REVIEW OF LOW-BUDGET MEASURES FOR THE PREVENTION OF TRAFFIC ACCIDENTS AT LEVEL CROSSINGS

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Abstract

Level crossing (LC), as an intersection of road and railway, is a traffic point with a high risk for the occurrence of traffic accidents. The causes of most traffic accidents on LCs are the result of LC user's risky behaviour. Accidents happen on both passive and active LCs, indicating that the highest level of safety equipment does not guarantee "Vision 0". Therefore, in the absence of sufficient financial resources for the infrastructure manager for road and railway levelling or LC protection at the highest level, which includes barriers or half-barriers, the so-called low-budget measures are implemented. This paper provides a review of good practice examples of implemented low-budget measures that contributed to accident prevention and increasing safety on LCs. In the literature, accident prevention measures on LCs are usually classified as educational, infrastructural, and technological. In this research, our focus was primarily on measures implemented on road infrastructure. First, we selected recommended measures from projects dedicated to safety on LCs, and then we searched the literature describing practical examples of applied low-budget measures. The collected findings can be recommendations for decision-makers to choose optimal low-budget measures for implementation.

Keywords: level crossing, rail safety, low-budget measures, accident prevention

1 Introduction

A level crossing (LC) represents a point in the transport network where road and railway infrastructure interact. It is a location where a railway line or industrial track and a road intersect at the same level, including pedestrian and cycle paths or other roads [1]. Level crossings can vary in design and complexity. According to the European Union Agency for Railways (ERA), there are two types of LCs: active and passive. Passive LCs are only equipped with traffic signs (crossbuck or St Andrew's cross), while active LCs are equipped with sound and warning systems in conjunction with barriers or half-barriers [2]. LC also represents the location of high-risk of traffic accidents. Eurostat data for 2022 show that 28.6% of accidents in railway transport occur at LCs [3]. In 2022, accidents at LCs in Croatia accounted for 36% of all railway accidents, indicating that Croatia's rate slightly surpasses the European Union average in this regard. There are currently 1,444 level crossings on the Croatian railway network, and 42% are currently active [4]. The development of preventive measures is crucial due to the grave consequences typically associated with accidents at LCs. This study examines low-budget infrastructure solutions targeting accident reduction at both active and passive LCs. These measures, already implemented in various projects, programs, pilot studies, expert reports, and scientific research, are analysed, possibilities of implementation in local conditions are investigated and then categorized between road and railway stakeholders.

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The potential advantages of these measures include a substantially improved cost-benefit ratio. Decision-makers can utilize this study to formulate preventive programs or initiate pilot projects for new measures. Following the introduction chapter, the study provides background information on previous research, applied methodology, results which contains selected and categorized low-budget measures based on their respective areas of application and a summary of the main findings and the limitations of the research.

2 Background

To collect data on examples of good practice in the application of low-budget accident prevention measures on LCs, we searched the data and insights from SELCAT project funded by CORDIS and SAFER LC project funded by Horizon Europe, LC safety programs implemented in various countries and scientific literature databases. These sources collectively serve as the foundation for our review of low-budget measures and their efficacy in enhancing LC safety. An overview of the prevalence and patterns of traffic accidents at LCs, highlighted key contributing factors such as visibility issues, signage deficiencies, and driver behaviour, while also examining the multifaceted challenges inherent in improving LC safety. SELCAT aimed to gather and share knowledge on LC risk assessment, technology, and methodology. It specifically focused on studying advanced technologies to effectively reduce existing risks and actively contribute to minimizing LC accidents [5]. SAFER LC project aimed to decrease fatalities and serious accidents at LCs. The project focused on integrating solutions, innovating technically, adapting infrastructure for road users, fostering stakeholder cooperation, and developing a toolbox of innovative solutions [6]. Current Croatia's national LC safety program has been adopted for the period from 2023 to 2027. and contains proposals for final solutions of priority LCs (upgrades) and additional measures such as systematic education of LC users, technical, technological and organizational measures, and low-budget infrastructure measures [7]. Network Rail (UK) published a strategy for reducing risks at LCs [8]. The Australian government founded a programme to enhance safety at LCs for the period 2022 to 2027 [9].

3 Methodology

The methodology in this research utilized a multi-faceted approach to select and evaluate low-budget measures for accident prevention at LCs. The primary sources of data included European projects SELCAT and SAFER LC which provided valuable insights into innovative strategies and best practices. Additionally, information was gathered from railway infrastructure managers, through the search of safety reports and programmes for mention of preventive measures. To ensure comprehensive coverage of the topic the search was also conducted through literature databases Web of Science, Scopus and an additional check was made through other literature databases using appropriate keywords and filters related to LC safety and low-budget interventions: "level crossing", "infrastructure measures", "low-budget measures" and "accident prevention". The examination of the feasibility, costs and the researcher's assessment of various measures led to the categorisation as a low-budget measure.

4 Results

The investigation of low-budget infrastructure measures for improving LC safety involved a meticulous selection process. The primary focus was on identifying infrastructure interventions involving alterations to road markings, equipment, and traffic signs. A filtration process was employed to isolate low-budget measures which were first categorised based on the type of LC following ERA standards.

The next stage involved classifying measures according to distinctions between Motorized Road Users (MRU) and Vulnerable Road Users (VRU). Finally, the authors classified measures in alignment with the rulebook on traffic signs, signalling and equipment on roads as per Croatian legislation [10].

4.1 Classification

The final process of measures classification yielded six distinct categories, totalling n = 62 selected infrastructure measures for the LC: markings on pavement and other road surfaces (4.2, n = 17), road traffic signs and traffic lights enhancement measures (4.3), road traffic equipment and traffic calming measures (4.4), signal devices, barriers, and half-barriers enhancement measures (4.5), and railway traffic information and detection measures (4.6).

4.2 Markings on the pavement and other road surfaces

The measures considered in this subsection are longitudinal markings on the road, cross markings on the road, and other markings on the road and other traffic surfaces. The search process revealed n = 10 low-budget measures (Figure 1). Initial measures feature coloured markings at danger zones in LCs where VRUs are endangered by approaching trains [6]. These markings are also applicable to all road users and may be designed as pavement patterns or as specific colour coatings [6]. In urban locations, coloured marks involve the combination of yellow band, train band and red stripes of different widths and lengths (simulator test in France) [6]. Combining measures with road markings proves beneficial [6]. Rumble strips ahead of LCs improve recognition, slow approach speeds, or deter zig-zag driving [6, 11-16]. Replacement of asphalt with timber surfacing reduces approach speeds [17]. Pavement signs, though short-term, enhance detection and awareness (field test in Germany). Anti-slip surfacing added to asphalt can enhance the safety of VRUs but can also be applied to MRUs [6].

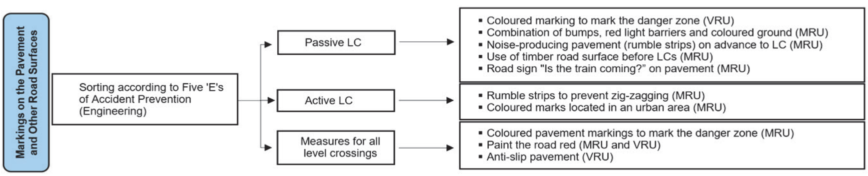

Figure 1 Measures of markings on the pavement and other road surfaces

4.3 Road traffic signs and traffic lights enhancement measures

Road signs encompass danger signs, explicit commands, notification signs, traffic management signs, supplementary plates, and variable traffic signs, while traffic lights serve multiple functions including traffic, pedestrian, and cyclist management, as well as marking LCs and road works. The search process revealed n = 17 low-budget measures (Figure 2). Warning lights are mentioned as a prevention measure as part of the SELCAT project [5]. Safety measures regarding traffic lights in this subsection include installing lights on pavements activated by approaching road vehicles [13], flashing lights activated with approaching trains (similar to aircraft runways) [18], ground signalling combined with other measures (speed bumps) and matrix of LED lights installed around LC [6]. Traffic sign “STOP” at LC mandates stopping in front of LC [19, 20], however, a study [21] suggested adding it to the active LC.

The additional signs can supplement existing signs promoting train recognition, especially on winding roads. Adding additional yield signs for better train detection or replacement of stop signs with yield signs on low-traffic roads can reduce speed and improve recognition of LC [6]. Sign "Look for Train" engages road users visually and encourages them to "search" for approaching trains [6, 22]. Warning lights improve detection and perception at LC [23-25], similar to LED enhance traffic signs [26, 27]. Addition signs to warn people not to drive onto tracks (high congestion) or warning panels deterring people from risking their lives can positively affect the promotion of correct behaviour [6, 28]. Child-friendly appropriate signs can be placed at the LC. Signs and varied colour schemes signs can improve visibility under different conditions and deterrent signs with safety messages can increase correct behaviour [6].

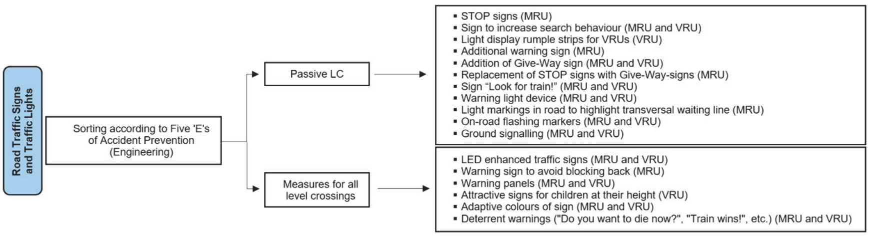

Figure 2 Collection of road traffic signs and traffic light enhancement measures

4.4 Road traffic equipment and traffic calming measures

Road traffic equipment comprises a wide range of equipment for marking road elements and other equipment complemented by traffic calming measures. The search process revealed n = 10 low-budget measures (Figure 3). Conventional speed bumps can be placed on the approach to LC [6, 24, 29] or the active inverted speed bumps which activate when a vehicle exceeds a defined speed [6]. Reduction of speed limit and automatic speed enforcement reduces the risk of traffic accidents [6, 30]. The illusion of a tunnel to reduce approach speed is created with strategically placed white poles [6]. Sound-emitting bumps and flashing posts warn of approaching LC and reducing the distance of public lighting poles can create an illusion of increased speed on approach to LC [6]. Camera installation can decrease traffic violations, and installation of road elements (e.g. islands) can prevent barrier circumvention [6, 13, 31]. Beneficial is to combine multiple measures like bumps and flashing sticks. With an assumption that drivers are more likely to obey traffic lights [6] replacement of LC signalling devices with road traffic lights is made but a simulation environment study showed that this is not the case [32].

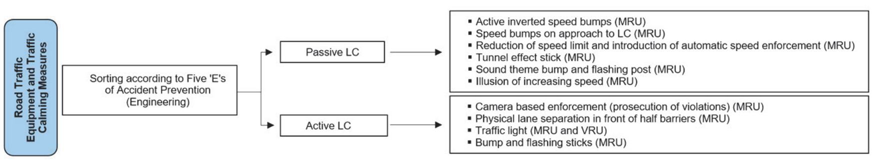

Figure 3 Collection of road traffic equipment and traffic calming measures

4.5 Signal devices, barriers and half-barriers enhancement measures

The search process of low-budget measures in which changes to LC warning and control devices are revealed n = 12 low-budget measures (Figure 4).

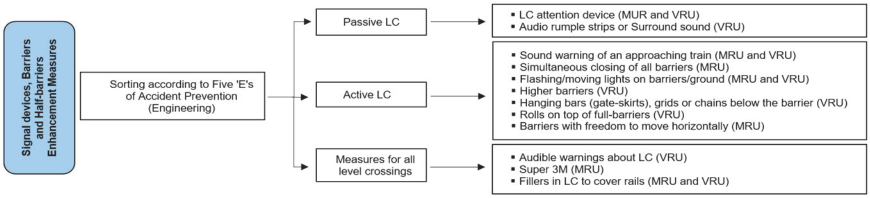

Figure 4 Signal devices, barriers and half-barriers enhancement measures

One measure is a device that warns road users of approaching trains, comprising a transmitter on the train or railway vehicle and an attention device. The train's signal activates the attention device, triggering a yellow flashing light as it nears the LC [33]. Additionally, a matrix of loudspeakers around the LC emits progressively louder sounds to alert pedestrians and motorists [6]. Sound warnings specifically for approaching trains are implemented at the active LC (with additional technology at the passive LC) [6, 23]. Simultaneous closing of barriers on both sides of the road can deter zigzag driving [6]. Addition lights installed on barriers can increase visibility [6, 23]. Increasing barrier height may prevent VRU traffic violations [6, 34]. This can be complemented with hanging bars, grids, or chains below to prevent violations [6, 35]. Rollers on barriers help prevent climbing over the barriers, while horizontally movable barriers are aimed at road users stuck between barriers. Audible warnings caution VRUs near the LC via sound messages in multiple languages [6]. Audible device reduces the possibility of accidents if implemented for MRUs [21]. Solar-powered films on crossbucks react to oncoming vehicle lights, and additional fillers prevent users from becoming trapped between barriers [6].

4.6 Railway Traffic information and detection measures

At LC useful traffic information may enhance safety and provide additional information to road users, while detection measures provide early warning and better recognition of LC. The search process revealed n = 13 low-budget measures (Figure 5) that include LED panels displaying train information for pedestrians, information on a countdown to LC closure or information via stickers on the inside of barriers informing drivers of barriers breakability if stuck. Digital displays offer warnings and messages for road users, aiming to alleviate waiting discomfort. Weather updates and community information posts are installed, along with displays showing the next train arrivals and up-to-date schedules of trains for pedestrians. Better environmental design improvements for track recognition, while mirrors allow road users to spot trains from both directions [6]. Train detection can be increased by the installation of low-budget detectors between tracks [6, 36]. Wind panels generate train-like sounds, contributing to awareness for VRUs [6].

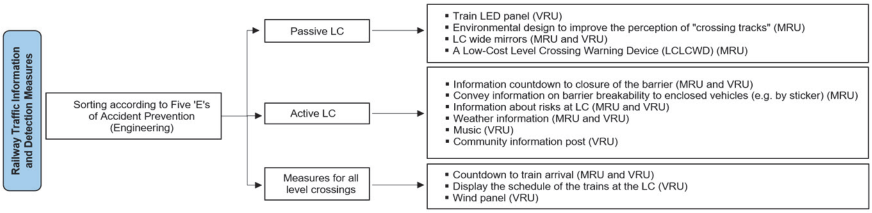

Figure 5 Collection of railway traffic information and detection measures

5 Discussion and conclusion

In this study, the emphasis was placed on identifying low-budget infrastructure measures, with the exclusion of those requiring substantial alterations to road and rail infrastructure. The selection of included measures underwent several stages. Both, measures tested as part of simulation at testing grounds/laboratory and real environment were included. These proved to be valuable sources for possible implementation of measures or further testing on a larger scale. Markings on roads and other surfaces have the possibility of enhancing road users' awareness and recognition of LC. However, they also require constant maintenance and their effectiveness can be reduced under different weather conditions or they can generate increased noise. Traffic signs and lights have a positive effect on recognition, awareness and promotion of good behaviour at the LC, but are still affected by bad weather conditions. Other possible problems could be mental overload and the overreliance of road users on these measures. Road equipment and calming measures could reduce approach speed towards LC, recognition and reduce traffic violations. Disadvantages could be in maintenance (especially in winter), noise pollution and a general feeling of discomfort that these measures produce in drivers. Potential benefits of changes made to signal devices and barriers may be better recognition, increased attention, awareness and accident avoidance. Some disadvantages are the same as previous measures, e.g. noise and light pollution, decreased effectiveness in different weather and lighting conditions with the need for maintenance. Measures providing information and better detection give road users valuable knowledge regarding traffic rules and different conditions in proximity to the LC, including lowering the risk of accidents. Such systems could also fail or encourage road users to speed up to cross before LC closure. The limitation of this study is that only low-budget measures were included in the research. Therefore, some measures such as in-vehicle detection and information systems and other ITS solutions are excluded from the study. In future studies, authors will expand the current set of measures and present more detailed information on the effectiveness, implementation and cost of measures.

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