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Towards automated tram systems – risk analysis case studies

Abstract:

Development towards higher grade of automation (GoA) levels has been a global trend in trains and metros, but so far not in trams due to their complex and highly dynamic operating environment. However, currently rail operators are also showing increasing interest on higher automation levels in tram systems to increase their efficiency and safety. Higher GoA levels in a tram system introduces changes in operating principles, new roles for personnel, and new types of safety risks in daily operations. New approaches and tools are needed to identify new safety and reliability risks arising from autonomous operation and to evaluate intelligent (preventive) safety solutions. In this paper, we present two studies where risk analysis methods were applied in the conceptual level to identify new autonomy related safety risks in tram operations. The research results can be applied widely in automation development in railway systems.

Keywords: tram, autonomy, safety, risk analysis

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1 Introduction

Development towards higher grade of automation (GoA) has been a global trend in trains and metros. Trams operating in street level among other traffic are operated by human drivers, but railway operators are also showing increasing interest on higher automation levels in tram systems to increase their efficiency and safety (Connolly, 2018). There will be several intermediate stages in the roadmap towards automated tram operations, such as automatic driving between stops, automatic start and stop, and automatic door operations at a stop. Making depot automation commercially viable could be a first stage of introducing autonomous driving, including the legal and economic conditions that must be fulfilled for the approval and operation of an autonomously driving tram (Flaherty, 2021).

Higher automation levels in a tram system introduces new types of safety risks in daily operations in street level among other traffic. It is therefore essential to identify and assess the new safety risks and uncertainties in the early concept design phase, so that they can be eliminated, mitigated, or reduced to an acceptable level in the tram system design. According to the International Association of Public Transport (UITP) (UITP, 2018) and the international standard IEC 62290-1 (2014) there are four Grades of Automation (GoA) for railway systems: GoA1 – GoA4, which are illustrated in Table 1. In the Table 1 ATP = Automatic Train Protection, ATO = Automatic Train Operation and UTO = Unattended Train Operation.

Table 1Grades of automation in railway systems according to UITP (2018)

Grade of Automation	Type of train operation	Setting train in motion	Stopping train	Door closure	Operation in event of disruption
GoA1	ATP with driver	Driver	Driver	Driver	Driver
GoA2	ATP and ATO with driver	Automatic	Automatic	Driver	Driver
GoA3	Driverless	Automatic	Automatic	Train attendant	Train attendant
GoA4	UTO	Automatic	Automatic	Automatic	Automatic

In this paper, we present two studies where risk analysis methods were applied in the conceptual level to identify new autonomy related safety risks in tram operations. In the first study, the subject was an automatic transfer of trams at a depot area, and in the second study the subject was the use of an automated door system in an autonomous tram.

2 Methods

In the first study the aim was to identify hazards and foreseeable problems related to the automatic transfer of trams in the depot area and in the halls, to assess the risks and define ways to manage the automation related safety risks. The starting point of the analysis was defining the principles of moving trams in the depot area and defining the work tasks in the tram storage hall and maintenance hall as well as other operations and traffic outside the depot area. The risk analysis was carried out by a group of experts on tram operations applying the Operating Hazard Analysis (Vincoli, 2006) approach.

In the second study the aim was to identify and analyse the effects of increasing level of tram autonomy (from GoA1 to GoA4) on the use of automated tram door and its functionalities. At the beginning of the work, the stages of the tram's daily operation were defined from the departure to the line to the return to the depot, as well as the use of the tram's doors at stops and in special situations. The analysis was conducted with two different methods first by utilising Preliminary Hazard Analysis (PHA) approach (Vincoli, 2006) and secondly by using System Theoretic Process Analysis (STPA) approach (Leveson & Thomas, 2018; Heikkilä et al, 2022).

3 Results and conclusions

In cities trams share the same infrastructure with other traffic which makes higher autonomy much more difficult than metros and city trains that have an independent network. Many of the new autonomy related safety risks in trams arise from the complexity of sharing the same street infrastructure with cars, cyclists and pedestrians, and unexpected behaviour of the tram passengers. The results of the analyses in this study show that the main safety functions of the tram door systems utilized now in GoA1 level operation are already capable for GoA4 operation e.g., safety edges and door locking control functions. Although changes are required in the operational principles and technical implementation of the tram control systems to enable the transition from GoA1 level to GoA4. Situational awareness information from the door area needs to be improved, because they are no more observed by the tram driver. Handling of abnormal situations and emergencies needs to be carefully considered e.g., ability to remotely handle safe evacuation in case of fire or traffic accident.

In depot area the operating principles are quite the same when transferring trams or train or subway cars on the tracks. The main hazards related to automatic driving in the halls and in the depot are collision with a person, a person falling or being crushed, collision with another tram, vehicle, work machine, hall door or an obstacle on the tracks. The results including multiple causes of hazards, as well as the safety requirements defined based on them and proposed measures to eliminate or reduce the safety risks form a good basis for more detailed risk analyses of automatic driving the trams in a depot. Increasing the level of autonomy of tram systems places new demands on the functions of the different subsystems of the tram and on the management of failures and problems in different operating situations. The new risks of unmanned driving were identified, and new information was obtained on which things to be prepared for.

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4 Bibliography

Kate Connolly, K. 2018. Germany launches world's first autonomous tram in Potsdam. The Guardian, World. https://www.theguardian.com/world/2018/sep/23/potsdam-inside-the-worlds-first-autonomous-tram

Flaherty, N. 2021. *Fully automated depot has self-driving trams.* Technology News, August 27, 2021. https://www.eenewseurope.com/en/fully-automated-depot-has-self-driving-trams/

UITP (2018). World Report on Metro Automation. UITP Statistic Brief. Available: https://cms.uitp.org/wp/wp-content/uploads/2020/06/Statistics-Brief-Metro-automation_final_web03.pdf

IEC 62290-1:2014 Railway applications - Urban guided transport management and command/control systems - Part 1: System principles and fundamental concepts.

Vincoli, J. W. (2006). Basic Guide to System Safety. Hoboken, NJ: John Wiley & Sons, Inc.

Leveson, N. & Thomas, J. 2018. STPA Handbook.

Heikkilä, E., Malm, T., Välisalo, T., Tiusanen, R., Hämäläinen, M. & Järvinen, M. (2022) *Systemic safety analysis of a tram door system considering increasing level of automation.* Poster in the Transport Research Arena (TRA) Conference in Lisbon 14.-17.11. 2022.