Cipali Toll Road Safety Audit

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Abstract. The toll road is freeways to accelerate and shortening of travel time, this is due to the
existing arterial road which is decrease congested, especially in weekends. Increasing density of
the traffic, the car accidents occur on toll roads has increased also. One of causes of vehicle
accidents on toll roads is by the lack of marking, sign, complementary buildings and poor
pavement condition. This study would be discussed the existing conditions of the Purbaleunyi
Toll Road based on direct observation of complementary buildings ,signs and marking and also
in terms of pavement on toll roads. The observation data would be compared with the results of
accident data from the Bina Marga that can help us to find out black area and grey area on the
toll road in driver safety in terms of complementary buildings, marking , signs and pavement on
toll roads.

1. Introduction
In 2015, totally of 47 toll road development projects are part of the National Strategic Project by
President of Republic Indonesia for the period 2015-2019 began to be implemented. Even the
Presidential Regulation , number 3 of 2016 is issued so that the implementation of the National
Strategic Project can be accelerated. In view of the Republic of Indonesia Law Number 38 of 2004
concerning roads, article 44 paragraph 3 states that toll roads have to specifications and level of
services more than arterial public roads. For the example there are no intersections, fully contro
lled exits or entrances (access), and high plan speed.

Concerns have arisen when road construction continues but the road safety system is still not
optimal in the implementation [1]. Accidents occurred throughout 2016, more than 26,000 people
died and 143,000 suffered minor or severe injuries. In March 2010 the UN General Assembly
declared the Decade of Action (DoA) for Road Safety 2011 - 2020 which purpose to control and
decrease the fatality rate of past accident victims. Cross globally by increasing activities carried out
on a national, regional and global scale[2,3].

Total accidents occur of Cipali toll road in 2016, are 811 times. In accordance the long-term
strategy prepared by the Government of Indonesia in the Road General National Safety Plan
(RGNSP)[2]. It is necessary to implement road safety using a cost-efficiency approach through
curative and preventive measures in order to deal with victims, prevention injury, and prevention of
accidents [4,5]. This study solicits to solve road safety problems that occur on roads in Indonesia,
especially toll roads because services provided by toll roads should be higher than public roads. In
preventing accidents, it is necessary to know which areas have high potential for accidents so that
they can be handled according to the characteristics of each road [5-7].

The aims to determine the existing geometric and pavement condition, road complementary
buildings , signs and markings are in accordance with the technical standards that have been
applied, so as to obtain accident-prone areas of direct observation. Then the results of direct
observation are compared with traffic accident as secondary data . The results of the analysis of
accident-prone areas from direct survey were to find out whether the accident-prone areas obtained
from the data.
Road Safety Audit
Road Safety Audit is a form and module of formal testing of an existing road section or a road/traffic project in which an independent and qualified team reports on potential collisions on the project[7,10-14]. Road safety audits are one way to prevent accidents for the already operating roads or newly ones. Road safety audits on new roads need to be carried out on all process, starting from the design, form of roads, guidance and operations. Road safety audits were initially developed for new roads, but are increasingly being used to check and improve existing road safety.[10,11,29]

Design Speed
Design Speed (DS), on the road segment the speed is chosen as the basis of road geometric planning that allows vehicles to move safely and comfortably in sunny weather conditions, design traffic volume, and meaningless road side effects [15,19]. The DS for each road function can be determined from Table 1 The DS for each road function can be determined from Table 1.

| Class | Function       | Design Speed |
|-------|----------------|--------------|
|       | Primary arteries | 80 - 100     |
| II    | Primary Collector | 80 - 100 | 60 - 70 |
| IIIA  | Secondary Arteries | 80 - 100 | 60 - 70 |
| IIIB  | Secondary Collector | 80 | 50 |
| IIIC  | Secondary Local | 60 | 40 |

Road Alignment
Road alignment is a major factor in determining the level of safety and efficiency in meeting traffic needs. The alignment is influenced by topography, traffic characteristics and road functions.[15,19]

Road Markings
A sign that is on the surface of the road that includes equipment or signs that form longitudinal lines, transverse lines, oblique lines and other symbols that serve to direct the traffic flow and the limit area of interest of traffic.[16]

Traffic signs
Road Signs are the main tool in managing, warning and directing the traffic. An effective signs must fulfill the following[17]:
1. Meet the needs
2. Attract attention and get respect for road users.
3. Give a message that is simple and easy to understand.
4. Provide enough time for road users to respond.

Road Median
In high traffic flows, it is often necessary to have a median to separate traffic flows in opposite directions. So the median is a path that is located in the middle of the road to divide the road in each direction [17,19].
Broadly speaking, the median functions as:
1. Provide a neutral area that is wide enough where the driver can still control his vehicle in times of emergency.
2. Provide sufficient distance to limit / reduce glare against headlights from vehicles in the opposite direction.
3. Adding a sense of grandeur, comfort and beauty to every driver.
4. Secure side freedoms from each direction of traffic flow.

Road Pavement
Subgrade is generally not able to withstand the weight of vehicles on it, so need a construction that can withstand and distribute the traffic load it receives. The road pavement technology continues to develop, now its common to used flexible pavement with asphalt concrete construction. With this mixture we get a mixture that is dense and high stability. The traffics loads of flexible pavement structure, were distributed to the subgrade in stages in each layers [29]. [18] The traffic load is distributed from the surface layer to the layers below it. The layer thickness below as the good quality pavement express by CBR value, the result is the pressure from the vehicle load is received by the subgrade becomes decrease.

2. Research Methodology
2.1 Data Collection Methods
The survey method with field observations was carried out at a predetermined location. Primary data obtained through direct observation, in this study is a survey on locations that are determined in various aspects, namely geometric straight, turn left and right turn, pavement, signs, markings and complementary buildings at the Cipali toll road.

2.2 Data Analysis Method
Field observation methods
For field observations, a comparison is made between the existing conditions of the Cipali toll road in terms of geometric, hardening and road complementary structures against technical standards.

The equivalent accident number (EAN) method
Areas of traffic accident prone, are areas that have a high number of traffic accidents, high risk and accidents on a road section (Warpani, 1999). The technique for ranking accident sites can be done with the accident rate approach and quality control statistics, or weighting based on accident values [24].

One method for calculating accident numbers is to use the EAN (Equivalent Accident Number) method [24,27,28] which is the weighting of accident equivalent numbers referring to the cost of traffic accidents.

EAN is calculated by adding up the number of accidents at each kilometer of the road length then multiplied by the weight value according to the severity. The standard weight values used are People Died (PD) = 12, Severe injuries (SI) = 3, Suffered Minor (SM) = 3 [26].

EAN formula:

\[ EAN = 12 \text{PD} + 3 \text{SI} + 3 \text{SM} \]

The determination of accident-prone locations is based on the accident rate per kilometer of the road that has a weighted EAN value exceeding a certain limit value. This limit value can be calculated among others by using the Upper Control Limit (UCL\text{index}) and Upper Control Limit (UCL) methods.[26,27]. The Upper Control Limit (UCL\text{index}) value is determined using the following equation:

\[ UCL\text{index} = C + 3 \sqrt{C} \]

Information:
C = Average number of EAN accidents
The UCL (Upper Control Limit) value is determined using the following equation: $\text{UCL} = \lambda + \Psi \times \sqrt{[(\lambda/m) + ((0.829)/m) + (1/2 \times m)]}$

Information:
$\lambda = \text{Average number of EAN accidents} \quad \Psi = \text{probability factor} = 2.576 \\
m = \text{Review of road accident rates (EAN)}$

3. Analysis and Discussion
3.1 Data collection
Data on transportation aspects surveyed in the field are how the pavement conditions of the Cipali toll road and also the condition of signs, road markings, and geometric. This survey uses a gopro camera to get video results, which will then be examined and noticed.

| KM     | Road Conditions | Pavement Condition       | Signs          | Markings               |
|--------|-----------------|--------------------------|----------------|------------------------|
| 75.4 – 93.0 | Straight | The road is level and smooth | none          | Longitudinal Markings |
| 85.2 – 86.0 | Straight | Uneven and bumpy | Rest Area | Longitudinal Markings |
| 104.6 – 105.0 | Bend Right and Clim | Road is flat and smooth | Warning bend to the right | Longitudinal Markings |
| 132.0 – 136.6 | Straight | Road uneven and bumpy | The minimum speed limit is 60 Km / Hour & the maximum speed limit is 100 Km / Hour | Longitudinal Markings |

Based on Minister Regulation No. 13 of 2004 article 39, paragraph 2, before reaching the part of road where there is a warning signs of dangers, warning signs must be installed at least 80 meters for roads with design speeds of 60km / hour to 80km / hour and at least 100 meters for roads at speed planned 60km / hour to 100km / hour. The absence of signs in several road sections is a form of violation of Ministerial Regulation No. 13 of 2004.

Accident Equivalent Number (EAN) value
The value of the accident equivalent number is according on the weighting value of Jasa Marga, the severity of accident victims PD: SI: SM = 12: 3: 3.
Examples of EAN calculations on the Cipali Toll Road can be seen in table 3, accident data on the Cipali toll road in 2017.
Table 3. Cipali Toll Road Accident Data Source: PT Lintas Marga Sedaya

| Name of Road Section | Km          | Total Accident | People Died | Severe Injuries | Suffered Minor |
|----------------------|-------------|----------------|-------------|----------------|---------------|
| Cikampek - Cikopo    | 67.10 - 78.00 | 79             | 17          | 41             | 55            |
| Cikopo – Kalijati    | 78.10 - 98.00 | 152            | 38          | 102            | 132           |
| Kalijati – Subang    | 98.10 - 110.00 | 177            | 42          | 91             | 151           |
| Subang - Cikedung    | 110.10 - 138.00 | 267            | 73          | 181            | 223           |
| Cikedung - Kertajati | 138.10 - 159.00 | 69             | 11          | 28             | 51            |
| Kertajati - Sumberjaya | 159.10 - 175.00 | 44            | 9           | 18             | 31            |
| Sumberjaya - Palimanan | 175.10 - 188.00 | 45             | 7           | 21             | 33            |

Subang - Cikedung with fatalities 73 people died, 181 severe injuries and 223 with suffered minor.

The equivalent number value is calculated as follows:
EAN = 12xPD + 3xSI + 3xSM
EAN = (12 * 73) + (3 * 181) + (3 * 223) = 2088

The number of EAN (m) in the Subang - Cikpapan segment is 2088. After all the EAN values have been calculated, the next step is to find the average accident value (λ) obtained from the total EAN value divided by the number of road segments. The average value of accidents (λ) in 2017 is 834.

Calculation of boundary values is performed to determine the extent of accident vulnerability level for each section of the road, where each section of the road has a different level of accident vulnerability. This calculation is a reference to determine the road segments that are included in accident-prone areas on the Cipali toll road. Example of calculating the value of UCL (Upper Control Limit) on the road section of Subang - Cikedung with average accident rate (λ) = 834; the value of the probability factor (Ψ) = 2.576, and the number of accident equivalent numbers (m) = 2436. Obtained the upper control limit value of the Subang - Cikpapan road segment = 917.2359167. The upper control limit value is obtained by entering the average value of the equivalent accident number in 2017 of 883.7143 to Equation 3 and obtained the value of BKA = 870.2904905.

The results of the analysis of UCL and UCL\text{index} values using the calculation example above for 7 road segments in 2017 are described in Table 4.

4. Discussion

1. From the field observation results, in actual conditions there are many shortages of signs and poor pavement condition on the Cipali Toll Road. It can be seen that the pavement conditions are completely uneven and bumpy at Km. 85.20 - Km. 86.00 and Km. 132.00 - Km. 136. 60. Also there are no warning signs to warn drivers that there are no uphill signs at Km. 104.60 - Km. 105.00, and the section on the Cipali Toll Road that does not have signs are the Cikopo way towards Palimanan.

2. From the results of the analysis of traffic accident data, it can be concluded the location of traffic accident prone obtained for 2017, there are three roads section namely the Cikopo - Kalijati segment (Km. 78.10 - Km. 98.10) with UCL = 895.991593 > UCL\text{index} = 870.2905, Kalijati - Subang (Km. 98.10 - Km. 110.00) with UCL = 897.8889362 > UCL\text{index} = 870.2905, and Subang
- Cikampek - Cikopo (Km. 67.10 - Km. 78.00) UCL917.2359167 =
>UCLindex = 870.2905. That shows the three sections are accident-prone areas on the Cipali toll road.

Table 4. Value of Equivalent Accident Numbers, Upper Control Limit and Control Limits

| Name Of Road Section | Equivalent Accident Numbers | Km | 12 x PD | 3 x (SI + SM) | Total | UCL  | UCLindex |
|----------------------|-------------------------------|-----|---------|---------------|-------|------|----------|
| Cikampek - Cikopo    |                               | 67  | 204     | 288           | 492   | 874.4275367 | 870.2905 |
| Cikopo - Kalijati    |                               | 78  | 456     | 702           | 1158  | 895.991593  | 870.2905 |
| Kalijati - Subang    |                               | 98  | 504     | 726           | 1230  | 897.8889362 | 870.2905 |
| Subang - Cikedung    |                               | 110 | 876     | 1212          | 2088  | 917.2359167 | 870.2905 |
| Cikedung-Kertajati   |                               | 138 | 132     | 237           | 369   | 869.0278048 | 870.2905 |
| Kertajati-Sumberjaya |                               | 159 | 108     | 147           | 255   | 863.15289   | 870.2905 |
| Sumberjaya-Palimanan |                               | 175 | 84      | 162           | 246   | 862.6386122 | 870.2905 |

5. Conclusions and Suggestions

The conclusions of the results of the analysis in this study are:
1. From the results of direct observation, the existing geometric conditions, complementary buildings, are good enough. However, there is a lacks of signs and bumpy roads in the area on some Cipali toll roads, but it does not affect the comfort of the driver for road users, according to the interview at the time of the dissemination.
2. From field observation, it can be concluded that there are several Cipali Toll road sections which have no signs at all at Km. 75.40 - Km. 76.20, Km. 80.00 - Km. 80.80, Km. 91.20 - Km. 93.00.
3. From observation, it can also be concluded that in the Km.132.00 - Km.136.60 sections there are still many road conditions with uneven and smooth pavement.
4. From the results of the analysis of traffic accident data, it can be concluded that the traffic accident prone sections obtained for 2017 are the Cikopo - Kalijati segments (Km. 78.10 - Km. 98.10), Kalijati - Subang (Km. 98.10 - Km. 110.00), and Subang - Cikedung (Km. 110.00 - Km. 138.00). That shows that the three sections are accident-prone areas on the Cipali toll road.

Suggestions
1. When driving a vehicle for direct observation it is better to control a constant speed.
2. When using the camera it is better to know the memory capacity to record and have a good enough quality to record complementary building images.

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