s)}$ is pavement condition index for each unit and CDV is corrected deducting value for each unit.

$$PCI = \sum PCI_{(s)} / N \quad (3)$$

With PCI is pavement condition index value for all pavements, $PCI_{(s)}$ is pavement condition index for each unit and N is number of each unit.

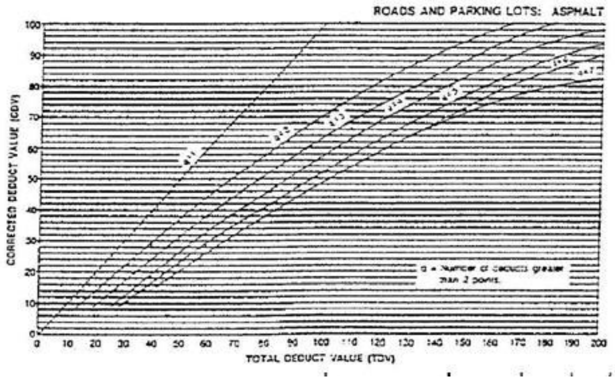

Figure-2. The relationship between TDV and CDV [16].

METHODS

The study location

The study location was in Brobot Street, Bojongsari, Purbalingga, Central Java, Indonesia.

Data collection and analysis

Traffic accident data from Purbalingga Police from 1 January 2016 to 31 December 2018 [15] was used to determine the black spot location using the equivalent accident number and Upper Control Limit (UCL) method [17-19]. The weightage accident number is 12 for death victims or fatality (FAT), 3 for a severe injury (SVI), 3 for minor injuries (MNI) and 1 for property damaged only (PDO) [17].

Lane and shoulder width of roads are obtained using walking wheel tape measure, while the condition of asphalt pavement surface, longitudinal and transverse cracking and lane or shoulder drop off were acquired based on field observation. Vehicle speeds of passenger car, microbus, large bus, truck, and motorcycle were obtained in the field using speed gun. The statistical analysis of vehicle speeds results, include the mean, the amount of data, minimum and maximum for each type of vehicles. Stop sight distance and preceding sight distance measured based on the design speed, PIEV time, gravitation acceleration, and coefficient of friction. Stop sight distance (Js) is the minimum distance needed by each driver to stop the vehicle safely when he sees any obstacles [20].

$$Js = \frac{V_R}{3.6}T + \frac{\left(\frac{V_R}{3.6}\right)^2}{2gf} \quad (4)$$

With V_R is design speed in km/h, T is PIEV time (2.5 second), g is gravitation acceleration (9.8 m/s^2) and f is coefficient of friction for flexible pavement (0.35-0.55).

Preceding sight distance (Jd) is the distance that allows a vehicle to passing vehicle in front of it safely until the vehicle returns to its original lane [20]. Preceding sight distance (J_d) in meter can be determined using Equation 5.

$$Jp = d_1 + d_2 + d_3 + d_4 \quad (5)$$

With:

d_1 = distance traveled during response time or PIEV time (m).

d_2 = the distance traveled to passing vehicle and return to its lane (m).

d_3 = the distance between the vehicle that precedes the vehicle coming from the opposite direction after the passing vehicle process is finished (m).

d_4 = the distance traveled by a vehicle coming from the opposite direction, the amount taken is equal to 2/3 d_2 (m).

RESULTS AND DISCUSSIONS

Road geometric condition and vehicle speed

a. Road geometric condition

Brobot Street, Bojongsari, Purbalingga based on the rooad function is collector road with double lanes 2 way without median (2/2 UD). Its width is 8.00 m with a shoulder width of 100 cm. Furthermore, its lane shoulder drop off is 7.50 cm on the left and 8 cm on right. Based on Standard Geometric Design for Rural Road, minimum shoulder width is 150 cm and road width is 6.00 m [21].

b. Vehicle speed, stop and preceding sight distance

Vehicles speed data in Brobot Street, Bojongsari, Purbalingga was distributed into four types of vehicles namely motorcycles, passenger cars, microbus, and large bus and trucks. Stop sight distance and preceding sight distance are measured based on the design speed and the vehicle's maximum speed in the field [22]. The maximum speed limit of vehicles in Brobot Street, Bojongsari, Purbalingga is 40 km/h. The number of vehicles has taken as many as 110 vehicles (40 motorcycles users, 30 passenger car users, 10 microbus and 30 large bus and truck), with an S-curve of vehicle speed as shown in Figure-3. Based on Figure-3, it can be seen that 100% of passenger cars users and motorcycle users exceed the maximum speed limit in the field is 40 km/h, 80% microbus and 73.33% large bus and truck exceed the maximum speed limit in the field.

Based on survey in the field using speed gun Bushnell, maximum speed of motorcycles is 78 km/h, passenger car is 67 km/h, microbus is 50 km/h, large bus and trucks are 53 km/h. The maximum speed of all type vehicles in Brobot Street, Bojongsari is 78 km/h. In traffic safety, speed is the main risk factors for the occurrence of crashes [23-25]. The average speed of motorcycle at 61.2 km/h, passenger car at 55.1 km/h, microbus at 45.7 km/h, large bus and truck at 43.8 km/h. While the average speed those of 110 vehicles are 53.4 km/h. The statistical analysis of vehicle speeds results, include the mean, mode, median, variance, standard deviation, the amount of data, and 15th, 50th, 85th, and 98th percentiles for each type of vehicles and total vehicles shown in Table-1.

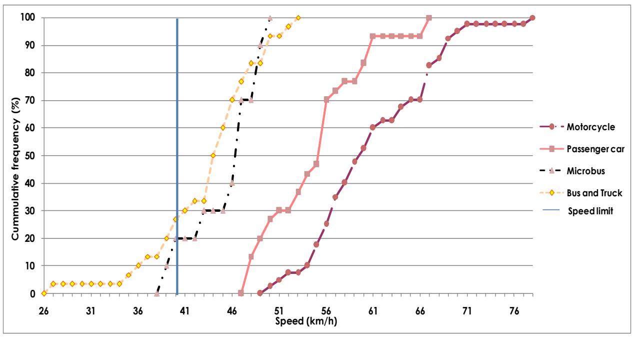

Figure-3. S-curve of vehicle speed in Brobot Street, Bojongsari, Purbalingga.

The stop sight distance and preceding sight distance for each vehicle in Brobot Street is follows:

a) Stop sight distance of motorcycle is 122.60 m and the preceding sight distance of motorcycle is 480.61 m.

b) Stop sight distance of passenger cars is 97.02 m and preceding sight distance of passenger cars is 394.06 m.

c) Stop sight distance of microbus is 62.84 m and preceding sight distance of microbus is 274.48 m.

d) Stop sight distance of large bus and trucks is 68.4 m and preceding sight distance of large bus and trucks is 294.33 m.

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Table-1. Characteristics and statistical analysis of vehicle speed in Brobot Street, Bojongsari, Purbalingga.

Statistical analysis		Motor cycle	Passenger car	Micro-bus	Large Bus and Truck	Total
Mean (km/h)		61.2	55.1	45.7	43.8	53.4
Modus (km/h)		67.0	56.0	47.0	44.0	56.0
Median (km/h)		60.0	56.0	47.0	44.5	54.0
Variance (km/h)		39.9	27.9	14.5	30.9	85.0
Standard dev. (SD)		6.3	5.3	3.8	5.6	9.2
Amount of data (n)		40	30	10	30	110
Minimum speed (km/h)		50	48	39	27	27
Maximum speed (km/h)		78	67	50	53	78
Percentile (km/h)	15	55.0	49.0	41.1	39.0	44.0
	50	60.0	56.0	47.0	44.5	54.0
	85	68.2	60.7	49.0	49.3	63.3
	98	72.5	67.0	49.8	52.4	69.8

Road pavement condition

a. Longitudinal and transverse cracking

Longitudinal and transverse cracking occurs extensively in single or parallel and sometimes slightly branched road pavements. In Brobot Street, Bojongsari, Purbalingga along 300 m, the total longitudinal crack length is 42 m with the width crack less than 5 mm, which is classified as a low severity level (L). PCI values for longitudinal and transverse cracking in Brobot Street are determined as follows:

a) Density = {(42) / (8.0 x 300)} x 100% = 1.75%.

b) From Figure-4, the relationship curve between distress density and deduct value for longitu-dinal/transverse cracking, with a density 1.75% and the width crack les than 5 mm is classified as a low severity level of damage (L) of 5.

c) On a 300 m road section reviewed not divided into several unit segments (q = 1), so the total deduct value is 5.

d) From Figure-5, the relationship curve between total deduct value and corrected deduct value (CDV), the total deduct value 5 and q = 1 is 6.

e) PCI = 100 - CDV = 100 - 6 = 94. The pavement condition index for longitudinal and transverse cracking in Brobot Street is 94. It is classified in good condition.

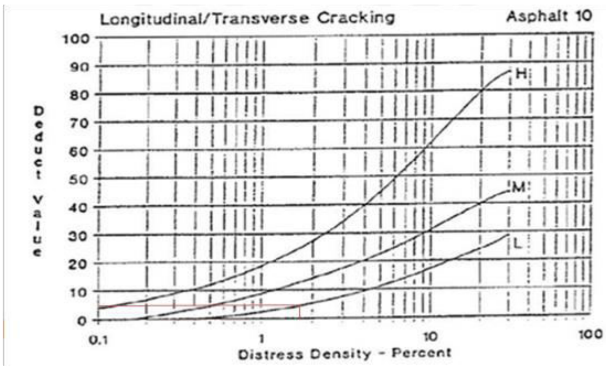

Figure-4. The relationship curve between distress densities and deduct value for longitudinal and transverse cracking.

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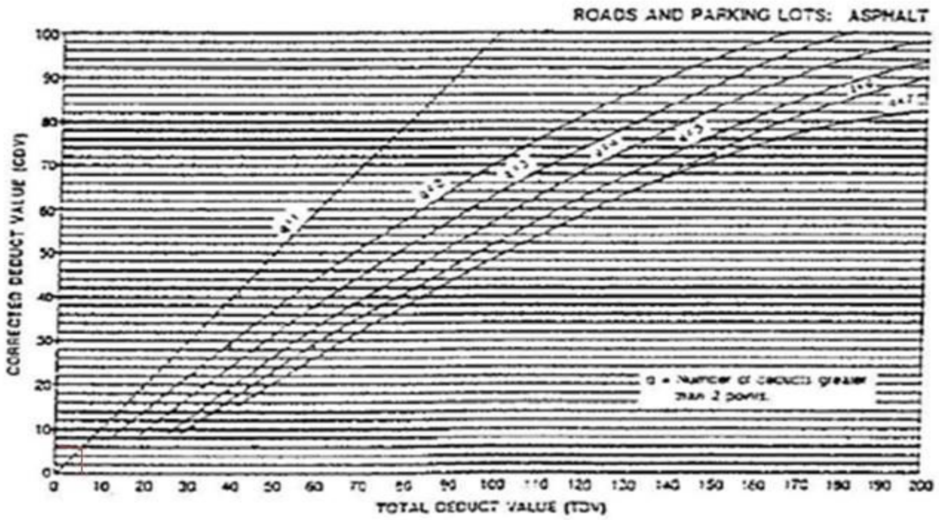

Figure-5. The relationship curve between total deduct value and corrected deduct value.

b. Lane or shoulder drop off

Shoulder drop off is the elevation difference between the pavement edge and the road shoulder. In Brobot Street, Bojongsari position of road shoulder elevation toward pavement edge elevation is 8 cm on right side, which is classified as medium severity level (M).

a) Density = {(300) / (8.0 x 300)} x 100% = 12.50%.
b) From Figure-6, the relationship curve between distress density and deduct value for lane or shoulder drop off, the deduct value with a density 12.50% (the highest density value is 15%) and medium severity level (M) of 23.
c) On 300 m road section reviewed not divided into several unit segments (q=1), total deduct value 23
d) From Figure-5, the corrected deduct value with total deduct value 23 and q = 1 is 23.
e) PCI = 100 - CDV = 100 - 23 = 77. The pavement condition index for lane or shoulder drop off in Brobot Street is 77. PCI is classified in satisfactory condition.

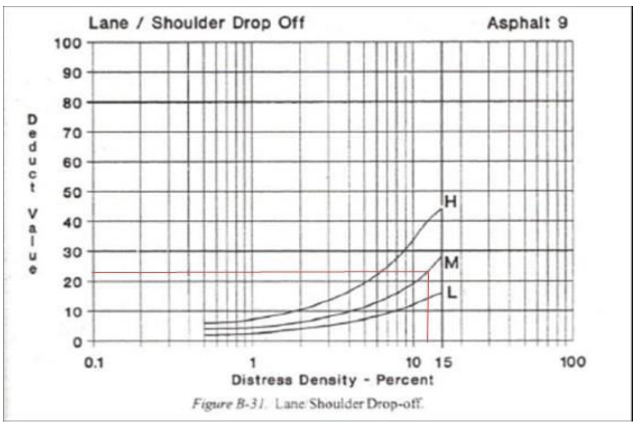

Figure-6. The relationship curve between distress density and deduct value for lane or shoulder drop off.

Road equipment facilities

The road markings on Brobot Street, Bojongsari, Purbalingga are quite good with the dashed longitudinal markers and full markings of the solid line visible. Street lighting is sufficient with the average distance between lighting lamps in the field 50 m, the standard requirements for street lighting are 48 m. Traffic signal, curve direction, and warning sign are very lack with standard sign of Ministry of Transportation Republic of Indonesia PM No. 13, 2014 [26]. While the standard of road marking is Ministry of Transportation Republic of Indonesia PM No. 67, 2018 [27]. Number of night accidents was correlated with substandard illuminance and traffic flow [28] and road user attitude [29].

Road safety audit

Three parameters that analysed in road safety audit in black spot area include road geometric condition, road pavement condition, and harmonization of road equipment facilities. In road geometric, four parameters analysed namely stop sight and preceding sight distance, as well as lane, and shoulder width [30]. Analysis of safety deficiencies of road infrastructure for pavement condition covers two aspects namely rutting and lane or shoulder drop off. Harmonization of road equipment facilities includes speed limit sign, curve direction sign, warning sign, signal, road markings, and lightning. Based on Law Republic of Indonesia No. 22, 2009 (Traffic and Land Transport), traffic accident is classified in three categories, fatal accidents, severe accidents, and slightly or minor accidents [31]. The result of measurement and field observation of the road geometric condition, road pavement condition, and harmonization of road equipment facilities and severity rates of casualties can be seen in Table-2 and the result of the road safety audit on infrastructure deficiencies and the recommendations to increased road safety in Brobot Street, Bojongsari, Purbalingga can be seen in Table-3.

Table-2. Result of measurements and field observations of the geometric conditions, road pavement condition, and harmonization of road equipment facilities and severity rates of casualties in Brobot Street, Bojongsari, Purbalingga.

<table>
<tr><th>No.</th><th>Aspect (unit)</th><th>Standard</th><th>Measurement results</th><th>Deviation (%)</th><th>Fatality</th><th>Severe injured</th><th>Minor injured</th></tr>
<tr><td>I.</td><td colspan="7">Road geometric condition</td></tr>
<tr><td>1.</td><td>Stop sight distance of motorcycle (m)</td><td>75</td><td>122.60</td><td>63.47</td><td>0</td><td>0</td><td>2</td></tr>
<tr><td></td><td>Stop sight distance of passenger car (m)</td><td>75</td><td>97.02</td><td>29.36</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td></td><td>Stop sight distance of micro bus (m)</td><td>75</td><td>62.84</td><td>-16.21</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td></td><td>Stop sight distance of bus and truck (m)</td><td>75</td><td>68.40</td><td>-8.80</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>2.</td><td>Preceding sight distance of motorcycle (m)</td><td>350</td><td>480.61</td><td>37.32</td><td>5</td><td>0</td><td>3</td></tr>
<tr><td></td><td>Preceding sight distance of passenger car (m)</td><td>350</td><td>394.06</td><td>12.59</td><td>3</td><td>1</td><td>1</td></tr>
<tr><td></td><td>Preceding sight distance of micro bus (m)</td><td>350</td><td>274.48</td><td>-21.58</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td></td><td>Preceding sight distance of bus and truck (m)</td><td>350</td><td>294.33</td><td>-15.91</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>3.</td><td>Lane width of road (m)</td><td>3.00</td><td>4.00</td><td>-33.33</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>4.</td><td>Road shoulder width (m)</td><td>1.50</td><td>1.00</td><td>33.33</td><td>2</td><td>0</td><td>0</td></tr>
<tr><td>II.</td><td colspan="7">Road pavement condition</td></tr>
<tr><td>1</td><td>Longitudinal and transverse cracking</td><td>85</td><td>94</td><td>-10.59</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>2.</td><td>Lane or shoulder drop off (PCI)</td><td>85</td><td>77</td><td>9.41</td><td rowspan="2">3</td><td rowspan="2">0</td><td rowspan="2">1</td></tr>
<tr><td></td><td>Lane or shoulder drop off (cm)</td><td>< 1 cm</td><td>8 cm</td><td>700</td></tr>
<tr><td>III.</td><td colspan="7">Harmonization of road equipment facilities</td></tr>
<tr><td>1.</td><td>Number of speed limit sign[1)]</td><td>1</td><td>0</td><td>100</td><td rowspan="2">2</td><td rowspan="2">1</td><td rowspan="2">2</td></tr>
<tr><td></td><td>Speed limit sign condition (%)</td><td>100</td><td>0</td><td>100</td></tr>
<tr><td>2.</td><td>Number of curve direction sign</td><td>3</td><td>0</td><td>100</td><td rowspan="2">0</td><td rowspan="2">0</td><td rowspan="2">3</td></tr>
<tr><td></td><td>Curve direction sign condition (%)</td><td>100</td><td>0</td><td>100</td></tr>
<tr><td>3.</td><td>Number of warning sign</td><td>1</td><td>0</td><td>100</td><td rowspan="2">1</td><td rowspan="2">0</td><td rowspan="2">2</td></tr>
<tr><td></td><td>Warning sign condition (%)</td><td>100</td><td>0</td><td>100</td></tr>
<tr><td>4.</td><td>Traffic signal</td><td>available</td><td>No</td><td>100</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>5.</td><td>Road markings [2)]</td><td>available</td><td>available</td><td>0</td><td rowspan="2">0</td><td rowspan="2">0</td><td rowspan="2">1</td></tr>
<tr><td></td><td>Road markings condition (%)</td><td>100</td><td>85</td><td>15</td></tr>
<tr><td>6.</td><td>Distance between lightning (m)</td><td>48</td><td>50</td><td>4.17</td><td rowspan="2">0</td><td rowspan="2">0</td><td rowspan="2">1</td></tr>
<tr><td></td><td>Lightning condition (%)</td><td>100</td><td>100</td><td>0</td></tr>
</table>

[1)]: Ministry of Transportation Republic of Indonesia, PM No. 13, 2014 [26];
[2)]: Ministry of Transportation Republic of Indonesia, PM No. 67, 2018 [27].

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Table-3. Result of the road safety audit on deficiencies in the geometric conditions, road pavement condition, and harmonization of road equipment facilities in Brobot Street, Bojongsari, Purbalingga.

No.	Aspect	Probabili-ty value	Severity level	Risk valuation	Risk category	Recommendations
I.	**Road geometric condition**					
1.	Stop sight distance	4	10	40	Negligible	Passive response
2.	Preceding sight distance	2	100	200	Fair	Active response
3.	Lane width	0	0	0	Negligible	Passive response
4.	Shoulder width	2	100	200	Fair	Improve the road shoulder to 1.5 m wide (increased 0.5 m).
II.	**Road pavement condition**					
1.	Longitudinal and transverse cracking	0	10	0	Negligible	Passive response
2.	Lane or shoulder drop off	5	100	500	Extreme	Immediate response: Level its elevation with lane edge of road.
III.	**Harmonization of road equipment facilities**					
1.	Speed limit sign	5	100	500	Extreme	Immediate response: Install maximum speed limit sign of 40 km/h.
2.	Curve direction sign	5	10	50	Low	Monitoring Install the guardrail along curve.
3.	Warning sign	5	100	500	Extreme	Immediate response: Install the warning sign along black spot location.
4.	Traffic signal	5	100	500	Extreme	Immediate response: Install the traffic signal (warning light 1 or 2 phase).
5.	Road markings	1	10	10	Negligible	Passive response
6.	Lightning	1	10	10	Negligible	Passive response

The results of analysis of infrastructure deficiency and road safety audit in Brobot Street, Bojongsari, Purbalingga, Central Java from three aspects road geometric condition, road pavement performance, and harmonization of road equipment facilities as follows:

a) The results of road safety audit of geometric infrastructure deficiencies reviewed four aspects namely stopping sight distance, preceding sight distance, lane and road shoulder width. However, the stop sight distance is in the negligible risk category (passive response), preceding sight distance in fair risk category (active response), while the lane width is in the negligible risk category. This form of handling is based on risk routine monitoring with scheduled road safety inspections. Road shoulder widths in the fair risk category, recommendation improve the road shoulder to 1.50 m wide (increased 0.50 m) along with the construction.

b) The results of road safety audit of its pavement infrastructure deficiencies include two types of damages on highways namely longitudinal and transverse cracking and lane or shoulder drop off. The type of shoulder or lane drop off entering into the category of very dangerous or extreme risk category, which means that in this case there is a need for total technical handling in the form of increased construction thickness parallel to the pavement. The type of longitudinal and transverse cracking categorized into negligible risk category and in the form of handling based on the risk is passive response.

c) From the results of the audit of harmonization of road equipment facilities, the speed limit sign, warning sign, and traffic signals signs are categorized in the very dangerous or extreme risk. This means there is a need for total technical handling in the form of installation of speed limit and warning signs with a maximum of 2 (two) weeks after the results of road safety audit are approved. Curve direction signs are categorized into low risk category with its installation the guardrail along curves. For the other road equipment facilities, road markings and lighting, it is categorized into negligible risk category. The handling is in routine monitoring with scheduled road safety inspections.

Sustainable safety [32], sustainable transport [33], and towards zero strategy aims to ensure that road safety policies continue to evolve within a strategic framework [34]. Politicians need to be able to estimate whether the expected benefits of a programme justifies investment [35]. The operational and management characteristics associated with reduced crash and injury risk include: safety training, management commitment, scheduling or journey planning, freight type, worker participation, incentives and safety policies [14].

CONCLUSIONS

Based on the results, the following conclusion can be drawn:

a) Three parameters were used to analyze road safety audit in Brobot Street, Bojongsari, Purbalingga namely road pavement condition, road geometric condition, and harmonization of road equipment facilities.

b) Road geometry involves shoulder width, while road pavement condition involve lane or shoulder drop off. In addition, harmonization of road equipment aspect involves speed limit sign (40 km/h) and warning sign along black spot location.

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