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Piotr JASKOWSKI[1] ORCID 0000-0002-6563-1917, piotr.jaskowski@pw.edu.pl – corresponding author
Ewa WELCZ-JĘDRA[1] ewa.welcz.stud@pw.edu.pl
Przemysław SKOCZYŃSKI[2] ORCID 0000-0002-6808-7494, przemyslaw.skoczynski@its.waw.pl
[1] *Warsaw University of Technology (Politechnika Warszawska), Poland*
[2] *Motor Transport Institute (Instytut Transportu Samochodowego), Poland*

INSPECTION OF ROAD TRAFFIC SAFETY AT ROAD-RAIL CROSSINGS OF THE WARSAW COMMUTER RAILWAY

Inspekcja bezpieczeństwa ruchu drogowego na przejazdach drogowo-kolejowych Warszawskiej Kolei Dojazdowej

Abstract: *Accidents at road-rail crossings are a significant road safety problem and have a high cost in terms of consequences. According to Polish law, it is the responsibility of the road manager to manage and monitor safety properly. There is a perceived lack of unambiguous and consistent procedures or tools that allow for unambiguous risk assessment. This article aggregates the different approaches and requirements for a railway road crossing safety assessment. As a result, an inspection of four level crossings of the Warsaw Commuter Railway was carried out, indicating negligence on the part of the road manager in terms of proper maintenance and signage of the road at the access to the road-rail crossing. The work carried out is a prelude to proposing a complete road safety audit procedure to be carried out by the road manager.*
Keywords: road-rail crossings, road safety audit, lighting measurements

Streszczenie: *Wypadki na przejazdach drogowo-kolejowych stanowią istotny problem bezpieczeństwa ruchu drogowego i wiążą się z wysokimi kosztami ich skutków. Zgodnie z polskim prawem to zarządca drogi jest odpowiedzialny za właściwe zarządzanie bezpieczeństwem i jego monitorowaniem. Dostrzegalny jest brak jednoznacznych i spójnych procedur lub narzędzi, które pozwalają na jednoznaczną ocenę zagrożeń. Artykuł agreguje różne podejścia i wymagania w zakresie przeprowadzenia oceny bezpieczeństwa przejazdu drogowo-kolejowego. Przeprowadzono kontrolę czterech przejazdów Warszawskiej Kolei Dojazdowej, wskazując na zaniedbania zarządcy drogi w zakresie prawidłowego utrzymania i oznakowania drogi na dojeździe do przejazdu drogowo-kolejowego. Wykonane prace są wstępem do zaproponowania pełnej procedury audytu bezpieczeństwa*

ruchu drogowego, możliwego do przeprowadzenia przez zarządcę drogi.

Słowa kluczowe: przejazdy drogowo-kolejowe, audyt brd, pomiary oświetlenia

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1. Introduction

The issue of safety at road-rail level crossings (RLXs) in Europe, including Poland, has drawn significant attention from researchers and infrastructure managers due to the high risk of accidents at these junctions. Data indicates that level crossings are hotspots for collisions, contributing to a considerable number of fatalities and material damage annually. Each year, more than 400 people are killed in over 1,200 accidents at road-rail level crossings in the European Union, highlighting their role as a critical risk point in transportation infrastructure [1]. This phenomenon stems from the inherent conflict between rail and road traffic, particularly at at-grade crossings, where visibility and design inadequacies often exacerbate safety risks [2], [3]. Research indicates that inadequate visibility significantly contributes to collision risks, with studies showing that limited visibility reduces drivers' ability to judge train speeds accurately, ultimately leading to riskier decisions [4], [5].

Despite measures to improve infrastructure, rolling stock and better equipment for passenger vehicles, incidents still occur at road-rail crossings. According to the current regulations in Poland, railway incidents are divided into 1) serious accident (one fatality or at least five seriously injured persons or damage cost of at least EUR 2 million), 2) accident (unintentional, sudden event or sequence of events involving a railway vehicle causing negative consequences for human health), 3) incident (any event other than an accident or serious accident, affecting the safety of railway traffic) [6]. In 2023, there were 2429 railway incidents and 677 accidents, representing 30.1% of the total number of railway accidents in Poland (4.0% increase over 2022) and 1752 incidents (6.6% increase over 2022) [6]. In the context of incidents at road-rail crossings, the number of accidents was 204 (up 6.3% in 2022), and the number of incidents was 720 (up 19.2% in 2022)[6]. The main participants in road traffic accidents at road-rail crossings are cars, accounting for about 67% of all participants (Table 1). The alarming increase in incidents at road-rail crossings points to the need to undertake a detailed analysis [2] in the context of road safety assessment [7].

As of 31 December 2023, there are 12,126 level crossings on active lines of the national railway network in Poland, of which 11,603 are on lines operated by PKP PLK S. A. [4] (table 2). According to the Regulation of the Minister of Infrastructure and Development of 20 October 2015, the technical conditions are to be met by railway lines and railway sidings intersections with roads and their location [9]. There are six categories

(A-F) of railway level crossings (RLCs). The detailed characteristics of each crossing are related to how it is secured for the duration of the train passage:

- A-RLC on which an authorised employee directs traffic;
- B-RLC on which traffic is directed by an automatic crossing system (ACS) equipped with traffic signals (roadside signals) and barriers;
- C-RLC on which traffic is directed by an ACS equipped with traffic signals only;
- D-RLC which is not equipped with traffic safety systems and devices;
- E-Pedestrian crossing equipped with: a semi-automatic or automatic crossing system turnstiles, barriers or mazes;
- F-RLC or pedestrian crossing located on an internal road, equipped: with barriers, permanently closed and opened by users as required; by the technical conditions laid down for category A or B.

Table 1

Traffic participants in accidents at level crossings and road crossings in 2019-2023 [8]

No.	Rail traffic participant	2019	2020	2021	2022	2023
1.	Car driver	135	106	157	123	127
2.	Pedestrian	26	15	20	17	22
3.	Truck driver	10	15	15	18	8
4.	Delivery truck driver	9	15	13	5	19
5.	Farm tractor driver	5	8	3	5	5
6.	Cyclist	2	3	2	6	4
7.	Other	12	7	6	7	5
Total		199	169	216	181	190

The audit of road safety at level crossings is an important issue that requires a comprehensive approach due to the number of factors involved that lead to incidents on the railways [10]. The central aspect that cannot be quickly eliminated is the psychological factor [11] and the conviction that the risk of a collision at a level crossing is low [12]. It is also essential to properly maintain signage at road-rail crossings, particularly for lower-category crossings [13], [14], [15].

The article aims to prepare a preliminary procedure for assessing road traffic safety at road-rail crossings of the Warsaw Commuter Railway (WKD). The need for the study stems from the completed modernisation connected with the construction of the second track, which is associated with an increase in the volume of train traffic. The rapid urbanisation of the areas near the WKD railway route has resulted in an increase in the volume of traffic at road-rail crossings. The simultaneous increase in both collision groups translates into an increased likelihood of road incidents, which the infrastructure manager should counteract.

Table 2

Number of crossings on active railway lines at the end of 2023. [8]

No.	Infrastructure manager	Railway level crossings						Total
		A	B	C	D	E	F	
1.	PKP PLK	2064	1652	1760	4764	458	905	11603
2.	PKP LHS	33	10	45	105	8	50	251
3.	DSDiK	0	1]1	11	43	2	8	69
4.	JSK	9	4	0	21	1	14	46
5.	WKD	0	0	3	31	4	3	45
6.	KPK – Linie kolejowe	3	2	0	33	1	1	38
7.	PMT Linie Kolejowe	1	0	3	9	1	5	24
8.	CARGOTOR	0	0	0	14	0	7	21
9.	Infra SILESIA	9	0	0	1	2	2	14
10.	Maczki-Bór	5	0	0	2	0	1	8
11.	Euroterminal Sławków	3	0	0	2	0	0	5
12.	PKP SKM Trójmieście	0	0	0	1	1	0	2
13.	PKM	0	0	0	0	0	0	0
Total		2130	1674	1822	5026	478	996	12126

2. Methods

2.1. Regulations in Poland

Railroad crossings in Poland are regulated by several acts, standards and guidelines to ensure safety and define technical standards. Annex No. 1 to the Railway Transport Act of 28 March 2003 (Journal of Laws of 2024, item 697) defines elements of railway infrastructure, including, inter alia, level crossings and level crossings, together with devices and systems ensuring safety of road and pedestrian traffic, provided that they form part of a railway line, railway siding or other railway route, or serve their management, operation of transport of persons or goods, or maintenance of the [16]. The Minister of Infrastructure and Development Ordinance of 20 October 2015 on the technical conditions to be met by the intersections of railway lines and railway sidings with roads and their location [9] sets out detailed technical conditions for the design, construction and maintenance of level crossings. The regulation also sets out the road manager's responsibilities for carrying out:

- Measurements of traffic volumes at category A, B and C level crossings shall be carried out by the road manager, at least every 5 years.
- Visibility measurements.

The road manager shall measure traffic volumes at level crossings of categories A, B and C at least every 5 years. However, for category D, the frequency of measurements depends on the product of the traffic: every 5 years if the product of the traffic does not exceed 20,000; every 2 years if the product of the traffic is between 20,000 and 40,000; every year if the product of the traffic is greater than 40,000. The measurements are carried out in April-May or September-October. They shall be carried out during two consecutive days: Tuesday-Wednesday or Wednesday-Thursday. The road manager shall inform the railway manager of the planned measurement dates, and a representative of the railway manager may participate in the traffic measurements. It should be mentioned that additional traffic volume measurements may be ordered at the request of the competent authorities, the State Commission for the Investigation of Railway Accidents, the Railway Commission, the road manager or the railway manager.

Visibility of the level and level crossing from the road is a key factor in ensuring the safety of road users [17]. Under normal atmospheric conditions, the driver of a road vehicle or pedestrian approaching a level crossing should have adequate visibility. This visibility should include horn rods, traffic signals and road signs. Research has underscored the importance of appropriate sight distances, which ensure that road users can detect oncoming trains with sufficient time to react. For instance, Kallberg emphasises that road users must be capable of traversing the crossing more swiftly than an approaching train can reach it from the point of visibility [18]. This analysis necessitates a detailed understanding of the surrounding infrastructure, as poor visibility due to design constraints or obstructive terrain significantly heightens collision risks [18], [19]. Such considerations are crucial when implementing road safety audits and traffic safety inspections [7].

Table 1 shows the minimum distances measured on the axis of the public road at a height of 1 m above the lane axis depending on the permissible speed of the road crossing. The observation point on a public road should be at least 60 m from a level crossing or crossing (Table 3). For internal roads, this distance can be reduced to 35 m, while at pedestrian crossings, it can be as short as 5 m.

Visibility of the front of a train from the road in front of a level crossing. Under normal atmospheric conditions, the front of an approaching train, or at least its signal lanterns, shall be visible to drivers of road vehicles from a distance of 20 metres, measured from the extreme rail in the axis of the carriageway, at all times when the train is approaching a category D level crossing. For new category A, B or C level crossings located at new locations, the visibility of the train front end from the public road shall be ensured from a distance of 5 metres. The method for assessing the conditions of visibility of the train front end from the public road in front of a level crossing, i.e. the so-called visibility triangles, is shown in Figure 1

Table 3

Distance of the observation point from the speed limit for road vehicles [16]

The permissible speed of road vehicles on the road in km/h	Distance of observation point in m
100	140
90	120
80	100
70	80
≤ 60	60

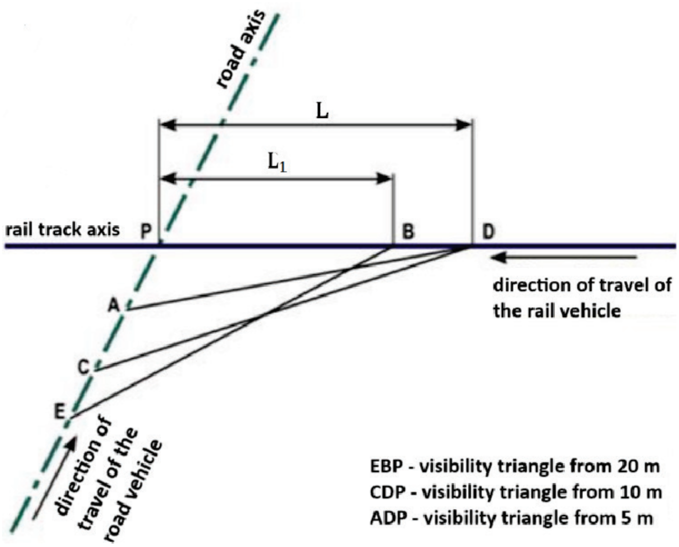

Fig. 1. Visibility triangles at road-rail crossings [16]

The figure above shows points P, A, C and E from which visibility is measured at various distances from the track. The visibility triangles are marked EBP (20m), CDP (10m), and ADP (5m). The larger the visibility triangle, the better the visibility and the better the chance of crossing the track safely. A shorter distance means a smaller triangle, which affects the increased risk of collisions and accidents.

2.2. Lighting requirements

Providing adequate lighting conditions is essential to maintain the safety of road users at lower-category crossings [20]. Studies have explored enhancements to lighting and signage to improve driver awareness, particularly at passive crossings which lack active signalling devices [13]. For instance, advanced flashing lights at passive crossings have been evaluated for their effectiveness in capturing driver attention, suggesting improved visual cues can significantly mitigate risks [13]. The requirements for minimum illumination of the carriageway surface are set out in the document Guidelines for the Design of Equipment for the Illumination of Urban Roads and Streets, Part 1: Basic and specific requirements, Benchmarks and standards recommended by the Minister responsible for Transport WR-D-72-1 [21]. The requirements are shown in Table 4, depending on the road situation. It should be noted that in the case of segregated pedestrian crossings over tracks, requirements analogous to the highest class of lighting for pedestrian crossings on the road apply. The measurement of road-rail lighting includes surveying the roadway surface and pavements. Traffic should be stopped for the safety of those carrying out the survey, which is often the reason for not carrying out a lighting survey.

Table 4

Selected lighting requirements for track crossings [21].

Part of the road	$E_{śr}$ [lx]	U_0 [-]
Pedestrian way adjacent to the carriageway	10	0,25
Pedestrian and cycle path adjacent to the carriageway	10	0,25
Roadway	20	0,4
Separate pedestrian crossing over the tracks	50	0,4
Separate bicycles crossing over tracks	50	0,4

2.3. Example of an audit checklist

The only available document containing instructions for road safety auditors to inspect a level crossing is that of the General Directorate for National Roads and Motorways (GDDKiA) [22]. The document indicates the control questions involved in carrying out a road safety audit:

- Are there visibility restrictions caused by a lack of maintenance of greenery or the introduction of additional road furniture once the road is in operation?
- Does the development around the road affect the legibility of the road and visibility restrictions?
- Is there good visibility for train and vehicle drivers?

- Are the safe accumulation zones between the barrier and the track sufficient?
- Is special lighting needed for the crossing area?
- Is the crossing clearly recognisable? Is there good visibility of the tramway and railway line?
- Are the carriageway widths and other dimensions of the crossing properly selected for motor vehicles? Are the safe accumulation zones between the barrier and the tracks of sufficient length?
- Does the crossing have good signage and other traffic organisation devices and lighting?
- Is there good visibility of the railway and tramway line (irrespective of the crossing protection) at the accesses to the crossing?
- Have speed and overtaking restrictions been planned with signs and/or other means of speed reduction provided?
- Has the potential for dangerous pedestrian encroachment on the crossing been reduced?

The questions relate to the road safety criteria and focus on verifying the mutual visibility of road users. An essential element is guiding the vehicle driver through the road by properly marking and distinguishing the location of the road-rail crossing.

2.4. Causes of accidents at road-rail crossings

The State Commission for the Investigation of Railway Accidents presents its annual report on railway incident analysis. The experts identify the causes of incidents at road-rail crossings related to [6]:

- failing to comply with the prohibition of entering a crossing beyond a traffic signal giving a ban on entry signal by two red signals alternately flashing,
- failure to stop as a result of a set ‘Stop’ sign and failure to observe due caution by drivers of road vehicles,
- passing under closing turnstiles,
- bypassing semi-crossings,
- lack of the required visibility triangle,
- failure to take special precautions before a level crossing with closed horns and properly working traffic lights, and failure of the driver of the road vehicle to react to the audible signal ‘Keep alert’ given by the train driver
- blocking of the crossing by road vehicles entering the tracks without the possibility of exit,
- failure to adjust speed to prevailing road conditions, causing the driver to run into the side of the train on cat D crossings or into the turnpike on cat B crossings,
- failure to observe signs and other traffic signals,

- improper behaviour when a road vehicle is stationary on the tracks, failure of the driver of the road vehicle to react to the 'Attention' signals given by the train driver when crossing a level crossing, and consequently entering the crossing directly under the oncoming train,
- failure of a road vehicle to stop in front of a traffic signal with a light signal prohibiting the entry of vehicles on the crossing and an audible signal, and entering directly in front of an oncoming train at a properly secured and signalised category C crossing,
- driving a road vehicle onto a level crossing despite the warning on the traffic signals being activated - failure of the driver to exercise caution at a category B crossing and stopping the road vehicle in the crossing zone before the turnpike closes the exit.
- failure of a road vehicle to stop in front of traffic signals, despite the impossibility of continuing the journey due to a traffic jam and getting stuck on the level crossing after the turnpike is closed,
- failure of a vehicle to stop in front of a traffic signal prohibiting entry to the crossing, failure of a road vehicle to stop in front of a railroad crossing despite signals broadcast on the traffic signals warning of an oncoming train and the start of the closing of the horns.

Virtually all causes of incidents at road-rail crossings are due to inappropriate behaviour on the part of the vehicle driver and failure to give priority to the train. However, it should be emphasised that safety is a vector of many factors that can be divided into several main categories:

- technical factors:
  - technical condition of the track and carriageway surface;
  - adequate horizontal and vertical signposting;
  - type of safety devices (e.g. toll-gates, traffic lights and signal lights);
  - visibility of the crossing for drivers and train drivers;
  - lighting of the crossing in reduced visibility conditions;
- organisational and procedural factors:
  - road and rail traffic regulations;
  - emergency procedures and organisation of work at level crossings;
  - road and rail traffic management systems;
  - coordination between road managers and railway operators;
- human factors:
  - behaviour of road users (bravado, carelessness, ignoring signalling);
  - education and risk awareness among drivers and pedestrians;
  - errors by rail and road operators;
  - compliance by drivers and train drivers;

- environmental factors:
  - atmospheric conditions (fog, rain, snow, reducing visibility and vehicle adhesion);
  - terrain and geometry of the crossing,
  - the presence of buildings restricting visibility.

2.5. Testing ground

The main research problem is identifying the causes of accidents at road-rail crossings operated by the WKD and assessing the effectiveness of existing safety measures. An essential element of safety management on the WKD line is the characterisation of 45 level crossings: 4 category B, three category C, 31 category D, four category E, three category F. It should be emphasised that only a few road-rail crossings on the WKD line are equipped with physical entry blocks. The limitations are due to the geometry of the railway line, the dense development in the immediate vicinity and the impossibility of holding up traffic for long periods due to congestion on the road network. The need to link safety and controllability of the road network consequently leads to inappropriate driver behaviour [2] and the ineffectiveness of the measures adopted by the PAC to prevent collisions [3].

The Warsaw Commuter Rail network is located in the south-western part of the Warsaw agglomeration. It runs through the territory of three counties: the capital city of Warsaw, Pruszków and Grodzisk Mazowiecki, covering 2 Warsaw districts: Ochota and Włochy, as well as six communes: Michałowice, Pruszków, Brwinów, Podkowa Leśna, Milanówek and Grodzisk Mazowiecki. There are 28 stations and passenger stops along the line. The average distance between stops along the route is 1,250 m. The average transport speed is 36.0 km/h. There are 45 level crossings along the railway line.

3. Results and discussion

A testing ground related to four areas was selected to conduct road traffic safety inspections at road-rail crossings. The selected crossings are on municipal roads in Grodzisk Mazowiecki (Fig. 2).

During the audit, the requirements presented in Chapter 2 and the standards to which the road-rail crossings should conform were verified. The photographic documentation for crossing No. 2 (Figs. 3, 4) and crossing No. 3 (Figs. 5, 6) is presented below, with directions A assumed to access the crossing to the south and B to the north. Following the requirements of the visibility assessment, the photographs show the access to the crossing from a distance of 100 and 60 metres. Significantly, some road-rail crossings have limited visibility due to the railway infrastructure (Fig. 7), considerably impacting visibility maintenance.

Fig. 2. The Grodzisk Mazowiecki testing ground

Fig. 3. View of level crossing No. 2 direction A (left 100 m, right 60 m)

Fig. 4. View of level crossing No. 2 direction B (left 100 m, right 60 m)

Fig. 5. View of level crossing No. 3 direction A (left 100 m, right 60 m)

Fig. 6. View of level crossing No. 3 direction B (left 100 m, right 60 m)

Fig. 7. View of level crossing No. 3 from STOP line.

Table 5 shows the number of eligible criteria in the context of the road-rail crossings analysed.

Table 5

Preliminary results

Description	Number of road-rail crossings meeting the criterion
Visibility on the approach	2
Visibility at the stop line	3
Lighting	4
Road signs	0
Speed management	3
Road lane maintenance	3
Compliance with a STOP sign	0
Pedestrian traffic	2

Based on the site visit, the visibility of the approach was verified; they pointed out the limitations due to the dense development and maintenance of the road lane (especially the lack of vegetation correction). Regarding visibility at the stop line, the main problem is the railway infrastructure, which, due to the width of the road lane, is located in a way that makes it difficult to see an approaching train. The lighting measurements showed that all crossings meet the criterion and provide visibility at night. The main problem is incomplete or damaged road markings, which are the responsibility of the road manager. A significant observation during the audits is the lack of compliance by vehicle drivers with the STOP sign and the lack of pedestrian infrastructure in two of the cases analysed.

4. Conclusions and summary

One of the key criteria for road safety is mutual visibility. According to the regulations, every road-rail collision crossing should be subjected to a visibility assessment and traffic volume measurements to determine the traffic product. The results are the basis for deciding the crossing category and the need for road safety measures according to the technical conditions. The study's preliminary results indicate that most of the road-rail crossings on the WKD line do not meet the technical conditions for road-rail crossings. The main broad factors are the lack of fulfilment of the visibility criterion and the lack of implementation of measures adequate to the current road/rail traffic volumes.

Infrastructure management is pivotal in ensuring safety at these crossings. Effective management practices must involve risk assessments that account for the socio-technical systems involved in RLXs. This includes considering various road users' behaviours and decision-making processes, such as vehicle operators and cyclists [23]. In the context of improving road safety, in addition to proper maintenance of the infrastructure, measures should be taken regarding driver education campaigns [24]. Include risk management in the context of road-rail crossings [3], [25] and use machine learning for accident analysis [26], [27] to reduce the likelihood of their occurrence. Furthermore, comprehensive infrastructure audits are essential for identifying vulnerabilities in existing designs and highlighting necessary upgrades to align with European safety standards and initiatives, such as the EU's "Vision Zero" commitment, which seeks to eliminate fatalities at RLXs [3], [23]. Railroad crossings in Poland have shown persistent challenges, highlighting the need for enhanced protective measures and rigorous safety protocols [28].

Preliminary results indicate the need for a detailed analysis of road-rail crossings for the entire PAC network. The pilot inspection of WKD road-rail crossings will form the basis for developing a procedure for infrastructure managers to conduct road safety assessments. The target procedure should include monitoring of crossings and verification of compliance with the STOP sign. The evaluation of road-rail crossings should also consider the impact on the road network using a simulation tool in the context of category A and B crossings.

5. References

1. M. Heddebaut, 'Safety at Level Crossings', *TOTJ*, vol. 5, no. 1, pp. 21–22, Oct. 2011, DOI: 10.2174/1874447801105010021.
2. A. Anagnostopoulos, 'High-speed railway and safety: Insights from a bibliometric approach', *High-speed Railway*, vol. 2, no. 3, pp. 187–196, Sep. 2024, DOI: 10.1016/j.hspr.2024.08.004.
3. A. Anagnostopoulos, 'Assessing Safety and Infrastructure Design at Railway Level Crossings Through Microsimulation Analysis', *Future Transportation*, vol. 5, no. 1, p. 24, Mar. 2025, DOI: 10.3390/futuretransp5010024.
4. A. Blagojević, S. Kasalica, Ž. Stević, G. Tričković, and V. Pavelkić, 'Evaluation of Safety Degree at Railway Crossings to Achieve Sustainable Traffic Management: A Novel Integrated Fuzzy MCDM Model', *Sustainability*, 2021, DOI: 10.3390/su13020832.
5. C. Liang, M. Ghazel, O. Cazier, and E.-M. El-Koursi, 'Developing Accident Prediction Model for Railway Level Crossings', *Safety Science*, 2018, DOI: 10.1016/j.ssci.2017.08.013.
6. T. Ryś, 'Raport roczny za rok 2023 z działalności Państwowej Komisji Badania wypadków kolejowych', 2023.

7. M. Ladich and D. Miletics, 'Adaptation of road safety inspection method to railway level crossings', *Pollack*, Aug. 2024, DOI: 10.1556/606.2024.01043.
8. Urząd Transportu Kolejowego, *Sprawozdanie ze stanu bezpieczeństwa ruchu kolejowego*. 2023.
9. *Rozporządzeniem Ministra Infrastruktury i Rozwoju z dnia 20 października 2015 r. w sprawie warunków technicznych, jakim powinny odpowiadać skrzyżowania linii kolejowych oraz bocznic kolejowych z drogami i ich usytuowanie*.
10. V.-P. Kallberg, 'Safety Audits at Finnish Level Crossings', *TOTJ*, vol. 5, no. 1, pp. 80–87, Oct. 2011, DOI: 10.2174/1874447801105010080.
11. P. M. Salmon, G. J. M. Read, N. A. Stanton, and M. G. Lenné, 'The crash at Kerang: Investigating systemic and psychological factors leading to unintentional non-compliance at rail level crossings', *Accident Analysis & Prevention*, vol. 50, pp. 1278–1288, Jan. 2013, DOI: 10.1016/j.aap.2012.09.029.
12. J. Luoma, 'How Drivers Understand Safe Behaviour and Perceive Risks at Passive Railway-Road Level Crossings', *TOTJ*, vol. 5, no. 1, pp. 88–91, Oct. 2011, DOI: 10.2174/1874447801105010088.
13. G. S. Larue, C. N. Watling, A. A. Black, and J. M. Wood, 'Getting the Attention of Drivers Back on Passive Railway Level Crossings: Evaluation of Advanced Flashing Lights', *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2673, no. 2, pp. 789–798, Feb. 2019, DOI: 10.1177/0361198119828679.
14. J. Haces-Garcia, A. Haces-Garcia, F. Haces-Garcia, and F. Haces-Fernandez, 'Advanced Warning System to Improve Safety at Train Grade Crossings', *Sustainability*, vol. 13, no. 21, p. 11779, Oct. 2021, DOI: 10.3390/su132111779.
15. Ł. Foryś and R. Plocki, 'Bezpieczeństwo w ruchu drogowym w Polsce - prognoza liczby wypadków', *ZN SGSP*, vol. 84, pp. 179–191, Dec. 2022, DOI: 10.5604/01.3001.0016.1809.
16. *Ustawa z dnia 28 marca 2003 r. o transporcie kolejowym (Dz. U. z 2024 r. poz. 697)*.
17. A. Kampczyk, 'An Innovative Approach to Surveying the Geometry of Visibility Triangles at Railway Level Crossings', *Sensors*, vol. 20, 22, p. 6623, Nov. 2020, DOI: 10.3390/s20226623.
18. V.-P. Kallberg, 'Determination of Sight Distance Requirements for Finnish Level Crossings', *TOTJ*, vol. 5, no. 1, pp. 71–79, Oct. 2011, DOI: 10.2174/1874447801105010071.
19. V. Singhal *et al.*, 'Artificial Intelligence Enabled Road Vehicle-Train Collision Risk Assessment Framework for Unmanned Railway Level Crossings', *IEEE Access*, 2020, DOI: 10.1109/access.2020.3002416.
20. W. Hao and C. Kamga, 'The effects of lighting on driver's injury severity at highway-rail grade crossings', *J of Advanced Transportation*, vol. 50, no. 4, pp. 446–458, Jun. 2016, DOI: 10.1002/atr.1353.

21. *Wytyczne projektowania urządzeń do oświetlenia dróg zamiejskich i ulic Część 1: Wymagania podstawowe i szczegółowe Wzorce i standardy rekomendowane przez Ministra właściwego ds. transportu WR-D-72-1*.
22. Generalna Dyrekcja Dróg Krajowych i Autostrad, *Instrukcja dla Audytorów Bezpieczeństwa Ruchu Drogowego. Część II*. 2009.
23. V. Beanland, M. Fitzharris, K. L. Young, and M. G. Lenné, 'Driver inattention and driver distraction in serious casualty crashes: Data from the Australian National Crash In-depth Study', *Accident Analysis & Prevention*, vol. 54, pp. 99–107, May 2013, DOI: 10.1016/j.aap.2012.12.043.
24. J. Pasha *et al.*, 'A Comprehensive Assessment of the Existing Accident and Hazard Prediction Models for the Highway-Rail Grade Crossings in the State of Florida', *Sustainability*, vol. 12, no. 10, p. 4291, May 2020, DOI: 10.3390/su12104291.
25. A. Berrado, 'A Framework for Risk Management in Railway Sector: Application to Road-Rail Level Crossings', *TOTJ*, vol. 5, no. 1, pp. 34–44, Oct. 2011, DOI: 10.2174/1874447801105010034.
26. E. Kozłowski, A. Borucka, A. Świderski, and P. Skoczyński, 'Classification Trees in the Assessment of the Road–Railway Accidents Mortality', *Energies*, vol. 14, no. 12, p. 3462, Jun. 2021, DOI: 10.3390/en14123462.
27. A. Jamal, T. Mahmood, M. Riaz, and H. M. Al-Ahmadi, 'GLM-Based Flexible Monitoring Methods: An Application to Real-Time Highway Safety Surveillance', *Symmetry*, vol. 13, no. 2, p. 362, Feb. 2021, DOI: 10.3390/sym13020362.
28. E. Macioszek, A. Kurek, and B. Kowalski, 'Overview of safety at rail-road crossings in Poland in 2008-2018', *Transport Problems*, vol. 15, no. 4, Part 1, pp. 57–68, 2020, DOI: 10.21307/tp-2020-048.