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Uncertainty of Net Present Value calculations and the impact on applying integrated maintenance approaches to the UK rail industry

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Abstract

The Public performance indicator (PPI) is an important Key Performance Indicator for Network Rail and monitored carefully by the organisation and their external stakeholders. Condition monitoring is of increasing interest within network rail as a suitable method for increasing asset reliability and improving the PPI metric. As condition monitoring methods are identified each will need assessment to establish the cost and benefit. Benefit can be measured in cost savings as poor PPI performance results in fines. Within many industries Net Present Value (NPV) calculations are used to determine how quickly investments will break-even. Cost-risk is a term that is used to describe the financial impact of an unexpected event (a risk). This paper outlines a more detailed approach to calculating NPV which considers the cost-risk effect of changes of the denial of service charging rate. NPV prediction is of importance when assessing when to deploy different fault detection strategies to maintenance issues, and therefore the cost-risk of the NPV calculation should be used to support asset management decisions.

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Keywords: Cost engineering; through-life cost; cost-benefit; KPI; NPV; rail industry

1. Introduction

Cost engineering methods have seen a diversification of interest over recent years: where the traditional challenges of accurately determining and reducing cost of producing a product have expanded to include the challenge of considering the whole life cost (WLC) of the product. This mirrors the shift within the manufacturing industry towards seeing the product as a component of a delivered service. This servitization concept is gaining interest in many industrial sectors [1]. Rolls Royce, for example, are moving away from selling engines and move towards supplying “power by the hour” [2]. This shifting focus has meant that cost engineering, with its interests in cost estimation and cost control, has had to increasingly consider the WLC of a product or service and in particular the cost of maintenance has become a topical issue. As maintenance has increased in interest to cost engineering research, the traditional focus on manufacturing has become too specific and organisations with asset-management challenges have become more relevant.

One of the challenges cost engineers in industry and academia often face is to advise on the possible risk mitigation choices and predict cost consequences [3]. NASA has a strong interest in estimates being prepared with cost-risk factored into the estimate. Cost-risk assessment involves identification of risk and a translation of those risks into cost impact [3]. Within this paper changes in denial of service charging rates is considered a risk, the financial consequences of which constitute the cost-risk.

In maintenance condition based monitoring might be considered industry best practice, but this approach brings with it costs that need examining if a data-driven decision on the choice of maintenance strategy is to be made. A consideration of the issues surrounding cost of condition

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monitoring data has been previously presented [4], in which the cost relevant issues related to data gathering and data storage were given focus.

This paper will seek to examine the specifics of the situation at Network Rail by outlining cost-risk caused by Office of Rail Regulation decisions that potentially endanger installation of condition monitoring projects. This is done by showing a development of an existing case study with further cost-risk details being applied to the Net Present Value (NPV) calculation.

2. Background

Determining the cost of asset ownership is a challenge faced in many industries and organisations: NATO [5] and the defence industry have well defined terminology but continue to struggle to accurately calculate life-cycle cost, whole-life cycle cost and total ownership cost. Within the oil & gas industry methods like Markov-chain to predict the cost of maintenance [6] or Real Options (RO) are used to make cost-efficient decisions over the life-cycle [7].

Often the first stage of a WLC assessment is the Net-present value (NPV) calculation, which is used to indicate the return achieved from an investment. Commonly used in the oil and gas industry and financial sector as well as less obvious sectors such as the PV solar energy [8], NPV predictions are an important part of the decision process when considering the feasibility of a given project [9].

One of the methods that better technologies can benefit NR is to reduce the costs associated with denial of service. The framework for payments between train operating companies (TOC's) is referred to as "schedule 8" within the rail industry. Schedule 8 is overseen by the Office of Rail Regulation (ORR) and was updated at the start of the latest control period (CP5). The stated intention is for the schedule 8 targets and rates to be cost-neutral between TOC's and NR. A change in the rate of schedule 8 by the ORR is a risk that significantly influences the NPV calculation for a condition monitoring project.

The PPI is a key performance indicator within Network Rail and of significance for several reasons:

• PPI results are made available to the public. Therefore poor performance results in damage to the organisations brand and sufficient public and/or media attention can result in political intervention

• PPI and denial of service are related. A financial penalty is paid to a train operating company (TOC) when denial of service is caused by Network Rail.

The work of Marquez et al. [10] use expected values of the schedule 8 costs to calculate the "penalty saving". Penalty saving and reduction of maintenance costs are the two cost components that could be responsible for eventually making an investment in condition monitoring systems "break-even" (producing a positive NPV). Within the calculations presented by Marquez [9] the quickest that the point actuator condition monitoring system "pays" for itself is less than 8 years. As this is longer than a rail industry CP, it is worth noting that the Office of Rail Regulation is therefore very likely to reset both the target quantity of permitted delay minutes and the payment rate between NR and the TOC's. This adds a significant risk to the calculation and therefore it is a much more complex issue to calculate the "break-even point" than previously thought.

Looking at the recent trend for the penalty minute rate to rise we might draw the conclusion that this is a good thing that will likely make better equipment, technology or methods more cost effective, (in addition to the original intention of providing a strong incentive to achieve a punctual train service). The schedule 8 fees are only part of the discussion.

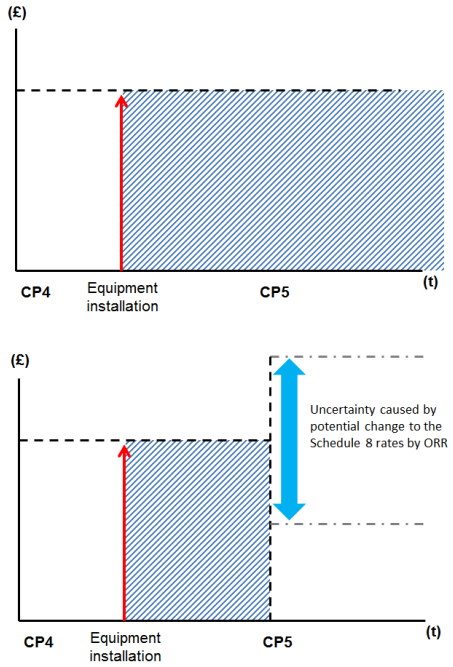


Fig. 1: Illustrative comparison between the assumed and real situation

The seemingly good news from raising schedule 8 rates is strongly mitigated by the Office of Rail Regulation setting the target for delay minute totals across the network. If NR reduces the delays across the network then the Office of Rail Regulation will eventually make the targets more difficult to achieve. The minutes saved no longer are working towards over-achieving the targets set by the Office of Rail Regulation, but are required to achieve expected performance. In effect, a change in targets will lower the number of "saved" delay minutes.

Figure 1 shows the schedule 8 related return on investment rate in schematic form, where denial of service related cash

flow is graphed against time. The illustrative equipment is installed part way through CP4. We therefore see that the intention from Office of Rail Regulation to make NR performance better could well result in unintended consequences. Therefore it is clear that NR need to consider the cost-risk caused by uncertainty in both penalty fines and targets for total delay minutes if NPV calculations are to be meaningful.

Relevant to this is the work of Mouter et al. [11] which reviews the problems that occur when presenting decision makers with uncertainty information during cost-benefit analysis. While the topics covered in that paper are outside the scope of this work, it is worth mentioning as it highlights the problems likely to occur if uncertainty information is presented.

3. NPV Estimation Methodology

The form of a simple NPV estimation is shown in equation 1 [10]:

$$NPV_t = \frac{CF_t}{(1+k)} \tag{1}$$

Where *NPV* is the net present value. *CF* is the cash flow, and *k* is the rate of return. Equation 1 can be expanded into equation 2 [10]:

$$NPV = I_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+k)^{t-1}} \tag{2}$$

Which assumes that the schedule 8 rates involved are constant between times $t=1$ and T. I_0 is the initial expenditure (in this example, cost of condition monitoring equipment and the cost of installation.

The above function can trend positively or negatively depending on the values. The work of Marquez et al. [10] explored the impact of a range of schedule 8 rates to explore the range of rates that are in place on the network and the expected number of saved minutes from the introduction of condition monitoring. The issue of the Office of Rail Regulation changing the schedule 8 rates each CP was not explored by Marquez et al. [10].

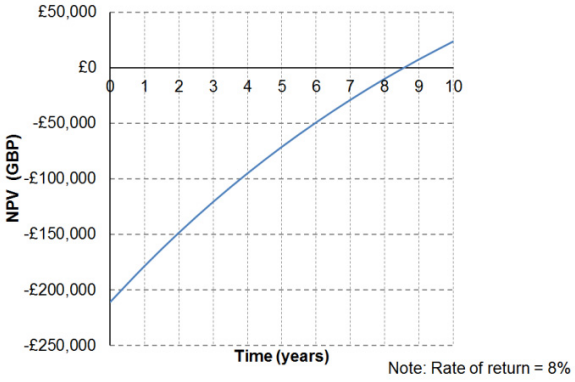


Fig. 2: NPV when targets and rates are kept constant

Figure 2 shows the most consistent case; where targets for delay minutes and rates are kept constant. This makes planning easier for Network Rail, however the Office of Rail Regulation has shown a willingness to change these rates in the past. A change to the schedule 8 costs can be represented in the NPV calculation by requiring summation over two different time periods, using different cash-flow values.

$$NPV = I_0 + \sum_{t=1}^{T_1} \frac{CF_t}{(1+k)^{t-1}} + \sum_{T_1}^{T_2} \frac{CF_t'}{(1+k)^{t-1}} \tag{3}$$

The changes between equations 2 and 3 allow for a step change within the regulation. CF_t and CF_t' are the different cash-flow values from the different CP's.

The value of examining the potential uncertainty of the CF_t values is that it allows an organisation to better assess its improvement plans and avoid making costly investments that have a probability of not providing a positive return.

4. Results

To add to the previous scenario examined by Marquez et al. [10], two further cases were considered; a best-case scenario (where the regulator makes extremely favourable decisions) and a worst-case scenario. The worst case scenario represents a situation where the regulator very dramatically reduces schedule 8 fines. These two scenarios are used as possible boundaries for what will happen during the following control period.

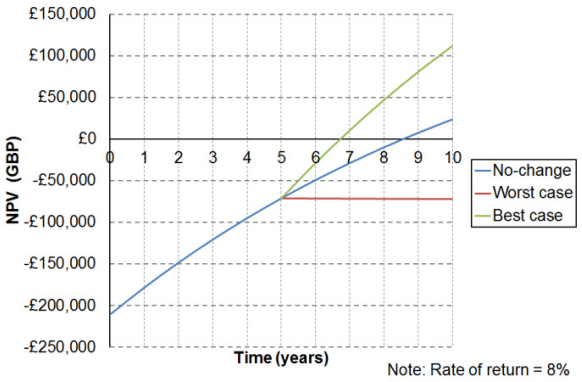


Fig 3: Diverging NPV values due to different cost-risk scenarios

Without any Office of Rail Regulation adjustments the expected break-even point was between years 8 and 9. The above "worst-case" is a situation where the schedule 8 rate is reduced by 50% (to 42.5 GBP/delay minute) The "best-case" scenario assumes a schedule 8 rate increase by 150% of previous (to 127.5 GBP/delay minute).

The break-even point is between years 6 and 7 for the best-case scenario while the worst-case scenario indicates that the capital investment will not break-even. For both the "best-case" and "worst-case" scenarios the number of delay minutes influenced by the RCM equipment was not changed.

5. Discussion

NPV is used widely within a range of industries for decision making on feasibility of projects. Often this analysis has to use uncertain information and be aware of the cost-risk factors that can influence the analysis. The discussion of this problem has focused on NR deploying improvements the situation applies just as much for the TOC's. The analysis presented here of the NPV should be of keen interest to the rail industry within the UK. Indeed, the arrangement of separate rail infrastructure and train operating organisations is not unique to the UK, anywhere with a system of delay related penalty fees being paid between organisations is very likely to have similar problems with calculating breakeven points using NPV.

While this analysis is still in a preliminary stage, the influence of this sort of analysis will be of broader interest once the WLC analysis is completed in more detail. The difficulty will be in making sensible schedule 8 cost predictions over the many CP's included in a WLC estimate: the range of uncertainty is likely to be very large. It is sensible to wonder if such swings in the schedule 8 fine rate are possible: those within the UK rail industry will know that between CP4 and CP5 the schedule 8 fine rate approximately doubled. Such dramatic changes in the regulatory environment will almost certainly result in the industry (and NR in particular) becoming concerned with the risk involved in such events. With the regulator making such dramatic decisions the "best-case" and "worst-case" scenarios explored here are shown to be conservative.

NR has previously released data from the TRUST system, which includes details of the delays experienced on the network, the fines that are levied and the number of delayed minutes caused. Analysis of this data provided a typical cost/delay-minute of 47.22 GBP (this value was derived by assuming that "capped" and "pinned" trains were billed separately). This figure is similar to the worst-case scenario, and implies that the project explored within Marquez et al. [10] will likely never break-even. Another implication of this calculated value is that the broader network would not benefit from such an expensive condition monitoring approach and that it might be reserved for the truly critical points of the network where traffic and the schedule 8 rates are both high.

Another issue that might be considered is that the initial cost of the RCM system is unfeasibly high. While this paper has sought (as closely as possible) to follow the calculations done by Marquez et al. [10] and used the equipment and installation costs as presented within that source. Further work should reveal if the switch actuator condition monitoring equipment cost of ~200k GBP are sensible.

It is perhaps worth noting that the paper of Marquez et al. [10] was published in 2008 and used data from 2006. Their analysis therefore has a rate of return of 8% and that represents a relatively booming economy, where return on investment is quite high. Considering the recession of recent years this rate of return might be considered inaccurate. Performing the calculations with a lower rate of return makes the RCM more feasible more quickly; indeed, "The pre-tax allowed Rate of Return for Control Period 5, to be used for the purpose of 3rd party investments carried out under the investment framework, is set at 4.93%" [12]. Lower expected rates of return helps to make projects quickly break-even. The effects of different rates of return might be considered more minor than the schedule 8 related costs-risk, however over a longer time period such risk could become considerable.

6. Conclusions

The method of how the Office of Rail Regulation sets targets at the network level is clearly of significance to decision making within the Rail industry. The Office of Rail Regulation can be assumed to examine past performance, but if there are models that are used to predict and forecast the networks behaviour these would be extremely interesting.

Considering the schedule 8 related cost-risk we might reasonably expect NR to respond by deploying projects with lower initial capital cost, particularly if the analysis indicates that the NPV is positive before the end of the CP. Such a reaction is clearly against the intention of the Office of Rail Regulation. The PPI is an important metric within Network Rail and the policy might be to deploy better

technology/methods into some applications knowing that the investment will not break-even.

To build further upon the analysis presented here a more detailed WLC cost estimate should be prepared and the cost-risk associated with denial of service considered. Then a more detailed method for assessment of value can be made for the approx. 60 year life-cycles expected.

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