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Opportunistic inspection planning for Railway eMaintenance

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Abstract: Railway infrastructure is a complex system that comprises of several subsystems which interacts in hierarchical, multi-distributive and multi-user environment. It is a difficult task to perform inspections for all the assets at an instant because the train management system decides when to conduct different types of inspection techniques on several assets in a particular track section. There are two main wastes of resources for inspection planning occurred in maintenance; under usage due to inaccurate prediction of failure and over usage because the necessary information already has been acquired from other sources. These irregularities lead to wastage of resources, for instance, human, machine and time that has tremendous implications on cost, availability and manpower. This paper proposes a methodology by using intelligent functional test outcome to assess the performability of an asset and integrating the data to the eMaintenance cloud platform of Swedish railway infrastructure. By implementing this methodology, we can achieve better planning of resources for optimal performance of assets. A case study is performed on Switches and Crossings of Swedish railway infrastructure for the applicability of the proposed methodology.

Keywords: eMaintenance, Opportunistic Inspection planning, Switches and crossings, Swedish railway, Intelligent functional test.

1. INTRODUCTION

Railways are the important means of transport not only for the passengers that will travel across distant locations, but also for the cargo to supply goods to industries. As similar to other transportation means, the railway infrastructure is a complex system with different hierarchies and different types of subsystems while involving the partners from different fields. The operation and maintenance of the infrastructure is the most important, because frequent shutdowns reflect the dissatisfaction among the users and has impending costs on the partners as well, see (Ben-Daya, Kumar, & Murthy, 2016). In this regards, inspections are of one of the important aspects of maintenance at which the regular events of inspections will be useful to obtain the condition of the assets and also provide basis for operation of the fleet.

To maintain the condition of the asset, there are different types of inspection planning techniques available pertaining to a particular asset. Especially in the Swedish infrastructure there are several inspection techniques to monitor the condition of the asset either by the continuous or discrete manner depends on the planning maintained by the traffic management system (TMS). There are several inspection planning standards and procedures are existing in the literature but those approaches are confined to a specific case study.

The incorrect inspection planning causes several problems because planning has to be done with machines, human and also allocated time by the TMS. At some times, even before conducting the planned inspection (for working condition), the asset will go into inoperative condition (for corrective maintenance) thus the planned inspection action needs to be updated. Hence, the planned inspection is of no use because the correcting action has performed on the asset. This has lead to under usage of resources because the effort instrumented on this record will go into drain and further lead to dissatisfaction of users.

At some other times, the condition of asset is acquired from the different source of database. In such cases, planning and performing of inspections doesn't provide any new information. This problem is defined as over usage since extra effort implicates cost and wastage of scheduled slots. Furthermore, Swedish railway infrastructure is operated by Trafikverket and they carry out inspections by planning, monitoring and recording the inspections in different data sources. By extracting information from raw data through different data sources we are able to identify the performance of the asset as well. One of the main issues in this case arises due to the disparate types of data sources that is commonly a problem in the Trafikverket database. Hence, there is need of data aggregation of existing data sources to form a eMaintenance cloud.

In order to solve above problems, an intelligent functional test outcomes has been utilized to obtain the status of the condition with advanced algorithm. In current industrial setup, the startup automatic checkups are readily available to detect the faulty equipment. However, in the proposed intelligent functional test, the systems are checked-up whenever the testing is feasible. The test integrates the historical and new set of data to track the trend of degradation which is the main difference from the automatic routine startup checkups. It is important to note that intelligent

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functional test makes opportunity to reduce the risk of appearing failure during the start-up routine test. With this approach, the operation and maintenance personnel have ample time to make decisions for the maintenance and failure consequences. For a particular asset like switches and crossings, the tests can be performed by remote control and monitoring and acts as a feasible study to implement this intelligent functional test.

Depends on this functional testing, a framework for opportunistic inspection planning is proposed to reconfigure the inspection planning and scheduling dictated by the traffic management system and suggest the different recommendations back to TMS with less wastage of resources. This can be done by integrating the data sources from Trafikverket and with expert in place, the user can perform inspection planning and give as a training input to this algorithm for better suggestions. The opportunistic planning is based on the risk, cost and benefit functions further to facilitate the process in the future to obtain intelligent planning of inspection to perform railway infrastructure in a better way.

In co-operation with Trafikverket, Luleå University of Technology has developed a eMaintenance platform to monitor the asset status of Swedish railway infrastructure. This platform will facilitate with the framework we proposed in this paper for the opportunistic planning and acts as an add-on feature. In this paper, we considered switches and crossings (S&C) as a case study whether it's record is stored in the data sources and we demonstrated how in the practice it will provide suggestions. The S&Cs are of important asset because it is more prone to failures because of multivariate loads and several inspection records are available so that this concept can be implemented.

This paper is structured as follows: chapter 1 provides the introduction of the concept of the paper, chapter 2 will look into existing inspection planning procedures in general and also in a railway case, chapter 3 provides the flow chart of intelligent functional test, chapter 4 introduces the eMaintenance concept and a case study and chapter 5 provides the decision support of opportunistic inspection planning framework in general. The case study demoed this concept in case of switches and crossings in the Swedish railway infrastructure.

2. CURRENT INSPECTION PLANNING PROCEDURES

The current inspection planning procedures, in generic terms can be identified as a scheduling problem. However, in mechanical systems the degradation is the prime cause of the asset failure. In different industrial settings there are number of techniques used to identify the degradation trends and malfunctioning of the asset. Inspection planning prudently allocates resources to carry out efficient and effective inspection to accurately determine the condition of the system or subsystem asset (Nechval et al., 2009; Seneviratne et al., 2015). This involves balancing the cost of inspection, including the necessary downtime, against the benefits of inspection, including the effectiveness of that inspection (Straub, 2004; Straub & Faber, 2006). The inspection planning process comprises of three parts, the preliminary analysis for inspections, development of the inspection frame program and the detailed inspection plan.

The reliability based and risk based approaches were developed by researchers from 1963 onwards for the planning of inspections (Straub & Faber, 2006). Furthermore, different methodologies were used by different researchers, for instance, multi criteria decision making (MCDM) methods, such as analytic network process and analytic hierarchy process; fuzzy logic, genetic algorithms, artificial neural networks and Bayesian networks. (Yang et al., 2011).

Recently, artificial intelligence techniques have also emerged and been used successfully in condition based maintenance planning (Zio & Bazzo,2010). In addition, the expert systems were developed by a number of researchers using fuzzy inference systems, artificial neural networks with back propagation algorithms, and adaptive network based fuzzy inference systems for predicting and forecasting failure rates in production facilities (Al-Garni et al., 2006).

In the railway infrastructure assets, primarily the tracks and related asset play a vital role in the performability of overall service. For instance, S&C is one of the most degradable parts and need more attention inspection for the operational capabilities. Therefore, diagnostic and prognostic information is necessary in the proper planning of inspections and maintenance of S&C. Moreover, the correct, real time diagnostic and prognostic information will suppress the under usage and over usage. The intelligent functional test is a method that utilized to identify the proper functionality of the asset and deliver the prognostic information. The outcome of the intelligent functional test can be exploited for legitimate inspection planning program for S&C to mitigate the wastage, cost, usage of manpower and increase the availability of the asset.

3. INTELLIGENT FUNCTIONAL TEST

Emerging new technologies, for instance, cloud computing, wireless sensor networks, IoT, enable us to perform proper data collection, inspection planning, and increase accuracy of the prediction, which leads to optimal and more effective maintenance decision making. The intelligent functional test is a novel methodology to identify the performance and the health status of the asset. When performing the test there may be a need to add some new functionality or feature to the current control system or may require designing a new embedded device. By utilizing the outcome of this test the inspection planning can be updated which finally leads to cost reduction and more efficient scheduling. The decision outcome regarding the tuning the current inspection planning may achieve by the comparison of cost benefit for intelligent functional test versus the risk of asset failure.

In the most of advance machines like aircrafts, trains, robotic systems and, vehicular systems perform several routine checks to identify the availability of the asset by default before progressing to the operational mode. The intelligent functional test can be performed either in operational or non-operational mode. For instance, intelligent functional test can