Blackspot Analysis of Road Traffic Crashes in Surabaya - Manyar Toll Road, East Java

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Abstract. Traffic crashes are one of the problems that cannot be prevented, especially on toll roads. Knowing the crash element, including crash number, type, factor, and fatality, could lead the investigation to set crash solving and prevention by finding the blackspot point. Surabaya-Manyar toll roads were reported as crash-prone locations, with 149 crashes from 2014-2018. This research concerns the impact on a specific period obtained by PT. Margabumi Matrajaya was ranging from 2014-2018 at Surabaya-Manyar toll road. The objectives aim to analyze the crash element using submitted data from PT. Margabumi Matrajaya to find the blackspot at each line. The collected data were the primary data from field observation and documentation and secondary data, consisting of crash data, road length, time of the crash, what types of vehicles were involved in the crash, and wound victim data. The locations of crash-prone points (Blackspots) on the Surabaya - Manyar Toll road are as follows: The locations of crash-prone points (Blackspots) on the Surabaya Toll road - Manyar line mostly occurred at Km 9 + 925 - 16 + 400 mostly in 2018, on the Romokalisari - Kebomas section, and for Manyar - Surabaya line, occurred at Km 3 + 500 - 0 + 000 mostly in 2016, on the Tandes - Dupak section. Therefore, to decrease the crash number in Surabaya - Manyar toll road, PT. Margabumi Matrajaya should add traffic sign as blackspot area, speed trap, warning sign like slippery road ahead warning, crossroad, and merging traffic.

1. Introduction

The main problem of transportation problems apart from traffic jams is the high rate of crashes that cause casualties. Traffic crashes are one of the biggest causes of fatality in Indonesia. It is predicted that the traffic crashes fatality ranking will increase, from the 9th to the 3rd in 2020 after heart disease and depression (WHO, 1999). The number of victims due to traffic crashes in Indonesia is still high. Based on obtained data from toll road associations, in 2017, there were 1,075 crashes on toll roads, while in 2018, there were 1,135 crashes [1]. Based on that analysis and evaluation data of East Java Regional Police, there were 211 crashes in East Java with 42 people in a fatality, 30 people severely injured, and 248 people with minor injuries, with total material loss. 356,510,000 [2].

The Surabaya - Manyar Toll Road is a toll road with a length of 20.7 km connecting the City of Surabaya with Gresik in East Java. This toll road is part of Trans Java toll road, which is connected to the Surabaya - Gempol toll road in the east and the planned Tuban - Gresik toll road in the west under the management of PT. Margabumi Matraraya. The number of gates from the direction of Surabaya - Manyar is eight gates, while from the direction of Manyar - Surabaya, there are five gates. This toll road has been operating since 1993 and is the primary access linking Surabaya with Jakarta via the Pantai Utara route [3].
Based on data from PT. Margabumi Matraraya, from 2014 to 2018, there have been 149 crashes, with seven fatality cases, 31 severe injury cases, and 62 minor injured cases. They reported that the biggest causes of crashes are humans and vehicles. But until now, there is no certain statistical data on what the leading cause of the collision was [4].

The high number of traffic crashes is an indicator of the need to reduce traffic crashes. Historically, crashes occurred in a particular area. The number of traffic crashes significantly happens in the same location or road. Sometimes the video results in the incident spot appear blurry and unclear. Researchers [12] can overcome this by using the Wavelet method. Knowing the crash-prone area (blackspots) leads to a decrease or even a high number of traffic crashes. Crash on blackspot area may occur for a variety of reasons, such as hidden junction on a fast road, low or concealed warning signs at crossroads, a sharp drop or corner in a straight road, etc., related to the particular cause of the crash where they often occurred [8–10].

The research objective was to determine the crash-prone areas (black spots) on the Surabaya-Manyar Toll Road. The method used to determine a crash-prone point (black spot) location is where the crash rate is high with the incidence in the same km caused by a particular cause [11]. A black spot is a point or area that shows that the area is a crash-prone area that can be seen from crash data in one year where until now the main cause is still unknown, this can be seen from the fact that there are still occur some crashes every month that cannot be predicted. However, considering that there are still many vehicles, exceptionally light vehicles such as cars that use toll road access and many toll road users do not obey the available signs. Therefore, knowing the blackspot is essential in this research. The crashes could be minimized and lead the next research on the main factor causing the historical crash in certain areas.

2. Methodology
The method of collecting data was obtained from PT. Margabumi Matraraya as operator and Highway Patrol of the East Java Regional Police for 2014 - 2018 on the Surabaya - Manyar Toll Road on average daily traffic and crash data. Meanwhile, primary data is only used to ascertain road conditions and road completeness in crash-prone areas (black spots). The analysis used was the analysis of the level of crashes and the crash-prone regions on the Surabaya-Manyar Toll Road.

3. Result and Discussion
3.1. Daily traffic average and traffic crash number
The following data is the daily traffic average volume in Surabaya - Manyar Toll Road from 2014 - 2018, to see volume growth from year to year. Table 1 showed that the daily traffic average increased year by year from 2014 to 2017 and decreased from 2017 to 2018. Even the decrease was found in 2018, but that average was still on the average of 2014-2018 daily traffic volume, 29.120.636,8 vehicles/day. This average daily traffic volume is categorized in a high number of daily traffic that significantly leads to the crash road. Moreover, the city of Manyar - Surabaya road is a toll road with a high-speed limit. In a certain period of day, daily traffic volume increases, the speed of driven decreases, and the road will be congested. Furthermore, the number of interactions between the user of the road increases. Generally, road safety is the main effect of daily traffic volumes and congestion [13].

After knowing the daily traffic, several traffic crash was correlated due to the occurred effect. Table 1 also showed that the number of the crash increased from 2014-2016 (from 21 cases to 32 cases, and 42 cases) and decreased in 2017 (25 cases) which then risen again in 2018 (29 cases). According to the daily traffic average that increased year by the year 2014-2017, this was also followed by the increasing number of the road crash. The crash is one of the decreasing safety road phenomena. Retallack and Ostendorf described that crash rates were picked when traffic volume was under 400 vehicles/hour and lowest at flow between 1000 and 1500 vehicles/hour. As the increasing traffic volume above 1500 vehicles per hour, the crash rate also increased [1]. This also happens in Surabaya-Manyar toll road that the work of average daily traffic achieved 29.120.636,8 in the highest volume/day in 2017.
Table 1. The volume of daily traffic average and crash number in Surabaya - Manyar toll road from 2014-2018

| Year | Daily average (Vehicles/day) | Crash number (Cases/year) | % of crash number |
|------|----------------------------|---------------------------|-------------------|
| 2014 | 27,949.123                 | 21                        | 14                |
| 2015 | 28,396.040                 | 32                        | 23                |
| 2016 | 29,154.945                 | 42                        | 28                |
| 2017 | 30,195.162                 | 25                        | 16                |
| 2018 | 29,907.914                 | 29                        | 19                |

$\bar{x} = 29,120,636.8, \sum = 149, \Sigma = 100$

3.2. Victims type of traffic crash

PT. Margabumi Matrajaya also showed the number of the victims, including fatality, severely injured, and minor injuries. As the number of the crash increased it also effect to increasing the victim number. Table 2 showed that the victim number in a fatality, severely injured, and minor injuries. All cases/year showed the number of deaths was lowest, severely injured was higher, and minor injured was the highest. Even WHO reported that the fatality rate of Indonesia was in safe grade (2018; 12.2 road fatalities per 100,000 inhabitants per year), injured victims contributed to the cause of decreasing road safety [14], [15].

Table 2. Victims type of traffic crash in Surabaya - Manyar toll road from 2014-2018

| Victims type          | 2014 | 2015 | 2016 | 2017 | 2018 | Σ     |
|-----------------------|------|------|------|------|------|-------|
| Fatality              | 1    | 2    | 2    | 5    | 1    | 11    |
| Severe injured        | 8    | 9    | 15   | 4    | 10   | 46    |
| Minor injured         | 12   | 21   | 25   | 16   | 18   | 92    |
| **Σ**                 | 21   | 32   | 42   | 25   | 29   | 149   |

3.3. Traffic crash factor

Crash factors become the main element to concern more in decreasing the fatality of crash road. Those factors are divided into human, vehicle, road, and environment. From Table 3 it could be known that the highest factor number in Surabaya-Manyar toll road (2014-2018) was human (105 cases), followed by a vehicle with 36 cases. Road and environmental factors were not detected starting from 2015. A human-related error was reported as the main factor in road traffic crashes since upgrading the quality of the road, vehicle, and environmental factors were manipulated and prevented [16]. Some regulation related to safety drive was structured, but that human being often obeyed it. The occurrence of collisions at certain spots is sometimes influenced by road factors that have unstable ground conditions. In fact, by some researchers, [5–7] stability is an absolute requirement for the use of infrastructure, including road conditions.

3.4. Traffic crash occurred time

Some crashes also pointed to specific periods. PT. Margabumi Matrajaya (Table 4) reported that total cases of a collision between 2014-2018 occurred on sunny days from 06.00-18.00 am with 84 cases. While at 19.00-05.00 pm occurred 65 cases. As it is known, all type of vehicle was on the road 06.00-18.00 to go for office work with car, bus, or even loading car affecting congestion that leads to crash [17]. While at night, vehicle composition was pointed to only a heavy loading truck with a low-speed limit.
Table 3. Traffic crash factor in Surabaya - Manyar toll road from 2014-2018

| Factor     | Year 2014 | Year 2015 | Year 2016 | Year 2017 | Year 2018 | Σ   |
|------------|-----------|-----------|-----------|-----------|-----------|-----|
| Human      | 13        | 20        | 23        | 22        | 27        | 105 |
| Vehicle    | 2         | 10        | 19        | 3         | 2         | 36  |
| Road       | 4         | 2         | 0         | 0         | 0         | 6   |
| Environment| 2         | 0         | 0         | 0         | 0         | 2   |
| Σ          | 21        | 32        | 42        | 25        | 29        | 149 |

However, the number of crashes at night was also high. In some crashes, generally, the driver declined the following installation of overhead lighting [2].

Table 4. Traffic crash occurred time in Surabaya - Manyar toll road from 2014-2018

| Occurred time | Year 2014 | Year 2015 | Year 2016 | Year 2017 | Year 2018 | Σ   |
|---------------|-----------|-----------|-----------|-----------|-----------|-----|
| 06.00 - 18.00 | 8         | 21        | 30        | 9         | 16        | 84  |
| 19.00 - 05.00 | 13        | 11        | 12        | 16        | 13        | 65  |
| Σ             | 21        | 32        | 42        | 25        | 29        | 149 |

3.5. Traffic crash-based vehicle type

![Vehicle type diagram](image)

Figure 1. Traffic crash-based vehicle type in Surabaya - Manyar toll road from 2014-2018

Related data of traffic crash occurred time showed that the pick crash happened on a sunny day. Figure 1 showed that the highest percentage of vehicle type on the collision in Surabaya-Manyar toll road 2014-2018 was 49%, the bus was 45%, and the truck was 6%. Car contributed significantly in sunny days due to human activities in working pick hour, early morning, or even late evening.
3.6. Traffic crash-prone area (Blackspot)

Knowing blackspot leads to prevent and decrease traffic crashes [18] [19]. Table 5 described the average crash of Surabaya - Manyar line in 2018. From that data, $\sum a = 19$ as the total of the crash and $n = 2$ as location observed. By this following formula (1), the average crash of Surabaya - Manyar line per year is known at 9.50.

| Traffic crash location         | Number of a traffic crash |
|--------------------------------|----------------------------|
| Tandes - Romokalisari          | 5                          |
| Romokalisari - Kebomas         | 14                         |
| $n = 2$                        | $\sum a = 19$              |

$$X_{average} = \frac{\Sigma a}{n} = \frac{19}{2} = 9.50 \text{ crashes/year}$$ (1)

Figure 2. Blackspot location for section Surabaya - Manyar mostly in 2018 in 1 = Km 3+500 - 9+925 Tandes - Romokalisari section and 2 = Km 9+925 - 16+400 Romokalisari - Kebomas section.

Figure 2 showed the average crash of Surabaya - Manyar line by red line in y-axis as 9.50. Number 1 is the Km 3+500 - 9+925, Tandes - Romokalisari section, while number 2 is Km 9+925 - 16+400, Romokalisari - Kebomas way. Number 2 as Km 9+925 - 16+400 exceeds the average crash/year in the red line (9.50) and points to the first-rate from 2014-2018. Therefore, that way formed as blackspot area for Surabaya - Manyar line mostly in 2018 with 14 cases. As it is known, along this lane is a long lane with a straight line without any lighting, a sign of limit speed, and a speed trap (Figure 3). Hence driver could pass at high speed then obey the standard driving role.

Table 6 described the average crash of Manyar - Surabaya line in 2018. From that data, it was known that $\sum a = 21$ was the total of the crash and $n = 4$ as location observed. By this following formula (2), the Manyar - Surabaya line’s average crash line per year is known in 5.25.
Figure 3. Site location of Surabaya - Manyar toll line at Km 9+925 - 16+400 in Romokalisari-Kebomas section

Table 6. Number of a traffic crash in Manyar - Surabaya line

| Traffic crash location       | Number of a traffic crash |
|-----------------------------|----------------------------|
| Tandes - Dupak              | 9                          |
| Romokalisari - Tandes       | 3                          |
| Kebomas - Romokalisari      | 6                          |
| Manyar - Kebomas            | 3                          |

\[ n = 4 \quad \sum a = 21 \]

\[ X_{\text{average}} = \frac{\sum a}{n} = \frac{21}{4} = 5.25 \text{ crashes/year} \] (2)

Figure 4 showed the average crash of Manyar - Surabaya line by red line in the y-axis as 5.25. Number 1 is the way of Km 3+500 - 0+000, Tandes - Dupak section. Number 1 as Km 3+500 - 0+000 exceeds the average crash/year in the red line (5.25) and points as the first-rate mostly in 2016. Therefore, that way formed as blackspot area for Manyar - Surabaya line in 2016 with 9 cases. As it is known, along this way, is a long way with the straight lane, blend, and incline without any sign of them (Figure 5). Hence driver has to decrease their speed and could not anticipate it.

4. Conclusion

The number of accidents on the Surabaya - Manyar Toll Road from 2014 to 2018 consecutively there were 21 cases with a death rate of 14%. In 2015 there were 32 cases with a death ratio of 23%. In 2016 there were 42 cases with a mortality rate of 28%. In 2017 there were 25 cases with a mortality rate of 16%, and in 2018 there were 29 cases with a mortality rate of 19%. The locations of crash-prone points (Blackspots) on the Surabaya - Manyar Toll road are as follows: The locations of crash-prone points (Blackspots) on the Surabaya Toll road - Manyar line mostly occurred in 2018 on Surabaya - Manyar line, which is at Km 9 + 925 - 16 + 400, on the Romokalisari - Kebomas section, and mostly in 2016 on
Figure 4. Blackspot location for Manyar - Surabaya section mostly in 2016. 1 = Km₃ + 500 – 0 + 000, pada ruas Tandes - Dupak in 2 = Km₀ + 925 – 3 + 500, Romokalisari - Tandes section, 3 = Km₁₆ + 400 – 9 + 925, Kebomas - Romokalisari section, and 4 = Km₂₀ + 732 – 16 + 400, Manyar - Kebomas section.

Figure 5. Site location of Manyar - Surabaya toll line at Km₃ + 500 – 0 + 000 in Tandes - Dupak section.

Manyar - Surabaya line, namely at Km 3 + 500 - 0 + 000, on the Tandes - Dupak section. Therefore, to decrease the crash number in Surabaya - Manyar toll road, PT. Margabumi Matrajaya should add traffic sign as blackspot area, speed trap, warning sign like slippery road ahead warning, crossroad, and merging traffic.
References

[1] B. Ostendorf and A. E. Retallack, “Current Understanding of the Effects of Congestion on Traffic Accidents,” Int. J. Environ. Res. Public Health, vol. 16, no. 2, pp. 3400, 2019.

[2] S. Plainis, I. J. Murray, and I. G. Pallikaris, “Road traffic casualties: Understanding the night-time death toll,” Inj. Prev., vol. 12, no. 2, pp. 125–128, 2006.

[3] D. P. Bhakti, “Indonesia’s Toll-Road Infrastructure Finance, Jasa Marga and its Corporatization,” SSRN Electron. J., vol. 1, no. July, 2014.

[4] M. Razif and S. F. Persada, “The calculation of average vehicles emission from environmental audit in toll-road Surabaya-Gresik at Indonesia,” Int. J. ChemTech Res., vol. 9, no. 6, pp. 657–668, 2016.

[5] Shiyi Liu, Zhenning Su, Ming Li, and Longtan Shao. Slope stability analysis using elastic finite element stress fields. Engineering Geology, 273:105673, 2020.

[6] Yufeng Tian and Zhanshan Wang. A new multiple integral inequality and its application to stability analysis of time-delay systems. Applied Mathematics Letters, 105:106325, 2020.

[7] Mustafa Turkylmazoglu. Single phase nanofluids in fluid mechanics and their hydrodynamic linear stability analysis. Computer Methods and Programs in Biomedicine, 187:105171, 2020.

[8] S. Moalimadani, M. R. Keymanesh, and A. Nasrollahaabar. “Identification and management of black spots case study of Haraz road.” J. Middle East Appl. Sci. Technol., no. September, pp. 780–785, 2014.

[9] P. L. Stephen, G. G. Kelakom, J. M. Sojan, K. S. Steeleakshi, and N. B. Vishnu, “Identification and Analysis of Accident Blackspots Using GIS,” Int. Res. J. Eng. Technol., vol. 05, no. 03, pp. 3455–3459, 2018.

[10] W. Kowtanapanich, Wichuda Tanaboriboon, Yordphol Chadbunchachai, “Applying public participation approach to black spot identification process: a case study in Thailand.” IATSS Res., vol. 30, no. 1, pp. 73–85, 2006.

[11] H. Chen, “Black Spot Determination of Traffic Accident Locations and Its Spatial Association Characteristic Analysis Based on GIS,” J. Geogr. Inf. Syst., vol. 04, no. 06, pp. 608–617, 2012.

[12] Muhammad Kusban, A. Susanto, and O. Wahyunggoro. Excellent performance of palmprint recognition by using wavelet filter. ICIC Express Letters, 11:1315–1321, 08 2017.

[13] Z. Christoforou, S. Cohen, and M. G. Karlaftis, “Integrating Real-Time Traffic Data in Road Safety Analysis,” Procedia - Soc. Behav. Sci., vol. 48, pp. 2454–2463, 2012.

[14] A. P. Muthusamy, M. Rajendran, K. Ramesh, and P. Sivaprakash, “A review on road traffic accident and related factors.” Int. J. Appl. Eng. Res., vol. 10, no. 11, pp. 28177–28183, 2015.

[15] C. Timmermans et al., “Analysis of road traffic crashes in the State of Qatar,” Int. J. Inj. Contr. Saf. Promot., vol. 26, no. 3, pp. 242–250, 2019.

[16] E. Petridou and M. Moustaki, “Human factors in the causation of road traffic crashes,” Eur. J. Epidemiol., vol. 16, no. 9, pp. 819–826, 2000.

[17] M. Mohanty and A. Gupta, “Investigation of adolescent accident predictive variables in hilly regions,” Int. J. Inj. Contr. Saf. Promot., vol. 23, no. 3, pp. 291–301, 2016.

[18] M. Ghadi and Á. Török, “Comparison Different Black Spot Identification Methods,” Transp. Res. Procedia, vol. 27, pp. 1105–1112, 2017.

[19] K. H. Jadav, H. J. Padhya, and P. S. Shah, “Identification and improvement of black spot for collision: a case study of road stretch surat,” Int. J. Res. Anal. Rev., vol. 7, no. 1, pp. 943–946, 2020.