A strategic decision-support tool for the risk-informed asset management of railway track infrastructure

Railways serve as a key sustainable mode of transportation for passengers and freight in urban, suburban, regional, and national contexts. With the rise in road traffic, which is seen as a less green form of transport and associated congestion, there is an increasing demand for railways to expand their capacity, availability and carry goods and passengers at ever higher speeds. Such increases in usage result in faster railway track degradation rates and higher maintenance costs.

As a result, the UK is projected to spend £18.5bn on operation and maintenance during 2019-24, an increase of 25% compared to the previous five years. Since maintenance funding is provided from the public purse, maintenance investments should be made in an equitable and transparent manner which maximises benefits to all stakeholders whilst minimising the costs to the environment.

Railway track condition, and therefore maintenance strategy, directly impacts track use costs, including train operation, accident, environmental and delay costs. Therefore, maintenance decisions can only be taken responsibly when the costs and benefits of maintenance alternatives (i.e., total railway transport costs) are compared on a long-term, whole-life-cycle cost (WLCC) basis.

Further, decisions and strategies for renewing, maintaining and operating railway infrastructure need to consider any ambiguities inherent in the data, including future uncertainties. In part due to the segregation of the railway

![Image 1: RITRAK's risk-informed approach to identifying economically justifiable track maintenance strategy](image-url)
industry, in which the management of the infrastructure is apart from the ownership and operation of rolling stock, existing asset management decision support tools in the railway industry tend to focus on particular elements of the system and do not perform such a holistic analysis.

To address this, a unique risk-informed decision support tool that uses a Whole Life Cycle Cost Analysis (WLCCA) approach under uncertainty has been developed to take into account the costs and benefits of track maintenance strategies to track maintainers, train operators, users and the environment. The concept of the approach is summarised in image 1 and the resulting tool, known as RITRAK, provides strategists and asset managers with an equitable and transparent means of evaluating the economics of maintenance strategies.

As illustrated in image 1, RITRAK adapts an approach where the (uncertain) costs and benefits of different candidate maintenance strategies are compared to achieve the most appropriate maintenance strategy ie the strategy with the lowest total railway transport cost. The WLCCA model at the heart of RITRAK considers the direct and indirect costs to all stakeholders and includes track construction; track inspection; track maintenance (realignment; ballast renewal and cleaning; routine maintenance); capacity loss; spillage; risk of derailments; train operation; environmental costs; transport mode change and end-of-asset-life value.

Changes in track quality over time due to track deterioration or maintenance are determined using a probabilistic based model. Monte Carlo simulation and Fuzzy Logic are used within RITRAK to deal with uncertainty through probabilistic risk assessment allied to expert opinion. Images 2-5 illustrate a number of windows within the web-based RITRAK tool. The tool features a user-friendly interface to upload datasets associated with track condition, track maintenance history and the whole lifecycle cost analysis (see image 2). The window showing the track deterioration model that predicts the track behaviour when subjected to different maintenance strategies is seen in image 3. The risk assessment window shown in image 4 captures experts’ opinions regarding the severity and probability of derailments associated with different maintenance strategies. The results are presented in a dynamic interface (image 5) that allows user-interaction and report downloads.

RITRAK can be used to support strategic planning and programming levels of railway asset management. For example, in the cases when there is a shortage in the annual track maintenance budget, RITRAK can be used to inform plausible maintenance strategies that realise the maximum benefit, in terms of minimising total railway transport costs, for the available budget. Senior managers and decision makers can also use RITRAK to improve long-term investment choices. For example, the tool allows the implications of reductions in maintenance budgets on total railway transport costs to be scrutinised and investment to be targeted to the areas of the railway network providing the greatest benefit.

The RITRAK tool was applied to case studies on three different routes on the UK mainline network (commuter, intercity passenger and mixed traffic routes) and demonstrated that economically-beneficial maintenance standards could be adopted if railway track use costs are considered, and by doing so validated the applicability and usability of the developed approach.

The annual train operation costs (fuel consumption and train maintenance costs alone) could rise by up to £500 per metre if the track quality deteriorated from good to poor condition. A sensitivity analysis was carried out to quantify the contribution of maintenance and track use to the total transport costs.
of a 200-metre-long track section. Image 6 presents the results of 10,000 possible scenarios generated using Monte Carlo simulations.

The analysis found that the environmental impacts of train operation (associated with CO$_2$, NO$_x$ and SO$_2$ emissions) due to deteriorating track quality had the highest contribution to the total railway transport costs (see image 6).

The analysis also indicated that approximately £6,400,000/year could be saved on the London to Birmingham route if a total railway transport cost approach is adopted to maintenance decision-making. The detailed results of these case studies are given in Sasidharan, Burrow and Ghataora (2020).

In summary, the whole-life-cycle, whole-system approach encapsulated within the RITRAK decision support tool, enables cost-effective railway track maintenance strategies to be determined which are transparent and equitable through consideration of the costs and benefits to all stakeholders and the environment. It is an essential component of any holistic asset management approach.

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A unique holistic decision support platform for risk-informed infrastructure asset management that considers costs and benefits to track and rolling stock owners and operators, users and the environment.

**OPTIMISATION PERFORMANCE METRICS**

- To predict track performance,
- Identify maintenance strategies
- Monitor safety and budgets

**SCENARIO ANALYSIS**

- To compare alternative maintenance strategies

**ENVIRONMENTAL IMPACTS**

- Of construction, maintenance, operation and renewal of track assets

**TRACK CONDITION**

- To predict changes in track performance over time

**RISK MANAGEMENT**

- To deal with uncertainties and risk in decision-making

**PERFORMANCE METRICS**

- To predict track performance, identify maintenance strategies and monitor safety and budgets

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