Identification and evaluation of level crossing for train accident mitigation using geographic information system application

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Abstract. The condition of most of the railways in Indonesia, especially in southern West Java, intersects the highway. Increased train traveling and public transportation on these level crossings potentially risks accidents to occur between trains and public transportation. To prevent this accident and secure railroad travel, it is necessary to identify and evaluate the existence of the level crossings. This study aims to gather information, so that it becomes a database on the southern cross of West Java. The identity of the plot is in the form of: number of gatekeepers and KM, gatekeeper coordinates, intersection status, road status, alignment condition, road completeness (signs and markers), and gate type and road emplacement conditions. The method used in this study was a survey method. Data were analyzed using spatial analysis with the application of Geographic Information Systems. Based on the result, the number of level crossings in southern West Java consists of the Bandung – Tasikmalaya and Tasikmalaya – Maos tracks. The number of survey point locations is 563 points. With the availability of databases and track information on the southern cross of West Java, the data can be used for the purposes of railroad accident transportation mitigation in the form of a road map with a detailed and accurate identity.

1. Introduction
Train is a vehicle that moves on the railroad and can transport large quantities, be it freight or passenger, which is one of the important modes of transportation and has a significant role in the national economy [1]. Most of the existence of the railroad network in Indonesia intersects with the highway, in which such a fact increases the risk of accident given that railroad transportation and public transportation intersects on the highway, so as to prevent such accident and to secure train travel the existence of level crossings must be managed and monitored properly [2].

The level crossings that does not own a license must be closed. Meanwhile, crossings which have existed prior to the enactment of the law are strived to not be level crossings. Due to their vital functions and roles, supervision and inspection of a level crossing gate is needed in order to ensure the safety of the operation of the railroad [3].

One means of supervision is to conduct an inventory of level crossing points located in the southern West Java in the form of maps using geographic information systems. It aims to determine and map the number and conditions of the existing level crossings in southern West Java area.

Studies on level crossings have often been conducted, but those related to railroad accident mitigation attempts are limited. Some studies involve level crossings such as a study regarding the existing level of service condition analyzes the queues that occur at the level crossing. It also examines
the need for a change for level crossing located on the same level as an underpass. Furthermore, changes in road performance can be identified. On queuing calculation with 5-minute headway, traffic intensity ($\lambda$) per day > 1 because $\lambda > \mu$ which results in long queues and unpredictable time in the queue/system. It is most likely to increase congestion, for example on the Citayam road section, hence it is necessary to improve the performance of the crossing gate to avoid longer queue [3].

The feasibility of a level crossing can be observed from the speed of the train, the time lapse between trains passing through the crossing, road class, and alignment position. The result of the analysis shows that a level crossing is feasible if the speed of a train passes through a level crossing at $< 60$ km/hour, the time interval between one train with the next train (head way) that passes at the level crossing is at least 6 minutes, the crossing road is a class III road, and is not located on the railroad arches or over a road bend [4].

In the study regarding the effect of level crossing on traffic characteristics (Case Study of the Railroad Crossing on Jalan Sisingamangaraja, Medan), it is found that the level crossing between road and railway track is a matter which must be considered in transportation because it can affect the performance of road section that intersects with the track. Intersection is two or more segments that meet or intersect. Intersection is one of the most important part of the road network systems that must be designed while taking into account efficiency, safety, speed, operating costs, and capacity. Similar to two roads intersect, a road and a railway which intersect is also called an intersection (crossing) [5].

On the other hand, to obtain preliminary information about the type of suitable handling is done at a crossing using traffic volume survey data under normal conditions on Sunday. Also, this model can be used for level crossings with characteristics similar to crossings at the study site, such as ± 7-meter road width, urban road status, collector road function, and normal traffic variations.

Other countries, such as Finland, attempt to compare accidents at active or passive and both level crossings and risk factors as the background. Passive railway level crossings do not have a warning equipment system although there are warning signs installed. Active level crossings are equipped with an automatic warning system for road users to indicate approaching trains. This data includes all fatal motor vehicle accidents at level crossings in Finland during 1991-2011 (n = 142). All these accidents have previously been examined in detail by the Road Accident Investigation Team. Most of the accidents occur at the passive level crossings [6].

Compared to active level crossings, related to the number of fatal accidents, passive level crossings become proportionately riskier during the study period. Almost all of the direct risk factors for accidents are of human errors: observation errors by road users at the passive level crossings and the risk taken at the active level crossings. The environment does not support level crossing security which means that most of the accidents occur at passive level crossings. The speed limit of road and railway is high, visibility is sufficient, and level crossings are located uphill. An active warning device is effective to prevent accidents due to road user errors. Equipping the most dangerous passive level crossings with a low-cost or conventional warning system is most likely to safety. Alternatively, a number of level crossings can be completely eliminated. The minimum requirement is that environmental factors at passive level crossings support road users to cross safely [6].

A study entitled “An Automated System to Mitigate Loss of Life at Unmanned Level Crossings” is conducted in India, where level crossings are not maintained well so it becomes alarming because of the increased railroad accidents in India. There is an urgent need to develop an information system that can inform road users before approaching an unmanned level crossing with the characteristics of each crossing. Each unmanned level crossing is observed to collect the characteristics of the unmanned level crossing on the Shahdra-Shamli-Tapri train route using the Global Positioning System (GPS) and sensors. It, then, is stored and analyzed using the GIS software. The location of the train station is also surveyed. A level crossing is stored as a point with characteristics in the geographic information system database, while roads and railroad tracks are stored as track features and villages as polygon features. Statistics on traffic accident at unmanned level crossings from 2008 to 2013 are analyzed. Characteristics of road traffic crossing unmanned level crossings, i.e. traffic volume, peak hour factor, and daily average traffic are also analyzed in the study. The study possibly leads to the development of
a warning system for road users so that they are aware of the different characteristics of the unmanned level crossings to raise awareness regarding safety [7].

2. Methods
This study uses a survey method of which data were obtained through field survey activities with research instruments in the form of observation guidelines (checklist), secondary data were obtained from PT KAI and relevant references related to Indonesian railroad safety. The obtained database was further analyzed spatially using the geographic information system application through the ArcGIS software.

Data visualization in the form of a track map contains information about the track database which consists of: number of gatekeepers and KM, gatekeeper coordinates, crossing status (officially guarded or not guarded), road status, alignment conditions, road completeness (signs and markers), type of gate, gatekeeper status, road emplacement conditions (flexible, stiff, or clay pavement), and photos of level crossings on railroad tracks.

The research method and stages of conducting the study can be explained as follows
1. Preparation: this stage includes planning, establishing methods, forming teams, and collecting secondary data in the form of road maps and railroad maps in southern West Java.
2. Data Collection: this stage includes collecting data and processing the existing level crossing information in southern West Java region including 1) Bogor – Padalarang, 2) Padalarang – Bandung, 3) Bandung – Tasikmalaya, 4) Tasikmalaya – Maos.
3. Identification and Evaluation: this stage includes identifying and evaluating the result of data collection on level crossings in southern cross of West Java.
4. Data Input: this stage includes inputing indicators in the form of number of gatekeepers and KM, gatekeeper coordinates, crossing status (officially guarded or not guarded), road status, alignment conditions, road completeness (signs and markers), type of gate, gatekeeper status, road emplacement conditions (flexible, stiff, or clay pavement), and photos of level crossings on railroad tracks in the southern cross of West Java into the ArcGis application.
5. Reporting: this stage includes presenting the result of analysis, evaluation, comparison, final conclusions, and standards in monitoring and inspecting the level crossings.

These activities were conducted on the railroad in the southern cross of West Java located at: 1) Bogor – Padalarang, 2) Padalarang – Bandung, 3) Bandung – Tasikmalaya, and 4) Tasikmalaya – Maos. The study was conducted for eight months in 2019.

3. Results and Discussion

3.1. Distribution of Level Crossings in the Southern Cross of West Java
Based on the result of the survey, 563 level crossings were obtained. Among these 563 crossings, there are official and unofficial level crossings. It starts from Bogor Station to Maos Station in Cilacap District, Central Java. The highest number of level crossings is in Garut District of 80 level crossings and the least number of is in Sukabumi with a total of 12 level crossings. The following are the level crossing distribution on the figures 1-4.
Figure 1. The map of Distribution of the Bogor-Padalarang Cross-Section

Figure 2. The map of Distribution of the Padalarang – Bandung Cross-Section
Figure 3. The map of Distribution of the Bandung - Tasikmalaya Cross-Section

Figure 4. The map of Distribution of the Tasikmalaya - Maos Cross-Section
3.2. Characteristics of Level Crossings in the Southern Cross of West Java

Each level crossing has different characteristics. The characteristics used as variables in this study are crossing status (officially guarded or not guarded), road status, road completeness (signs and markers), type of gate, and gatekeeper status. The characteristics of the obtained level crossings can later be used as consideration. All of the characteristics used are shows in the table 1- 5.

**Table 1.** The status of Crossings in the Southern Cross of West Java

| No | Section                  | officially guarded | officially not guarded | Not officially guarded | Fly Over/Underpass |
|----|--------------------------|--------------------|------------------------|-----------------------|--------------------|
| 1  | Bogor - Padalarang       | 34                 | 31                     | 70                    | 2                  |
| 2  | Padalarang - Bandung     | 3                  | 2                      | 5                     | 3                  |
| 3  | Bandung - Tasikmalaya    | 32                 | 18                     | 69                    | 11                 |
| 4  | Tasikmalaya - Maos       | 11                 | 21                     | 60                    | 6                  |

**Table 2.** The status of Roads in the Southern Cross of West Java

| No | Section                  | Non-status | Village road | District road | City road | Provincial road |
|----|--------------------------|------------|--------------|---------------|-----------|-----------------|
| 1  | Bogor - Padalarang       | 21         | 82           | 22            | 12        | 0               |
| 2  | Padalarang - Bandung     | 1          | 6            | 2             | 4         | 0               |
| 3  | Bandung - Tasikmalaya    | 56         | 43           | 1             | 29        | 1               |
| 4  | Tasikmalaya - Maos       | 65         | 39           | 5             | 10        | 1               |

**Table 3.** The Road completeness in the Southern Cross of West Java

| No | Section                  | complete | uncomplete |
|----|--------------------------|----------|------------|
| 1  | Bogor - Padalarang       | 0        | 180        |
| 2  | Padalarang - Bandung     | 0        | 30         |
| 3  | Bandung - Tasikmalaya    | 0        | 217        |
| 4  | Tasikmalaya - Maos       | 0        | 136        |

**Table 4.** The Road completeness in the Southern Cross of West Java

| No | Section                  | Mechanic | Electric | Do not have gate |
|----|--------------------------|----------|----------|------------------|
| 1  | Bogor - Padalarang       | 31       | 19       | 87               |
| 2  | Padalarang - Bandung     | 1        | 5        | 7                |
| 3  | Bandung - Tasikmalaya    | 15       | 35       | 80               |
| 4  | Tasikmalaya - Maos       | 9        | 15       | 74               |
Table 5. The Status of gatekeepers in the Southern Cross of West Java

| No | Section                  | PT KAI | Private | Do not have gatekeeper |
|----|--------------------------|--------|---------|------------------------|
| 1  | Bogor - Padalarang       | 31     | 2       | 104                    |
| 2  | Padalarang - Bandung     | 3      | 0       | 10                     |
| 3  | Bandung - Tasikmalaya    | 31     | 3       | 96                     |
| 4  | Tasikmalaya - Maos       | 11     | 0       | 87                     |

Based on the conducted study, there are 563 level crossings in the southern cross of West Java, starting from Bogor Station to Maos Station. These level crossings can be a problem if the level crossing does not meet the applicable regulatory standards. These problems include traffic jams and accidents. High growth rates have an impact on increasing population mobility. Level crossing remains a problem which must be considered, since population growth and population movements keep increasing in Indonesia. These regulatory standards can be seen from several aspects related to the characteristics of the level crossings including crossing status, road status, crossing sign completeness, gate type, and gatekeeper status.

Based on the variable of crossing status, most of the level crossings in the southern cross of West Java are dominated by unofficial crossing status. With a percentage of around 47%, the number of unofficial crossings needs to be reviewed and later considered by policy holders to close the crossing or make the crossing official and safeguarded. From the first aspect, it can be concluded that the percentage of official and manned crossings in the southern cross of West Java remains very low, at only 14% which further increases the risk of accidents. Hartono [11] states that one of the main causes of accidents at level crossings is unofficial level crossings.

The road status is closely related to the decision to construct a level crossing. The higher the road status the more crowded vehicles are more likely to pass. District or city roads tend to be more crowded because they connect important areas in the District or city. The more crowded the vehicle, the more likely it is to build a supporting infrastructure at the level crossing to reduce the risk of accidents. Based on the road status data, most of the road status at the level crossing in the southern cross of West Java are of village and non-status road status. Non-status roads are generally footpaths made by local residents to further accelerate travel time without having to take the existing roads. It certainly increases the risk of accidents at this certain location [14].

A sign is one of the road equipment in the form of symbols, numbers, letters, sentences and/or a combination meant to warn, prohibit, order, or instruct road users [12]. Based on the definition, sign is an important aspect to reduce the risk of accidents at a level crossing. However, the actual practice is different. Based on the result of the study, of the existing 563 level crossings none of which has complete signs, meaning that the existing regulations have not been able to be implemented comprehensively by related entities. It is certainly a big obligation for the related entities given that sign is considered to be an important aspect based on the definition [15].

The crossing gate functions as a partition for road users when the train crosses a level crossing. The existence of the crossing gate is certainly important in preventing road users from breaking through the crossing when the train crosses the road. Based on the obtained data, most of the level crossings do not have crossing gate. This aspect is still related to crossing status in which unofficial level crossings remain commonly found. Only 76 level crossings have crossing gate. Such an issue must be addressed immediately so that the risk of accidents can be minimized.

A gatekeeper at a level crossing should also be put into consideration [13]. The presence of a gatekeeper can help reduce the risk of accidents at a level crossing [16], since they can directly manage the situation real time. Similar to the previous aspects, the presence of a gatekeeper remains few of which percentage is less than 30%.
4. Conclusion
Alongside the increase in rail transportation, road transportation in urban areas which connect urban areas with rural areas have increased along with economic growth and development occurring in the area. In a study conducted in the southern cross of West Java, 563 survey points were obtained starting from Bogor Station to Maos Station. The percentage of official and manned crossings, road status and road completeness in the southern cross of West Java South remains very low, so that this condition is most likely to further increase the risk of accidents. Therefore, improvements are needed, crossing gate must be replaced, and road signs must be added to reduce the number of accidents in the future.

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