Road safety analysis on Achmad Yani frontage road Surabaya

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Abstract. This research discusses road safety analysis on the operation of frontage road on the west side of Achmad Yani Road Surabaya. This research began by conducting survey on secondary data of traffic accidents. In addition, primary data survey was conducted to obtain traffic data, geometric road data, and other supporting data at the study site along the west side frontage of Ahmad Yani Road Surabaya. Devices used in this research include camera, handy cam, speed gun, counters of vehicles, rolling meter, computer and others. In outline, the stages to conduct this research are divided into 4 stages, namely 1. the preparation stage, 2. data collection and processing, 3. analysis and discussion, and 4. conclusion. The results of this study showed that the accident characteristics of the frontage road are (i) 3 accidents occurred per month, (ii) motorcycles was accounted for the largest proportion of accidents which amounted to 74.6 percent, (iii) there were 3 accident victims per month, and (iv) material losses per month worth 1.2 million. The accident rate in 2016 was 0.04 crashes per one million vehicle travels per kilometer, while during 2 months in 2017 it was 0.15 accidents per one million vehicle travels per kilometer. Black spot area of accident is located on Sta 2 + 800 to 2 + 900 which is in front of Graha Pena building and DBL Arena. The high rate of accidents is influenced by the speed of the vehicle which 85 percentile exceeds the speed limit of 40km per hour.

1. Introduction

Road safety is an important aspect in the issue of eco-friendly transportation or green transport. It becomes increasingly important as the phenomenon of the increase traffic accidents on the roads [1]. Traffic accidents can occur anytime and anywhere; these depend on the rider’s condition, the technical condition of the vehicle and its roads, and the weather [2, 3, 4]. Recently, the number of traffic accidents has increased steadily. Based on the data of Land Transportation in Figures, the number of traffic accident incidents on the road from year to year did fluctuate, but the trend increased with an average growth of about 10% per year. Similarly, the number of vehicles involved, the number of victims, and material losses also increased [5, 6, 7].

Road traffic accidents in urban areas are interesting to assess, as the number of accidents in urban area is greater than in non-urban areas. Similarly, traffic accidents occured in major cities, such as Surabaya, are also estimated to be larger than those in small cities [7, 8]. The portrait of road traffic accidents in Surabaya also reflects the phenomenon in Indonesia. The number of road traffic accident casualties caused by motorcycles is higher than other types of vehicles [9].

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The rapid economic growth in Surabaya needs to be supported by the provision of adequate road infrastructure. Currently, the road network in Surabaya has been too complex, the mobility of the population was very high as well. The road capacity which is unable to service the vehicle flow will potentially lead to congestion and traffic accidents [10, 11, 12]. Therefore, Surabaya Government have built frontage road on Jalan Achmad Yani, which is the access road in and out of Surabaya on the south side. Frontage road on the west side of Jalan Ahmad Yani Surabaya which is located at the southern end of Surabaya City is a busy and crowded highway because it is the entrance gate of vehicles from outside cities to Surabaya. Therefore, it makes frontage road on the west side of Ahmad Yani road Surabaya more prone to traffic accident.

The data obtained shows that the frequency of accidents is higher every year since frontage road on Jalan Achmad Yani was opened. There are 26 events in 12 months (2016) and 65 events in 5 months (2017). Due to a lot of accidents occur on the frontage road, it is particularly important to perform road safety analysis at that location.

2. Literature Review

The study of traffic accidents continues to grow. Several previous studies that examined road accidents and frontage roads include: Xie and Zhang [13] who examined roads in Toronto, Canada; Ackaah and Salifu [8] who examined roads in Ghana; and Polus and Cohen [14] who examined roads in Israel. In addition, Li, Lord, and Zhang [4] reviewed the frontage road in Texas and Machsus [9] reviewed the model of accident prediction on roads and intersections in Surabaya – Indonesia.

The accident rate is the number of traffic accidents compared to the volume of traffic and the length of the road. The accident rate expressed accidents per 100 million vehicles per kilometer journey. This method is commonly used to calculate roads that have similar traffic types [15]. The annual accident rate is formulated as follows:

\[ Tk = \frac{Fk \times 10^6}{LHRt \times n \times L \times 365}, \text{(100MVKT)} \]

where:
- \( Tk \) = Accident rate, 100 MVKT (Million Vehicle-Kilometre of Travel)
- \( Fk \) = Accident Frequency on the road for n years of data
- \( LHRt \) = Average of Traffic Volume
- \( N \) = Number of years of data
- \( L \) = Length of road, Km

The accident rate formula is used to analyze annual accident data. If it is necessary to analyze the monthly accident data, then the accident rate formula must be developed or transformed. The transformation results for the monthly accident rate are formulated as follows:

\[ Tk = \frac{Fk \times 10^6}{LHRt \times n \times L \times 30}, \text{(MVKT)} \]

where:
- \( Tk \) = accident rate, MVKT
- \( Fk \) = Frequency of accidents on the road for n data months
- \( LHRt \) = Average of Traffic Volume (smp)
- \( N \) = Number of months of data
- \( L \) = Length of road (Km)
- MVKT = Accident rate unit (number of accident / One Million Vehicle-Kilometre of Travel)

The fatality rate is the number of fatal traffic accidents compared to the volume of traffic and the length of the road. This fatality rate states the number of fatal accidents (causing death) per 100 million vehicle kilometres [15]. The annual fatality rate is formulated as follows:
Tkf = \frac{Fk \times 10^8}{LHRt \times n \times L \times 365} \cdot (100MVKT) \quad (3)

where:
TF = Fatality rate MVKT
Ff = Frequency of fatal accident on the road for n years of data
LHRt = Average of Traffic Volume (smp)
N = Number of years of data
L = Length of road, Km
100MVKT = Unit of accident level (number of accident / one hundred million vehicle-kilometre of travel)

The formula of the fatality rate is used to analyze the annual fatality data. If necessary to analyze monthly fatality data then the formula of the fatality rate must be developed or transformed. The transformation results for the monthly fatality rate are formulated as follows:

Tkf = \frac{Fk \times 10^8}{LHRt \times n \times L \times 30} 
\cdot (100MVKT) \quad (4)

where:
TF = Fatality rate, MVKT
Ff = Frequency of fatal accident on the road for n data months
LHRt = Average of Traffic Volume (smp)
N = Number of months data
L = Length of road, Km
100MVKT = Accident rate unit (number of accident / one hundred million travels-kilometre of travel)

Calculating the accident rate on each segment of the divided road segments per 100 meters is used as a method to determine black spot area. The highest accident rate calculation at a particular location indicates that the location is prone to accidents. At this accident which is prone location should be prioritized in mitigation to reduce traffic accidents rate [16, 17].

3. Material and Method

The location of this study is on the west side frontage road of Jalan Ahmad Yani Surabaya-Indonesia. Data used in this study are the number of traffic accidents, vehicle volume, vehicle speed, road geometry and land use. Data used in this research is the data which was collected since frontage road operate in 2016. Some devices used in this research are camera, handy cam, speed gun, vehicle counter, rolling meter, computer, stationery and others.

In outline, the stages to conduct this research are divided into 4 stages, namely 1. the preparation stage, 2. data collection and process, 3. analysis and discussion and 4. conclusion. Based on the result of traffic counting survey conducted on peak hour, it was obtained 2 important data which are the average daily traffic volume (ADT) and the degree of saturation (DS) of the road segment in this study location. Accident data obtained from Traffic Accident unit of Surabaya city resort is classified based on the number of accident incidents. Moreover, it is based on categories injuries: minor injury, heavy injury, and death. Then, these data used to calculate accident rate, fatality level, and black spot area. Based on the results of the survey speed, it can be calculated that the value of speed at the condition of 85 percentiles for each classification of vehicle types. Furthermore, it was conducted a correlation analysis between vehicle speed factor with accident rate. Finally, it was found solutions to reduce and avoid the occurrence of accidents and also formulated suggestions for this research, especially related to the utilization of research results and further research development.

Traffic flow data in this study is the data flow of incoming vehicles from and to the frontage road. While the types of vehicles surveyed are classified into: motorcycles (MC), light vehicles (LV), heavy vehicles (HV), and non-motorized vehicles (UM). Implementation of traffic surveys on frontage road...
was undertaken on weekdays. Survey time that was conducted during peak hour of the morning was at 6 am to 9 am. Surveys were conducted by using the camera recording method which used the following devices: digital camera, tripod, and memory card. The number of points to be surveyed is 11 points/locations. Point 1 located between STA 0+000 - 0+140, point 2 located between STA 0+140 - 0+160, point 3 located between STA 0+160 - 0+620, point 4 located between STA 0+585 - 0+690, point 5 located between STA 0+690 - 1+230, point 6 located between STA 1+230 - 1+640, point 7 located between STA 1+640 - 1+800, point 8 located between STA 1+800 - 2+800, point 9 located between STA 2+800 - 3+120, point 10 located between STA 3+120 - 3+800, point 11 located between STA 3+800 and 4+200. Speed survey was undertaken using electronic measurement method, namely speed gun.

Figure 1. Location of traffic survey (point 2).

4. Results and Discussions
This section deals with the results and discussion of the characteristics of traffic accidents, the accident rate and the level of fatality, the determination of black spot area, the evaluation of vehicle speeds, and the reduction of accident rates.

4.1. Characteristics of traffic accidents
The characteristics of traffic accidents can be obtained from field observations and accident statistics data during the frontage road operates. The construction of the road on the west side of Jalan Ahmad Yani Surabaya is intended as a frontage road facility for the movement of traffic from the south to the north. By operating frontage road, it increased the road capacity. Furthermore, it improved the performance of Jalan Ahmad Yani Surabaya. Nevertheless, the operation of frontage roads also has negatively impacted that increased the number of traffic accidents. The result of field observations indicated that it has no vehicle classification arrangement which regulates the permissibility of vehicles through fast lanes and or slow lanes. It means that mixed traffic occurs at the study site. It happens because riders are free to choose to pass the fast lane or slow lane (frontage road). These conditions will certainly affect on the high potential for accidents on a road [16, 18].

Traffic accidents statistics since frontage road operates, i.e. from January 2016 to the end of May 2017 can be read in Table 1 below.

Table 1. Characteristics of traffic accidents in frontage road.

| No | Type of Vehicle                  | Unit  | Year 2016 (12mons) | Year 2017 (5mons) | Total | Percentage (%) | Monthly Average |
|----|---------------------------------|-------|--------------------|-------------------|-------|----------------|-----------------|
| 1  | Number of Accidents             | accidents | 26                 | 65                | 91    | 6.5            |                 |
| 2  | Type of Vehicle                 |        |                    |                   |       |                |                 |
|    | - Two-Wheeled Vehicles          | unit   | 28                 | 68                | 96    | 71.6           | 6.9             |
|    | - Four-Wheeled Vehicles         | unit   | 4                  | 6                 | 10    | 7.5            | 0.7             |
|    | - Pedestrians                   | person | 7                  | 21                | 28    | 20.9           | 2.0             |
Table 1 presents that the accident characteristic is shown by the frequency of accidents. There were 42 accidents since 17 months of frontage road operated or 6.5 accidents per month in average. In terms of the type of vehicle involved, the highest proportion of accident was caused by two-wheeled vehicles or motorcycle by 71.6%, while four-wheeled vehicles contributed 7.5% of accidents’ number, and the rest by 20.9% were pedestrians or riding no vehicle. Furthermore, the numbers of accident victims were 91 people by 17 months or 6.5 people per month in average. While the classification of the victims died, serious injuries and minor injuries respectively were 8.8%, 8.8%, and 82.4%. Whereas, average material losses were 2.5 million per month.

4.2. Accident and fatality rates

Accident and fatality rates in each month in 2016 can be read in Table 2, while Table 3 shows the accident and fatality rates in January until May 2017.

Table 2. Number of accidents, number of casualties, accident rate and fatality rate in 2016.

| No | Month   | Number of Accidents | Number of Casualties | Accident Rate | Fatality Rate |
|----|---------|---------------------|----------------------|---------------|---------------|
|    |         | MD | LB | LR |               |               |
| 1  | January | 0  | 0  | 0  | 0.00          | 0.00          |
| 2  | February| 1  | 0  | 1  | 0.02          | 0.00          |
| 3  | March   | 3  | 1  | 2  | 0.06          | 1.93          |
| 4  | April   | 2  | 0  | 2  | 0.04          | 0.00          |
| 5  | May     | 1  | 0  | 1  | 0.02          | 0.00          |
| 6  | June    | 2  | 0  | 1  | 0.04          | 0.00          |
| 7  | July    | 0  | 0  | 0  | 0.00          | 0.00          |
| 8  | Augustus| 1  | 0  | 1  | 0.02          | 0.00          |
| 9  | September| 2 | 0  | 1  | 0.04          | 0.00          |
| 10 | October | 5  | 1  | 3  | 0.10          | 1.93          |
| 11 | November| 0  | 0  | 0  | 0.00          | 0.00          |
| 12 | December| 9  | 0  | 9  | 0.17          | 0.00          |

|              |                |               |          |              |
| Amount       | 2              | 3             | 21       | 0.32         |
| Total Amount | 26             |               |          | 0.04         |
| %            | 7.7            | 11.5          | 80.8     |              |

Table 3. Number of accidents, number of casualties, accident rate and fatality rate in 2017.

| No | Month | Number of Accidents | Number of Casualties | Accident Rate | Fatality Rate |
|----|-------|---------------------|----------------------|---------------|---------------|
|    |       | MD | LB | LR |               |               |
| 1  |       | 0  | 0  | 0  | 0.00          | 0.00          |
| 2  |       | 1  | 0  | 1  | 0.02          | 0.00          |
| 3  |       | 3  | 1  | 2  | 0.06          | 1.93          |
| 4  |       | 2  | 0  | 2  | 0.04          | 0.00          |
| 5  |       | 1  | 0  | 1  | 0.02          | 0.00          |
| 6  |       | 2  | 0  | 1  | 0.04          | 0.00          |
| 7  |       | 0  | 0  | 0  | 0.00          | 0.00          |
| 8  |       | 1  | 0  | 1  | 0.02          | 0.00          |
| 9  |       | 2  | 0  | 1  | 0.04          | 0.00          |
| 10 |       | 5  | 1  | 3  | 0.10          | 1.93          |
| 11 |       | 0  | 0  | 0  | 0.00          | 0.00          |
| 12 |       | 9  | 0  | 9  | 0.17          | 0.00          |

|              |                |               |          |              |
| Amount       | 2              | 3             | 21       | 0.32         |
| Total Amount | 26             |               |          | 0.04         |
| %            | 7.7            | 11.5          | 80.8     |              |
| Accidents | Casualties | Rate | Rate |
|-----------|------------|------|------|
|           | MD         | LB   | LR   |
| 1         | January    | 14   | 1    | 1    | 12  | 0.27 | 1.93 |
| 2         | February   | 12   | 1    | 0    | 11  | 0.23 | 1.93 |
| 3         | March      | 13   | 1    | 2    | 10  | 0.25 | 1.93 |
| 4         | April      | 15   | 1    | 2    | 12  | 0.29 | 1.93 |
| 5         | May        | 11   | 2    | 0    | 9   | 0.21 | 3.87 |

| Amount    | 65        |
|           | 0.25      |

Table 2 presents that the highest monthly accident rate in 2016 occurred in December by 0.17 accidents per one million vehicle-kilometre of travel, while for monthly fatality rates occurred in March and October by 1.93 accidents per one hundred million vehicle-kilometre of travel. The annual accident rate in 2016 was 0.04 accidents per one million vehicle-kilometre of travel, while the annual fatality rate in 2016 was 0.32 accidents per one hundred million vehicle-kilometre of travel.

Table 3 shows that the higher monthly accident rate in 2017 occurred in April, by 0.29 accidents per one million vehicle-kilometre of travel, while for monthly fatality rates occurred in May by 3.87 accidents per one hundred million vehicle-kilometre of travel. In terms of these two data, the annual accident rate in 2017 was 0.25 crashes per one million vehicle-kilometre of travel, while for the annual fatality rate was 2.32 accidents / hundred million vehicle-kilometre of travel.

The results of the accident and fatality rate calculation indicate that frontage road has a high accident and fatality rate since its first operation period. It is indicated that the presence of western side frontage has positive impact on the smoothness of traffic but it has negative impact as well. Frontage road increased the magnitude of accident and fatality rate.

4.3. Location of black spot area

The location of black spot area was obtained from the accident and the fatality rate on each segment road which is divided by 100 meters. The highest result of accident rate calculation at a particular location indicates that the location is one of black spot areas. Examples of accidents and fatalities rates are as follows:

- Accident rate on STA 2+800 to 2+900 in 2016

\[ T_k = \frac{F_k \times 10^6}{LH \times M \times 1 \times 30} = \frac{7 \times 10^6}{410189 \times 12 \times 0.1 \times 30} = 0.47 \]

Accident rate calculation results for other locations are presented in Appendix A.

- Fatality rate on STA 2+800 to 2+900 in 2016

\[ T_k = \frac{F_k \times 10^8}{LH \times M \times 1 \times 30} = \frac{1 \times 10^8}{410189 \times 12 \times 0.1 \times 30} = 6.77 \]

Fatality rate calculation results for other locations are presented in Appendix A.

Based on the calculation result of the accident and fatality rate, it was found that the area of STA 2+800 to STA 2+900 were the most vulnerable area to traffic accidents. Black spot areas which are in front of Graha Pena and DBL Arena buildings had the highest accident and fatality rate of 0.47 and
6.77. If the highest score between the accident rate and the fatality rate is different, then accident rate will be the priority to determine the black spot area.

The results of speed survey in peak hour of holidays and weekdays were calculated by 85 percentile of speed in each segment. Then, it was calculated the average of the four segments as shown in Table 4. The result of speed calculation, which is shown in the table 4, shows that the vehicle speed on holiday was higher than on the working day, with the largest average deviation reached 8 km / hour. This speed difference occurs in each type of vehicle. In addition, it happens to all peak hours ie morning, afternoon and evening. It means that traffic volume on holidays is less than on weekdays, so drivers can drive at higher speeds on holidays.

Table 4. Vehicle speed at peak hours on holidays and working days.

| Peak Hour | Type of Vehicle     | Holiday  | Weekday | Deviation |
|-----------|---------------------|----------|---------|-----------|
| Morning   | Light Vehicle (LV)  | 63.9     | 55.9    | 8.0       |
|           | Heavy Vehicle (HV)  | 55.9     | 49.6    | 6.2       |
|           | Motorcycle (MC)     | 63.7     | 58.2    | 5.6       |
| Afternoon | Light Vehicle (LV)  | 61.1     | 57.8    | 3.3       |
|           | Heavy Vehicle (HV)  | 57.7     | 52.9    | 4.8       |
|           | Motorcycle (MC)     | 62.6     | 59.4    | 3.3       |
| Evening   | Light Vehicle (LV)  | 61.3     | 58.7    | 2.6       |
|           | Heavy Vehicle (HV)  | 50.6     | 46.6    | 4.0       |
|           | Motorcycle (MC)     | 63.6     | 60.2    | 3.4       |

If it is associated by regulation of maximum urban speed limit by 40 km / h, then the data in Table 4 shows that there is violation of the maximum speed limit on the frontage road. The maximum allowable speed limit is 40 km / hours. It is clearly visible on the maximum speed warning signs which is installed in Jalan Ahmad Yani as shown in Figure 1. Therefore, the high accident rates on the frontage road were closely related to the 85 percentile vehicle speed which exceeds 40 km / hours. Moreover, the geometric condition of frontage road of Jalan Ahmad Yani is flat with an average road width of 15 meters. These reasons encourage the riders to drive at high speed.

Speed exceeding the threshold could potentially increase the risk of traffic accidents. Someone who drives at speeds > 40 km / hours will have difficulty to control the vehicle in urgent conditions such as the vehicle in front of it stop abruptly or it avoids damaged road conditions. The braking distance until the vehicle stops completely are directly proportional to vehicle speed. Vehicle speeding at 40 km / hours will be stopped optimally at a distance of about 20-100 meters after the braking process. However, the distance is also influenced by other factors, eg slippery road conditions will extend the required distance of vehicle to stop completely after the braking process [19].

4.4. Reduction of accident rate

Based on the discussion in this study, so the reduction of accident and fatality rate on the frontage road can be solved by some alternative as follows:

- Reducing mixed traffic by normalizing the frontage road function. Mixed traffic can be minimized by setting certain types of vehicles that are allowed to pass through the frontage road. For example, public vehicles and motorcycles must pass through frontage road and be forbidden to pass through fast lanes;
- Installation of rumble strips in black spot area. It is important to reduce the vehicle speed at black spot area.
- The addition of PCTL (Pedestrian Crossing Traffic Light) to reduce the potential of accidents between vehicles with pedestrians or road splinters;
- Painting road markings and completing signs at black spot area.
• Penalizing traffic violators, particularly for violations of speed limits.

5. Conclusion

• Characteristic of traffic accidents occurring along the west side frontage road of Jalan Ahmad Yani shows that there are mixed traffic. Since 17 months of frontage road operates, there were 6.5 accidents per month in average. In terms of the type of vehicle involved, the highest proportion of accident was caused by two-wheeled vehicles or motorcycle by 71.6%, while four-wheeled vehicles contributed 7.5% of accidents’s number, and the rest by 20.9% were pedestrians or riding no vehicle. Furthermore, the number of accident victims were 91 people by 15 months or 6.5 people per month in average. While the classification of the victims died, serious injuries and minor injuries respectively were 8.8%, 8.8%, and 82.4%. Whereas, average material losses were 2.5 million per month.

• The annual accident rate in 2016 was 0.04 accidents per one million vehicle-kilometre of travel, while for 5 months in 2017 was 0.25 accidents per one million vehicle-kilometre of travel.

• Black spot areas located along west side of frontage road on Jalan Ahmad Yani which is on STA 2 + 800 to 2 + 900, located in front of Graha Pena and DBL Arena building, with accident rate by 0.47 accidents per one million vehicle travels per kilometre, and a fatality rate by 6.77 million accidents per kilometre.

• The high rate of accidents is influenced by the vehicle speed factor that is 85 percentiles which exceeds the allowable speed limit 40 km per hour. The vehicle speed at the 85th percentile condition that crossed the frontage road segment on the west side of Jalan Ahmad Yani for LV classification is 50 km per hour, the HV classification is is 47.5 km per hour, and the MC classification is 67 km per hour.

• Alternatives of counter measures to reduce accident rates include: (i) reducing mixed; (ii) installing of rumble strips at the spot black spot area, (iii) installing PCTL (Pedestrian Crossing Traffic Light); (iv) painting road markings; and (v) penalizing traffic violators, particularly for violations of speed limits.

6. References

[1] Petrov A. and Petrov D., 2016, Assessment of Spatial Unevenness of Road Accidents Severity as Instrument of Preventive Protection from Emergency Situations in Road Complex. in 7th International Scientific Practical Conference "Innovative Technologies in Engineering", IOP Publishing, IOP Conf. Series: Materials Science and Engineering 142 012116, doi:10.1088/1757-899X/142/1/012116

[2] Sakhapov RL. et al. 2016, Risk management model in road transport systems. In 5th International Conference on Mathematical Modeling in Physical Sciences (IC-MSquare 2016), IOP Publishing, Journal of Physics: Conference Series 738 012008, doi:10.1088/1742-6596/738/1/012008

[3] Li, X. G., Lord, D., Zhang, Y., & Xie, Y. C. 2008. Predicting Motor Vehicle Crashes Using Support Vector Machine Models. Accident Analysis and Prevention, 40(4), p.1611–1618.

[4] Li, X. G., Lord, D., & Zhang, Y. 2011. Development of Accident Modification Factors for Rural Frontage Road Segments in Texas Using Results from Generalized Additive Models. ASCE Journal of Transportation Engineering, 137(1), 74–83.

[5] Direktorat Jenderal Perhubungan Darat, 2015. Perhubungan Darat Dalam Angka (PDDA). Jakarta.

[6] Machsus, Rachmad Basuki, and Amalia F. Mawardi, 2015. Generalized Additive Models for Estimating Motorcycle Collisions on Collector Roads. In the 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5), doi: 10.1016/j.proeng.2015.11.105, ISSN: 1877-7058, September 15-18, 2015, Surabaya, Indonesia.
[7] Machsus, Harnen S., Wicaksono A., and Djakfar L., 2013. The Prediction Models of Motorcycle Accidents on Surabaya Arterial Roads Using Generalized Linear Models. Middle-East J. Sci. Res., 18 (12): 1859-1866, 2013. ISSN 1990-9233, © IDOSI Publications.

[8] Ackaah W. and Salifu. M. 2011. Crash prediction model for two-lane rural highways in the Ashanti region of Ghana. IATSS Research, 35, p.34-40

[9] Machsus, Harnen Sulistio, Achmad Wicaksono and Ludfi Djakfar. 2014. The Effect of Access Points on Motorcycle Accident Rates on Surabaya Arterial Roads. Australian Journal of Basic and Applied Sciences (AJBAS), 8 (10), p.38-43

[10] Ispas N. and Trusca D., 2016, Urban planning and traffic safety at night. 7th International Conference on Advanced Concepts in Mechanical Engineering, IOP Publishing, IOP Conf. Series: Materials Science and Engineering 147 (2016) 012130, doi:10.1088/1757-899X/147/1/012130

[11] Nambuusi et.al. 2008. A review of accident prediction models for road intersections. Steunpunt Mobiliteit & Openbare Werken – Spoor Verkeersveiligheid. RA-MOW-2008-004

[12] Karacasu Murat et al. 2016, Traffic Perception in Eskişehir Province. World Multidisciplinary Earth Sciences Symposium (WMESS 2016), IOP Publishing, IOP Conf. Series: Earth and Environmental Science 44 052060, doi:10.1088/1755-1315/44/5/052063

[13] Xie, Y., & Zhang, Y. 2008. Crash Frequency Analysis Using Generalized Additive Models. Transportation Research Record, 2061, 39–45.

[14] Polus A. and Cohen M. 2011. A new, non-canonical Poisson regression model for the prediction of crashes on low-volume rural roads. IATSS Research, Volume 35, Issue 2, March 2012, pages 98-103.

[15] National Highway Traffic Safety Administration (NHTSA). 2012. Traffic Safety Facts 2012, A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System, U.S. Department of Transportation, Washington, DC 20590. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812032

[16] Zhang, Y. et al. 2012. Crash frequency analysis of different types of urban roadway segments using generalized additive mode. Journal of Safety Research 43, 107–114

[17] Akalin KB. et al. 2016, Curve Estimation of Number of People Killed in Traffic Accidents in Turkey. World Multidisciplinary Earth Sciences Symposium (WMESS 2016), IOP Publishing, IOP Conf. Series: Earth and Environmental Science 44 (2016) 052060, doi:10.1088/1755-1315/44/5/052060

[18] Mansur A., and Nasution MI. 2016, Identification of Behavior Based Safety by Using Traffic Light Analysis to Reduce Accidents. ICET4SD, IOP Publishing, IOP Conf. Series: Materials Science and Engineering 105 012033, doi:10.1088/1757-899X/105/1/012033

[19] Reynolds CCO. et al. 2009. The impact of transportation infrastructure on bicycling injuries and crashes: A Review of the Literature. Environmental Health

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Appendix A. Black spot area based on accident rate per road segment

| No Station | Number of Accidents | LHR<sub>T</sub> (smp) | T<sub>k</sub> (12 mons) | T<sub>k</sub> (5 mons) |
|------------|---------------------|----------------------|------------------|------------------|
| 1 0+000 - 0+100 | 0 | 0 | 410189 | 0.00 | 0.00 |
| 2 0+100 - 0+200 | 2 | 2 | 410189 | 0.14 | 0.33 |
| No | Station                  | Death 2016 | Death 2017 | \( LHR_T \) 2016 | \( T_f \) 2017 |
|----|-------------------------|------------|------------|-------------------|----------------|
| 1  | 0+000 - 0+100           | 0          | 0          | 410189            | 0.00           |
| 2  | 0+100 - 0+200           | 0          | 1          | 410189            | 0.00           |

### Appendix B. Black spot area based on fatality rate per road segment

| Station | \( LHR_T \) | \( T_f \) |
|---------|-------------|------------|
| 0+200 - 0+300 | 0.00 | 0.00 |
| 0+300 - 0+400 | 0.07 | 0.49 |
| 0+400 - 0+500 | 0.00 | 0.00 |
| 0+500 - 0+600 | 0.00 | 0.00 |
| 0+600 - 0+700 | 0.00 | 0.00 |
| 0+700 - 0+800 | 0.14 | 0.00 |
| 0+800 - 0+900 | 0.27 | 0.49 |
| 0+900 - 1+000 | 0.00 | 0.16 |
| 1+000 - 1+100 | 0.00 | 0.00 |
| 1+100 - 1+200 | 0.00 | 0.49 |
| 1+200 - 1+300 | 0.00 | 0.00 |
| 1+300 - 1+400 | 0.00 | 0.33 |
| 1+400 - 1+500 | 0.00 | 0.00 |
| 1+500 - 1+600 | 0.00 | 0.00 |
| 1+600 - 1+700 | 0.00 | 0.16 |
| 1+700 - 1+800 | 0.00 | 0.00 |
| 1+800 - 1+900 | 0.00 | 0.16 |
| 1+900 - 2+000 | 0.00 | 0.00 |
| 2+000 - 2+100 | 0.00 | 0.00 |
| 2+100 - 2+200 | 0.14 | 0.16 |
| 2+200 - 2+300 | 0.00 | 0.00 |
| 2+300 - 2+400 | 0.00 | 0.00 |
| 2+400 - 2+500 | 0.00 | 0.81 |
| 2+500 - 2+600 | 0.00 | 0.65 |
| 2+600 - 2+700 | 0.00 | 0.00 |
| 2+700 - 2+800 | 0.00 | 0.00 |

**Note:** The values are based on the fatality rate per road segment.
|   |          |   |   | 410189 |   |   |
|---|----------|---|---|--------|---|---|
| 3 | 0+200 - 0+300 | 0 | 0 | 410189 | 0.0 | 0.0 |
| 4 | 0+300 - 0+400 | 0 | 1 | 410189 | 0.0 | 16.3 |
| 5 | 0+400 - 0+500 | 0 | 0 | 410189 | 0.0 | 0.0 |
| 6 | 0+500 - 0+600 | 0 | 0 | 410189 | 0.0 | 0.0 |
| 7 | 0+600 - 0+700 | 0 | 0 | 410189 | 0.0 | 0.0 |
| 8 | 0+700 - 0+800 | 0 | 0 | 410189 | 0.0 | 0.0 |
| 9 | 0+800 - 0+900 | 0 | 0 | 410189 | 0.0 | 0.0 |
|10 | 0+900 - 1+000 | 0 | 0 | 410189 | 0.0 | 0.0 |
|11 | 1+000 - 1+100 | 0 | 0 | 410189 | 0.0 | 0.0 |
|12 | 1+100 - 1+200 | 0 | 0 | 410189 | 0.0 | 0.0 |
|13 | 1+200 - 1+300 | 0 | 0 | 410189 | 0.0 | 0.0 |
|14 | 1+300 - 1+400 | 0 | 0 | 410189 | 0.0 | 0.0 |
|15 | 1+400 - 1+500 | 0 | 0 | 410189 | 0.0 | 0.0 |
|16 | 1+500 - 1+600 | 0 | 0 | 410189 | 0.0 | 0.0 |
|17 | 1+600 - 1+700 | 0 | 0 | 410189 | 0.0 | 0.0 |
|18 | 1+700 - 1+800 | 0 | 0 | 410189 | 0.0 | 0.0 |
|19 | 1+800 - 1+900 | 0 | 0 | 410189 | 0.0 | 0.0 |
|20 | 1+900 - 2+000 | 0 | 0 | 410189 | 0.0 | 0.0 |
|21 | 2+000 - 2+100 | 0 | 0 | 410189 | 0.0 | 0.0 |
|22 | 2+100 - 2+200 | 0 | 0 | 410189 | 0.0 | 0.0 |
|23 | 2+200 - 2+300 | 0 | 0 | 410189 | 0.0 | 0.0 |
|24 | 2+300 - 2+400 | 0 | 0 | 410189 | 0.0 | 0.0 |
|25 | 2+400 - 2+500 | 0 | 0 | 410189 | 0.0 | 0.0 |
|26 | 2+500 - 2+600 | 0 | 0 | 410189 | 0.0 | 0.0 |
|27 | 2+600 - 2+700 | 0 | 0 | 410189 | 0.0 | 0.0 |
|28 | 2+700 - 2+800 | 0 | 0 | 410189 | 0.0 | 0.0 |
|29 | 2+800 - 2+900 | 1 | 1 | 410189 | 6.77 | 16.3 |
|30 | 2+900 - 3+000 | 1 | 0 | 410189 | 6.77 | 0.0 |
|31 | 3+000 - 3+100 | 0 | 0 | 410189 | 0.0 | 0.0 |
|32 | 3+100 - 3+200 | 0 | 0 | 410189 | 0.0 | 0.0 |
|33 | 3+200 - 3+300 | 0 | 0 | 410189 | 0.0 | 0.0 |
|34 | 3+300 - 3+400 | 0 | 0 | 410189 | 0.0 | 0.0 |
|35 | 3+400 - 3+500 | 0 | 1 | 410189 | 0.0 | 16.3 |
|36 | 3+500 - 3+600 | 0 | 2 | 410189 | 0.0 | 32.5 |
|37 | 3+600 - 3+700 | 0 | 0 | 410189 | 0.0 | 0.0 |
|38 | 3+700 - 3+800 | 0 | 0 | 410189 | 0.0 | 0.0 |
|39 | 3+800 - 3+900 | 0 | 0 | 410189 | 0.0 | 0.0 |
|40 | 3+900 - 4+000 | 0 | 0 | 410189 | 0.0 | 0.0 |
|41 | 4+000 - 4+100 | 0 | 0 | 410189 | 0.0 | 0.0 |
|42 | 4+100 - 4+200 | 0 | 0 | 410189 | 0.0 | 0.0 |