BLACKSPOT LOCATION AND RECOMMENDATION TO REDUCE NUMBER AND SEVERITY OF ACCIDENTS ON PURBALEUNYI TOLL ROAD

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Abstract

Toll roads, as land transportation infrastructure, have an important role in Indonesia. With a high number of road crashes in Indonesia, with about 40,000 people die on the road each year, the determination of blackspot locations is crucial. The aim of this study is to analyze blackspot location on a toll road in Indonesia and, furthermore, to provide recommendations in order to reduce number and severity of accident. A case study is carried out on a toll road, named Purbaleunyi Toll Road, in West Java. Accident rate value and UCL method are used in this study to determine blackspot locations. The results indicated that there are many blackspot locations along the toll road and recommended solutions provided are adherence to traffic regulation, adherence to vehicle worthiness,dissemination of road safety importance to road users, and the implementation of blackspot treatments continuously.

Keywords: blackspot location, road crashes, toll road, blackspot treatments

Abstrak

Jalan tol merupakan prasarana transportasi darat yang sangat penting di Indonesia. Tingginya jumlah kecelakaan lalulintas di Indonesia, khususnya kecelakaan lalulintas di jalan, dengan sekitar 40.000 orang meninggal di jalan setiap tahun, menyebabkan penentuan lokasi *blackspot* sangat penting. Tujuan penelitian ini adalah melakukan analisis lokasi *blackspot* di jalan tol di Indonesia dan lebih jauh lagi, untuk memberikan rekomendasi untuk mengurangi jumlah dan tingkat keparahan kecelakaan. Studi kasus dilakukan di Jalan Tol Purbaleunyi, di Jawa Barat. Nilai tingkat kecelakaan dan metode UCL digunakan dalam penelitian ini untuk menentukan lokasi *blackspot*. Hasil penelitian menunjukkan bahwa ada banyak lokasi *blackspot* di sepanjang jalan tol ini dan direkomendasikan solusi yang terkait dengan kepatuhan terhadap peraturan lalulintas, kepatuhan terhadap kelayakan kendaraan, diseminasi program keselamatan jalan kepada pengguna jalan. Selain itu perlu dilakukan penanganan *blackspot* secara terus-menerus.

Kata-kata kunci: lokasi *blackspot*, kecelakaan lalulintas, jalan tol, perawatan *blackspot*

INTRODUCTION

Indonesia is a developing country with high population number and rapid increase of vehicle number each year, while infrastructure development including toll road is also increasing, but not as rapid as population and number of vehicle growth. Road crashes data in Indonesia indicated that over 40,000 people died on road crashes each year. Therefore, determination of blackspot locations is crucial in order to reduce number and severity of

accident happened. Moreover, Asian Development Bank has estimated that road crashes cost in Indonesia is approximately 2.8 percent of GDP annually (IndII, 2010).

The aim of this study is to determine blackspot location on toll road in Indonesia and then based on analysis to provide recommendations in order to reduce not only the number but also the severity of accident. Case study is carried out on Purbaleunyi Toll Road in West Java, wherein road accident data is relatively high and well recorded. Accident rate value and UCL method is used in this study to determine blackspot locations. Results in this study will be beneficial not only to toll roads in Indonesia but also to other road function in Indonesia and in other developing countries that have similar road condition.

IndII, 2010 and MTI, 2007 indicated that there is a difference between accident and crash. An accident is an unexpected and unintentionally incident on the road involving vehicle with or without other road users that cause casualty or property damage only. Whereas, a crash is an impact cause human or animal wounded.

In order to reduce number and severity of accident and crash, and furthermore to have a road safety, a number of components have to be considered i.e. human behavior, vehicle condition, road network condition including geometric design, pavement surface, road furniture, and environment, and also road and traffic regulation.

Road Crashes is a large problem in Indonesia. Data indicated that 40,000 people die on road crashes each year. Among Asean countries, Indonesia is only at the seventh below Singapore, Brunei Darussalam, Myanmar, Vietnam, Malaysia, and Cambodia in the effort to design safer road (ADB, 2004).

The determination of blackspot location is crucial. A blackspot is a location on the road that has a high number of crashes. It might be at an intersection or on a curve road of highway. It is known for its crash frequency and usually also for its crash severity. Each country has specific definition of blackspot. In Victoria, Australia, blackspot is defined as a location that has three fatalities in five years (IndII, 2000; Turner, 2007). In New Zealand, a blackspot is defined as a concentration of urban crashes within a 30m radius, or a concentration of open road crashes within a 250 m radius, and three or more fatal or serious injury crashes in five years (Ministry of Transport, New Zealand, 2009). Moreover, in Netherlands, blackspot is defined as an intersection or s short road section with six or more killed or injured person in three successive years (Moning, Herman J., 2008).

In order to determine blackspot locations, adequate good crash database is required. While it is still difficult to obtain accurate, up to date and complete number of traffic accident data in developing countries (Jordan, Phillip, 2011; IndII, 2010; MTI, 2007).

Accident data per km long in year 2010 and 2011 was obtained from Purbaleunyi Toll Road Division, PT Jasa Marga (PT Jasa Marga, 2010; PT Jasa Marga, 2011), West Java Province and Police of West Java Province, Indonesia. The data needed for analysis consists of geometric toll road data, segments of Purbaleunyi toll road, accident numbers, accident causes, accident locations, accident date, accident weather, accident type,and average daily traffic (ADT) volume. Table 1 provides summary of number, fatality, kinds, and cause of accident on Purbaleunyi Toll Road.

METHOD AND ANALYSIS

Road condition is important to be identified while analysing blackspot location. As a toll road, Purbaleunyi toll road has to fulfill a number of technical requirements that higher than those for other roads with lower road hierarchy (Ministry of Public Work, Republic of Indonesia, 2005). In more detail, it has 3.6m lane width, 2.75 m outer shoulder width, 0.75 m inner shoulder width, and 3.5 m median width, with design speed between 60 km/h and 80 km/h.

Moreover, toll road has very limited road access, no passing zone, has guardrail, available traffic signs, good road markings, good pavement condition including zero pothole, along the road. Although toll road has to fulfill higher technical requirement, it can be seen in Table 1 that number of accidents is still high. Therefore, determination of blackspot location is crucial.

Value of Accident Rate

Accident rate is a value of accident depenfds on number of accident, average daily traffic volume, and length of road segment. Accident rate can be determined using formula 1 **(**Departemen Permukiman dan Prasarana Wilayah Republik of Indonesia, 2004**):**

$$T_k = \frac{(F_{k\times 10^8})(100JPKP)}{LHR\times n\times L\times 365} \quad (1)$$

with:

T_k = accident rate, 100 JPKP
F_k = accident frequency on road segment during n year
LHR = average daily traffic (ADT) volume
n = year number of data f
L = length of road segment, km
100JPKP = rate accident dimension (accident number per 100 of vehicle travel per km)

UCL Method

Control Chart is a graph used to evaluate a performance of quality process in statistic. Three parameters used in UCL method are center line, Upper Control Limit (UCL), and Lower Control Limit (LCL) (Ott, R.Lyman, Longnecker, M. 2001). Blackspot locations on road segment of Purbaleunyi toll roadare identified if accident rate value is higher than UCL value. Formula 2 is used to determine UCL value **(**Departemen Permukiman dan Prasarana Wilayah Republik of Indonesia, 2004**):**

$$\text{UCL} = x + (2.576\sqrt{\frac{x}{m}} + \left(\frac{0.829}{m}\right) + \left(\frac{1}{2}\right)m \quad (2)$$

with:

UCL = Upper Control Limit
x = mean of accident rate in accident dimension per exposure
m = exposure dimension, km

Table 1 Accident Data on Purbaleunyi Toll Road (PT Jasa Marga, 2010, 2011; Sutandi and Surbakti, 2012)

Accident Data	Year	
	2010	2011
Number of road crashes	295	307
Number of people involved	636	573
Number of road segment	10	10
Light injuries	64.15 %	56.70 %
Heavy injuries	29.72 %	34.43 %
Fatality	6.13 %	8.87 %
Number of road crashes on Jatiluhur-Padalarang Barat	46.67 %	40.91 %
Number of road crashes on other nine corridors	55.33 %	59.09 %
Single accident	43.50 %	42.00 %
Multiple accident	56.50 %	58.00 %
Human error (not alert, sleepy, drunk, poor discipline)	70.37 %	79.11 %
Vehicle (flat tire, broken brake, broken machine)	24.69 %	19.63 %
Road merging	3.7 %	0.63 %
Exhaust fumes	0.61 %	0.00 %
Stopped car	0.62 %	0.63 %
Clear weather	70.98 %	79.74 %
Other weather	29.02 %	20.26 %
Accident on straight road	80.86 %	86.69 %
Accident on turning road	19.14 %	13.31 %
Accident on dry road surface	80.86 %	87.97 %
Accident on wet road surface	19.14 %	12.03 %
Road crashes on shoulder	13.58 %	18.35 %
Road crashes on left lane	47.53 %	43.67 %
Road crashes on right lane	26.54 %	23.41 %
Road crashes on toll gate	1.85 %	1.89 %
Road crashes on interchange	1.23 %	0.63 %
Road crashes on ramp	0.02 %	3.2 % %
Road crashes at median	0.61 %	1.26 %
Road crashes on ROW	8.64 %	7.59 %

In order to determine blackspot accurately, Purbaleunyi Toll Road that has 2 directions and eleven toll gates will be analyzed per km per road segment per direction. Steps in analysis in order to determine blackspot location based on accident data record per kilometer are as follow:

a. to divide Purbaleunyi Toll Road into 2 parts, direction A (Jakarta to Bandung) and direction B (Bandung to Jakarta) as provided in Table 2;
b. to divide Purbaleunyi Toll Road into 10 road segments (PT Jasa Marga, 2010, 2011) as provided in Table 2;
c. to count average daily traffic (ADT) volume per direction per road segment as provided in Table 2;
d. to count number of accident data per direction per road segmentper km long. Summary of number of accident data per direction per road segment is provided in Table 3;

e. to count accident rate per direction per road segment per km long using formula 1. Summary of accident rate per direction per road segment is provided in Table 4;
f. to count Upper Control Limit (UCL) per direction per road segment per km long using formula 2. Summary of UCL per direction per road segment is provided in Table 4;
g. to determine blackspot location per km long on Purbaleunyi toll road as provided in Table 5. Blackspot location is determined if accident rate value higher than UCL value. Furthermore, Figure 1 describes number of blackspot locations during year 2010 and 2011 and Figure 2 describe distribution of blackspot locations along Purbaleunyi toll road (Gosalim,W., 2012);
h. to provide recommended solution in order to reduce number and severities of accidents, based on previous steps of analysis.

Table 2 Average Daily Traffic (ADT) Volume per Road Segmenton Purbaleunyi Toll Road

No	Road Segment		Average Daily Traffic (ADT) Volume			
			2010		2011	
	Name	Length (km)	Direction A	Direction B	Direction A	Direction B
1	Kalihurip-Sadang	10	27.199	25.972	31.174	35.546
2	Sadang-Jatiluhur	8	24.420	23.079	27.795	32.127
3	Jatiluhur-Padalarang BRT	16	23.554	22.625	26.670	31.260
4	Padalarang BRT-Padalarang	2	1.835	2.133	12.950	16.032
5	Padalarang-Pasteur	5	36.627	36.737	44.266	45.745
6	Pasteur-Pasir Koja	5	34.995	34.670	46.792	38.336
7	Pasir Koja-Kopo	4	33.815	30.620	45.233	34.233
8	Kopo-Moh. Toha	3	31.573	28.892	42.769	32.590
9	Moh. Toha-Buah Batu	2	29.217	27.614	40.098	30.998
10	Buah Batu-Cileunyi	36	21.738	20.934	31.606	23.964

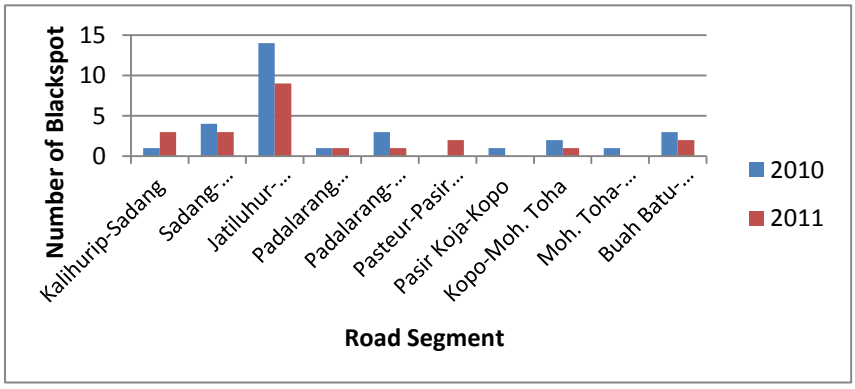

Figure 1 Number of Blackspot Location on Purbaleunyi Toll Road (Gosalim,W., 2012)

Table 3 Number of Accident Data per Direction per Road Segmenton Purbaleunyi Toll Road

No	Road Segment	Number of Accident			
		2010		2011	
		Direction A	Direction B	Direction A	Direction B
1	Kalihurip-Sadang	11	14	10	14
2	Sadang-Jatiluhur	13	13	19	10
3	Jatiluhur-Padalarang BRT	72	72	73	73
4	Padalarang BRT-Padalarang	0	3	3	2
5	Padalarang-Pasteur	11	8	11	10
6	Pasteur-Pasir Koja	7	5	7	9
7	Pasir Koja-Kopo	10	6	6	6
8	Kopo-Moh. Toha	7	7	12	4
9	Moh. Toha-Buah Batu	1	4	6	1
10	Buah Batu-Cileunyi	20	11	17	14

Table 4 Accident Rate and Upper Control Limit (UCL) per Direction Per Road Segment on Purbaleunyi Toll Road

No	Road Segment	Accident rate (T_k)				Upper Control Limit (UCL)			
		2010		2011		2010		2011	
		Direction A	Direction B	Direction A	Direction B	Direction A	Direction B	Direction A	Direction B
1	Kalihurip-Sadang	11,080	14,768	8,788	10,791	20,984	25,997	17,754	20,581
2	Sadang-Jatiluhur	18,231	19,291	23,410	10,660	30,559	31,934	37,202	20,399
3	Jatiluhur-Padalarang BRT	23,263	24,219	20,831	17,772	37,017	38,225	33,917	29,961
4	Padalarang BRT-Padalarang	0	192,667	31,733	17,089	1,329	229,752	47,573	29,067
5	Padalarang-Pasteur	16,456	11,932	13,616	11,987	28,235	22,160	24,451	22,223
6	Pasteur-Pasir Koja	10,960	7,902	8,197	12,864	20,818	16,473	16,901	23,432
7	Pasir Koja-Kopo	27,007	17,895	12,114	16,006	41,723	30,121	22,409	27,641
8	Kopo-Moh. Toha	15,186	17,895	19,217	8,407	26,553	28,417	31,839	17,205
9	Moh. Toha-Buah Batu	4,689	19,843	20,498	4,419	11,595	32,647	33,489	11,163
10	Buah Batu-Cileunyi	15,754	8,998	9,210	10,004	27,308	18,054	18,357	19,480

Table 5 Blackspot Location along Purbaleunyi Toll Road

No	Road Segment	Blackspot location per km			
		2010		2011	
		Direction A (location)	Direction B (location)	Direction A (location)	Direction B (location)
1	Kalihurip-Sadang	1 (km 69-70)	1 (km 70-71)	1 (km 73-74)	2 (km 69-70; 72-73)
2	Sadang-Jatiluhur	2 (km 77-78; 79-80)	2 (km 76-77; 79-80)	1 (km 79-80)	2 (km 79-80; 80-81)
3	Jatiluhur-Padalarang BRT	9 (km 84-85; 94-95; 98-99; 101-102; 108-109; 110-111; 111-112; 112-113; 113-114)	5 (km 86-87; 91-92; 92-93; 100-101; 115-116)	4 (km 85-86; 100-101; 106-107; 119-120)	5 (km 84-85; 86-87; 92-93; 93-94; 113-114)
4	Padalarang BRT-Padalarang	0	1 (km 121-122)	0	1 (km120-121)
5	Padalarang-Pasteur	1 (km 126-127)	2 (km 122-123; 123-124)	1 (km 123-124)	0
6	Pasteur-Pasir Koja	0	0	1 (km 130-131)	1 (km 130-131)
7	Pasir Koja-Kopo	0	1 (km 134-135)	0	0
8	Kopo-Moh. Toha	0	2 (km 135-136; 138-139)	1 (km138-139)	0
9	Moh. Toha-Buah Batu	0	1 (km 139-140)	0	0
10	Buah Batu-Cileunyi	2 (km 146-147; 147-148)	1 (km 145-146)	0	2 (km 145-146; 147-148)

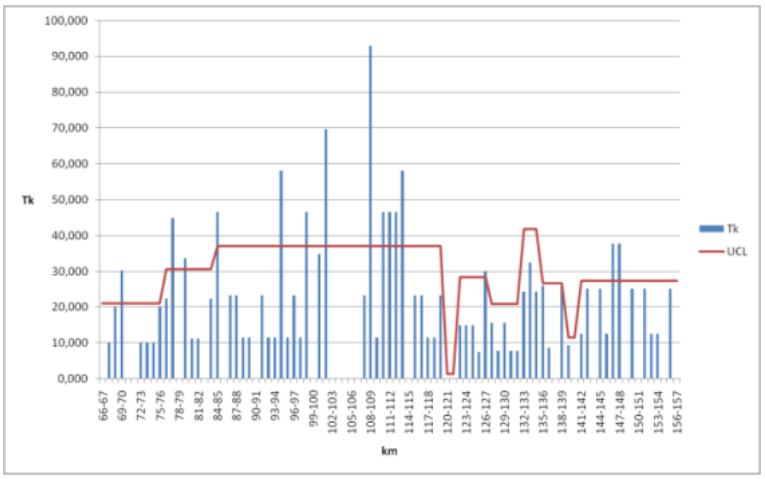

Figure 2a Distribution of Blackspot location, Direction A, 2010

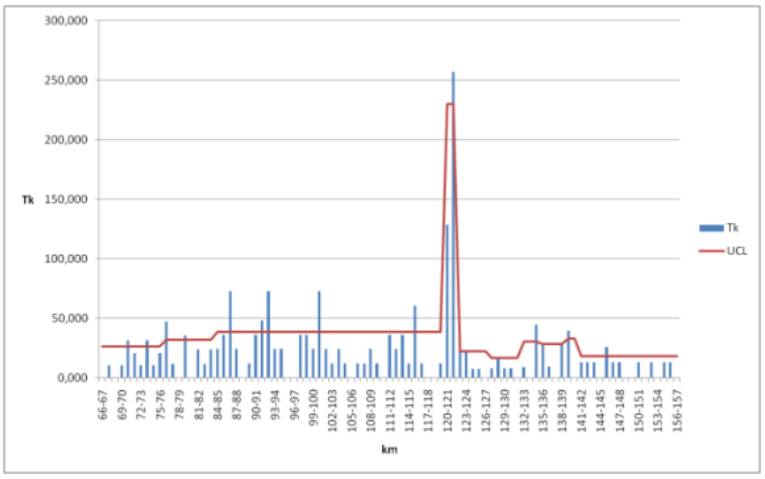

Figure 2b Distribution of Blackspot location, Direction B, 2010

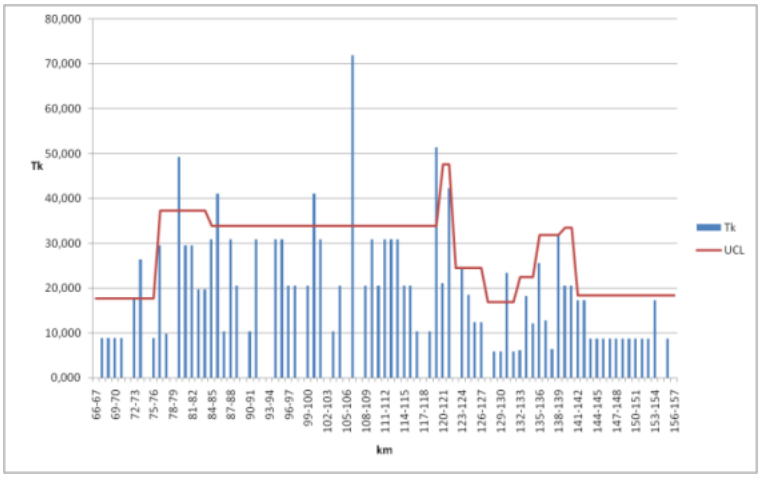

Figure 2c Distribution of Blackspot location, direction A, 2011

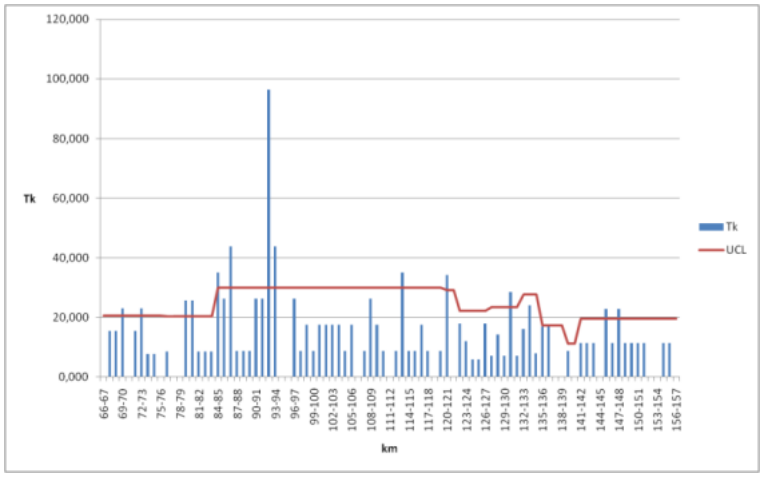

Figure 2d Distribution of Blackspot location, Direction B, 2011

Figure 2 Distribution of Blackspot Location along Purbaleunyi Toll Road (Gosalim,W., 2012)

Recommended Improvement

As indicated in Table 1, in average, casualties consist of 60.4% light injuries, 32.1% heavy injuries, and 7.5% fatality. Furthermore, most accident occurred are a single accident (42.75%) because of human error (74.74%), vehicle (22.16%), road geometric (2.17%) and at clear weather (75.36%). Based on accident location, the most accidents are accident on straight road (83.78%) on dry road surface (84.42%) occurred on the left lane (45.63%), on the right lane (24.98%), and on shoulder (15.97%) respectively (Sutandi0 and Surbakti, 2012). It happened because toll road has to fulfill higher technical requirements, usually has straight road and standard shoulder width, so that human error is the largest cause of accident whereas road geometric is those the lowest cause, and drivers who do not adhere to the traffic regulation, overtake other vehicles through the shoulder.

Moreover, Table 5, Figure 1 and Figure 2 show blackspot locations on Purbaleunyi toll road and Jatiluhur-Padalarang Barat road segment has the highest percentage of accident (43.79%) among others. Although based on data, it is indicated that the highest cause of road accident is human error, but actually interaction among human, vehicle, and road is strong. This type of accident can be caused by driver skill, driver behavior, driver health condition, and vehicle condition.

Furthermore, based on previous analyze, solutions that can be recommended and can be applied practically in order to reduce road safety problems are as follow:

a. Force road users especially drivers to adhere to traffic regulation through having driving license legally, giving traffic ticket to road users who break the traffic regulation;
b. Adherence to the vehicle worthiness;
c. For long term goal, dissemination since the beginning through education at kindergarten and primary school regarding the importance of road safety for road users is very important;
d. Implementation of blackspot treatments continuously:
    - Implementation and maintenance of road furniture including traffic signs, traffic markings, median, road lighting, crash cushion, curve alignment markings, road geometric, and road surface pavement along the road especially on every blackspotlocation;
    - Implementation of road safety audit regularly by road authority and the most important thing is to follow up any result reported from the road safety audit;
    - Implementation of Intelligent Transportation Systems (ITS) to inform road users regarding traffic, road and environment conditions using Variable Message Signs (VMS) especially on blackspot locations and Incident Management involving incident detection, incident analysis, and incident clearance.

- Availability of good accident database management to have accurate, complete, up to date, and continuous accident database and good control from Traffic Management Centre (PATH, ITS, 2011; Batarliene, Nijole, 2009; Sutandi, 2008; Smiley, Alison, 2007; ITS, 2001).

CONCLUSIONS

This study analyzes blackspot locations on toll road,and then provide recommendations to reduce number and severity of accident.Case study is carried out on Purbaleunyi Toll Road in West Java, Indonesia. Accident rate value and UCL method is used in this study.Results indicated that there are many blackspot locations along Purbaleunyi. Furthermore, recommended solutions provided are adherence to traffic regulation, adherence to vehicle worthiness, dissemination of road safety importance to road users, and implementation of blackspot treatments continuously including implementation of Variable Message Signs (VMS) and Incident Management as a part of Intelligent Transportation Systems (ITS) that support by good accident database management. Results in this study are not only beneficial to toll roads in Indonesia but also to other road function in Indonesia and in other countries that have similar road condition.

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