Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 27 (2017) 205–214

Transportation Research Procedia

www.elsevier.com/locate/procedia

20th EURO Working Group on Transportation Meeting, EWGT 2017, 4-6 September 2017, Budapest, Hungary

Assessment of maintenance strategies for railway vehicles using Petri-nets

Daniel Eisenberger[a], Dr. Olga Fink[a]*

[a]*Zürich University of Applied Sciences, Technikumstrasse 9,8400 Winterthur, Switzerland*

Abstract

The density of railway traffic has been steadily increasing over past years and decades. The developments have implicated a growing need for efficient operation and maintenance of railway rolling stock systems. Also the increased operation of articulated trains has induced new challenges on maintenance organization and planning.

Selecting optimal maintenance strategies for each component does not only influence the availability of the railway vehicles but also the operational performance and the profitability of the operator. Suitable tools to analyse, compare and optimize different maintenance strategies are therefore required.

Petri nets are such a mathematical tool that and have been applied for maintenance modeling and simulations of different applications. Several types of Petri nets with different properties have been introduced. One of the recently proposed extensions of Petri nets are the Abridged Petri Nets (APN) which fulfill the specific requirements of railway rolling stock maintenance.

In this paper, we propose the application of APN in combination with the Monte-Carlo simulation for railway rolling stock maintenance evaluation. In a first step, the applicability of the APN approach was demonstrated on a theoretical case study comprising a condition based maintenance strategy for a system. In a second case study, several real application case studies were modeled and compared based on the processes and real application field data of three railway vehicle components.

The tool can be further extended by pre-defining selected strategies that be easily implemented within an overall decision support system.

Peer-review under responsibility of the scientific committee of the 20th EURO Working Group on Transportation Meeting.

Keywords: maintenance strategy; railway vehicles; petri-nets; abridged petri nets;

* Corresponding author. Tel.: +41 58 934 49 52; fax: +41 58 934 49 52;.
E-mail address: fink@zhaw.ch

2352-1465 © 2017 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the scientific committee of the 20th EURO Working Group on Transportation Meeting.
10.1016/j.trpro.2017.12.012

1. Introduction

The density of railway traffic has been steadily increasing over past years and decades. Some links within the railway networks are even operated close to their capacity limits. Concurrently, also the complexity of the railway rolling stock and the infrastructure systems, and the operational impact of their failures have also risen sharply in the recent years. These developments have implicated a growing need for efficient operation and maintenance of railway rolling stock systems.

Also the increased operation of articulated trains has induced new challenges on maintenance organization and planning. One of the approaches to cope with these challenges has been the introduction of modular maintenance. Particularly, condition-based maintenance strategies have been gaining attention and need to be evaluated before a shift from classical maintenance strategies can be implemented.

An adequate maintenance strategy should always consider the operational parameters of the system and meet the strategic goals of the company in terms of reliability, availability and cost. Selecting optimal maintenance strategies for each component does not only influence the availability of the railway vehicles but also the operational performance and the profitability of the operator. Suitable tools to analyse, compare and optimize different maintenance strategies are therefore required that fulfill the essential preconditions of railway vehicles, are flexible and the results of which are easy to interpret.

Several approaches have been introduced to evaluate different maintenance strategies (Wang et al. 2007; Madlener et al. 2015; Huynh et al. 2012). These include Bayesian Networks (Bouillaut et al. 2013), fuzzy linguistics (MECHEFSKE & WANG 2003) and Monte-Carlo simulations (Marseguerra et al. 2002).

Petri nets have been increasingly applied to model and simulate maintenance strategies (Clavareau & Labeau 2009; Volovoi 2004; Hosseini et al. 2000). Petri nets present an approach to mathematically describe processes based on basic set theory. Several extensions have been introduced to Petri nets, such as timed Petri nets, stochastic Petri nets (Volovoi 2004), colored Petri nets and dualistic Petri nets (Dawis et al. 2001). Particularly these extensions have made Petri nets more attractive for the applications to maintenance engineering and planning. They enable the modelling of the different maintenance process steps and are able to model the failure and degradation behavior based on defined stochastic behavior.

Recently, a new compact type of Petri nets has been introduced: the Abridged Petri nets (Volovoi 2013). They are similar to stochastic Petri nets. However, they provide a more compact and intuitive model representation and enable a more intuitive understanding of the modeled processes. If the Abriged Petri nets are combined with Monte-Carlo simulation, they also provide a good tool for evaluating the maintenance strategies quantitavely.

In this paper, we propose to apply the Abridged Petri nets to maintenance strategy evaluation of railway rolling stock components and demonstrate how their specific requirements and boundary conditions can be implemented in Petri net models to enable a suitable and easy to use decision support tool.

2. Current maintenance challenges in the railway industry

A regular maintenance is essential to preserve the railway vehicles and their components in the operational state operable and remedy faults and failures. Omitted or inadequate maintenance activities can cause train delays, cancellations, hazardous situations and even fatal accidents. These adverse events affect the competitiveness and profitability of the railway operators and are therefore of high importance.

The complexity of maintenance processes has been increasing. This is due to several reasons. Articulated trains have been progressively replacing train compositions comprising locomotive and passenger coaches. This results in more complex requirements on maintenance planning. Additionally, purely mechanical systems are progressively being replaced by complex mechatronic devices and systems that combine mechanical, electronic and information technology, with very different degradation and failure characteristics. Selecting an optimal maintenance strategy and evaluating its impact on the reliability, availability and also the life cycle costs of the system is therefore indispensable. The evaluation of maintenance strategies requires a modelling of the impact of the possible alternative strategies on system performance and also on the life cycle costs. However, the increased complexity of the systems and also the increased requirements on the performance of the systems in terms of their reliability, availability and safety have amplified the complexity of evaluating the maintenance strategies.