JICE Journal Innovation of Civil Engineering

Vol. 5, No. 2, pp. 137-145, 2024
Submit: 12-11-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

MAPPING RAILWAY LEVEL CROSSING ACCIDENT PATTERNS IN DAOP 8 OF EAST JAVA PROVINCE

Achmad Wicaksono[1], Lasmini Ambarwati[2], Ita Suhermin Ingsih[3]

[1,2] Civil Engineering Department, Universitas Brawijaya, Malang, 65145, Indonesia
[3] Graduate Student of Civil Engineering Department, Engineering Faculty, Universitas Brawijaya, Malang, 65145, Indonesia

e-mail: wicaksono68@ub.ac.id

ABSTRACT

Railway-level crossing safety is a major issue in the transport system, especially in East Java where accidents occur frequently. This study aims to find the trend of accidents at the level crossing of DAOP 8 East Java and create data-driven preventive measures. The study used a mixed method approach, agent-based simulation, questionnaires, and interviews in addition to analyzing historical accident data. The results showed a significant prevalence of crashes in metropolitan locations, with higher risks during peak hours and homecoming periods. The largest incidences were reported in Sidoarjo and Surabaya, with significantly increased risk at night. The significant contributing factors are the presence of large vehicles, obstacles, weather, occurrence at night, and the presence of a crossbar.

Keywords: *Data-based prevention; DAOP 8 East Java Province; Level crossings; Risk analysis; Train accidents.*

1. Introduction

In the global transportation system, road safety at level crossings is a critical concern. Where highways and railroads converge at the same height, level crossings have become accident blackspots, leading to numerous fatalities and material losses [1-4]. The WHO estimates that vehicle accidents would claim 237,000 lives globally by 2020, with level crossings accounting for 36,000 of those deaths [5, 6]. In nations including Australia, Serbia, the European Union, the United States, the Czech Republic, and France, grade crossing incidents also make up a sizable fraction of all railroad accidents. [7-10].

The state of safety at level crossings in Indonesia is likewise extremely alarming. According to statistics, there were 271 incidents at Indonesian railway crossings in 2021, with 67 fatalities and 92 injuries. In addition to causing serious material losses and upsetting rail travel schedules, these accidents have a detrimental effect on the victims and their relatives.

Human factors, automobiles, the environment, and pedestrian infractions are only a few of the many complicated issues that contribute to accidents at railway crossings. Human factors are the primary cause of infractions at level crossings, where driver conduct and attitude, including heeding warnings and signals play a significant part. The limited mobility of big vehicles and the potential of light cars to break crossing laws also contribute to accidents. Drivers may find it challenging to observe and respond to approaching trains due to environmental factors like bad roads, poor visibility, and the physical state of damaged crossings. Another major reason is infractions committed by people who cross beneath the crossing bar when a train is coming.

An efficient method for locating high-risk regions and creating suitable remedies is crash pattern mapping [11]. 60% of crashes occurred at 20% of level crossings, according to research by Ghazel [12] that employed spatiotemporal analysis to pinpoint collision blackspots. Up to 85% of crash probabilities could be predicted using machine learning techniques, such as those employed by Yan

Vol. 5, No. 2, pp. 137-145, 2024
Submit: 12-11-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

et al. [13], depending on factors including traffic volume, crossing features, and meteorological conditions. Early warning systems can be up to 70% more effective when past crash data is combined with real-time data.

According to research by Read et al. [14], specific infrastructure upgrades based on risk assessments could lower the likelihood of fatal crashes in key areas by as much as 70%. According to Raib [15], a multidisciplinary strategy including engineers, psychologists, and transport safety professionals is crucial for developing prevention techniques. This approach has been demonstrated to boost intervention effectiveness by approximately 50%. Although there is still little research on level crossing safety in Indonesia, particularly in the East Java Operation Area (DAOP) 8, it is urgently needed [16].

According to research by Jusuf [17], motor vehicles were involved in 65% of train accidents in East Java, with 40% of these incidents taking place near level crossings. This study revealed that 80% of accidents at DAOP 8 level crossings were caused by road user behavior elements, particularly those involving sign and barrier violations. Traffic density and accident frequency were found to be significantly correlated by Jusuf [17], with the danger rising by as much as 200% during peak hours.

According to a feasibility assessment by Tjahjono [6], installing an automated warning system at 50 DAOP 8 level crossings might result in a 55% decrease in accidents in three years. A pilot program in five districts in East Java demonstrated a 40% decrease in unsafe conduct among local road users, underscoring the significance of a community-based strategy in raising safety awareness.

Research gaps still need to be addressed, even though earlier studies have offered valuable insights into the elements that affect safety at railway crossings. Most studies focus on individual factors in isolation without comprehensively considering the interactions and interrelationships between factors.

There will be a substantial academic and practical impact from this research. Academically, this study will add to the body of knowledge about the variables influencing traffic safety at level crossings and offer a more thorough comprehension of the previously unexplored interplay between internal and exterior elements. Other researchers who wish to carry out additional research on this subject might also use the study's findings as a guide.

In practice, the safety factors that affect accidents at railway level crossings can serve as the foundation for creating accident models and taking into account the opinions of stakeholders when creating educational initiatives, policies, and plans for infrastructure upgrades as well as assessing the success of previous attempts to increase level crossing safety.

Figure 1. Research Location in DAOP 8, East Java, Indonesia

Vol. 5, No. 2, pp. 137-145, 2024
Submit: 12-11-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

2. Materials and Methods

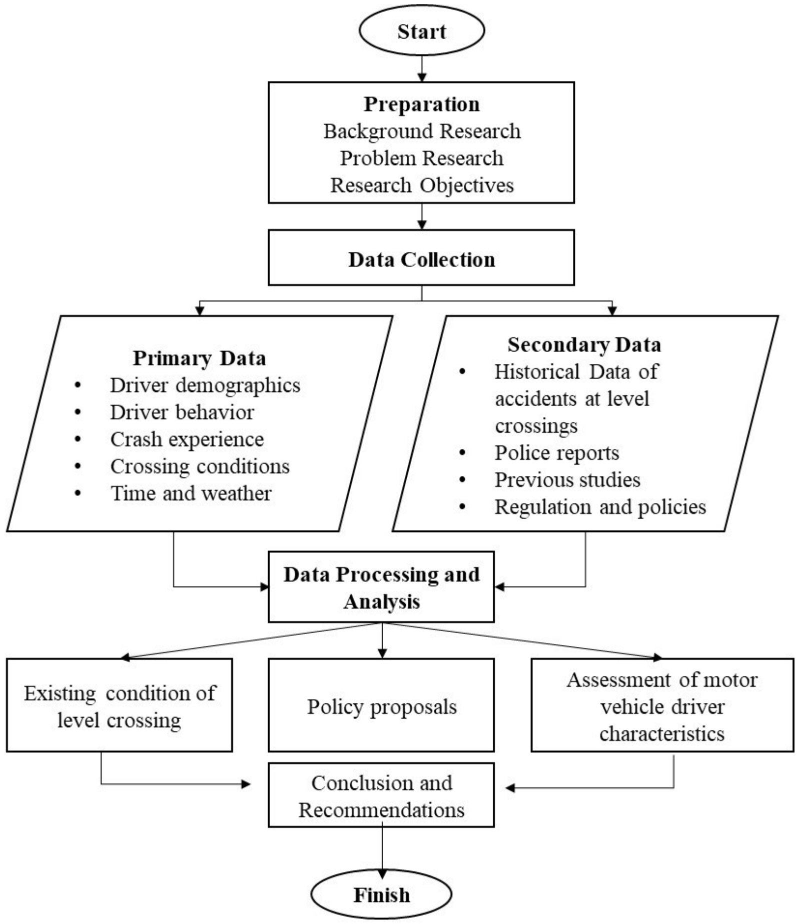

Figure 2. The conceptual framework of Assessment variables influencing accidents at the railway level crossing

This study adopted a mixed-method approach combining quantitative and qualitative analysis to comprehensively understand the crash patterns at the DAOP 8 East Java level crossing [18], as explained in Figure 1. In Figure 2, the first stage involved collecting historical crash data over the past 5 years from the databases of PT Kereta Api Indonesia (Persero) and the East Java Regional Police, following the protocol proposed by Tey [13] to ensure the completeness and accuracy of the data. The data collected included location, time, type of vehicle involved, weather conditions, and other contributing factors, following the framework developed by Larue et al. [19].

Using the procedure created by Ahmed et.al [20], this study surveyed and interviewed road users and railway workers in-depth to improve our understanding of the behavioral elements that contribute to accidents. Key themes about danger perception and behavior at level crossings were identified through thematic analysis of qualitative data using NVivo software. Additionally, the time-lapse video analysis method was used to undertake direct observation at blackspot areas. This allowed for the quantification of risk behavior and near-miss incidents. By the suggestions of Xu et.al [21], methodological triangulation was used to integrate quantitative and qualitative data to evaluate the results and create a comprehensive picture of accident dynamics.

3. Results and Discussion

A mixed-method technique, which blends quantitative and qualitative analysis, was utilized to analyze the data. This study investigates several factors related to railway crossing incidents in the

JICE Journal Innovation of Civil Engineering
Vol. 5, No. 2, pp. 137-145, 2024
Submit: 12-11-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

DAOP 8 East Java region in 2024. The information examined includes the temporal and spatial distribution of accidents, the profiles of the victims, the contributing variables, and the success of current preventative initiatives, as illustrated in Figure 3 - Figure 4. This project intends to dramatically improve safety at railway crossings in the DAOP 8 East Java region by mapping out accident patterns in detail and identifying important risk variables.

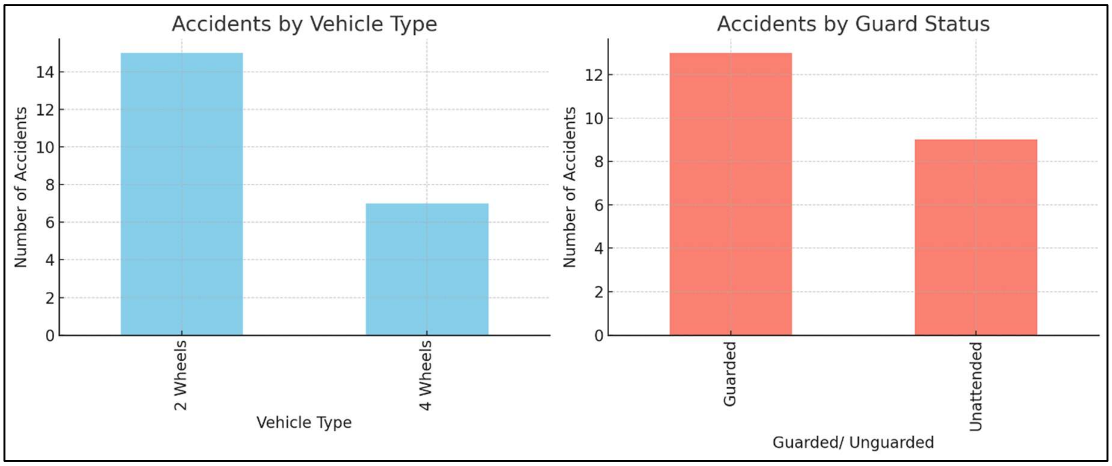

Figure 3. Number of Crashes by Vehicle Type and Guarding Status

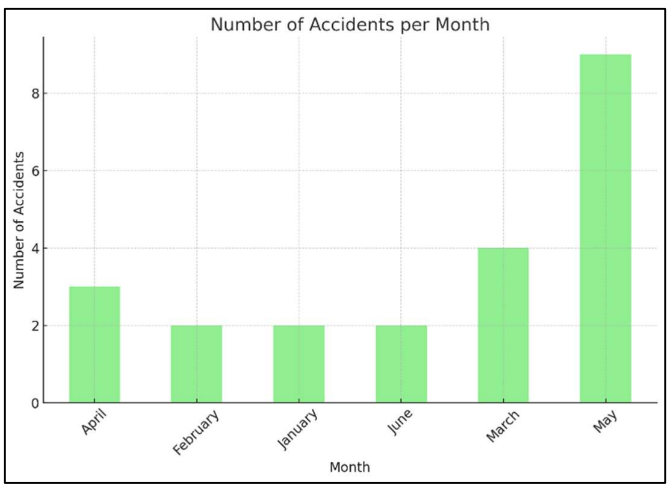

Figure 4. Number of Accidents per Month

This geographic variance may be caused by elements like the volume of traffic, the number of level crossings, and the features of the local infrastructure. Interesting variations in crash frequency over the year are shown by temporal analysis. The biggest number of wrecks occurred in June (11 events), followed by May (10 incidents). The time leading up to and during the Lebaran homecoming season, when traffic numbers often rise significantly, corresponds with this notable increase. Seven occurrences were reported in each of July and August, suggesting that the danger is still significant during the summer vacation. On the other hand, February had the fewest incidences, with two accidents, while January and March each had three incidents, as illustrated in Figure 4.

From the start of the year to a peak in June, these monthly patterns demonstrate a steady rise, which is followed by a slow fall in the second half of the year. There is a distinct trend in the breakdown of accidents by day of the week. Incidents occur more frequently throughout the week

JICE Journal Innovation of Civil Engineering
Vol. 5, No. 2, pp. 137-145, 2024
Submit: 12-11-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

than on the weekends. With ten incidences, Monday had the most accidents, followed by Tuesday and Wednesday, each with nine events. Eight instances were reported on Thursday and Friday. Even though it was the weekend, there were five instances on Saturday and the fewest, two, on Sunday, however, saw the fewest incidents, just two. The higher traffic volumes on weekdays, particularly during the morning and evening rush hours when many people are travelling to and from work or school, may be the cause of this pattern.

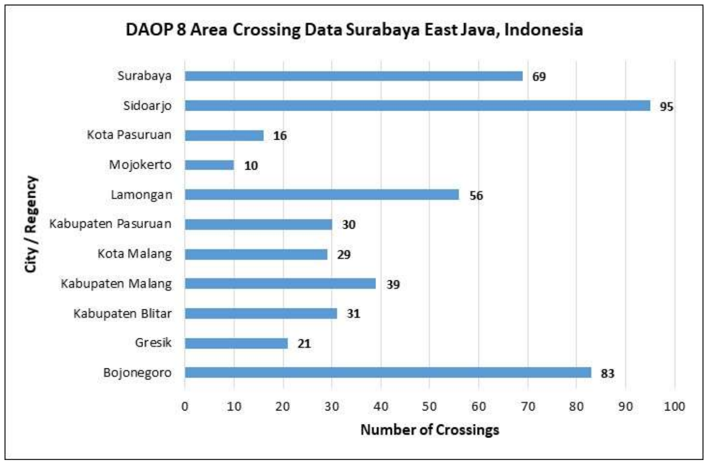

Figure 5. Crossing Data in DAOP 8 Region

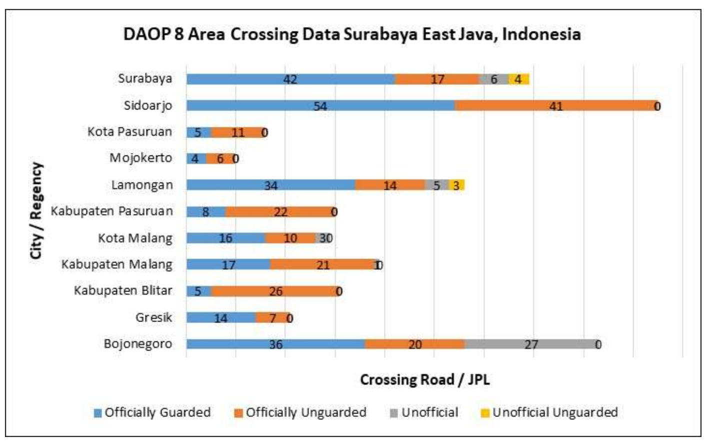

Figure 6. Crossing Data in DAOP Region 8 by Guarding Status

The 2024 accident data at the DAOP 8 Surabaya level crossings provide crucial information about the trends, patterns, and contributing elements of the occurrences. Effective prevention measures can be designed and implemented with the use of this information. Within the DAOP 8 Surabaya area, there is a notable difference in the geographic distribution of accidents. With 10 events (19.61% of the total), Sidoarjo had the most accidents, followed by Surabaya with 9 incidents (17.65%). While Blitar and Malang each had five events (9.80%), Mojokerto and Jombang both recorded six incidents (11.76%). With four incidents (7.84%), Kertosono came next, followed by Pasuruan and Bangil, each with two incidents (3.92%). Kediri and Tulungagung had the fewest incidents, each with one (1.96%), as illustrated in Figure 5-Figure 6. This pattern suggests that high population and traffic density in urban and suburban areas are more likely to experience accidents.

As seen in Figure 5, nine occurrences were reported during the midnight to early morning (9 p.m. to 6 a.m.) timeframe, suggesting that even though traffic levels are typically lower during these

Vol. 5, No. 2, pp. 137-145, 2024
Submit: 12-11-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

times, there is still a risk. Eight accidents over six hours occurred during the comparatively safer afternoon hours (9 a.m. to 3 p.m.). Accidents have a major effect on people's safety. There were 12 fatalities, 22 serious injuries, and 40 minor injuries from the 51 accidents that were reported. The fatality rate is fairly high, as seen by the ratio of fatalities to total accidents of about 1:4.There may be long-term effects on victims' productivity and health, as seen by the nearly twofold increase in serious injuries compared to fatalities The fact that there were 74 victims overall from 51 incidences shows that, on average, multiple people are hurt in each mishap, highlighting the need for more efficient preventative measures. This analysis has important ramifications for accident prevention tactics at DAOP 8 Surabaya level crossings.

Taking into consideration local features that may lead to high risk, primary attention should be directed to places with high accident frequency, such as Sidoarjo, Surabaya, Mojokerto, and Jombang. It is necessary to create temporal strategies that give priority to high-risk times like May and June as well as morning and evening rush hours. Enhanced monitoring and safety initiatives during these times may be a good place to start.

Priority should be given to infrastructure upgrades, such as the installation of automated barriers and more advanced warning systems, particularly in high-risk areas. It is necessary to enhance public awareness of the risks associated with level crossings, particularly during times of high risk.

To lessen the frequency and severity of upcoming incidents, cooperation between PT KAI, local governments, and the community is crucial in putting comprehensive preventative plans into practice. Stakeholders can create more focused and efficient interventions to enhance safety at the DAOP 8 Surabaya level crossing by comprehending the trends and risk variables found in this investigation.

The geographic distribution of accidents at DAOP 8 Surabaya level crossings shows a high concentration in urban and suburban areas, in line with the findings of several prominent researchers [3], [19], [22]. Sidoarjo and Surabaya, which recorded the highest number of accidents, have similar characteristics to accident blackspots identified in previous studies in various countries [22]. Factors such as high traffic volumes, urban infrastructure complexity, and a higher number of level crossings contribute to increased risk, as suggested by some researchers [3]. These findings underscore the importance of a location-based approach in prevention strategies, focusing on high-risk urban and suburban areas [11]. As recommended by some experts, the implementation of more sophisticated warning systems and stricter law enforcement in these locations could significantly reduce the risk of accidents [11].

This study carries out in-depth insights into the factors influencing crash severity at the DAOP 8 East Java level crossing. This study identifies the relative contribution of various variables to the risk of serious crashes such as train speed, automatic barriers, time of accident occurrence, vehicle types, and weather conditions.

Train speed approaching a level crossing was shown to be a significant risk factor, with a serious crash increasing by 8% for every 10 km/h increase. This finding is consistent with previous studies by Liang et al. [22], which emphasized the importance of train speed management in the level crossing area. Implementation of early warning systems and automatic deceleration technologies, as proposed by Kim et al. and Hong [11], could be an effective solution to reduce speed-related risks.

The presence of automatic barriers showed a substantial protective effect, reducing the odds of serious crashes by 58%. These results support Djorddevic et al.'s [23] findings on the effectiveness of safety infrastructure at level crossings. However, as Evans and Sage [3] remind us, physical infrastructure must be combined with effective warning systems and road user education to maximize its safety impact.

The time of the incident, especially at night, has been shown to significantly increase the risk of serious crashes. This is consistent with observations by Larue et al. [9] on the increased risk of crashes in low-light conditions. Implementation of adaptive lighting systems and increased visibility of signs, as recommended by Liang et al. [14], are effective strategies to reduce the risk of night crashes.

The type of vehicle involved, especially, heavy vehicles, showed a substantial increase in the risk of serious crashes. This finding aligns with studies by Zhang et al. [24], which identified vehicle

Vol. 5, No. 2, pp. 137-145, 2024
Submit: 12-11-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

characteristics as an important factor in crash severity. Targeted prevention strategies for heavy vehicle drivers, including specific training and awareness campaigns proposed by Ahmed et.al [20], may help reduce this risk.

Weather conditions, particularly, heavy rain, have also significantly increased the risk of serious crashes. These results are consistent with the findings of Larue et al. [19], and Kasalica [24] on the impact of environmental conditions on crossing safety. Implementing real-time weather warning systems and adjusting operations based on weather conditions, as recommended by Kim et al., can help mitigate weather-related risks [23].

Based on the results of this study, several suggestions can be put forward to improve safety at the DAOP 8 East Java level crossing. First, it is necessary to prioritize infrastructure improvements at high-risk locations, especially installing automatic barriers and more sophisticated warning systems, in line with the recommendations of Liang and Ghazel [14] . Second, the implementation of a train speed management system and increased visibility in the crossing area, especially for night operations, needs to be done immediately, following the suggestions of Liang [14]. Third, the development of targeted education programs and awareness campaigns, especially for heavy vehicle drivers and during high-risk periods such as the homecoming season, is highly recommended, in accordance with the findings of Tjahjono et al. [6] and Evans [3]. Fourth, the use of technologies such as IoT, machine learning, and V2X communication systems for real-time monitoring and early detection of risky situations needs to be further explored, as proposed by Yan, et al. [41]. Fifth, closer collaboration between PT KAI, local governments, and communities in implementing and evaluating comprehensive prevention strategies is needed, referring to the approaches recommended by Bureika [18] and Salmon et al. [17].

From analysis, the overall significance of the model and the Nagelkerke R^2 value of 0.38 indicates that the model has good predictive power, although there is still unexplained variation. This is in line with Yan et al.'s [13] observations on the complexity of factors influencing accidents at level crossings. The results of this analysis reinforce the importance of a multifaceted approach to crash prevention strategies at level crossings. As advocated by various researchers [7], a combination of infrastructure improvements, speed management, visibility enhancement, road user education, and the implementation of advanced technologies is needed to reduce crash risk and severity effectively. Further research, where the previously described variables will be tested with appropriate models, including longitudinal studies and cross-regional comparative analyses, may provide a deeper understanding of the long-term effectiveness of various safety interventions at level crossings.

4. Conclusions

Several important conclusions can be drawn based on the research results and discussions that have been described. The accident pattern at the DAOP 8 East Java level crossings shows a high concentration in urban and suburban areas, with Sidoarjo and Surabaya recording the highest number of incidents. Temporal analysis reveals an increased risk of accidents during the Lebaran homecoming period and on weekdays, especially during peak hours. Factors that significantly affect the severity of accidents include train speed, the presence of automatic barriers, the time of the incident (especially at night), the type of vehicle involved, and weather conditions. These variables are in line with the findings of Yan [41] and Zhang et al. [42] on the complexity of risk factors at level crossings.

Finally, further research, including longitudinal studies and cross-regional comparative analyses, is needed to evaluate the long-term effectiveness of the various safety interventions implemented.

Acknowledgments

The researcher thanks the Engineering Faculty, Universitas Brawijaya, for supporting the research fund and PT KAI for providing Data on Railway Crossing Accidents.

Vol. 5, No. 2, pp. 137-145, 2024
Submit: 12-11-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

References

[1] J. Davey, A. Wallace, N. Stenson, and J. Freeman, "The experiences and perceptions of heavy vehicle drivers and train drivers of dangers at railway level crossings," Accid. Anal. Prev., vol. 40, no. 3, pp. 1217–1222, 2008, doi: 10.1016/j.aap.2008.01.005.

[2] Q. Ren and M. Xu, "Injury severity analysis of highway-rail grade crossing crashes in non-divided two-way traffic scenarios: A random parameters logit model," Multimodal Transp., vol. 3, no. 1, p. 100109, 2024, doi: 10.1016/j.multra.2023.100109.

[3] A. W. Evans, "Fatal accidents at railway level crossings in Great Britain 1946-2009," Accid. Anal. Prev., vol. 43, no. 5, pp. 1837–1845, 2011, doi: 10.1016/j.aap.2011.04.019.

[4] S. Das, X. Kong, S. M. Lavrenz, L. Wu, and M. Jalayer, "Fatal crashes at highway-rail grade crossings: A U.S. based study," Int. J. Transp. Sci. Technol., vol. 11, no. 1, pp. 107–117, 2022, doi: 10.1016/j.ijtst.2021.03.002.

[5] N. Wang, X. Yang, J. Chen, H. Wang, and J. Wu, "Hazards correlation analysis of railway accidents: A real-world case study based on the decade-long UK railway accident data," Saf. Sci., vol. 166, no. June, p. 106238, 2023, doi: 10.1016/j.ssci.2023.106238.

[6] T. Tjahjono, A. Kusuma, Y. Y. Pratiwi, and R. Y. Purnomo, "Identification Determinant Variables of the Injury Severity Crashes at Road-Railway Level Crossing in Indonesia," Transp. Res. Procedia, vol. 37, no. September 2018, pp. 211–218, 2019, doi: 10.1016/j.trpro.2018.12.185.

[7] A. W. Evans, "Fatal train accidents on Europe's railways: An update to 2019," Accid. Anal. Prev., vol. 158, no. May, p. 106182, 2021, doi: 10.1016/j.aap.2021.106182.

[8] C. Liang, M. Ghazel, O. Cazier, and E. M. El-Koursi, "Developing accident prediction model for railway level crossings," Saf. Sci., vol. 101, no. August 2017, pp. 48–59, 2018, doi: 10.1016/j.ssci.2017.08.013.

[9] G. S. Larue and C. Wullems, "Human Factors Evaluation of a Novel Australian Approach for Activating Railway Level Crossings," Procedia Manuf., vol. 3, no. Ahfe, pp. 3293–3300, 2015, doi: 10.1016/j.promfg.2015.07.406.

[10] A. W. Evans and P. Hughes, "Traverses, delays and fatalities at railway level crossings in Great Britain," Accid. Anal. Prev., vol. 129, no. April, pp. 66–75, 2019, doi: 10.1016/j.aap.2019.05.006.

[11] W. T. Hong, G. Clifton, and J. D. Nelson, "Railway accident causation analysis: Current approaches, challenges, and potential solutions," Accid. Anal. Prev., vol. 186, no. November 2022, p. 107049, 2023, doi: 10.1016/j.aap.2023.107049.

[12] C. Liang, M. Ghazel, O. Cazier, and E. M. El-Koursi, "Analyzing risky behavior of motorists during the closure cycle of railway level crossings," Saf. Sci., vol. 110, no. June 2017, pp. 115–126, 2018, doi: 10.1016/j.ssci.2017.12.008.

[13] L. Tey, "Microsimulation modelling of driver behaviour towards alternative warning devices at railway level crossings," Accid. Anal. Prev., vol. 71, pp. 177–182, 2014, doi: 10.1016/j.aap.2014.05.014.

[14] G. J. M. Read, J. A. Cox, A. Hulme, A. Naweed, and P. M. Salmon, "What factors influence risk at rail level crossings? A systematic review and synthesis of findings using systems thinking," Saf. Sci., vol. 138, p. 105207, 2021, doi: 10.1016/j.ssci.2021.105207.

[15] W. T. Hong, G. Clifton, and J. D. Nelson, "Railway accident causation analysis: Current approaches, challenges, and potential solutions," *Accid. Anal. Prev.*, vol. 186, no. November 2022, p. 107049, 2023, doi: 10.1016/j.aap.2023.107049.

[16] S. Soehodho, "Public transportation development and traffic accident prevention in Indonesia," IATSS Res., vol. 40, no. 2, pp. 76–80, 2017, doi: 10.1016/j.iatssr.2016.05.001.

[17] A. Jusuf, I. P. Nurprasetio, and ..., "Macro Data Analysis of Traffic Accidents in Indonesia.," *Journal of Engineering …*. pdfs.semanticscholar.org, 2017. [Online]. Available: https://pdfs.semanticscholar.org/1307/46942b18f5777172e4ab8cbc0094b4e5171e.pdf

[18] A. M. Crizzle, J. Malkin, G. A. Zello, R. Toxopeus, P. Bigelow, and M. Shubair, "Impact of electronic logging devices on fatigue and work environment in Canadian long-haul truck drivers," *J. Transp. Heal.*, vol. 24, no. April 2021, p. 101295, 2022, doi:

Vol. 5, No. 2, pp. 137-145, 2024
Submit: 12-11-2024 |
Accepted: 23-12-2024 |
Publish: 24-12-2024 |

10.1016/j.jth.2021.101295.
[19] G. S. Larue and A. Naweed, "Evaluating the effects of automated monitoring on driver non-compliance at active railway level crossings," Accid. Anal. Prev., vol. 163, no. October 2020, 2021, doi: 10.1016/j.aap.2021.106432.
[20] S. S. Ahmed, F. Corman, and P. C. Anastasopoulos, "Accounting for unobserved heterogeneity and spatial instability in the analysis of crash injury-severity at highway-rail grade crossings: A random parameters with heterogeneity in the means and variances approach," *Anal. Methods Accid. Res.*, vol. 37, p. 100250, 2023, doi: 10.1016/j.amar.2022.100250.
[21] Z. Xu, X. Zou, T. Oh, and H. L. Vu, "Studying freeway merging conflicts using virtual reality technology," J. Safety Res., vol. 76, pp. 16–29, 2021, doi: 10.1016/j.jsr.2020.11.002.
[22] C. Liang, "Developing accident prediction model for railway level crossings," Saf. Sci., vol. 101, pp. 48–59, 2018, doi: 10.1016/j.ssci.2017.08.013.
[23] B. Djordjević, E. Krmac, and T. J. Mlinarić, "Non-radial DEA model: A new approach to evaluation of safety at railway level crossings," Saf. Sci., vol. 103, no. December 2017, pp. 234–246, 2018, doi: 10.1016/j.ssci.2017.12.001.
[24] Z. Zhang, C. Trivedi, and X. Liu, "Automated detection of grade-crossing-trespassing near misses based on computer vision analysis of surveillance video data," Saf. Sci., vol. 110, no. August 2017, pp. 276–285, 2018, doi: 10.1016/j.ssci.2017.11.023.