Application of fuzzy fault tree analysis for evaluation of railway safety risks: an evaluation of root causes for passenger train derailment

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Abstract: The fault tree analysis (FTA) is a well-structured, precise, and powerful tool that can be used to assist the analyst in identification, evaluation, and analysis of all basic causes and paths ending up to the occurrence of a certain event. In the conventional approach, the probability of the basic events is considered either as a precise point value or as a random time-dependent variable. However, due to the inherent imprecision and uncertainty of the available data, it is often impossible to obtain an exact estimation of an event occurrence rate or its distribution function. In such cases, the fuzzy approach is among the best choices for analysing the system. This article presents a comprehensive and transparent study on the evaluation of the railway safety risks using the fuzzy FTA. For this purpose, a method for quantification and evaluation of the fault tree in the fuzzy environment is proposed. The method that is presented in this article is based on modifying the weighted averaging according to the levels defuzzification method. Therefore, it proposes a new importance distribution function for the level sets during the defuzzification process. Furthermore, it extends the minimal cut-set and the Fussell–Vesely importance measures of the conventional approach into the fuzzy environment. These importance measures can be effectively used for the ranking of the minimal cut-sets and the basic events according to their contribution to the top event probability. Also, a practical case study regarding a passenger train derailment is used to describe the proposed concepts. The planned methodology is relevant in several engineering applications.

Keywords: fault tree analysis, fuzzy logic, fuzzy importance measures, railway safety risks, passenger train derailment

1 INTRODUCTION

Railway transportation has played important role in moving passengers and goods since the first days of its revelation. Since its early days, there have always been safety-related issues in the minds of the railway operators. There is always the question of efficiency in measuring the risks and success in practically curbing the hazards. Therefore, the type of measures for risk identification and subsequent actions to improve safety turn into prime importance in railway operations.

It is well known that in restraining the problems that are associated with system safety, proactive procedures are always the most appropriate ones. A proactive procedure, by definition, is a set of actions and measures that are formed against a situation in the future rather than a situation in the present [1]. The risk management as a proactive process can be used as a base to improve the system safety level.

Fault tree analysis (FTA) is a well-structured, precise, and powerful tool that can be used for the risk assessment process. It assists the analyst to identify, evaluate, and analyse all of the basic causes and paths ending up to the occurrence of a certain event [2].

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