

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^{2,3}. 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 costs⁴. Therefore, maintenance decisions can only be taken responsibly when the costs and benefits of maintenance alternatives (ie 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

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of Birmingham and Research Associate at the University of Cambridge. He read for his PhD in Civil Engineering at the University of Birmingham by adopting a whole-life and whole-system approach to identifying cost-effective and risk-informed railway track maintenance strategies. Dr Sasidharan conducts research on developing risk-informed approaches and value-based decisions for managing and appraising investments for critical transport infrastructure. He is a recipient of the Prestige Award for Young Researchers from the World Transport Research Society.



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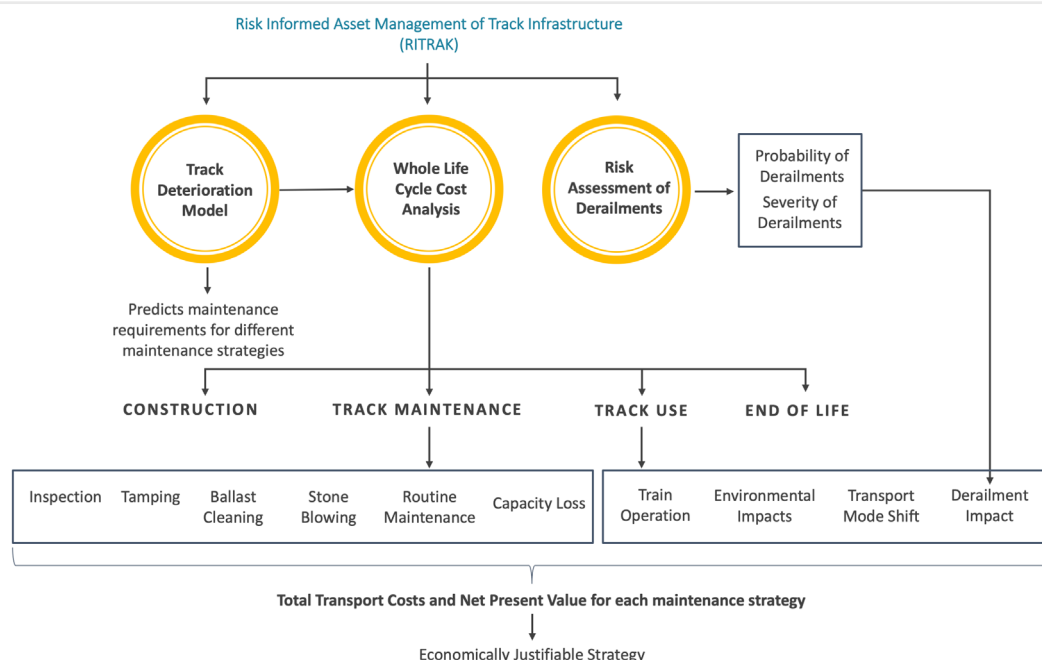


Image 1: RITRAK's risk-informed approach to identifying economically justifiable track maintenance strategy

Route Parameters		Data		Deterioration		Risk		Cost		Results	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100		NR Demo								Upload	
Construction		Section	Time	SD	Intervention						
Cost of land procured for track construction (per section)		0	Mon Feb 15 2010 05:00:00 GMT+0000 (...)	2.2							
Cost of operating equipment/machinery used for track construction (per section)		0	Mon Aug 09 2010 05:00:00 GMT+0100 (...)	2.6							
Average number of employees for operating a piece of equipment/machinery used for track construction		0	Mon Feb 21 2011 05:00:00 GMT+0000 (G...)	2.7							
Average employee cost for operating a piece of equipment/machinery used for track construction (per employee)		0	Mon Aug 15 2011 05:00:00 GMT+0100 (B...)	2.7							
Tamping		0	Tue Feb 21 2012 05:00:00 GMT+0000 (Gr...)	2.9							
Tamping Cost		0	Mon Sep 03 2012 05:00:00 GMT+0100 (B...)	3							
Stoneblowing		0	Tue Feb 26 2013 05:00:00 GMT+0000 (G...)	3.1							
Stoneblowing Cost		0	Fri Oct 25 2013 05:00:00 GMT+0100 (Brit...)	3							
Ballast Cleaning		0	Sat Jan 18 2014 05:00:00 GMT+0000 (Gr...)	3.1							
Ballast Cleaning Cost		0	Fri Aug 01 2014 05:00:00 GMT+0100 (Brit...)		BR						
Routine Maintenance		0	Fri Aug 08 2014 05:00:00 GMT+0100 (Bri...)	3.2							
Routine Maintenance Cost		0	Mon Mar 16 2015 04:00:00 GMT+0000 (...)	2.2							
Track Inspection		0	Thu Oct 01 2015 05:00:00 GMT+0100 (Br...)		TP						
Track Inspection Cost		0	Fri Oct 09 2015 05:00:00 GMT+0100 (Brit...)	2.3							
Track Inspection Cost		0	Tue Apr 05 2016 05:00:00 GMT+0100 (Br...)	2							
Track Inspection Cost		0	Tue Jun 28 2016 05:00:00 GMT+0100 (Br...)	2.7							
Ballast Removal		0	Sat Oct 01 2016 05:00:00 GMT+0100 (Bri...)		TP						
Ballast Removal Cost		0	Tue Feb 07 2017 05:00:00 GMT+0000 (G...)	2.5							
Ballast Removal Cost		0	Tue Mar 07 2017 05:00:00 GMT+0000 (G...)	2.5							
Capacity		0	Tue Apr 04 2017 05:00:00 GMT+0100 (Br...)	2.6							
Average delay cost for a train (per hour)		Previous		Page 1 of 2	20 rows	Next					

Image 2: Data entry-window for RITRAK

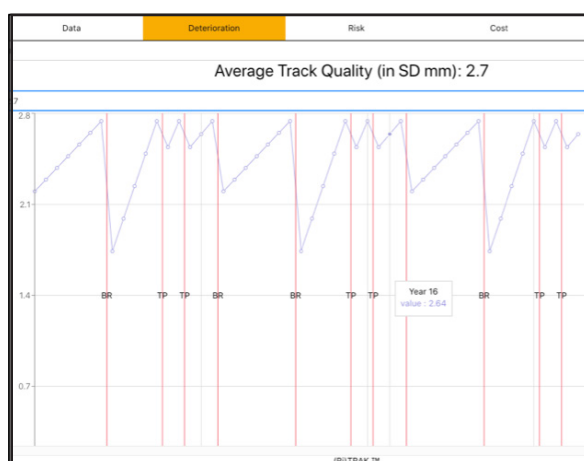


Image 3: Track deterioration modelling within RITRAK

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 is 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 opinion⁵.

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

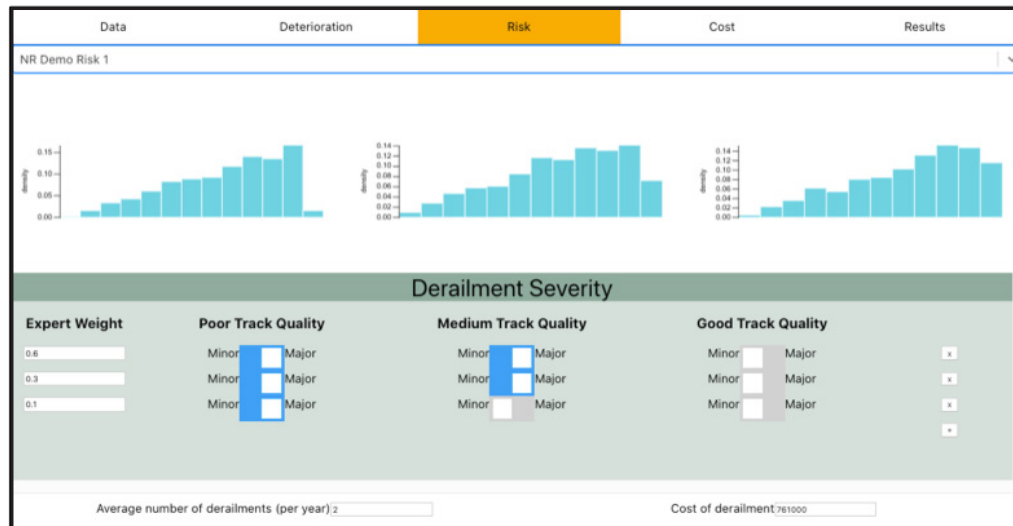


Image 4: Risk of Derailment model within RITRAK that captures expert opinion

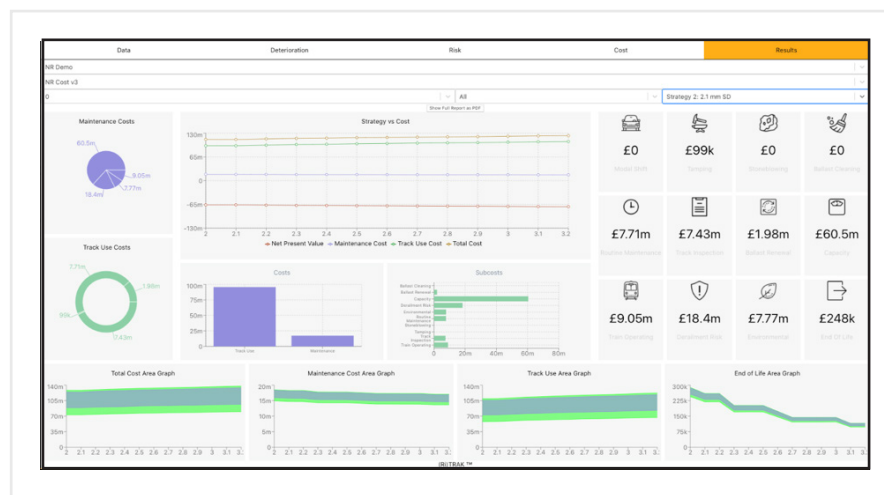


Image 5 Interface with results from the WLCCA employed within RITRAK

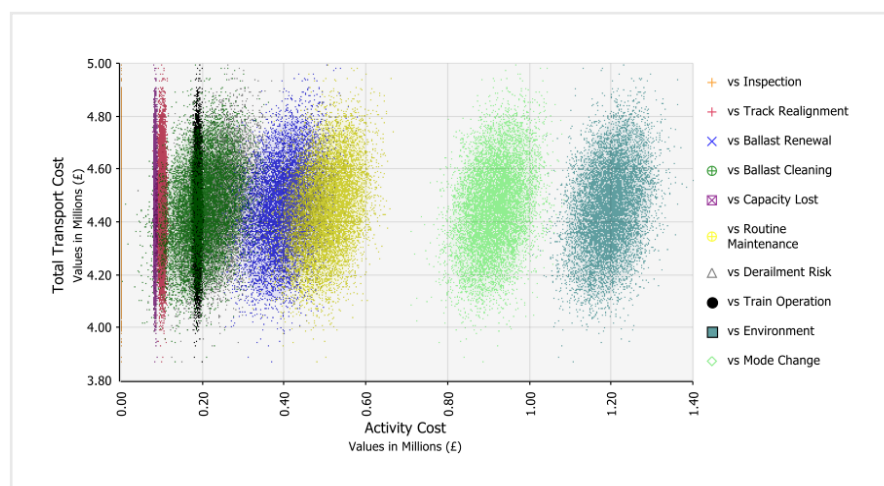


Image 6: Contribution of different whole-life-cycle cost elements towards the total railway transport costs

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 CO₂, NO_x and SO₂ 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)⁴.

In summary, the whole-lifecycle, 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.

ACKNOWLEDGEMENTS

The authors are grateful for the invaluable inputs from the RITRAK project steering group of Dr Mohammed Wehbi from Network Rail; Prof. Clive Roberts, Prof Nigel Cassidy, Dr Francesco Maria Colaccino, Dr Alan Tibbatts and Kate Jermy from the University of Birmingham; and Prof Simon Iwnicki from the University of Huddersfield. The development of RITRAK was funded through an EPSRC Impact Acceleration grant and by Intellex Consulting Services Ltd.

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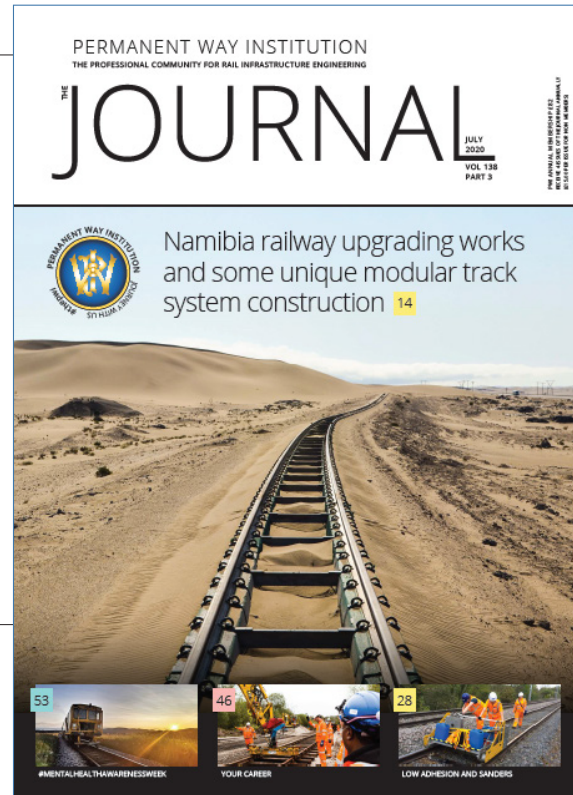
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TECHNICAL ARTICLE

AS PUBLISHED IN

The PWI Journal
July 2020

VOLUME 138 PART 3



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