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HIGHWAY AND RAILWAY CROSSING MANAGEMENT MODEL TO IMPROVE SIDOARJO-TARIK CROSSING SAFETY (COMPARISON BETWEEN INDONESIA AND MALAYSIA)

Dadang Supriyatno[1], Syaiful Syaiful[2], Sri Wiwoho Mudjanarko[3], Asri Kusuma Wardhani[3]*

[1] State University of Surabaya, Engineering Faculty, Vocational Program, Indonesia
[2] Ibn Khaldun University Bogor, Engineering Faculty, Civil Engineering Departement, Indonesia
[3] Narotama University Surabaya, Engineering Faculty, Civil Engineering Departement, Indonesia
* dadangsupriyatno@unesa.ac.id

The railway level crossings between Sidoarjo-Tarik in Sidoarjo Regency are mostly railway crossings without barriers that are prone to traffic accidents due to conflicts at railway crossings between road users and passing trains, which have the potential to cause accidents. This study aims to provide recommendations for handling in accordance with regulations on improving the safety of railway crossings between railways and roads and guidelines on technical guidelines for railway crossings between roads and railways. The survey conducted in this study was a road inventory to determine the geometry of railway level crossings and a survey of road user behavior to determine the behavior of road users crossing railway. Recommendations for handling the railway crossings between Sidoarjo-Tarik in Sidoarjo Regency that are appropriate to improve safety and prevent accidents are to install barriers and close category 2 to 4 meters of crossings.

Keywords: conflict, geometric, behavior, handling recommendations

HIGHLIGHTS

- This study analyzes the safety of railway level crossings along the Sidoarjo–Tarik line in Indonesia, with a comparison to practices in Malaysia.
- Field surveys and traffic analysis identified key risk factors, including road geometry, driver behavior, and insufficient safety measures.
- Findings show that Malaysia has more complete and effective safety infrastructure, while Indonesia requires further improvements.
- The paper proposes technical, social, and regulatory recommendations, such as installing barriers, constructing overpasses, and enhancing signage, to reduce accident risks.

1 Introduction

1.1 Background of the Study

Railway Crossings are still a concern that must be accounted for as population and mobility increase. There are still many level railway crossings that do not meet the standards, especially in Sidoarjo Regency. Between Sidoarjo and Tarik, there are 36 railway crossings, 6 of which are guarded, while the remaining 30 are not. There are 30 spots along on the supporting cross between Sidoarjo – Tarik, where indicates level crossings without doorstops that are prone to accidents. It is located at six spots along the route from Candi to Tarik, including Prambon: 1 point, Tarik: 1 point, Candi: 2 points, and Sidoarjo 2 points.

1.2 Objective of the Study

This study aims to provide recommendations on how to deal with issues in accordance with the regulations for improving safety at level crossings along the supporting cross between Sidoarjo-Tarik, as stated in [1], improving the safety of level crossings between railways and highway and technical guidelines [2], about technical guidelines for level crossings between highways and railways. Therefore, it is expected that this study would contribute to the consideration of railway crossing safety to the Government of Sidoarjo Regency, the Eastern Region Railways Division, and DAOP VIII Surabaya.

Railway tracks with level crossings play a crucial role in ensuring the seamless and safe interaction between rail and road transportation systems. At such intersections, railway tracks meet highways, which can be constructed with either rigid pavement (typically concrete) or flexible pavement (generally asphalt). These crossings require careful design, construction, and maintenance due to the unique demands posed by the interaction of different transport systems and materials [4] – [6]. One of the most important factors to consider is safety. Level crossings are high-risk zones where trains, vehicles, and pedestrians converge. The design must ensure that vehicles and pedestrians can cross the tracks without undue risk while trains maintain their operational efficiency. Clear visibility, appropriate signage, and signaling systems are essential for preventing accidents. Additionally, barriers or gates may be installed to control traffic flow when a train is approaching. Ensuring that the pavement and the tracks are flush and aligned minimizes the likelihood of vehicles getting stuck or losing control [7] – [10].

The type of pavement at the crossing is another critical consideration. Rigid pavements, made of concrete, provide a durable and long-lasting surface but can be more challenging to integrate with railway tracks due to their stiffness. On the other hand, flexible pavements, made of asphalt, offer more flexibility and are easier to repair, but they may require more frequent maintenance due to deformation under heavy loads. The choice between rigid and flexible pavement depends on the expected traffic loads, climatic conditions, and the maintenance strategy for the crossing [11], [12]. Drainage is a key factor in the performance of railway level crossings. Poor drainage can lead to water accumulation, which may weaken the pavement structure and cause track instability. This can result in uneven surfaces, increasing the risk of accidents. Proper drainage systems, such as culverts or drains, must be incorporated to manage water effectively and prevent damage to both the tracks and the pavement [13] – [15].

Load distribution at level crossings is another vital consideration. Highway pavements, whether rigid or flexible, must be designed to accommodate the dynamic loads of vehicles passing over the crossing. Similarly, railway tracks must withstand the concentrated loads of trains. The interface between the two systems must be designed to distribute loads evenly and prevent damage to either the tracks or the pavement. Special track structures, such as rubberized or composite panels, are often used at crossings to ensure smooth transitions and reduce wear and tear [16], [17]. Maintenance and durability are critical for ensuring the long-term functionality of level crossings. Both railway tracks and adjacent pavements are subject to significant wear due to heavy traffic and environmental factors. Regular inspections and timely maintenance, such as repairing cracks, replacing worn-out panels, or re-aligning tracks, are necessary to keep the crossing safe and operational. For flexible pavements, this may involve resurfacing, while for rigid pavements, it may include joint repairs or slab replacements [18].

1.3 Railway Level Crossing

According to the Regulation of the [2, 19], regarding Technical Guidelines for Level Crossings between highways and railways, the requirements for level crossings are as follows:

1.3.1 Level Crossing Regulation

Although railway crossings should be made non-level, this can still be averted by making the following arrangements:

- The time period between one train and the next (headway) that operates by the area is often at least 6 minutes on the rush hour (peak).
- On a train track, there must be at least 800meters between each track.
- Not located on a railway junction or highway junction as well.
- there are environmental conditions that provide a view for train drivers from above the crossing and for automobile drivers.
- The road that is crossed is class III road.

1.3.2 The Infrastructural Regulation

Road sections that can be made level crossings with railroads have the following regulations:

- The time period between one train and the next (headway) that operates by the area is often at least 6 minutes on the rush hour (peak).
- The road that is crossed is class III road.
- As many roads as possible, ideally with two lanes on each.
- Not located on a junction and/or horizontal alignment with a radius of at least 500meters.
- The slope level is less than 5 (five) percent from the outermost point of the railway.
- Ensure the clear sight distance is maintained.
- Based on RUTR regulation.

1.3.3 Level Crossing Settlement

There are level crossings with gates that are either automated or not, mechanical or electrical, and there are also level crossings without doors. Whenever a railroad crossing fulfills one of the following criteria, it must be non-level:

- There are at least 25 trains per day and a maximum of 50trains per day that operates on that area.
- Average daily traffic volume (LHR) of 1,000 to 1,500vehicles on inner-city roads and 300 to 500vehicles on out-of-town roads, or
- The multiplication results between the average daily traffic volume (LHR) and the train frequency between 12,500 to 35,000SMP. If more than that, a level crossing must be existed [19] – [21].

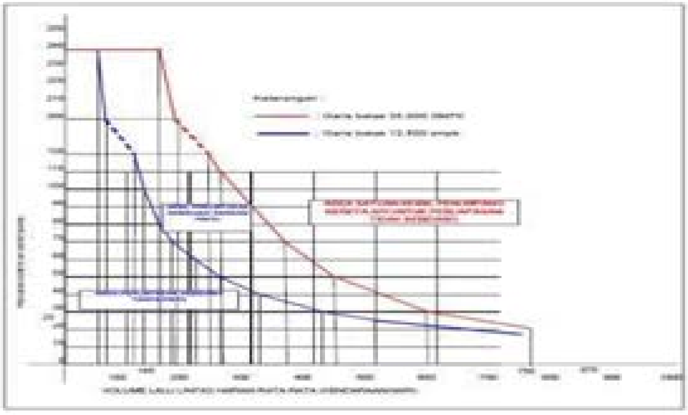

Fig. 1. Graphic for Settlement Area of the Railway Level Crossings Type [2]

2 Materials and methods

The types of materials on the level crossing surface between the railway track and the road are based on sources from [3], about Railway/Highway AT-Grade Crossing Surface Rehabilitation Manual. Recommendations and Guides are as follows:

2.1 Asphalt

Asphalt, which is set between and on the outside of the rails and can be used for inter-rural crossings with low traffic volumes, is the type of material required at the intersection of the rail surfaces.

Fig. 2. Type of Asphalt Surfaces on Rails [3]

2.2 Rubber Seal and Asphalt

Rubber seal and asphalt are used for crossings with moderate to high traffic volumes. This surface includes asphalt between the rails, rubber strips covering the rails, and asphalt placed on the rubber on the outside of the rails.

Fig. 3. Type of Rubber Seal and Asphalt Surface [3]

2.3 Timber and Asphalt

Timber and asphalt are also ideal materials for medium to high volume crossings. Asphalt is applied in the center of this surface, while timber is placed on both sides of the rail, and asphalt is coated on the timber on the outer and inner rail sides.

Fig. 4. Type of Timber and Asphalt Surface [3]

2.4 Concrete Panel

Concrete panels are typically used for high-traffic crossings. This surface is considered a premium surface since it is produced by putting concrete panels between the rails and the edges of the court.

Fig. 5. Type of Concrete Panel Surface [3]

2.5 Full-Depth Rubber

A track surface material that is applied to the concrete road's surface. Typically used on roads with heavy traffic and high purchasing costs.

Fig. 6. Type of Full-depth Rubber [3]

2.6 Combination

The combination surfaces are similar to full-depth timber surfaces, but they are formed up of different types of finely divided waste products mixed with polymer adhesives to bond the materials. They are mostly used in high-volume passages, and the installation cost of the material is higher compared to more common crossing surfaces.

Fig. 7. Type of Combination Surface [3]

2.7 Concrete Tub

Concrete tub materials are rarely used compared to other similar track materials. This material is generally used on highways with high traffic volumes and low-speed rail roads.

Fig. 8. Type of Concrete Tub [3]

2.8 Research methods

2.8.1 Location

This study conducted on level crossing of supporting railway in Sidoarjo-Tarik, Sidoarjo Regency.

Fig. 9. Location of KA Crossing Managing Study Source: Analysis Result 2022

2.8.2 Stages of Study Design

In this section, the stages of the study is being presented:

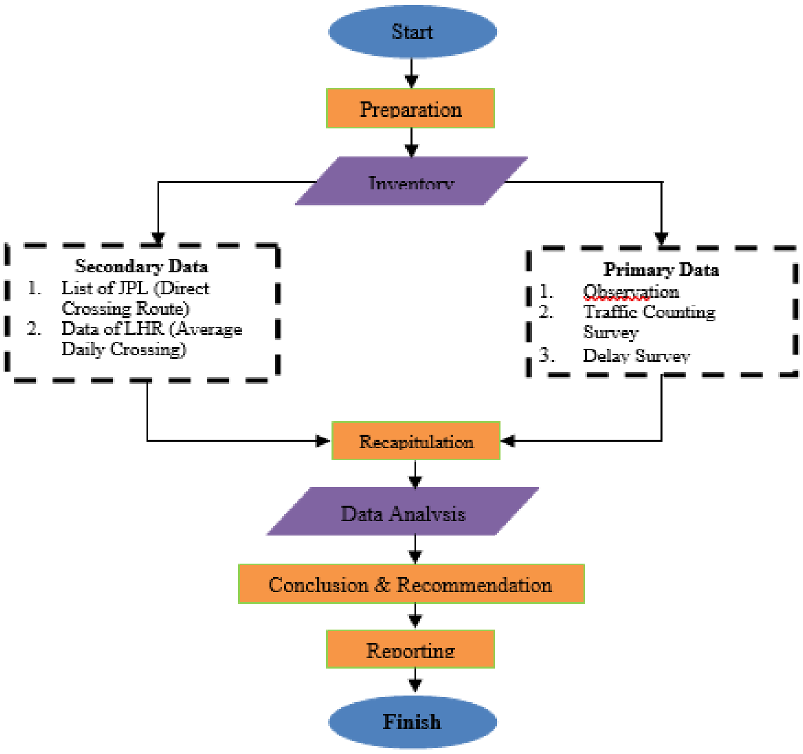

Fig. 10. Stage and research methods

3 Result and discussion

3.1 Traffic Conditions

Some locations at JPL Sidoarjo–Tarik crossing require specific management of traffic conditions; supporting data required for processing is in the form of average daily traffic (LHR). Regarding the samples collected are located in the Prambon and Raya Tulangan.

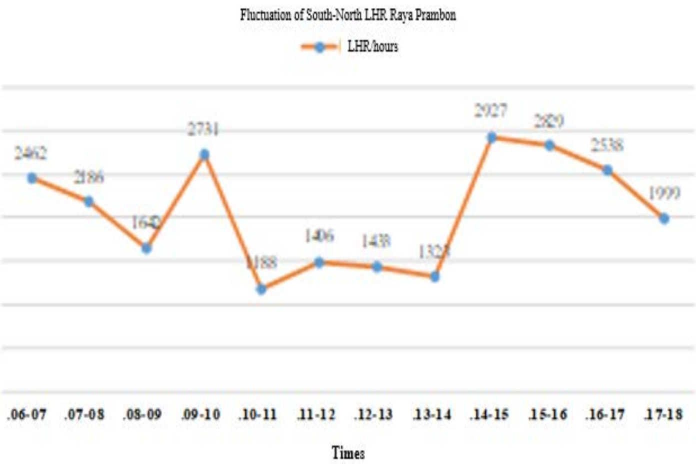

Fig. 11. Fluctuation of South-North LHR Raya Prambon

Table 1. Performance of South-North Prambon Road

No	Times	Total Q/LHR (vehicle/hours)	SMP/hours	Capacity	VCR	Level of Service (LOS)
1	06.00-07.00	2462	1482.9	3442	0.43	B
2	07.00-08.00	2186	1408.7	3442	0.41	B
3	08.00-09.00	1642	1127.6	3442	0.33	B
4	09.00-10.00	2731	1828.7	3442	0.53	C
5	10.00-11.00	1188	836.6	3442	0.24	B

No	Times	Total Q/LHR (vehicle/hours)	SMP/hours	Capacity	VCR	Level of Service (LOS)
6	11.00-12.00	1496	1181.3	3442	0.34	B
7	12.00-13.00	1433	1139.5	3442	0.33	B
8	13.00-14.00	1323	928.7	3442	0.27	B
9	14.00-15.00	2927	1951.3	3442	0.57	C
10	15.00-16.00	2829	1761.8	3442	0.51	C
11	16.00-17.00	2538	1593.1	3442	0.46	C
12	17.00-18.00	1999	1281.7	3442	0.37	B

Source: Analysis Result, 2022

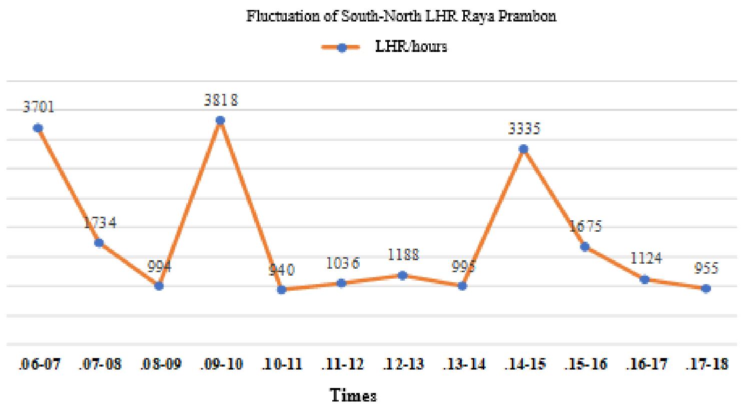

Fig. 12. Fluctuation of South-North LHR Raya Prambon

Table 2. Performance of South-North Prambon Road

No	Times	Total Q/LHR (vehicle/hours)	SMP/hours	Capacity	VCR	Level of Service (LOS)
1	06.00-07.00	3701	2001.3	3442	0.58	C
2	07.00-08.00	1734	1051.7	3442	0.31	B
3	08.00-09.00	994	740	3442	0.21	B
4	09.00-10.00	3818	2353.4	3442	0.68	C
5	10.00-11.00	940	639.1	3442	0.19	A
6	11.00-12.00	1036	841	3442	0.24	B
7	12.00-13.00	1188	882.3	3442	0.26	B
8	13.00-14.00	995	685.8	3442	0.20	B
9	14.00-15.00	3335	2019.8	3442	0.59	C
10	15.00-16.00	1675	1108.5	3442	0.32	B
11	16.00-17.00	1124	818.8	3442	0.24	B
12	17.00-18.00	955	689.6	3442	0.20	B

Source: Analysis Result, 2022

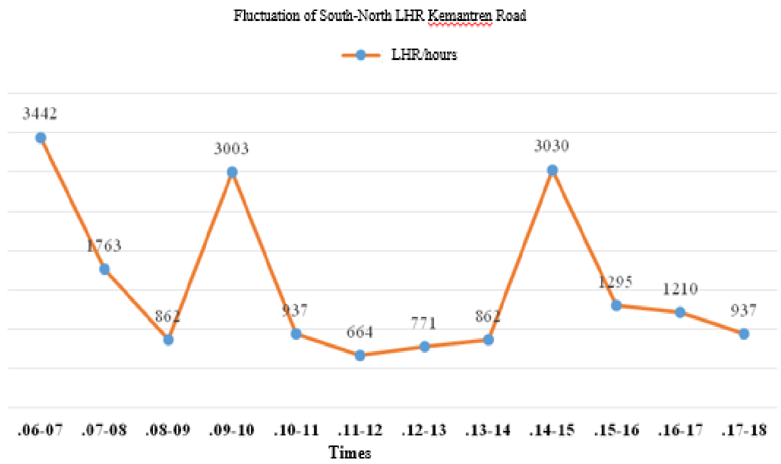

Fig. 13. Fluctuation of South-North LHR Kemantren Road

Table 3. Performance of South-North Kemantren Road

No	Times	Total Q/LHR (vehicle/hours)	SMP/hours	Capacity	VCR	Level of Service (LOS)
1	06.00-07.00	3442	1769.2	2170	0.82	D
2	07.00-08.00	1763	953.7	2170	0.44	B
3	08.00-09.00	862	503.9	2170	0.23	B
4	09.00-10.00	3003	1576.6	2170	0.73	C
5	10.00-11.00	937	557	2170	0.26	B
6	11.00-12.00	664	418.7	2170	0.19	B
7	12.00-13.00	771	459.4	2170	0.21	B
8	13.00-14.00	862	515.8	2170	0.24	B
9	14.00-15.00	3030	1619.7	2170	0.75	D
10	15.00-16.00	1295	742.2	2170	0.34	B
11	16.00-17.00	1210	681.7	2170	0.31	B
12	17.00-18.00	937	534.9	2170	0.25	B

Source: Analysis Result, 2022

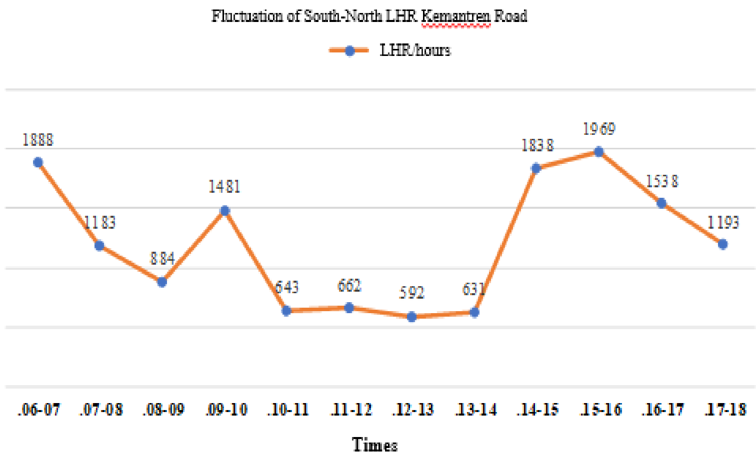

Fig. 14. Fluctuation of South-North LHR Kemantren Road

Table 4. Performance of Kemantren Road

No	Times	Total Q/LHR (vehicle/hours)	SMP/hours	Capacity	VCR	Level of Service (LOS)
1	06.00-07.00	1888	1005.5	2170	0.46	C

No	Times	Total Q/LHR (vehicle/hours)	SMP/hours	Capacity	VCR	Level of Service (LOS)
2	07.00-08.00	1183	656.7	2170	0.30	B
3	08.00-09.00	884	522.5	2170	0.24	B
4	09.00-10.00	1481	832.1	2170	0.38	B
5	10.00-11.00	643	404.2	2170	0.19	A
6	11.00-12.00	662	440.6	2170	0.20	B
7	12.00-13.00	592	358.7	2170	0.17	A
8	13.00-14.00	631	394.8	2170	0.18	A
9	14.00-15.00	1838	1014.2	2170	0.47	C
10	15.00-16.00	1969	1047.6	2170	0.48	C
11	16.00-17.00	1538	811.5	2170	0.37	B
12	17.00-18.00	1193	641.4	2170	0.30	B

Source: Analysis Result, 2022

3.2 Model Analysis of Delays at Crossings

This analytical procedure employs statistical calculation tools for Statistical Product and Service Solutions (SPSS) in order to save processing time and reduce calculation error rates. The recapitulation of these variables' values yielded the following results.

Table 5. Delay Variable Value of Prambon Crossing

No	Times	Y (Delay)	X1 (DS)
1	06.00-07.00	3	0.51
2	07.00-08.00	2	0.36
3	08.00-09.00	2	0.27
4	09.00-10.00	3	0.61
5	10.00-11.00	2	0.21
6	11.00-12.00	2	0.20
7	12.00-13.00	2	0.29
8	13.00-14.00	2	0.23
9	14.00-15.00	3	0.58
10	15.00-16.00	2	0.42
11	16.00-17.00	2	0.35
12	17.00-18.00	2	0.29

Source: Results of Survey Results Recapitulation

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.144	.186		6.158	.000
	Ds	3.008	.477	.894	6.302	.000

Fig. 15. Dependent variables DS/Road performance

$$Y = a + b1\ x1 \qquad (1)$$

Where:

Y = dependent variable (Ds/Road Performance)

a = constant value

b = coefficient of regression

X1 = the value of the independent variable 1 in this equation is the Time Delay

The following calculation output is generated as a result of the analysis using Statistical Product and Service Solutions (SPSS).

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.894[a]	.799	.779	.21275

Fig. 16. The Impact of Independent and Dependent Variables

The table above explains the percentage influence of the independent variable or predictor variable on the related variables. The value of the correlation / relationship (R) is 0.894. From the output, it is obtained that the coefficient of determination (R Square) is 0.799 which implies that the influence of the independent variable DS (Road Performance) on the dependent variable (Length of Delay) is 79.9%

The table above also explains that the output of annova: from the output it is known that the calculated F value = 39,711 with a significance level of 0,000 <0.05. Then the regression model can be used to predict the long delay variable or in other words there is an influence of the variable Ds or road performance (X) on the long delay variable (Y).

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.797	1	1.797	39.711	.000[b]
	Residual	.453	10	.045		
	Total	2.250	11			

Fig. 17. Delay Model at Prambon Crossing

Constant value (a) is 1,144, while the Delay Time (b) Regression coefficient) is 3,008 so that the regression equation can be formulated as follows.

$$Y = a + bX$$

$$Y = 1.144 + 3.008X$$

Thus, can be inferred:

A constant of 1.144 means that the value of the long delay consistency variable is 3.008. The regression coefficient X of 3.008 states that for every 1% addition of the Ds value or road performance, the delay time value increases by 3.008. The regression coefficient is positive, so it can be said that the direction of the influence of variable X on Y is positive.

Table 6. Value of Delay Variable of Kemantren/Tulangan

No	Times	Y (Delay)	X1 (DS)
1	06.00-07.00	3	0.64
2	07.00-08.00	2	0.37
3	08.00-09.00	2	0.24
4	09.00-10.00	3	0.56
5	10.00-11.00	2	0.22
6	11.00-12.00	2	0.20
7	12.00-13.00	2	0.19
8	13.00-14.00	2	0.21
9	14.00-15.00	3	0.61
10	15.00-16.00	3	0.41
11	16.00-17.00	2	0.34
12	17.00-18.00	2	0.28

Source: Results of Survey Results Recapitulation

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.889[a]	.790	.770	.23638

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.108	1	2.108	37.726	.000[b]
	Residual	.559	10	.056		
	Total	2.667	11			

Fig. 18. Influence of Independent Variables on Dependent Variables Source: Calculation Results, 2022

The table above explains the percentage influence of the independent variable or predictor variable on the related variables. The value of the correlation/relationship (R) is 0.889. From the output, it is obtained that the coefficient of determination (R Square) is 0.790 which implies that the influence of the independent variable Ds (Road Performance) on the dependent variable (Length of Delay) is 79.0%

The table above also explains that the output of annova: from the output it is known that the calculated F value = 37,726 with a significance level of 0,000 <0.05. Then the regression model can be used to predict the long delay variable or in other words there is an influence of the variable Ds or road performance (X) on the long delay variable (Y).

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.392	.168		8.295	.000
	Ds	2.646	.431	.889	6.142	.000

Fig. 19. Delay Model at Kemantren/Tulangan Crossing

Constant value (a) is 1,392, while the Delay Time (b) Regression coefficient) is 2,646 so that the regression equation can be formulated:

$$Y = a + bX$$

$$Y = 1.392 + 2.646X$$

These equations can be inferred:

A constant of 1,392 means that the consistent value of the delay variable is 2,646.

The regression coefficient X of 2,646 states that for every 1% addition of the Ds value or road performance, the delay time value increases by 2,646. The regression coefficient is positive, so it can be said that the direction of the influence of variable X on Y is positive.

Although the paper proposes infrastructure upgrades (overpasses, underpasses), it does not assess the economic feasibility or cost-effectiveness of these solutions.

3.3 Comparative Analysis of Level Crossing between Indonesia and Malaysia

Comparison of managing the level crossings in Indonesia, particularly Sidoarjo-Tarik, with level crossings in Malaysia reveals some general similarities. Still, in several handling level crossings located in Malaysian city areas, the majority of crossings or railroad lines are not parallel to the highway. In contrast, the background for handling crossings in Indonesia and Malaysia is related to the infrastructure and facilities used in both countries.

The following table can be used to generalize findings on the effectiveness of level crossing safety facilities in Malaysia and Indonesia, particularly at the Sidoarjo-Tarik level crossings.

Table 7. Comparison of Managing Facilities for JPL in Indonesia–Malaysia

No	Handling facilities	Indonesia	Malaysia
1	Warning signs	√	√
2	Command signs	√	√
3	Prohibition signs	√	√
4	Mechanical barriers	√	√

No	Handling facilities	Indonesia	Malaysia
5	Shock tape	√	√
6	Watch posts/substations	√	√
7	Fly over/over pass	√	√
8	Under pass	√	√
9	JPL pavement	√	√
10	Visibility distance	√	√
	Percentage of completeness	80%	100%

Source: Analysis Result, 2022

In Indonesia, the percentage of comprehensive level crossing tools and facilities is lower than in Malaysia, where it ranges from 80% to 100%.

Comparison in regulation and management of level crossings in Indonesia and Malaysia are as follows:

3.4 Regulation in Indonesia

The management of level crossings into non-level crossings must comply with the provisions of [2] which includes the number of trains that pass at that location at least 25 trains/day and as many as 50 trains / day and the average daily traffic volume (LHR) is 1,000 to 1,500 vehicles on inner-city roads and 300 to 500vehicles on out-of-town roads. From a management standpoint, there is overlap in management areas, so widening the policy bureaucracy area and also corporate management, which emerges because railway management is divided between two parties. Notably, the Ministry of Transportation in the infrastructure area and BUMN (PT.KAI) in the facilities area, delaying and complicating field policies.

Given the limited data, and the limited number of accidents caused by motorists at railroad crossings. The conclusion is that accidents at these level crossings are very small so that the impact on level crossings for motorists does not significantly affect. Level crossings exist because they refer to the construction of railroads in Indonesia.

3.5 Regulation in Malaysia

The conversion of level crossings to non-level crossings is based on avoiding high accident potential and also on the use of electric traction on railway infrastructure, thus without concern for train frequency or vehicle traffic. As a result, non-level crossings must be regulated. In terms of management in Malaysia, in the area of Railway Facilities and Infrastructure, under the supervision of 1unit that is the same and stands independently, which has a good influence, specifically shortening the bureaucracy, reducing the complexity for company management, planning, and field policies.

In Malaysia, because the crossings are managed by one agency, it is unlikely that accidents will occur due to level crossings. Accurate data has not been obtained, but with very strict management of level crossings, it is guaranteed that there will be no human error in this management.

3.6 Management Handling in Indonesia

Level crossing construction is not adjusted to the demands and current circumstances, and the majority of level crossing construction is merely modified to the budget ceiling, making it prone to continual damage. In Indonesia, the safety feature of the clear line of sight issue between drivers and motorcyclists is relatively restricted, therefore double security is required at level crossings, resulting in a waste of expense and ineffective signs.

For Indonesian conditions (high humidity and frequent flooding), a combination of rubber and asphalt is a cost-effective option as it is resistant to erosion, while concrete slabs last longer but are more expensive.

3.7 Management Handling in Malaysia

On the contrary, because the construction has been standardized and managed on a massive scale, there are no damaged level crossings. In Malaysia, the free sight distance between the driver and the driver of the vehicle is implemented by the applicable rules, so that the potential for an accident due to a very small free sight distance occurs and the installation of safety signs at level crossings can function optimally.

4 Conclusions

Based on level crossings in Malaysia, the conclusion of this comparative study is a recommendation for managing level crossings in Indonesia, particularly on the Sidoarjo-Tarik crossing. The percentage of comprehensive level crossing tools and facilities in Indonesia, particularly on the Sidoarjo-Tarik crossing, is lower than in Malaysia; the table above shows that the completeness of the safety facilities in Indonesia, particularly on the Sidoarjo–Tarik crossing, approaches 80%. While JPL in Malaysia, especially on the Johor–Kuala Lumpur and Sabah–Beauford routes, achieved 100% comprehensive level crossings. Short-term level crossing management is carried out by constructing supporting infrastructure facilities for level crossing safety, which will, of course, have no impact on road performance, with a solution consisting of applying identified level crossings to remain open, re-optimizing and accomplishing existing safety signs and equipment. Medium to long-term level crossing management is accomplished by constructing supporting infrastructure facilities for level crossing safety, which include solutions such as: 1) the Fly Over/over pass construction can take place at the JPL27 Prambon level crossing, 2) the Underpass can be established at level crossings or JPL number 16, particularly on the Tulangan highway near the station, 3) frontage Road development in detail begins with serial number JPL, which is transferred to the frontage along JPL 17-29, and then access is opened at JPL point number 23. The recommendation for dealing with the free sight distance of still-open level crossings is to qualify safety conditions of free space between the train driver and the motorized driver; 500 meters for train drivers at least, and a minimum distance of 150 meters for motorized drivers. Increasing the safety of level crossings can be accomplished by reducing the JPL at grade, which is still minimal in Indonesia due to the numerous direct intersections between drivers and trains. As a result, the improvement of level crossing facilities must be accomplished by no longer implementing JPL at grade, but instead replaced with an elevated crossing, or in this case, a Fly Over or underpass.

Future research should include a cost analysis of the proposed interventions, particularly the construction of overpasses, which require significant investment.

This paper has limitations in terms of data scope, as it relies on only two crossings (Prambon, Kemantren). Future studies should include a broader geographic coverage.

4.1 Recommendations

According to the Research Team, the following are some recommendations that can be applied to accident-prone railway crossings:

4.1.1 Recommendations on Railway Level Crossings

- Spasial Recommendation

  Avoiding the train not intersect with public roadways is the most effective strategy to prevent conflicts. This can be accomplished physically by replacing level crossings with a flyover or underpass.

- Social Recommendation

  There must be space for public discussion and education regarding level crossing traffic protocols. It is also important to investigate community engagement approaches for level crossings. For instance, providing dense local patrol posts around level crossings.

- Technical Recommendation

  - Crossroads Reconstruction
  - Clossing Gate

- Regulation recommendation

  Revision of laws and regulations related to development issues that cross the railway line as well as regulations that provide sanctions for traffic violations at JPL.

- Recommendations for traffic management at crossings

  In order to comply with regulations, traffic signs must be installed. Cleaning the area surrounding crossing signs so that motorists can see it clearly.

  - Recommendations for HR crossing gates, vehicle drivers and machinists
  - Some of the recommendations are as follows: Improving crossing guard discipline and competence, integrating knowledge of railroad traffic signs as standardized test material for acquiring a driver's license, and raising awareness and adherence to railway traffic signs.

4.2 Socialization of Railway Crossing Safety

It is essential to develop a curriculum at educational institutions or to establish understanding of the importance of driving safety at intersections at an early age. Furthermore, there is public awareness and education surrounding train tracks or crossings, as well as community and business participation to improve crossing safety.

4.3 Management and Engineering of Railway Crossings

Management and engineering at railrway crossings according to the Regulation of the Director General of Land Transportation of 2005 as follows:

4.3.1 Level crossing management and engineering includes:

- Construction maintenance of railway.
- Road surface construction and maintenance

- The closing of railway crossing

4.3.2 The implementation of traffic management and engineering at level crossings is carried out by:

- The Minister of Transportation for national highway
- The Government for provincial highway.
- Mayor for district/ city roads.

4.3.3 The implementation of traffic management and engineering includes:

- Inventory and identification of level crossings.
- Analysis and evaluation of existing crossing conditions, so as to produce a recommendation such as closing, opening without crossing gates, opening with doors (automatic or non-automatic).
- Installation of traffic signs and road markings in accordance with the guidelines.
- Improved free sight distance.
- Arrangements for stopping/parking of vehicles around the crossing.

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7 Conflict of interest statement

The authors declare that there is no conflict of interest regarding the publication of this paper.

8 Author contributions

Author contributions: Dadang Supriyatno: conceptualization, methodology, formal analysis, writing-original and draft preparation. Syaiful Syaiful: investigation, data curation: Sri Wiwoho Mudjanarko: Writing and review, editing, and visualization. Asri Kusuma Wardhani: project administration, supervision and data validation.

9 Availability statement

There is no dataset associated with the study or data is not shared.

10 Supplementary materials

No supplementary materials are included in this manuscript.

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