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ScienceDirect

Procedia Engineering 178 (2017) 409 – 418

Procedia Engineering

www.elsevier.com/locate/procedia

16th Conference on Reliability and Statistics in Transportation and Communication, RelStat'2016, 19-22 October 2016, Riga, Latvia

Lifecycle Based User Value Analysis of Rail - Road Level Crossings: Probabilistic Approach Using Monte Carlo Simulation

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Abstract

Railway operators are in continuous pressure to minimize maintenance and rehabilitation costs of infrastructures; at the same time they are expected to provide a reliable service by optimum allocation of natural and economical resources. Railway tracks and level crossings are long-lived assets where their service life stretch 30 to 100 years. This paper aims to show an approach that serve as a decision support whereby expert's knowledge can directly be integrated by using a delphiround. A proposed methodology is illustrated by application examples using level crossings commonly used in Austria by Wiener Lokalbahnen. Lifecycle based user – product performance – expectations and economic imperatives could be incorporated through the development of key performance metrics. Assessment criteria are set by allocation percentages for value criteria under these criteria are the sub value – contingencies where Monte Carlo simulation is used for probabilistic scenario analysis. The approach facilitates the first step for a detailed lifecycle cost analysis of infrastructures by supporting experts and non-expert decision makers to get a quicker overview on system benefits as well as serve as a bridge to the practical application of more robust data-driven lifecycle cost analysis.

Peer-review under responsibility of the scientific committee of the International Conference on Reliability and Statistics in Transportation and Communication

Keywords: maintenance, Lifcycle cost, probabilistic analysis, integrated lifecycle assessment

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Peer-review under responsibility of the scientific committee of the International Conference on Reliability and Statistics in Transportation and Communication
doi:10.1016/j.proeng.2017.01.079

1. Introduction

The big challenge in the railway sector today is that the increasing amount of transport of goods, wagons with larger axel loads and at the same time increasing speeds that demand the modernization of the system (Olofsson *et al.*, 2005; SB – LRA, 2007). Therefore, railway companies continuously strive to modernize rail routes in order to guarantee improvements for the users. As an essential goal of modernization of rail road; increasing number of routs are being modernized for more number of trains, passengers, freight trains and more frequent trains. The possible increase of speed increases the availability of the infrastructure and enhance attractivity of the rail transport that in turn improve sustainability. The routes that are modernized for more number of trains, passengers and freight transport need optimum measures for rail-road crossings that are safe. The challenge for the infrastructure owner lies on selection of level crossings with longer service life at minimum lifecycle costs, at the same time ensuring the societal demand for safe infrastructural system network authors.

Railway tracks and level crossings are long-lived assets where their service life stretch 30 to 100 years. Hence efforts are being done by various researchers and practitioners in the sector to fulfil the Reliability, Availability, Maintainability and Safety (RAMS) demands during the whole lifecycle. Given that level crossings have long service life, they will be exposed to increasing axel loads, speeds and traffic volumes for longer times. The new modernized routes demand new plan, design and dimensioning with corresponding level of EU guidelines (EN 2004/50 EC) and according to the technical specifications for interoperability (TSI). For rail operators, these components with their different demands and lifespans are important framework for the construction and maintenance and can massively influence the performance and the lifecycle costs of the whole system. Rail operators need therefore, decision processes with which the performance and lifecycle cost analysis (LCCA)can be compared. So far, there exist barely studies that assess the whole lifecycle cost of level crossing systems.

The performance of a railway infrastructures depend on, (i) a reliable design; (ii) optimal maintenance strategies supported by inspection monitoring methods (iii) reliable performance assessment approaches, (iv) suitable prediction techniques (Lichtberger, 2007; Quiroga, 2012). Hence, defining and planning the nature and frequency of maintenance play major role to sustain the quality of existing tracks at the most possible minimum lifecycle costs. In this regard, modelling of track deterioration is the basis for prediction and maintenance optimization processes (Yousefikia *et al.*, 2014). The type of deterioration models, currently available and being used, are either deterministic or probabilistic models. Deterministic models describe the condition by a functional correlation between structural condition attributes. These deterministic models are either polynomial (Jovanovic, 2004) or exponential (Veit, 2007). The practical implementation of such models requires detailed information about their variables and do not express uncertainties. Railway operators continuously endeavour to apply artificial intelligent based maintenance planning methods. These maintenance planning methods are dependent on numerous factors, track degradation model is among them (Quiroga, 2011; Quiroga and Schneider, 2012). Maintenance planning algorithms (Koza, 1992) based on; degradation models and stochastic variables were performed by (Michalewicz and Fogel, 2002; Lake and Ferreira, 2002) among others.

Monte Carlo simulation is implemented in random sampling from probabilistic distributions of each function parameter with long simulation runs. Monte Carlo approach is proven to be useful in simulation modeling many realizations. The typical uses of Monte Carlo modelling are (i) sampling; where information are gathered about a random object by observing many realizations; (ii) estimation, in which certain numerical quantities related to simulation are estimated and (iii) optimization, where randomness is introduced artificially to search the domain of the objective function more efficiently (Kroese *et al.*, 2014). Monte Carlo simulations have proven to be useful in design optimization, reliability analysis and optimization of multiple processes. Furthermore, because of its effectiveness in the field of lifecycle costing by solving problems that acquire different sources of uncertainty, Monte Carlo method plays a critical role in risk analysis (Wang *et al.*, 2012). In the Lifecycle assessment Monte Carlo method appears to be most popular method incorporating uncertainties in lifecycle assessment components (McCleese and LaPuma, 2002; Baker and Michael, 2009; Hung and Ma, 2009) among others.

Lifecycle cost (LCC), which is generally modelled in the design phase changes when the system enters into the operation and maintenance phase due to changes in stakeholder requirement that make the costs incurred during the operation and maintenance phase predominant. For complex assets such as track infrastructure, the cost of maintenance plays an important role in the LCC analysis, this is because the operation and maintenance phase