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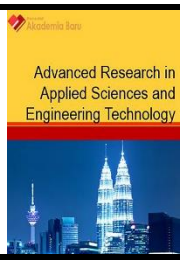

The Risk Priority Number (RPN) At A Level Crossings Along The Railway Line In Indonesia

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ABSTRACT

Indonesia has 7,464 km of railway lines along with the islands of Sumatra and Java. There are 5,239 level crossings along the railway line spread over 9 Operational Areas (Daop) and 4 Operations Divisions (Divre). According to data from the Directorate General of Indonesian Railways, throughout 2020, there have been 456 accidents at official and unofficial level crossings. Furthermore, according to statistical data, the number of accidents continues to increase every year. This study performs a risk assessment based on potential causes based on the frequency of occurrence, severity, and detection level. The method used is Failure Mode and Effect Analysis to conduct a risk assessment by identifying potential causes based on the probability of occurrence, assessing the level of impact caused, the frequency of accidents, and the ability to detect accidents on a scale of 1 to 5, which will then be calculated as Risk Priority. Number (RPN). Initial results were obtained. The results are that nine factors that cause accidents at level crossings have been identified, and 16 types of failures have been obtained from these factors. Level crossings that do not have doorstops are a potential cause with a risk priority number (RPN) of 80. The absence of guards contributes to the high severity of accidents. Based on observations, level crossings that do not have gates are dominated by unofficial level crossings. The second factor that must be an essential concern is the driver's behavior when passing at level crossings. The driver factor is very difficult to detect because it is necessary to disseminate information about maintaining safety at level crossings.

Keywords:
Risk; risk assessment; potential causes;
severity;occurrence; detection; RPN.

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1. Introduction

The level crossing is a complex system involving integrating highways, road users, railway drivers, signaling, guard operators, pedestrians, and others [1]. Consequently, they pose a significant challenge to rail and traffic safety [2]. According to Ryan *et al*., [3], accidents at level crossings at risk are caused by road users' behavior, which is an important factor throughout the world.

Indonesia has 7,464 km of railway lines along with the islands of Sumatra and Java. There are 5,239 level crossings along the railway line spread over 9 Operational Areas (Daop) and 4 Operations Divisions (Divre). Of the 1570 level crossings, unofficial level crossings do not have complete doorstops, guards, and warning signs. This is also found in some of the official level crossings. Such a situation has led to many accidents involving railways and pedestrians at level crossings

According to data from the Directorate General of Indonesian Railways, throughout 2020, there have been 456 accident cases that resulted in 57 victims dying at official and unofficial level crossings

spread throughout the Operational Area and Operations Division. From 2014 to 2020, accidents at level crossings in Indonesia still show an increasing trend.

This is an important concern because this incident resulted in high deaths and significant material losses. In this study, we carry out a risk assessment at level crossings based on potential causes based on the frequency of occurrence, severity, and level of incident detection

The key to determining safety and security issues and designing effective accident prevention measures at level crossings is understanding the situational factors and risk behaviors [4]. Several studies raise this issue, but few classify the main factors that are the potential causes of accidents at level crossings.

According to Anandarao [2] the Risk of a level crossing accident as a product of the accident rate and the expected consequences per accident [5]. The volume of rail traffic, the volume of road traffic, the visibility of the intersection from the road, obstructed view, the slope of the road, the width of the intersection, and the type of safety device at the intersection proved to affect the level of risk of accidents at level crossings [2,6,7].

Accidents that occur at level crossings based on research conducted by Liu *et al*., [8] focus on two aspects that affect safety equipment at level crossings: control systems and signals. Accidents can occur due to malfunctioning of the warning system and insufficient awareness and traffic safety and traffic culture [9].

1. Methodology

Several researchers carry out risk assessments on level crossings using various techniques and methods. Ghazel [10] conducted a risk assessment by simulating certain phenomena that could cause collisions at level crossings adjusted to the accumulation of vehicle queues in the level crossing zone using the Stochastic Petri-Net technique to reduce the level of risk. However, the study did not reveal the leading causes of the priority prevention that must be carried out / Risk assessment carried out by Bester *et al*., [11] to estimate the reliability and security of the proposed system by carrying out Markov and Fault mathematical modeling FaultTree Analysis (FTA).

This study used the Failure Mode and Effects Analysis method to carry out risk assessments. It starts with identifying potential causes based on the probability of occurrence. Then assessing the level of impact caused, the frequency of accidents, and the ability to detect accidents on a scale of 1 to 5, which will then be calculated as a Risk Priority Number (RPN) to determine the ranking of causes are prioritized for improvement.

The method is considered a practical and straightforward method but significantly impacts accidents at railroad crossings. To identify potential causes, the author conducted direct observations to 42 level crossings spread across three operational areas in Indonesia and operational divisions and conducted interviews with eyewitnesses, road users, and authorities [12,13].

3. Results

3.1 Failure Analysis

Identification was carried out by observation and interview methods at 42 cases in three railway operational areas in Indonesia, which often occurs at level crossing accidents. The identification results obtained 16 failures from 9 factors that are potential causes of accidents. From these factors, an analysis of the causes of failure of safety components or equipment in the level crossing system that results in accidents at level crossings is carried out in detail, shown in table 1.

Table 1
Failure Analysis (Failure Analysis) of the Level Crossing Safety Tool

Num	Factors	Failure Analysis
1	Construction of Level crossing	Street condition in the area of crossings is not flat and undulating, and the angle of intersection of the highway and the railway line is too small.
2	Doorstop	As many as 69% of the total accidents at level crossings observed it occurred at unofficial level crossings that did not have gates. Furthermore, there are also official level crossings that already have doorstops but don't function properly. That is, they don't close when the railway passes.
3	Traffic signs	Unofficial level crossings are not equipped with warning signs, so that road users do not know that there is a level crossing in the area. At level crossings that are officially equipped with signs but do not function optimally because some of the signs are damaged, the pictures or writings are not visible and the tone is covered by the leaves of the trees on the side of the road.
4	Road Markings	Many level crossings do not have road markings following those stipulated by the regulations of the ministry of transportation, so that the function of these road markings is not optimal. However, few accidents occur due to poorly functioning road markings.
5	Light Signals	Light signals at unofficial level crossings there are no light signals as a sign that the railway will pass. There are several official crossings on a plot of which there are light signaling devices that are not functioning correctly.
6	Voice cues Voice	Cues signals are also not found at unofficial level crossings.
7	Street lighting equipment	Many street lighting devices do not function optimally at some level crossings, especially at unofficial level crossings. Not functioning optimally due to good maintenance.
8	Guarding	Almost all unofficial level crossings are not equipped with security guards, but non-governmental organizations guard some unofficial plot crossings. Some of the official level crossings are also not equipped with guard officers.

Num	Factors	Failure Analysis
9	Level Crossing Users Behavior	The causes of accidents are often caused by road users who are less concerned and careful when entering the level crossing area. Bad habits of highway users who rush to break through the crossing gates.

3.2 Risk Analysis

At this stage, the type of failure will be determined based on the failure analysis of each safety device at the level crossing, which will then determine the effects of the failure.

Table 2
Effect Analysis and Failure Type Failure of The Level Crossing Safety Equipment

Num	Failure Analysis	Failure Modes
1	Street condition in the area of crossings is not flat and undulating, and the angle of intersection of the highway and the railway line is too small. As many as 69% of the total accidents at level crossings observed it occurred at unofficial level crossings that did not have gates. Furthermore, there are also official level crossings that already have doorstops but don't function properly. That is, they don't close when the railway passes. Unofficial level crossings are not equipped with warning signs, so that road users do not know that there is a level crossing in the area. At level crossings that are officially equipped with signs but do not function optimally because some of the signs are damaged, the pictures or writings are not visible, and the tone is covered by the leaves of the trees on the side of the road.	The road surface is uneven or bumpy. The angle of intersection of the highway and the small railway line. Buildings around the crossing that obscure the driver's view.Level
2	Many level crossings do not have road markings following those stipulated by the regulations of the ministry of transportation, so that the function of these road markings is not optimal. However, few accidents occur due to poorly functioning road markings. Light signals at unofficial level crossings there are no light signals as a sign that the railway will pass. There are several official crossings on a plot of which there are light signaling devices that are not functioning correctly. Cues signals are also not found at unofficial level crossings.	There is no doorstop. The doorstop cannot close. Open and close the doorstop manually
3	Many street lighting devices do not function optimally at some level crossings, especially at unofficial level crossings. Not functioning optimally due to good maintenance. Almost all unofficial level crossings are not equipped with security guards, but non-	There are no signs Signs are not maintained or damaged Trees cover Signs

Num	Failure Analysis	Failure Modes
	governmental organizations guard some unofficial plot crossings. Some of the official level crossings are also not equipped with guard officers.	
4	Street condition in the area of crossings is not flat and undulating, and the angle of intersection of the highway and the railway line is too small. As many as 69% of the total accidents at level crossings observed occurred at unofficial level crossings that did not have gates. And there are also official level crossings that already have doorstops but don't function properly. That is, they don't close when the railway passes. Unofficial level crossings are not equipped with warning signs, so that road users do not know that there is a level crossing in the area. At level crossings that are officially equipped with signs but do not function optimally because some of the signs are damaged, the pictures or writings are not visible, and the tone is covered by the leaves of the trees on the side of the road.	No road markings Road markings are not standard Not visible road markings
5	Many level crossings do not have road markings following those stipulated by the regulations of the ministry of transportation, so that the function of these road markings is not optimal. However, few accidents occur due to poorly functioning road markings. Light signals at unofficial level crossings there are no light signals as a sign that the railway will pass. There are several official crossings on a plot of which there are light signaling devices that are not functioning properly.	There are no light signals. Light signals are do not work.
6	Cues signals are also not found at unofficial level crossings. Many street lighting devices do not function optimally at some level crossings, especially at unofficial level crossings. Not functioning optimally due to good maintenance.	No sound signal sound The signal does not function properly
7	Almost all unofficial level crossings are not equipped with security guards, but non-governmental organizations guard some unofficial plot crossings. Some of the official level crossings are also not equipped with guard officers.	No street lighting
8	The causes of accidents are often caused by road users who are less concerned and careful when entering the level crossing area. Bad habits of highway users who rush to break through the crossing gates. Street condition in the area of crossings is not flat and undulating, and the angle of intersection of the highway and the railway line is too small.	No guard Negligent guard
9	As many as 69% of the total accidents at level crossings observed occurred at unofficial level crossings that did not have gates. And there are	Drivers break through gates Drivers at high speed in level crossings Driver heed the traffic signs

Num	Failure Analysis	Failure Modes
	also official level crossings that already have doorstops but don't function properly. That is, they don't close when the railway passes.	The behavior of drivers in a hurry when crossing level crossings

By determining the type of failure of each safety device, thus the type of failure becomes a potential cause of accidents that occur at level crossings. From these potential causes, an analysis of the effects is determined. Therefore, to understand the effect, it is necessary to measure the effect based on the severity caused to the operation of the level crossing system, as presented in table 3. The information presented in table 4. comes from the results of a group discussion forum (FGD) with the Directorate General of Indonesian Railway Safety.

Table 3
Analysis of the Effects of Failure of Level Crossing Safety Equipment

Num	Failure Mode	Failure Effect
1	The road surface is uneven or bumpy.	Vehicles passing through level crossings become unstable so that the driver becomes unfocused when going through a level crossing.
2	The angle of intersection of a highway and a small railway line	Potentially causing congestion in the level crossing area
3	Buildings around the crossing that obscure the drivers driver's	view Obstructing the view of the vehicles that will pass the level crossing.
4	There is no doorstop	There is no barrier for vehicles that will pass the level crossing when the railway is passing.
5	The doorstop cannot close	the driver will think that there is still a chance to pass the level crossing before the railway passes.
6	Open and close the doorstop manually	The crossing function is not optimal and can cause a human error in the operation of the manual doorstop.
7	No signs / damaged / covered in trees	driver does not know that he will be crossing a level crossing.
8	No road markings / Road markings are not visible / Non-standard road markings	Drivers do not know the limit to stop and wait when the railway crosses the level crossing.
9	No light signal The	driver does not reduce speed when crossing a level crossing.
10	There is no sound signal	
11	The sound signal is not functioning correctly.	driver does not hear the signal, so he does not slow down the speed of his vehicle when he is about to enter the level crossing area motorists
12	There is no street lighting	Unusualpassing a level crossing at a location will have difficulty mastering dark areas so that they do not prepare themselves when they pass through level crossings.
13	No guard / negligent guard	Less optimal control at level crossings if there is non-functioning safety equipment that requires manual operation.
14	The behavior of drivers who are in a hurry when crossing level crossings and Drivers breaking through doorstops	Drivers will be stuck in the middle of a railroad track
15	Riders at high speed in level crossings	Drivers cannot reduce speed when crossing level crossings
16	Drivers heed the traffic signs	Do not understand the meaning of each sign that is on a level crossing.

a. Analysis of Severity

The effect of the failure of each safety device function on level crossings that have been determined subjectively is measured in severity. Determining the severity level is done by giving the scale shown in Table 4.

Table 4
Severity Level

Rating	Type Severity	Explanation
1	Very Low	Failure does not have much impact.
2	Low	Failure to cause traffic disruption
3	Medium	Failure to cause damage to level crossing facilities
4	Severe	Failure to cause an accident to occur
5	Very Severe	Failure to cause an accident

Based on the type of severity in table 4, the severity of each failure can be determined, accidents at level crossings as shown in table 5.

Table 5
Severity Level of Potential Cause

Num	Failure Mode	Severity
1	The road surface is uneven or bumpy.	3
2	The angle of intersection of a highway and a small railway line	3
3	Buildings around the crossing that obscure the driver'sdriver's	3
4	There is no doorstop	5
5	The doorstop cannot close	5
6	Open and close the doorstop manually	3
7	No signs / damaged / covered in trees	3
8	No road markings / Road markings are not clearly visible / Non-standard road markings	2
9	No light signal The	3
10	There is no sound signal	3
11	The sound signal is not functioning properly The	3
12	There is no street lighting	3
13	No guard / negligent guard	4
14	behavior of drivers who are in a hurry when crossing level crossings and Drivers breaking through doorstops	5
15	Riders at high speed in level crossings	5
16	Drivers heed the traffic signs	4

From table 5, the potential causes that are categorized as very severe are the absence of doorstops at level crossings, doorstops that cannot be closed at railroad crossings at level crossings, high speed drivers when crossing level crossings, drivers breaking through the gates, absence of street lighting around level crossings and the lack and concern or attention of motorists to traffic signs in the level crossing area. In comparison, other factors have moderate and low effects.

b. Analyze of Occurrence

In this section, an analysis of the incidence rate is carried out based on the frequency of accidents at level crossings caused by potential causative factors in the 42 observed accident cases. The incidence rate is determined in table 6.

Table 6
The Occurance Rating

Rating	Occurrence Frequency	Explanation
1	< 5 cases	There are less than 5 cases of accidents caused by potential causal factors.
2	6 – 10 cases	Accidents are occurring between 5 – 10 times cases caused by the same potential causal factor.
3	11 – 20 cases	There are cases of accidents between 11 – 20 cases caused by the same potential causative factor.
4	21 – 30 cases	There are cases of accidents between 21 – 30 cases caused by the same potential causal factor.
5	>30 cases	There were more than 30 cases of accidents that occurred due to the same potential causal factors.

Based on the provisions in Table 6, the ranking of events caused by potential causes can be determined, as shown in table 7.

Table 7
The Occurrence Rating of Cause Potential

Num	Failure Mode	Frequency	Occurrence
1	The road surface is uneven or bumpy.	6	2
2	The angle of intersection of a highway and a small railway line	4	1
3	Buildings around the crossing that obscure the driver'sdriver's	5	2
4	There is no doorstop	26	4
5	The doorstop cannot close	7	2
6	Open and close the doorstop manually	3	1
7	No signs / damaged / covered in trees	29	4
8	No road markings / Road markings are not clearly visible / Non-standard road markings	26	4
9	No light signal The	26	4
10	There is no sound signal	26	4
11	The sound signal is not functioning properly The	2	1
12	There is no street lighting	26	4
13	No guard / negligent guard	38	5
14	behavior of drivers who are in a hurry when crossing level crossings and Drivers breaking through doorstops	16	3
15	Riders at high speed in level crossings	16	3
16	Drivers heed the traffic signs	16	3

From table 8. there are 38 cases of accidents at level crossings that are not guarded both at official and unofficial level crossings with an incidence rating of 5. For event rating 4, several accident cases occurred with potential causes 26 cases of no gates, **29 cases of** level crossings that do not have signs, damaged or covered by trees, 26 cases of non-standard road markings on level crossings without road markings, road markings not visible or non-standard road markings the presence of a sound signal or a non-functioning light signal, namely 26 cases and 26 cases at level crossings where there is no street lighting. For the case of accidents caused by human error, both driver and guard rated events 3. For accidents caused by other potential causes with events, rank 2 and 1.

c. Analysis of Detection

At the analysis, the stage measures levels of capability to detect all accidents that occur at level crossings based on their potential causes. This detection level is categorized on a 5 scale from the most difficult to the easiest to detect, as shown in table 9. This is aimed at detecting controls related to accidents at level crossings.

Table 9
Level of Capability Detection

Rating	Capability Detection	Explanation
1	95-100% (very easy)	almost certainly detect the cause of the accident
2	85-95% (Easy)	Possible easy to detect the cause of the accident
3	70-85% (moderate)	to detect the cause of the accident.
4	50 – 70% (Difficult)	Little opportunities of detecting the cause of the accident.
5	0 – 50% (Very Difficult) It is	very difficult to detect and predict the causes of accidents.

Based on table 9, the difficulty in detecting the emergence of potential causes can be determined that will result in accidents at level crossings. The detection rate of the potential causes can be seen in table 10.

Table 10
Detection Level of Potential Causes

Num	Failure tMode	*Detection*
1	The road surface is uneven or bumpy	2
2	The angle of the intersection of the highway and the railroad is small	2
3	Buildings around the crossing that obscure the driver's view	3
4	There is no doorstop	4
5	cannot close	5
6	DoorstopOpen and close the door latch manually	3
7	No signs / damaged / covered in trees	2
8	No road markings / Road markings are not clearly visible /standard road markings	2
9	Non-No signal lights	2
10	No audible signal or light signal does not work	2
11	Sound signal does not work properly	2
12	No street lighting	3

Num	Failure tMode	*Detection*
13	No guard / careless guard	1
14	Driver's behavior in a hurry when crossing level crossings and Riders breaking through bars gate	5
15	High-speed drivers in level crossing areas	5
16	Lack of concern for traffic signs	5

Potential causes that have the most challenging detection rate based on table 10 are doorstops that cannot close, the behavior of drivers who are in a hurry when crossing level crossings, drivers who break through gates, drivers with high speed in level crossings, and the driver's lack of attention to signs traffic. A doorstop that cannot be closed is a rare occurrence, but it is tough to detect due to the unexpectedness of the maintenance department and the sudden occurrence. All kinds of behavior of each driver when passing a level crossing area is challenging to predict because each driver has different behavior. The accidents caused by this are very many.

3.3 Calculation of Risk Priority Number (RPN)

From the acquisition of the level of severity, frequency of accident events, and the level of ability todetect potential causes of accidents at level crossings, it is possible to determine the priority level of risk, which will be a priority action to reduce and eliminate the causes of accidents at level crossings. The priority level of risk shows the seriousness of the effects caused, the likelihood that causes will cause failures related to the effects caused, and the ability to detect failures before an accident occurs, as shown in table 11.

Table 11
Calculation of The Risk Priority Number

Num	Failure tMode	Severity	Occurance	Detection	RPN
1	The road surface is uneven or bumpy	3	2	2	6
2	The angle of the intersection of the highway and the small railway line	3	1	2	6
3	Buildings around the crossing which obscures the driver's view	3	2	3	18
4	No doorstop	5	4	4	80
5	cannot close	5	2	5	50
6	DoorstopOpen and close the door latch manually	3	1	3	9
7	There are no signs / damaged / covered by trees	3	4	2	24
8	No road markings / Road markings are not clearly visible / Non-standard road markings	2	4	2	16
9	No light signals	3	4	2	24
10	No sound signals or non-functioning light signalssignals	3	4	2	24
11	Soundnot functioning properly	3	1	2	6
12	There is no street lighting	3	4	3	36
13	There is no guard / careless guard	4	5	1	20
14	Driver's behavior is in a hurry when crossing level crossings and Drivers break through gates	5	3	5	75
15	Riders listen n high speed in the area of level crossing	5	3	5	75

Num	Failure tMode	Severity	Occurance	Detection	RPN
16	Lack of concern for traffic signs	4	3	5	60 The

The Risk Priority Number obtained is used to determine priority actions that can be taken to reduce or even eliminate the causes of accidents at the Sebiang crossing. From the results of the RPN in table 11, the ratings of seriousness in making improvements and opportunities to identify and anticipate before an accident occurs are shown in table 12.

Table 12
Ranking of Potential Causes Based on RPN

Num	Type of Failure (Failure tMode)	RPN
1	No doorstop	80
2	The behavior of drivers who are in a hurry when crossing level crossings and Drivers breaking through gate barriersdrivers	75
3	High speedin level crossings	75
4	Lack of concern for traffic signs	60
5	Doorstops cannot close	50
6	No street lighting	36
7	There are no signs / damaged / covered by trees	24
8	No light signals	24
9	No sound signals or light signals do not work	24
10	No guards / careless guards	20
11	Buildings around crossings that obscure the driver's view	18
12	No road markings / Road markings are not clearly visible / Non-standard road markings	16
13	Unscrew the bars door manuallySound signals are	9
14	The road surface is uneven or bumpy	6
15	The angle of the intersection of the highway and the railroad is small	6
16	not functioning properly	6

4. Conclusion

From the results and discussion, it can be concluded that nine factors that cause accidents at level crossings have been identified, and 16 types of failures have been obtained from these factors. Level crossings that do not have doorstops are a potential cause with a risk priority number (RPN) of 80. The absence of guards contributes to the high severity of accidents, and this is similar to a study conducted by Barić *et al*., [14] that the presence of guards at level crossings was the most effective in reducing accident rates.

Based on observations, level crossings that do not have doorstops are dominated by unofficial level crossings. The second factor that must be an important concern is the driver's behavior when passing at level crossings. The driver factor is complicated to detect because it is necessary to disseminate information about maintaining safety at level crossings.

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