Road safety audit at black spot area: Case study in Tlahab Lor, Karangreja, Purbalingga

Cite as: AIP Conference Proceedings **2094**, 020020 (2019); https://doi.org/10.1063/1.5097489
Published Online: 17 April 2019

Gito Sugiyanto, Ari Fadli, Rizki Suciningtyas, Eva Wahyu Indriyati, and Mina Yumei Santi

Road Safety Audit at Black Spot Area: Case study in Tlahab Lor, Karangreja, Purbalingga

Gito Sugiyanto[1,a)], Ari Fadli[2], Rizki Suciningtyas[1], Eva Wahyu Indriyati[1] and Mina Yumei Santi[3,b)]

[1]*Department of Civil Engineering, Jenderal Soedirman University, Purwokerto, Central Java, Indonesia.*
[2]*Department of Electrical Engineering, Jenderal Soedirman University, Purwokerto, Central Java, Indonesia.*
[3]*Health Polytechnic of Minister of Health of Yogyakarta, Yogyakarta, Indonesia.*

[a)]Corresponding author: gito_98@yahoo.com
[b)]minayumeisanti80@gmail.com

Abstract. Traffic accidents are still one of the serious problems faced by the Indonesian Government. In 2014 recorded 95,906 cases of accidents with 28,297 people died. One effort to reduce the number of traffic accidents is identification black spot locations. One of the causes traffic accident is road infrastructure deficiency, so it is needed the road safety audit. The aim of this research is to analysis the road safety audit at black spot area in Purbalingga District. The study location is in Bayeman, Tlahab Lor, Karangreja, Purbalingga, Central Java. Database of traffic accidents from Purbalingga Police Traffic Unit in 2016 and 2017. There are three parameters analyzed i.e.: road geometric, road pavement condition, and harmonization of road equipment facilities. The result shows that from road geometric parameter there are two aspects i.e.: preceding sight distance and shoulder width. The recommendation is improving shoulder to 2 m wide and improves shoulder construction. Road pavement condition and lane/shoulder drop off must be repaired. Recommendation in harmonization of road equipment facilities aspect that involve installs the maximum speed limit sign of 30 km/h and 40 km/h and warning sign.

INTRODUCTION

Traffic accidents in Indonesia have now reached in critical conditions. One of the reasons is the high growth of motor cycle and car ownership in the last decade. Another factor that causes it is the low level of discipline of road users in traffic [1]. Based on traffic accidents data in 2006, there are 36,000 people died due to road accidents or 98 people died every day and 19,000 of them involved motorbike riders. Data from Traffic Corps Republic of Indonesia State Police [2], road transport accidents in 2014 recorded 95,906 cases of accidents with 28,297 people died, 26,840 people seriously injured, 109,741 people who were slightly injured, and IDR 250,110,380,000 in property damage.

Traffic accidents also occur due to several problems related to the management of road infrastructure [3-5], traffic accidents due to the deficiencies in road safety infrastructure. In Indonesia, road safety infrastructure is carried out by two government institutions, namely Directorate General of Highways and Directorate General of Land Transportation. Directorate General of Highways has the main authority and responsibility in planning road designs according to standards and improving black spot locations. Directorate General of Land Transportation has the responsibility to plan and implement harmonization of road signs or safety instructions on road functions. In practice, two institutions have not been optimally integrated in the field, for example there are often no signs of speed limitation on road that are adjusted to road functions and delays in handling signs and markings on new pavement surfaces and structurally damaged roads. This condition illustrates that in order to minimize deficiencies in road safety infrastructure, there are three important aspects: “forgiving road environment, self-explaining road, self-regulating road” [6-8]. The development of road transport infrastructure is a priority [4-5]. The deficiency of road infrastructure is a reduction or decrease in the road function so that it can trigger potential accidents. Therefore

1st International Conference on Material Science and Engineering for Sustainable Rural Development
AIP Conf. Proc. 2094, 020020-1–020020-10; https://doi.org/10.1063/1.5097489
Published by AIP Publishing. 978-0-7354-1824-0/$30.00

audit of road safety infrastructure deficiencies in black spot locations is based on accident data and direct measurements in the field of geometric and visibility deviations, conditions of road pavement damage, and disharmony of road equipment facilities for the function of these roads. A method is needed to determine the optimal maintenance time [9].

Bayeman Street, Tlahab Lor, Karangreja is the highest rank in traffic accident. There are 13 cases of accident with 16 people died, 1 people seriously injured, and 22 people who were slightly injured [10]. The aim of this research is to analysis the road safety audit at black spot area at Purbalingga District. Location of the study is in Bayeman, Tlahab Lor, Karangreja, Purbalingga, Central Java, Indonesia.

MATERIALS AND METHODS

Based on "Law 22, 2009 (Traffic and Land Transport), traffic accident is classified in three categories", fatal accidents, severe accidents, and slightly or minor accidents [11]. In traffic safety, speed is the main risk factors for the occurrence of crashes [12-14]. High speed increases the risk of accident [15], more serious crashes [16], and crash frequency [17]. Maximum speed limit was set at or below the 85th percentile speed [18,19]. Speed management and speed limits enforcement represent strategy to improve road safety [20-22]. Elvik [23] analyzed the relationship between speed limit and severity of injuries, fatal crashes increase of 1.58 if speed increased 1 km/h. The severity of crash also increases with speed [24]. Speed limit was introduced to reducing severity of crashes in black spot location [1, 25, 26], accident cost [27, 28], and generalized cost [29,30].

Research related to the speed limit with the risk of accidents concludes that reducing the speed limit will reduce the average speed of driving, number of accidents and severity of injuries. Research in Queensland on evaluating speed limits at 50 km/h concluded that the change in average speed for each 1 km/h would change the risk of accidents by 3%. The severity of injuries and fatality changed with changes in average speed [25]. Australia has reduced "the speed limit for urban areas from 60 km/h to 50 km/h to reduce the risk of traffic accidents". "Speed limitof urban streets in Great Britain were designated 20 mph [31]. The average speed in school safety zone for passenger car/light vehicle is 29.26 km/h and motorcycle is 34.75 km/h, meanwhile the speed limit is 25 km/h [32]. Almost 30% of casualty crashes occur on residential streets [33]. "The higher access density tended to increase crash occurrence on suburban arterials" [34]. In Japan, the highest accident rates occur when speed is reduced from 110 to 85 km/h [35]. In Sweden, effect reduced the speed limit from 90 km/h to 80 km/h, decreased the number of fatalities by 14 per year [36].

Safety deficiencies of road infrastructure

Classification of accident severity impact values and classification to measure design deviations of road facilities to their standards, based on the level of possibility and threat level. The level of likelihood is used to assess findings of deficiencies that do not have or are known history of previous accidents in the audited place. The threat level is used to assess deficiency points that have actually resulted in accidents. The matrix for determining the classification of chance of an accident and the severity of the victim is based on level of possibility and threat [7,8]. The opportunity value of road safety deficiencies can be measured qualitatively from the possibility of an accident in a location that is considered a black spot.

Value of pavement conditions

The advantage of the pavement management system is its ability to determine the existing conditions of the road and predict future conditions. To predict the conditions of pavement based on type, the level of damage based on the "Pavement Condition Index (PCI) developed by the United State Army Corps of Engineers". PCI is a numerical index between 0 for failed, and 100 pavement conditions for excellent pavement conditions. The PCI rating range is shown in Fig. 1.

Density. "Density is percentage of the area of a type of damage to area of a unit segment measured in square meters or meters in length" [37]. The type of damage value is also distinguished based on the level of damage. The density value equation is:

$$Density = \left(\frac{A_d}{A_s}\right) x\ 100\% \text{ or } Density = \left(\frac{L_d}{A_s}\right) x\ 100\% \quad (1)$$

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 (m) and A_s is total unit area in (m^2)

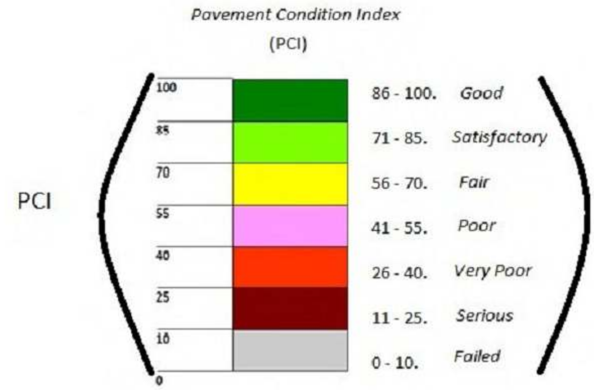

FIGURE 1. Scoring scale of *Pavement Condition Index* (PCI) [37]

Deduct Value (DV). "Deduct value is the value of each type of damage obtained from the density and deduct value relationship curves" [37]. The deduct value is divided into the level and types of damage.

Total Deduct Value (TDV). Total deduct value is value of the individual reduction value for each type of damage and the level of damage present in a unit of the study sample.

Corrected Deduct Value (CDV). Corrected deduct value is obtained from the curve of the relationship between TDV value and CDV value [37]. The curve selection according to the number of individual deducts value that has a value greater than 2. The CDV can be seen in Fig. 2.

If the CDV value is known, then the values for each unit can be known 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 deduct value for each unit.

$$PCI = \left(\frac{\sum PCI_{(s)}}{N}\right) x\ 100\% \quad (3)$$

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.

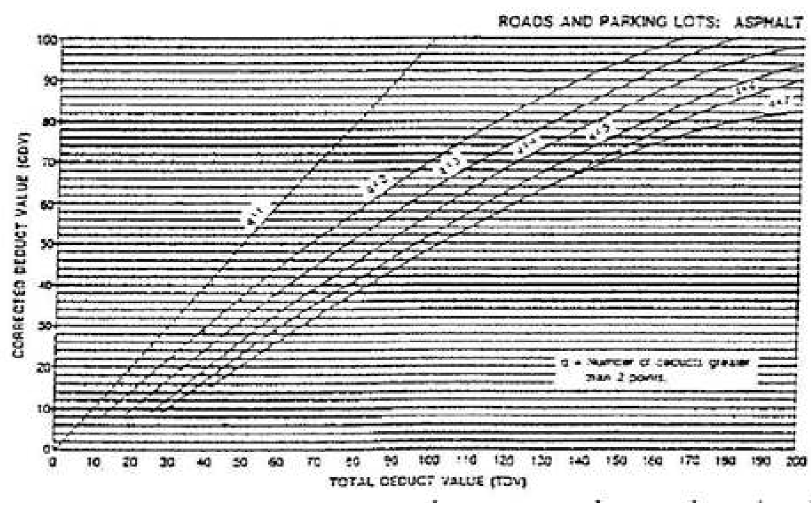

FIGURE 2. The relationship between TDV and CDV [37]

The study location

Location of the study is in Bayeman, Tlahab Lor, Karangreja, Purbalingga Regency, Central Java Province, Indonesia. The location of study is collector road. Traffic accident data from Purbalingga Police at January 2016 to December 2017 [10]. To determine the black spot location using the equivalent accident number [1, 38, 39].

RESULTS AND DISCUSSIONS

Geometric condition and road damage

The road width of Bayeman, Tlahab Lor is 6 m with a shoulder width of 30 cm. Lane shoulder drop off is 3 cm on left side and 10 cm on right side of the road. The condition of the asphalt road is not good enough because there are road damage longitudinal cracking and rutting type. The value of pavement conditions using the PCI method is as follows:

Rutting. Rutting is the asphalt pavement surface deformation in vehicle wheel track. In Bayeman, Tlahab Lor, Karangreja there are 10 points of rutting 1 m x 2 m along the road reviewed (300 m). The average depth of the path on the road is more than 25 mm so it is classified as high severity level (H). The PCI values can be find as follows:

a). Density = {(1x2x10) / (6x300)} x 100% = 1.1%.

b). From Fig. 3, the relationship curve between distress density and deduct value for rutting, the deduct value with a density 1.1% and high severity level of damage (H) is 27.

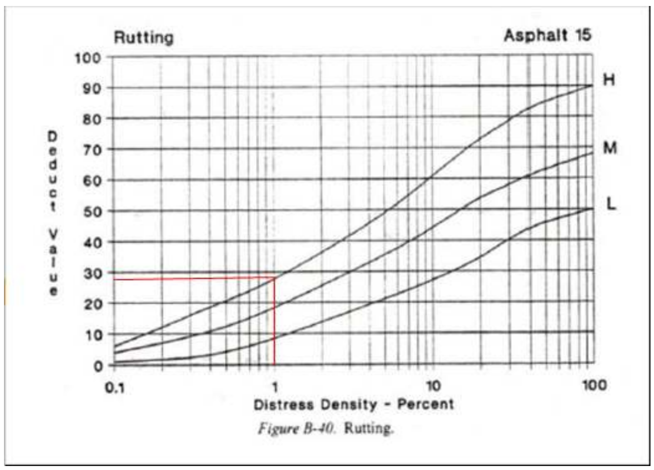

FIGURE 3. The relationship curve between distress density and deduct value for rutting.

c). On 300 m road section reviewed not divided into several unit segments (q = 1), the total deduct value is the same as deduct value is 27.

d). From Fig. 4, the relationship curve between total deduct value and corrected deduct value, the total deduct value 27 and q = 1 is 28.

e). PCI = 100 - CDV = 100 - 28 = 72.

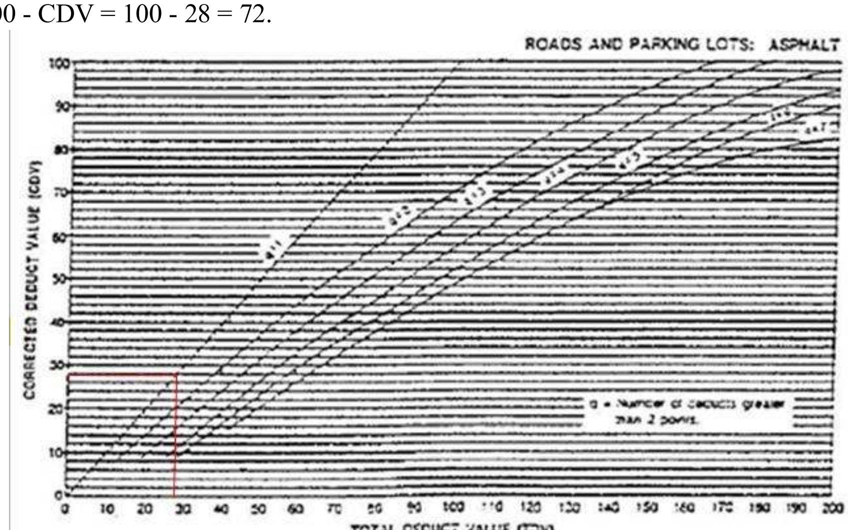

FIGURE 4. The relationship curve between total deduct value and corrected deduct value.

Longitudinal/transverse cracking. Longitudinal cracking is crack that occurs extensively on road pavements, can occur in a single or parallel form and sometimes slightly branched. In Bayeman, Tlahab Lor total longitudinal crack length extends 32 m with width crack ranging from 5-10 mm, which is classified as a low severity level (L).

a). Density = {(32) / (6x300)} x 100% = 1.8%.

b). From Fig. 5, the relationship curve between distress density and deduct value for longitudinal/transverse cracking, the deduct value with a density 1.8 % and low severity level of damage (L) is 5.

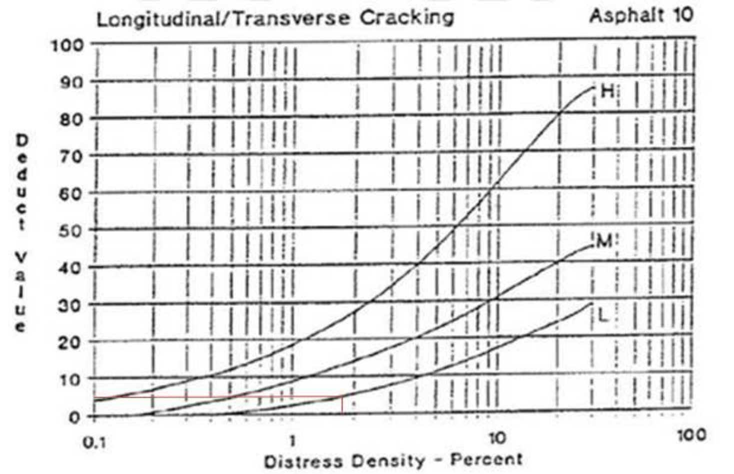

FIGURE 5. The relationship curve between distress density and deduct value for longitudinal/transverse cracking.

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

d). From Fig. 4, the corrected deduct value with total deduct value 5 and q = 1 is 6.

e). PCI = 100 - CDV= 100 - 6 = 94.

Lane/Shoulder Drop Off. Shoulder drop off the elevation difference between the pavement edge and the shoulder. In Bayeman, Tlahab Lor position of road shoulder elevation toward pavement edge elevation is 10 cm on right side, which is classified as medium severity level (M).

a) Density = {(300) / (6x300)} x 100% = 16.7%.

b) From Fig. 6, the relationship curve between distress density and deduct value for lane/shoulder drop off, the deduct value with a density 16.7% (the highest density value is 15%) and medium severity level (M) is 27.5.

c) On 300 m road section reviewed not divided into several unit segments (q = 1), the total deduct value is the same as deduct value is 27.5.

d) From Fig. 4, the corrected deduct value with total deduct value 27.5 and q = 1 is 28.

e) PCI = 100 - CDV = 100 - 28 = 72.

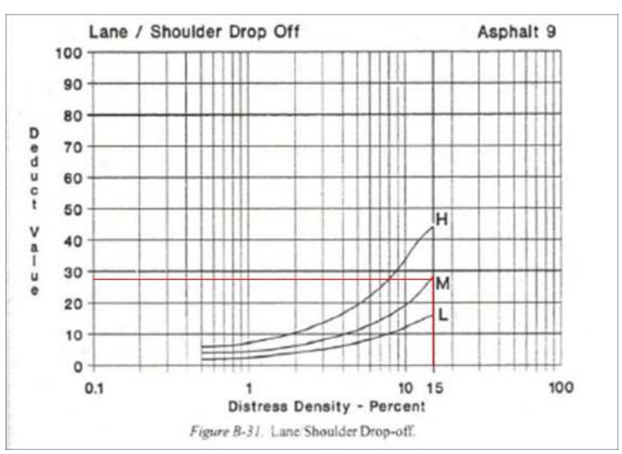

FIGURE 6. The relationship curve between distress density and deduct value for lane/shoulder drop off.

Speed, sight distance, and road equipment facilities

Vehicle speed data in Bayeman, Tlahab Lor was distributed into three types of vehicle i.e.: motorcycles, passenger cars, and large bus and trucks. Stop sight distance and preceding sight distance are measured based on the vehicle's maximum speed [3]. The maximum speed of motorcycles is 67 km/h, passenger car is 65 km/h, large bus and trucks are 65 km/h [40].

The stop sight distance and preceding sight distance is follows:

a. Stop sight distance and preceding sight distance of motorcycle is 97.02 m and 394.06 m
b. Stop sight distance and preceding sight distance of passenger cars is 92.66 m and 379.1 m.
c. Stop sight distance and preceding sight distance of large bus and trucks is 92.66 m and 379.1 m.

The road markings on Bayeman, Tlahab Lor road are quite good. The dashed longitudinal markers and full markings of the solid line are still clear. Street lighting is sufficient. The average distance between lighting lamps is 50 m, the standard requirements for street lighting are 48 m [BSN in [40].

Road safety audit

Three parameters that analyzed in road safety audit i.e.: road geometric condition, road pavement condition, and harmonization of road equipment facilities. In road geometric, there are four parameters that analyzed i.e.: stop sight distance, preceding sight distance, lane width, and shoulder width. The road geometric technical standards based on *Geometric for Rural Road* [41]. Analysis of safety deficiencies of road infrastructure for road pavement condition covers three aspects i.e.: rutting, longitudinal/transverse cracking, and lane/shoulder drop off. Harmonization of road equipment facilities includes speed limit sign, curve direction sign, warning sign, signal, road markings, and lightning. The result of measuring and observing the road geometric condition, road pavement condition, and harmonization of road equipment facilities can be seen in Table 1 and the result of the road safety audit on deficiencies can be seen in Table 2.

TABLE 1. Result of measurements and field observations of the geometric conditions, road pavement condition, and harmonization of road equipment facilities

No.	Aspect (unit)	Standard	Measurement results	Deviation (%)	Fatality	Severe injured	Minor injured
I.	**Road geometric condition [41]**						
1.	Stop sight distance (m)	75	97	29.4	0	0	0
2.	Preceding sight distance (m)	350	394.1	12.6	14	1	20
3.	Lane width (m)	3	3	0	0	0	0
4.	Shoulder width (m)	1.5	0.3	80	2	0	0
II.	**Road pavement condition**						
1.	Rutting (PCI)	85	72	15.3	1	0	1
2.	Longitudinal/transverse cracking	85	94	0	1	0	0
3.	Lane/shoulder drop off (PCI)	85	72	15.3	1	0	1
	Lane/shoulder drop off (cm)	< 1 cm	10 cm	900			
III.	**Harmonization of road equipment facilities**						
1.	Number of speed limit sign [42]	1	0	100	1	0	2
	Speed limit sign condition (%)	100	0	100			
2.	Number of curve direction sign	3	1	66.7	1	0	2
	Curve direction sign condition (%)	100	85	15			
3.	Number of warning sign	1	0	100	1	0	2
	Warning sign condition (%)	100	0	100			
4.	Traffic signal	available	No	100	1	0	2
5.	Road markings [43]	available	available	0	0	0	0
	Road markings condition (%)	100	90	10			
6.	Distance between lightning (m)	48	50	4.2	0	0	0
	Lightning condition (%)	100	85	15			

TABLE 2. Result of the road safety audit on deficiencies in the geometric conditions, road pavement condition, and harmonization of road equipment facilities

No.	Aspect	Probability value	Severity level	Risk valuation	Risk category	Recommendations
I.	**Road geometric condition**					
1.	Stop sight distance	2	1	2	Negligible	Passive response
2.	Preceding sight distance	2	100	200	Medium	Active response
3.	Lane width	1	1	1	Negligible	Passive response
4.	Shoulder width	4	100	400	Extreme	Improve shoulder to 2m wide and shoulder construction
II.	**Road pavement condition**					
1.	Rutting	2	100	200	Medium	Active response
2.	Longitudinal/transverse cracking	1	100	100	Low	Monitoring
3.	Lane/shoulder drop off	5	100	500	Extreme	Level its elevation with lane edge of road
III.	**Harmonization of road equipment facilities**					
1.	Speed limit sign	4	100	400	Extreme	Install maximum speed limit sign of 30 km/h and 40 km/h
2.	Curve direction sign	3	100	300	High	Install curve direction sign Install guardrail along curve
3.	Warning sign	4	100	400	Extreme	Install warning sign along black spot location
4.	Traffic signal	4	100	400	Extreme	Install traffic signal (warning light 1 or 2 phase)
5.	Road markings	2	1	2	Negligible	Passive response
6.	Lightning	1	1	1	Negligible	Passive response

The results of road safety audit in Bayeman, Tlahab Lor 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 road geometric infrastructure deficiencies of 4 aspects that reviewed i.e.: stopping sight distance, preceding sight distance, lane width, and shoulder width, stop sight distance and lane width entering into category of negligible risk and this form of handling based on the risk category is routine monitoring with scheduled road safety inspections. Shoulder width entering into the category of extreme, the recommendation is improving shoulder to 2 m wide and improves shoulder construction.
b. The results of road safety audit of road pavement infrastructure deficiencies include 3 types of road damage on highway section that reviewed i.e.: rutting, longitudinal/transverse cracking, and lane/shoulder drop off. The type of shoulder/lane drop off entering into the category of very dangerous or extreme risk, which means that in this case there is a need for total technical handling in the form of increasing the construction thickness of the road shoulder parallel to the pavement. For the type of damage to the flow into the risk category quite dangerous, it means that there is a need for technical handling in the form of repair of pavement damage with similar materials that meet the standards of road construction materials. For the type of longitudinal or transverse cracking categorized into low risk category and the form of handling based on the risk category is routine monitoring with scheduled road safety inspections.
c. From the results of the audit of harmonization of road equipment facilities, for speed limit signs, warning signs, and signals categorized into the category of very dangerous or extreme risk, this means there is a need for total technical handling in the form of installation of speed limit signs, warning signs as well as immediately with a maximum of 2 weeks after the results of the road safety audit are approved. For directional signs, they fall into the dangerous risk category, meaning that scheduled technical handling is a maximum of 2 months since the results of the road safety audit are approved in the form of completing or adding bend direction signs. For other road equipment facilities, road markings and lighting, it is categorized into low risk category. The handling is in routine monitoring with scheduled road safety inspections.

CONCLUSIONS

Based on the results, the following conclusion can be drawn: three parameters that analyzed in road safety audit in black spot area i.e.: road geometric condition, road pavement condition, and harmonization of road equipment facilities. The result shows that from road geometric parameter there are two aspects i.e.: preceding sight distance and shoulder width. The recommendation is improving shoulder to 2 m wide and improves shoulder construction. Road pavement condition and lane/shoulder drop off must be repaired. Recommendation in harmonization of road equipment facilities aspect that involve installs the maximum speed limit sign of 30 km/h and 40 km/h and warning sign.

ACKNOWLEDGMENTS

"This research was carried out by the financial support of BLU Jenderal Soedirman University, Ministry of Research, Technology, and Higher Education, Republic of Indonesia through Research Grant "*Penelitian Tindakan Berbasis Hasil Riset*". All the contributions are acknowledged".

REFERENCES

1. G. Sugiyanto, A. Fadli and M. Y. Santi, Identification of black spot and equivalent accident number using upper control limit method, ARPN Journal of Engineering and Applied Sciences **12** (2), 528-535 (2017) http://www.arpnjournals.org/jeas/research_papers/ rp_2017/jeas_0117_5650.pdf.
2. Traffic Corps (*Korlantas*) Republic of Indonesia State Police, Accident Data in *2014* (Traffic Corps Republic of Indonesia State Police, Jakarta, 2015).
3. G. Sugiyanto, B. Mulyono and M. Y. Santi, Karakteristik kecelakaan lalu lintas dan lokasi *black spot* di Kabupaten Cilacap, Jurnal Teknik Sipil **12** (4), 259-266 (2014) http://ft.uajy.ac.id/wp-content/uploads/ 2015/11/4.-Gito-Sugiyanto.pdf.
4. G. Sugiyanto. Characterization of asphalt concrete produced from scrapped tire rubber, Engineering Journal **21** (4), 193-206 (2017a) https://doi.org/10.4186/ej.2017.21.4.193.
5. G. Sugiyanto, Marshall test characteristics of asphalt concrete mixture with scrapped tire rubber as a fine aggregate, Jurnal Teknologi (Sciences and Engineering) **79** (2), 55-64 (2017b) https://doi.org/10.11113/jt.v79.6965.
6. Directorate General of Highways, *Kajian Kebutuhan Pelaksanaan Keselamatan Jalan di Indonesia* (Ministry of Public Works Republic of Indonesia, Jakarta, 2006).
7. Directorate General of Highways, *Penyusunan Sistem Manajemen dan Pedoman Keselamatan Jalan dalam Kegiatan Pembangunan Jalan* (Ministry of Public Works Republic of Indonesia, Jakarta, 2007).
8. A. T. Mulyono, B. Kushari, and H. E. Gunawan, *Audit Keselamatan Infrastruktur Jalan (Studi kasus Jalan Nasional km 78-km 79 Jalur Pantura Jawa, Kabupaten Batang),* Jurnal Teknik Sipil Jurnal Teoritis dan Terapan bidang Rekayasa Sipil, **16** (3), 163-174 (2009) http://journals.itb.ac.id/index.php/jts/article/view/2757.
9. R. Kareth, "*Penggunaan Life Cycle Cost Analysis* (LCCA) *dalam Menentukan Biaya Ekonomis untuk Penanganan Perkerasan Jalan Kabupaten Sorong Selatan (Studi kasus ruas Jalan Kota Teminabuan-Keyen)*" Master thesis, Faculty of Engineering Sebelas Maret University Surakarta, 2015 https://digilib.uns.ac.id/dokumen/detail/51725/.
10. Purbalingga Police Precinct, Traffic Accident in Purbalingga in 2016, unpublished (Purbalingga Police Precinct, 2017).
11. Ministry of Transportation Republic of Indonesia, *Indonesian Law No. 22 of 2009 on Road Transport and Traffic* (Ministry of Transportation Republic of Indonesia, Jakarta, 2009).
12. G. Nilsson, *Traffic Safety Dimension and the Power Model to describe the Effect of Speed on Safety*. (Lund Institute of Technology, Sweden, 2004) https://www.motor-talk.de/forum/aktion/Attachment.html?attachmentId=689000.
13. L. Aarts and I. V. Schagen, Driving speed and the risk of road crashes: a review, Accid. Anal. Prev. **38**, 215-224 (2006) https://doi.org/10.1016/j.aap.2005.07.004.
14. E. D. Pauw, S. Daniels, M. Thierie and T. Brijs, Safety effects of reducing the speed limit from 90 km/h to 70 km/h, Accid. Anal. Prev. **62,** 426-431(2014) https://doi.org/10.1016/j.aap.2013.05.003.

15. Global Road Safety Partnership (GRSP), *Speed Management (Road Safety Manual for Decision-Makers and Practitioners)*. (GRSP, Geneva, 2008). http://apps.who.int/iris/bitstream/handle/10665/43915/9782940395040_eng.pdf;jsessionid=700C3D0E9CFAA954A1725A2D900799AB?sequence=1.
16. M. I. M. Imprialou, M. Quddus, D. E. Pitfield and D. Lord, Re-visiting crash–speed relationships: A new perspective in crash modeling, Accid. Anal. Prev. **86,** 173-185 (2016) https://doi.org/10.1016/j.aap.2015.10.001.
17. X. Wang, Q. Zhou, M. Quddus, T. Fan and S. Fang, Speed, speed variation and crash relationships for urban arterials, Accid. Anal. Prev. **113**, 236-243 (2018) https://doi.org/10.1016/j.aap.2018.01.032.
18. Institute of Transport Engineers (ITE), *Speed Zoning Information* (2004). http://www.ite.org/standards/speed_zoning.pdf.
19. Massachusetts Highway Department (MHD), *Procedure for Speed Zoning on State and Municipal Roadways* (Traffic Engineering, Highway Department, Massachusetts, 2012) https://www.town.billerica.ma.us/DocumentCenter/View/5881/Procedures-for-Speed-Zoning-on-State-and-Municipal-Roadways?bidId=.
20. M. G. Augeri, P. Cozzo and S. Greco, Dominance-based rough set approach: An application case study for setting speed limits for vehicles in speed controlled zones, Knowl.-Based Syst. **89**, 288-300 (2015) https://doi.org/10.1016/j.knosys.2015.07.010.
21. M. H. Hosseinlou, S. A. Kheyrabadi and A. Zolfaghari, Determining optimal speed limits in traffic networks, IATSS Res. **39,** 36-41 (2015) doi:10.1016/j.iatssr.2014.08.003.
22. G. Sugiyanto and S. Malkhamah, Determining the maximum speed limit in urban road to increase traffic safety, Jurnal Teknologi (Sciences and Engineering) **80** (5),67-77 (2018) https://doi.org/10.11113/jt.v80.10489.
23. R. Elvik, A re-parameterisation of the power model of the relationship between the speed of traffic and the number of accidents and accident victims, Accid. Anal. Prev. **50**, 854-860 (2013) https://doi.org/10.1016/j.aap.2012.07.012.
24. Organization for Economic Cooperation Development, *Speed Management* (Transport Research Centre, Organization for Economic Cooperation Development (OECD) and European Conference of Ministers of Transport (ECMT), OECD Publishing, Paris CEDEX, 2006). https://www.itf-oecd.org/sites/default/files/docs/06speed.pdf.
25. E. Hoareau, S. Newstead, P. Oxley and M. Cameron, *An Evaluation of the 50 km/h Speed Limit in South East Queensland*, Journal Report No. 264 (Monash University Accident Research Centre (MUARC), Monash, 2002). https://www.monash.edu/__data/assets/ pdf_file/0005/216482/muarc264.pdf.
26. G. Sugiyanto, P. B. Santosa, A. Wibowo and M. Y. Santi, Hub and spoke airport networks in Indonesia based on Herfindahl-Hirschmann Index (HHI), Journal of Engineering and Applied Sciences **11** (8), 1804-1810 (2016a) http://medwelljournals.com/abstract/?doi =jeasci.2016.1804.1810.
27. G. Sugiyanto and M. Y. Santi, Road Traffic Accident Cost using Human Capital Method (Case study in Purbalingga, Central Java, Indonesia), Jurnal Teknologi (Sciences and Engineering) **79** (2), 107-116 (2017) https://doi.org/10.11113/jt.v79.5375.
28. G. Sugiyanto, The cost of traffic accident and equivalent accident number in developing countries (case study in Indonesia), ARPN Journal of Engineering and Applied Sciences **12** (2), 389-397 (2017c) http://www.arpnjournals.org/jeas/research_papers/rp_2017/jeas_0117_5631. pdf.
29. G. Sugiyanto, The impact of congestion pricing scheme on the generalized cost and speed of motorcycle to the city of Yogyakarta, Indonesia, Journal of Engineering and Applied Sciences **11** (8), 1740-1746 (2016) http://medwelljournals.com/abstract/?doi =jeasci.2016.1740.1746.
30. G. Sugiyanto, The effect of congestion pricing scheme on the generalized cost and speed of motorcycle, Walailak J. Sci. & Tech. **15** (1), 95-106 (2018) http://wjst.wu.ac.th/index.php/wjst/article/view/2347.
31. A. Tapp, C. Nancarrow, A. Davis and S. Jones, Vicious or virtuous circles? Exploring the vulnerability of drivers to break low urban speed limits, Transp. Res. A **91**, 195-212 (2016) https://doi.org/10.1016/j.tra.2016.06.007.
32. G. Sugiyanto, M. R. P. H. Diaz, M. Y. Santi and E. W. Indriyati, The evaluation of school safety zone implementation in elementary school (case study in Banyumas District, Central Java Province), Media Teknik Sipil UMM, **14** (2), 174-181 (2016b) http://ejournal.umm.ac.id/index.php/jmts/article/view/3706.
33. Austroads, *Urban Speed Management in Australia AP 118-96* (Austroads, New South Wales, 1996) https://austroads.com.au/publications/road-safety/ap-118-96.
34. X. Wang, J. Yuan, G. G. Schultz and S. Fang, Investigating the safety impact of roadway network features of suburban arterials in Shanghai, Accid. Anal. Prev. **113,** 137-148 (2018) https://doi.org/10.1016/j.aap.2018.01.029.

35. M. Tanishita and B. V. Wee, Impact of vehicle speeds and changes in mean speeds on per vehicle-kilometer traffic accident rates in Japan, IATSS Res. **41** (3), 107-112 (2017) https://doi.org/10.1016/j.iatssr.2016.09.003.
36. A. Vadeby and A. Forsman, Traffic safety effects of new speed limit in Sweden, Accid. Anal. Prev. **114**, 34-39 (2018) https://doi.org/10.1016/j.aap.2017.02.003.
37. M. Y. Shahin, *Pavement Management for Airports, Roads, and Parking Lots*, (Chapman & Hall, New York, 1994).
38. Directorate General of Highways, *Penanganan Lokasi Rawan Kecelakaan Lalu Lintas* (Ministry of Public Works Republic of Indonesia, Jakarta, 2004).
39. Directorate General of Land Transportation, *Pedoman Operasi* Accident Black spot Investigation Unit/*Unit Penelitian Kecelakaan Lalu Lintas* (ABIU/UPK) (Directorate General of Land Transportation, Ministry of Transportation Republic of Indonesia, Jakarta, 2007).
40. R. Suciningtyas, "*Audit Defisiensi Infrastruktur Keselamatan Jalan pada Lokasi Rawan Kecelakaan Lalu Lintas (Studi kasus Ruas Jalan Antar Kota Kabupaten Purbalingga*". *Skripsi*, Faculty of Engineering Jenderal Soedirman University Purwokerto, 2016.
41. Directorate General of Highways, *Tata Cara Perencanaan Geometrik Jalan Antar Kota* (Ministry of Public Works Republic of Indonesia, Jakarta, 1997).
42. Ministry of Transportation Republic of Indonesia, *Peraturan Menteri Perhubungan Republik Indonesia Nomor PM 13 Tahun 2014 tentang Rambu Lalu* Lintas (Ministry of Transportation, Jakarta, 2014).
43. Ministry of Transportation Republic of Indonesia, *Peraturan Menteri Perhubungan Republik Indonesia Nomor PM 34 Tahun 2014 tentang Marka Jalan* (Ministry of Transportation Republic of Indonesia, Jakarta, 2014).