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Product-Service Systems across Life Cycle

Integration of cost-risk assessment of denial of service within an intelligent maintenance system

L. Carlander[a], L. Kirkwood[a]*, E. Shehab[a], P. Baguley[a], I. Durazo-Cardenas[a]

[a]*Department of Manufacturing, Materials and Design, Cranfield University, Cranfield, UK*

* Corresponding author. *E-mail address:* l.kirkwood@cranfield.ac.uk

Abstract

As organisations become richer in data the function of asset management will have to increasingly use intelligent systems to control condition monitoring systems and organise maintenance. In the future the UK rail industry is anticipating having to optimize capacity by running trains closer to each other. In this situation maintenance becomes extremely problematic as within such a high-performance network a relatively minor fault will impact more trains and passengers; such denial of service causes reputational damage for the industry and causes fines to be levied against the infrastructure owner, Network Rail.

Intelligent systems used to control condition monitoring systems will need to optimize for several factors; optimization for minimizing denial of service will be one such factor. With schedules anticipated to be increasingly complicated detailed estimation methods will be extremely difficult to implement. Cost prediction of maintenance activities tend to be expert driven and require extensive details, making automation of such an activity difficult. Therefore a stochastic process will be needed to approach the problem of predicting the denial of service arising from any required maintenance. Good uncertainty modelling will help to increase the confidence of estimates.

This paper seeks to detail the challenges that the UK Railway industry face with regards to cost modelling of maintenance activities and outline an example of a suitable cost model for quantifying cost uncertainty. The proposed uncertainty quantification is based on historical cost data and interpretation of its statistical distributions. These estimates are then integrated in a cost model to obtain accurate uncertainty measurements of outputs through Monte-Carlo simulation methods. An additional criteria of the model was that it be suitable for integration into an existing prototype integrated intelligent maintenance system. It is anticipated that applying an integrated maintenance management system will apply significant downward pressure on maintenance budgets and reduce denial of service. Accurate cost estimation is therefore of great importance if anticipated cost efficiencies are to be achieved. While the rail industry has been the focus of this work, other industries have been considered and it is anticipated that the approach will be applicable to many other organisations across several asset management intensive industries.

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Keywords: Cost engineering; maintenance; cost-risk; cost optimisation; rail infrastructure

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1. Introduction

The UK rail industry is under intense pressures, in terms of capacity of the network, maintenance budgets and asset reliability. The UK faces a particularly difficult challenge in the modernization of the rail network as age of much of the infrastructure is significant. Anticipated rises in passenger numbers and operating services will raise the pressures on the capacity of the network [1]. Against this background of rising asset usage Network Rail is hoping to reduce maintenance costs [2]. To achieve both targets asset down-time incidents will have to be reduced through the very best practice in asset management. It is expected that increasing usage of autonomous systems will make a significant contribution towards reducing denial of service. While many view autonomous systems in terms of using UAV drones or robotic systems, much of the impact from the widespread application of autonomous systems will be in the area of software based decision support or decision making. The AUTONOM project is hoping to deliver much of the framework for such a system.

AUTONOM is funded by EPSRC [3] under the autonomous and intelligent systems program (AISP); and is also supported by key UK industrialists, including Network Rail. AUTONOM seeks to enable effective asset and maintenance decision-making in data-rich scenarios autonomously.

Uncertainty and Risk are an integral part of cost engineering. Uncertainty and risk assessment in industry is used to show more clearly the possible ranges of values. Single point estimates, (where a single value is presented as the estimate) can be misleading and give decision makers a false sense of certainty about the estimate. A three-point estimate is a popular method for presenting the least-costly, most-costly and most-likely estimates, however while it gives information on the range of an estimate it gives limited information on the shape of the probability distribution function.

If an organization has sufficiently detailed information then variables can be assigned ranges, and through a process of curve fitting, assigned probability distribution functions. The organization can then perform a Monte Carlo simulation to produce a more accurate estimate. Monte Carlo simulation is considered the industry best practice for dealing with uncertainty in data.

Cost estimation is not performed in isolation within the AUTONOM project, there is a focus on three technical areas: Data Fusion, Planning and Scheduling and Cost Analysis. All are part of an integrated strategy that could lead to better decision support for maintenance activities.

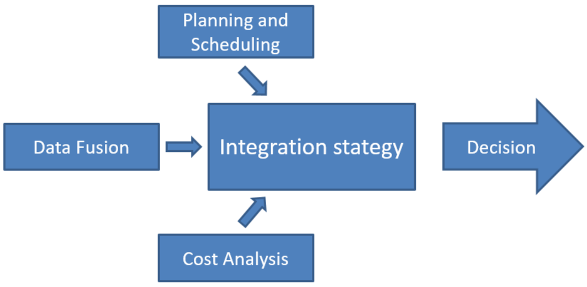

Figure 1: AUTONOM integration strategy [4]

The Data Fusion approach consists of gathering suitable data from multiple sources, so that data can be merged to supply inputs to an automated planning and scheduling model. The scheduling model uses a genetic algorithm approach to generate many different solutions and hunt towards a more optimal solution. This process is made more complicated by the need to schedule multiple maintenance tasks into an ordered list. The schedule is then used by the cost analysis, on which suitable cost engineering best practices are applied. These combined approaches will enable decision making within an integrated framework.

A challenge of this work has been to formulate cost models that can work with the limited information. The data-flows within the demonstrator limit the available information to use in the model calculation, as shown in in figure 2.

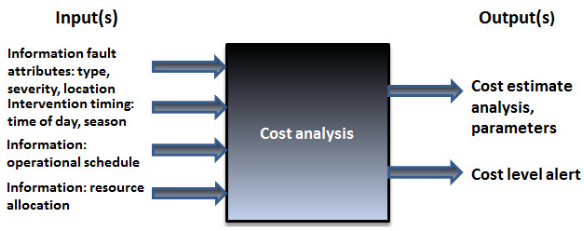

Figure 2 Cost analysis module I/O analysis

In the reported state of the demonstrator [5], the cost estimates generated were broken down into material costs,