Hierarchical task analysis to understand impacts of new technologies on rail level crossing systems

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SUMMARY

Automated enforcement cameras have been proposed as a new intervention to enhance railway level crossing behaviour and safety. Hierarchical task analysis was utilised in a novel way to consider the potential positive and negative impacts on road user behaviour. The findings can be used to support decision making around the use of enforcement cameras in this context.

KEYWORDS

Task analysis, Technology, Rail level crossings, Safety and Risk

Introduction

Collisions and fatalities at railway level crossings continue to be a public safety concern worldwide. In Australia, there were 39 crashes involving trains and road vehicles reported in the 2023–2024 financial year (Office of the National Rail Safety Regulator, 2024). In the UK, there were 53 fatalities at railway level crossings in the period 2014-15 to 2023-24 (Office of Rail and Road, 2024), and across European Union countries there were 234 fatalities at railway crossings in 2021 alone (European Union Agency for Railways, 2023). These statistics suggest that new types of controls are required to address safety risks at railway crossings, and there is growing interest in innovative safety solutions (Read et al., 2017; Silla, 2019; Wullems, 2011). One solution that has received some attention is the use of enforcement cameras, supported by artificial intelligence-based computer vision image processing, to deter non-compliant behaviours by road users. Despite their potential use, there is currently insufficient literature to determine their efficacy and potential impacts on road and rail users.

This study aimed to support decision making about the use of automated enforcement at railway crossings in Queensland, Australia. Hierarchical Task Analysis (HTA; Annett et al., 1971) was used to understand how enforcement cameras may influence behaviour (positively or negatively) at railway level crossing sites.

Method

Draft HTAs were developed by the research team based on previously published models (e.g. Read et al., 2017), the road rules, and the knowledge of research team members. Behaviour of car drivers, motorcyclists, and heavy vehicle drivers was modelled for the following level crossing types: active crossings with flashing lights, active crossings with flashing lights and boom barriers, passive crossings with stop signs, and passive crossings with give way signs.

The draft HTAs were reviewed and validated via workshops involving Human Factors and Ergonomics (HFE) and rail level crossing subject matter experts. Due to availability, two repeat workshops were held. A total of 12 participants (8 male, 4 female) attended across both workshops. Participants had an average of 10 years of experience in roles relating to railway level crossings. Participants were provided with a copy of the draft HTAs, and the workshop facilitator walked participants through each HTA, outlining the goals, sub-goals, plans and operations. Participants provided feedback on the accuracy and completeness of the HTA. Following the workshops, the research team incorporated the feedback and the updated HTAs were distributed via online survey for further review and comment by the workshop participants. Minor feedback was gained from this follow up process and was incorporated to create final versions of each HTA. Once the HTAs were validated, a workshop was held with three research team members (GR, KP and ZA) where the team systematically considered each operation in the HTA in terms of the potential positive and negative behavioural impacts of enforcement cameras.

Results

The overall goal of the HTAs across the four types was defined as achieving '*safe and efficient separation of road and rail traffic at level crossings*'. Seven sub-goals were defined: (1) control vehicle, (2) Detect presence of rail level crossing, (3) Approach rail level crossing and announce presence of train, (4) Detect cue to stop, (5) Decide whether to stop or proceed, (6) Stop vehicle at rail level crossing, (7) proceed through rail level crossing. Each sub-goal was associated with between four and fifteen operations, depending on the type of level crossing being modelled (e.g. active crossings with flashing lights, passive crossings with stop signs). Reviewing the HTAs for the impact of enforcement cameras identified a range of potential positive impacts, including:

- Slower speeds which provide more time to take evasive action, scan the environment, perceive and comprehend information in the environment.
- Longer headways which provide more space between vehicles, supporting vehicle control and taking evasive action, and reducing short stacking/queuing events.
- An additional decision-making goal of 'avoiding a fine', providing road users an additional incentive to stop at the crossing to avoid a fine, which may be more motivating than other goals (e.g., not being late).

A range of potential negative impacts were also identified, including:

- Road user attention being drawn to the camera meaning that attention might be diverted from vehicle control tasks (e.g., monitoring speed, braking), scanning for hazards, perceiving whether a crossing is active, and assessing other road user's behaviour.
- Misplaced road user compliance whereby fear of receiving a fine results in prioritising compliance over safety (e.g., road users stuck on the crossing not taking evasive action by crossing into an on-coming traffic lane when it would be appropriate to do so).
- Addition of complexity to decision-making on approach to crossings, adding to workload particularly in busy, urban environments.

Key takeaways

This study demonstrates the utility of HTA for early HFE analysis to consider the impacts of new technologies aimed to improve safety at railway level crossings, and more broadly, in other domains. The analysis identified both positive and negative impacts of automated enforcement cameras, some of which are context dependent. The results from this analysis can inform risk assessments and implementation plans, should such technologies be rolled out. We encourage further applications of HTA and other task analysis approaches to identify the positive and negative impacts of new technologies in both transport and other domains.

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