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Tramway Reliability and Safety Influencing Factors

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Abstract

The paper presents the factors have influence on the operation process safety of tramway rolling stock, and in consequence will have influence on service intervals. The main goal is to collect a set of factors, which will be important for planning of infrastructure and rolling stock operation research. After reviewing the state of knowledge, the paper presents a general analysis of the tram rolling stock subsystem. Then sources of data on the operation process were described. In later, processes occurring in operation and maintenance of tram vehicles were identified. Also influencing factors due to each process phase were described. Then a concept of operation research for a new rolling profile of wheels was introduced. The paper ends with a summary and further research perspectives.

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Keywords: tramway, reliability, saftey, operation research

1. Introduction

Operation and maintenance of technical systems is carried out within the schedule resulting from technical documentation and using requirements. In many cases intervals between maintenance are defined well enough. For complex sociotechnical systems it is often not so. The tramway is an example. The reason for this are conditions of use, impact of infrastructure and the predispositions of tram drivers. Therefore, the aim of the work is to prepare an inventory of tramway system characteristics may affect its safety.

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2. Literature review

A crucial aspect in the railway engineering practice is determination of the state of infrastructure and relating safety improving actions to it [2]. In [10, 14] decision models for determining the right time for technical service of infrastructure at minimum total costs have been designed.

A more detailed insight is provided by an analysis of consequences of original and the related secondary damage (excluding the traffic impact) [23]. Chen in [6] presented train services reliability and punctuality models.

The authors [18] proposed a disrupted train traffic management support model. The model is based on the costs of rail traffic reorganization or cancellation of trains in the context of railway employees (engine drivers and train traffic service staff).

The probability of delay suppression is directly related to the so-called “resistant timetables” [19] and resilience [9], i.e. an ability of the system to regain functionality after an event.

Safety of transportation systems is related to maintenance and security actions [16, 17] of the system that prevents occurrence of adverse events, such as [24] death, injuries, tangible property losses, natural environment losses.

In the case of railway transportation system an event tree and a fault tree can be used in adverse event risk analyses. In [1] such an analyses was expanded by addition of risk influencing factors. The problem was shown on an example of a single-track line, for which a peak event was a collision of two trains coming from two different directions. Barriers which aimed at preventing occurrence of peak events were catalogued and then a tree of events leading to the barrier faults were drawn up. Operational risk influencing factors were attributed to the basic events.

The studies [3, 4] explore security engineering in rail transportation system design. Articles discuss the issue of ERTMS (European Rail Traffic Management System) implementation, which in their structure also contain a unified European communications standard GSM-Rail. The problem of security at ERTMS implementation is all the more crucial if we take into account lack of experience in operation of such a system in conditions corresponding to the implementation (for Dutch railways in 2003). The basis for discussions [3] is risk identification for the implemented system. The [4] publication summarizes literature which introduces risk analysis components for a newly designed railway system (ERTMS).

A crucial aspect in the assessment is identification of Safety Integrity Levels (SIL). In the draft of the European standard [11] a simplified SIL table was used for railway traffic control, communication, data processing equipment and electronic systems significantly influencing the safety of rail transportation. In [5] representing railway transportation risk levels in the form of a table was suggested. In this way unacceptable risk, acceptable risk areas and a border area were obtained

In [8] risk assessment of hazardous load transportation was conducted by using events/vehicle-kilometers as a measure of event occurrence intensity. In [20] a model used in a risk analysis of hazardous material rail transportation was presented. The risk is determined as the product of intensity of derailment of carriages used for transport of hazardous materials, operational work related to transportation of hazardous materials, conditional probability of hazardous material release after derailment and consequences of hazardous material release from the carriage.

Increased behavioral and cognitive load has an impact on traffic safety (more than 90% of accidents in the rail transportation system occur after taking over the responsibility by a human [33], whereas disasters in transport occur in around 80% of cases due to a human error [15]. A human factor exists in the entire system not only in direct operation of trains by railway traffic control stations [25].

A weighty problem in the use of the rail transportation system is the SPAD (Signal Passed At Danger) phenomenon. The most common cause of this type of events is the machine operator’s error. The [12] source says that in 2011 more than 45% of accidents were caused by a train passing a stop signal in a dangerous way. SPAD events were examined qualitatively in [22].

Due to the crucial impact of those events on occurrence of safety failure they are examined in detail by using various methods (e.g. Bayesian networks [21]).

In the context of a human factor a science dealing with safety culture in sociotechnical systems should be noted. Models of the problems were synthetically introduced in [7].