Model of queuing in the railway level crossing (case study: Imam Bonjol railway level crossing in Blitar)

H Widyastuti1*, A Utami2, Z M Dzulfiqar3

1Department of Civil Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, East Java, Indonesia
2Department of Civil Engineering, Pertamina University, South Jakarta 12220, DKI Jakarta, Indonesia
3PT. Hutama Marga Waskita, East Jakarta 13840, Jakarta, Indonesia

E-mail: *hera.widyastuti@yahoo.co.uk

Abstract. A high number of accidents in railway level crossing causes loss of life and material. Furthermore, the losses are also experienced by users of traffic on the highway such as disturbance in the form of delay which can lead to increase the length of travel time where the vehicle will stop, and give impact to the emergency queue vehicle at railway level crossing. Considering those problems, there has been build two models which are: the first model is the queuing of traffic length and with considering the length and speed of the train, and the second model is the queuing of traffic with considering the gate closing time. The methodology applied was an observation on field and survey data and then calculation from Road Capacity Guidelines of Indonesia (PKJI 2014) and queue length calculation using the queuing analysis method. Data have been collected and analysed by making the model relationship using linear regression method. The result showed that there is a positive relationship between the train lengths with the duration of gate closing time. However, the train speed has a negative relationship. Moreover, the length of the train has a positive relationship with the length of the vehicle queue.

1. Introduction
Railway networks offer significant advantages for the transport of passengers and freight as they occupy 2-3 times less land per passenger than other modes of road transport [1]. In addition, the railway infrastructure can also be used to reduce traffic congestion so that society can move efficiently around the city and to connect the port area and the industry to the hinterland [2]. The increasing of vehicle volume and the rapid growth of population have affected the increasing of travel intensity resulting in an increased of direct-access to the city center [3]. On the other hand, the rapid growth of the population also raises the demand for access through large-capacity transportation modes through the railroad [4]. Those conditions give consequence to arise of new railway level crossings.

Railway level crossings create serious potential conflict points for collisions between road vehicles and trains. Safety at level crossings is a worldwide issue, which increasingly attracts the attention of relevant transport authorities, the rail industry and public [5]. Blitar is one of the cities in East Java where there are 18 railway level crossings both with and without barriers. Along with the
existence of railway level crossings in Blitar, the transportation office of Blitar plans to conduct an evaluation at the selected railway level crossings. Imam Bonjol railway level is selected to be experimental object due to high number of vehicles crossed this road. The high number of traffic is directly proportional to the risk of accidents at a railway level crossing. The closure of the railway level crossing on this road causes vehicle activities to be blocked and cause congestion. One of the congestion factors at the railway level crossings is the duration of closing time as the train passes through the crossing [6]. The uncertain duration of gate closing time cause road users to be undisciplined by break through the crossing gates while the train pass through the crossings [3]. Considering of those problem, it is necessary to make a model of relationship between closing of railway level crossing, length and speed of train and length of vehicle queue of in Imam Bonjol railway Level Crossings, Blitar.

2. Literature Review

2.1. Crossing/Intersection
Crossroads (intersection) are two or more sections of a road that meet each other, intersect or cross. The crossing between the road and the railroad is also called the intersection (crossing). The railway crossing is divided into two types. First type is Railway level crossing. According to the regulations of the director general of land transportation number: SK.770 / KA.401 / DRJD / 2005, Railway level crossing is the direct intersection between railway and road. The second type is Railway crossing, according to Road Traffic Planning Guidance with Railway Lane (No: 008 / PW / 2004), Railway crossing is crossing between railway and road in different level.

2.2. Non Signalized Intersections
Non Signalized intersections is an intersection without a Traffic Signal Equipment as a traffic controller. MKJ197 called the intersection as non-signalized intersection. The non-signalized intersection is one of the most complex locations in a traffic system. Non-signalized intersection analysis must consider a wide variety of prevailing conditions [7].

2.3. Traffic Management

2.3.1. Road Capacity
The calculation of road capacity (C) is to determine the performance of a highway segment to accommodate the number of vehicles per hour (vehicle / hour) on the existing road [8]. Based on the Indonesian Road Capacity Guidelines, to calculate Road Capacity can use the formula [7]:

\[ C = C_0 \times FCLJ \times FCPA \times FCHS \times FCUK \]  

where:
- C : road capacity (vehicle / hour)
- C0 : base capacity (vehicle / hour)
- FCLJ : capacity factors related to lane width
- FCPA : capacity factor related to separation of directions
- FCHS : related capacity factors Side barriers
- FCUK : capacity factor related to City size
2.3.2. Degree of Saturation
Degree of Saturation is a main parameter used to determine the performance level of service in a road segment. Value of Degree of Saturation (DS) are vary between 0 to 1. According to the Indonesian Road Capacity Guidelines, the degree of saturation can be calculated using the formula [7]:

\[ DS = \frac{Q}{C} \]  

where:
- DS : Value of degree of saturation
- Q : Traffic volume (vehicle/ Hour)
- C : Existing road capacity (vehicle/ Hour)

2.3.3. Analysis of Queue Length
At this stage the queue length will be calculated using Queuing analysis method, which is a derivative formulation of the shocked wave formula. In the calculation of the vehicle queue length some parameters will be obtained, those are: TQ (duration of the queue time), QM (vehicle queue), and queue length. The formula that will be used is [12]:

\[ TQ = \frac{\mu r}{\mu - \lambda} \]  

\[ QM = \frac{\lambda r}{3600} \]

2.3.4. Regression
Regression analysis technique is a technique that can be used to generate relations in numerical form and to generate relations in numerical form and to determine how the variables are interrelated [11]. In a simple linear regression analysis the variables used are expressed in the general form:

\[ Y = a + bx \]

3. Method
The data were collected using two approaches, those are: field video recordings at selected railway level crossings and direct traffic counting.

3.1. Experimental Objective
Railway Level Crossings safety is one of the most critical issues for railways. The uncertain duration of gate closing time cause road users to be undisciplined by break through the crossing gates while the train pass through the crossings. One of the congestion factors at the railway level crossings is the duration of closing time as the train passes through the crossing. For all these reasons, Imam Bonjol railway level crossing were selected for our field measurement campaign. For location detailed, can be shown in Figure 3.1.
3.2. Data Collecting
The data that will be used in this research is primary and secondary data. The secondary data to support the investigation come from dedicated database provided by PT. Kereta Api Indonesia, while primary data will be obtained by doing direct survey at Imam Bonjol railway level crossing. Table 1 shown types and function of data collected.

| Data Types                               | Function                                                                 |
|------------------------------------------|--------------------------------------------------------------------------|
| Train Schedule (Secondary Data)           | To determine the type of the train which pass through the railway level crossing that affected the closing of gate crossing |
| Geometric Data (Primary Data)            | To determine the road performance in the railway level crossings          |
| Length and Train Velocity (Primary Data) | To determine length and velocity of the train that affected the duration of gate of railway level crossing closing time |
| Closing time of Railway Level Crossing (Primary Data) | To determine the duration of gate closing as the train pass through the railway level crossing, |
| Traffic Data (Primary Data)              | To determine the vehicle queue when the of gate of railway level crossing are closed |

3.3. Data Analysis
In the analysis phase, an analysis of traffic data will be carried out before and after the train passes the railway level crossing. Then continued by analyse the capacity (C) and degree of saturation (DS) before and after the train passes. The length of gate closing time were recorded and continued by calculate the vehicle queue length by using shocked wave method [7].
When the railway level crossing closed, there will be vehicle delay which cause a queue [9]. So in the implementation of traffic analysis, the length and queue behavior are calculated when crossing begins to close until the crossing returns to open and the traffic flow returns to normal. The analysis used in queuing analysis is shocked wave method. In addition, the traffic analysis also calculated the road capacity by using a reference from the Indonesian Road Capacity Guide or PKJI 2014.

3.4. Data Analysis and Modelling

After the data are collected, data processing will be conducted and divided into two models. First model is relationship between the length of the train and the closing time of the railway level crossing, and the second model is relationship between the closing time of the railway level crossing and the length of the vehicle queue.

Multiple linear regression analysis is used to get the relationship of more than one variable while simple linear regression is used to get a mathematical relationship in the form of an equation between a single independent variable with a single independent variable [10]. Simple linear regression has only one variable associated with one non-independent variable, with the form $y = ax + b$ [11]. Formulation of model relationship between train length, train velocity and closing time of the railway level crossing are conducted by using Linear Regression with SPSS as a supporting software. Furthermore, to formulate the relationship model between the duration of closing Time and the Queue Lines using simple linear Regression.

3.5. Conclusion and Suggestion

Conclusion is based on the results obtained at the analysis stage. This research is expected to be a matter of consideration in designing early warning developments at railroad level crossings. Furthermore, this research is expected to be a reference material in conducting further studies and research related to early warning.

4. Analysis

4.1. Traffic Analysis

After amount of vehicle could be determined, calculation of light vehicle will be done, and so does the vehicle ratio, until the capacity of each direction and the saturation degree are found. From that analysis, the length of the vehicle queue also can be determined. The following Table 2 will show the capacity and DS at the Imam Bonjol railway level crossing.

| Data Types            | Imam Bonjol Railway Level Crossing |
|-----------------------|-----------------------------------|
| Time                  | 06:15-07:15 (Weekday) 06:30-07:30 (Weekend) |
| Peak Hour (vehicle/hour) | 1611 1576                  |
| Capacity (vehicle/hour) | 2321 2321                    |
| DS                    | 0.69 0.68                    |
4.2. **Traffic Analysis when Train Passing through Railway Level Crossing**

Traffic analysis when the train passing through railway level crossing is about the same with the preceding traffic analysis, which is using PKJI 2014. But, this sub-chapter will show the result of data analysis calculation and the vehicle queue length when the series of train passing through the railway level crossing. SKR conversion on Imam Bonjol Railway Level Crossing are mentioned in Table 3.

| Road       | Direction | 7:27 Skr /c | cycle time | Skr/hr |
|-----------|-----------|-------------|------------|--------|
| S         | 32        | 120         | 960        |
| U         | 37        | 120         | 1110       |

| Imam Bonjol       | Direction | 10:22 Skr /c | cycle/time | Skr/hr |
|-------------------|-----------|--------------|------------|--------|
| S                 | 21        | 81           | 933        |
| U                 | 30        | 81           | 1333       |

4.3. **Queuing Analysis**

At this stage, it will calculate the length of the queue using the Queuing analysis method. In the calculation of the queue using queuing analysis will be obtained TQ (duration of the queue time), QM (vehicle queue), and queue length.

Example of Queue length calculation:

On Jalan Imam Bonjol Utara, March 14, 2018, at 7:27:

\[
\mu = 2321 \text{ vehicle/hour} \\
r = 120 \text{ second} \\
\lambda = 1110 \text{ vehicle/hour}
\]

So, the duration of the queue:

\[TQ = \frac{2321 \times 120}{2321 - 1110} = 229.99 \text{ second}\]

The length of the vehicle queue in light vehicle units:

\[QM = \frac{\lambda r}{3600} = \frac{1110 \times 120}{3600} = 37 \text{ skr}\]

Where units of light vehicles are assumed to be private vehicles with a vehicle length of 3 meters so that the queue length

\[QM = 37 \times 3 = 111 \text{ meter}\]

4.4. **Comparative Analysis between Real Field Queue Length and Queuing Analysis Calculation**

At this stage in measuring the queue length of the vehicle using 2 methods, namely manual or field survey using meter and recorded by surveyors and the second using queuing analysis. Then compared the results of the length of the field survey queue with the calculation of queuing analysis using the ANOVA method, namely:

Hypothesis test

Ho: The average result of the length of the field survey queue by calculating the formula is all the same.

H1: The average result of the length of the field survey queue with the calculation of the formula is not the same.
Comparing the significant, alfa (a) = 0.05 if \( F_{count} \geq F_{Table} \) So, rejected \( H_0 \), accepted \( H_1 \) P-value < a

From the results of the ANOVA above, the results of F count and also P-value are obtained. Both parameters will be used to determine which hypothesis will be accepted and will be rejected. F recapitulation and P value of all processes can be seen in Table 4.

### Table 4. Recapitulation of F-count and P-value

| Direction | Conclusion | F-value | P-value | Explanation               |
|-----------|------------|---------|---------|---------------------------|
| North     | \( F_{count} \) | 0.184   | <       | \( F_{Table} \) 4.15     | Ho accepted, H1 rejected |
|           | P-Value    | 0.671   | > \( a \) | 0.05                      |                           |
| South     | \( F_{count} \) | 0.148   | <       | \( F_{Table} \) 4.15     | Ho accepted, H1 rejected |
|           | P-Value    | 0.703   | > \( a \) | 0.05                      |                           |

#### 4.5. Model Equations

In this study a relationship model will be created using multiple linear regression methods. The relationship model that is made is between the closing time of the railway level crossing with the length of the train circuit and the speed of the train, as well as the model of the relationship between the length of the vehicle queue and the length of the queue formula and the length of the field survey queue. From the analysis results using the SPSS auxiliary program, the results in Table 5 are obtained:

### Table 5. Model and significant equation output of Imam Bonjol

| Coefficients   | Standard Error | t Stat | P-value |
|----------------|----------------|--------|---------|
| Intercept      | -6.64911       | -0.4124| 0.685879|
| Tram length    | 5.649409       | 4.237357| 0.000717|
| Velocity (Km/hr) | -0.867659    | 2.347677| 0.033027|

From the results above, the model equation is obtained on the Imam Bonjol railway level crossing:

\[ Y = 5.649X_1 - 0.868X_2 - 6.649 \]

\( Y \) = Length of railway level crossings gate closing
time \( X_1 \) = Train length
\( X_2 \) = Train speed

The meaning of the equation is that each increase in one train circuit increases the length of closing time by 5.649 seconds, and the meaning of 0.868 means that the increasing speed of 1 km/h will reducing 0.868 seconds the length of the railway level crossing gate closing time.

From the results of data analysis in Table 5 also obtained a significant test of data with the results of the P-value circuit length of 0.000717 smaller than alpha where the alpha used is 0.05 so it can be stated that the number of train circuits has a significant relationship to the length of railway level crossing gate closing time. While the train circuit speed with P-value 0.0133027 is smaller than alpha, it means that the train speed has a significant relationship to the length of railway level crossing gate closing time. The second model is the relationship model between the length of railway level crossing gate closing time and the length of the vehicle queue using field survey data between the length of the closing time and the length of the vehicle queue and also the calculation data formula
queueing analysis queue length. In the equation used, x is the length of the closing time and y is the length of the vehicle queue. The linear regression results in the relationship between the length of the closure and the queue length of the formula for Imam Bonjol Railway Level Crossing can be seen in Figure 2.

The queue length on Imam Bonjol Railway Level Crossing needs to be reviewed because Imam Bonjol Street is a road that is quite heavy in traffic. With hourly traffic flow during peak hours it reaches 1611 vehicle / hour. So that when the train passes the crossing there will be a queue which results in a delay in the vehicle. The model of the vehicle queue length and railway level crossing gate closing time on weekday can be seen in Figure 2 and weekend condition can be seen in Figure 3.

![Figure 2. Regression chart Linear relationship Duration of gate closing time and the length of the queue (Weekday)](image)

The model equation formed is \( y = 0.6862x + 21.569 \) with the value of R-Square is 0.6961. This equation implies the increasing of 1 second railway level crossing gate closing time, it will added 0.686 meters of vehicle queue length.

![Figure 3. Regression chart Linear relationship Duration of gate closing time and the length of the queue (Weekend)](image)

The model equation formed is \( y = 1.1024x - 16.76 \) with the R-Square value is 0.842. Y is vehicle queue length and x express the duration of railway level crossing gate closing time. This equation implies the increasing of 1 second railway level crossing gate closing time, it will added 0.686 meters of vehicle queue length.

5. Conclusion
This research examines that railway level crossings create serious potential conflict points for collisions between road vehicles and trains. The uncertain duration of gate closing time cause road users to be undisciplined by break through the crossing gates while the train pass through the crossings.

Some conclusions obtained from some of the results made in this study are as follows.

- The results of the regression analysis of the relationship between the length of the train (number of trains / carriages) and the duration of gate closing time has a significant effect.
- The results of the regression model of the relationship between the duration of gate closing time with considering the length and the speed of the train on Imam Bonjol Street have a positive influence on the relationship model that is on Imam Bonjol Street $y = 5.649X_1 - 0.868X_2 - 6.649$. With $y$ is the duration of gate closing time, $x_1$ is the train length and $x_2$ is the train speed. Each increase in one train series increases 5.649 seconds of gate closing time, and -0.868 means that the increasing 1 km/hour of train speed will reduce 0.868 seconds of the railway level crossings gate closing time.
- The results of the regression analysis between the railway level crossings gate closing time with the length of the vehicle queue in Imam Bonjol Street (weekday) have a positive relationship. The equation model is $y = 0.6862x + 21.569$. This equation implies that the increasing of 1 second of railway level crossings gate closing time, it will add 0.6862 meters of vehicle queue length. The results of the regression analysis between the railway level crossings gate closing time with the length of the vehicle queue in Imam Bonjol Street (weekend) is $y = 1.1024x - 16.76$. This equation implies increasing 1 second of railway level crossings gate closing time, it will add 1.1024 meters of vehicle queue length.

References

[1] Lingamanaik S N, Thompson C, Nadarajah N, Ravitharan R, and Widyastuti H 2017 Using instrumented revenue vehicles to inspect track integrity and rolling stock performance in a passenger network during peak times Procedia Eng 188 pp 424–431
[2] Widyastuti H, Herijanto W, Kartika A A G, and Rahardjo B 2016 Railway infrastructure to support inter-modal transportation from port to hinterland (case Study-Manyar port) Procedia - Soc. Behav. Sci. 227 pp 181–185
[3] Utami A and Widyastuti H 2019 Model Panjang Antrian Kendaraan pada Perlintasan Sebidang Tampak Palang Pintu (Studi Kasus: Perlintasan Sebidang Jl . Gayung Kebonsari Surabaya) Jurnal Aplikasi Teknik Sipil 17 no 23 pp 27–34
[4] Palar B, Timboeleng J A, and Rompis S Y R 2016 Analisa Gelombang Kejatu pada Persimpangan no. 4 pp 559–566
[5] Tey L, Ferreira L, and Wallace A 2011 Measuring driver responses at railway level crossings Accid. Anal. Prev. 43 no. 6 pp 2134–2141
[6] Gruyter G and Currie 2016 Rail Road Crossing Impact : An International Synthesis Transp. Rev. 36 pp 793–815
[7] Directorate General Bina Marga 1997 Highway Capacity Manual Project (Hcm) 1 no. 1 pp 564
[8] Koloway B S 2009 Kinerja Ruas Jalan Perkotaan Jalan Prof Dr Satrio, DKI Jakarta J. Perenc. Wil. dan Kota 20 no 3 p hlm 215-230
[9] Irawati 2001 Pengaruh Derajat Kejenuhan Jalan Terhadap Tundaan Dan Panjang Antrian Pada Pintu Lintasan Kereta Api Dengan Variasi Lama Penutupan Jalan Studi Kasus Pintu Lintasan 1, Jalan Pecindilan Surabaya (Surabaya: Institut Teknologi Sepuluh Nopember)
[10] Supranto J 2000 Statistik teori dan aplikasi jilid I
[11] Tamin O Z 2003 Perencanaan dan Pemodelan Transportasi Edisi Kedua
[12] Adolf D M 1990 Traffic Flow Fundamentals (Amerika: Prentice-Hall Inc)