



Managing Major Railway Risks Effectively through BOWTIE Risk Control Diagram and Application of Innovation and Technologies

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Topics: *Metro Operations and Maintenance, Risk Management*

Keywords: Innovation and Technologies, Risk Control and Management, Collaboration and Challenges, *Safety Culture*

Background / Context

Metro construction and operations and maintenance in Mainland China has been undergoing rapid network expansion and ongoing evolution in technology applications in the last decade, with over 12,000 km route length under operations as of 2025. This paper gives an account of the latest applications of Innovation and Technologies in Hangzhou MTR Corporation to uplift the safety standard of railway operations and maintenance through elimination and mitigation of those high-consequence risks, and using train derailment as a salient example for illustration. In addition, the consistent efforts and standardized application of BOWTIE risk diagram across MTR Corporation Mainland China Business Units to systematically analyse and chart all the causes and consequences linkages for each Major Risk Scenario will be described. These collective efforts have enabled structured and regular benchmarking of design, maintenance, organisation, procedural, human factors, environmental, and external control measures across different operating lines, thereby generating specific and relevant hindsight and insight to enhance the regular review of risk controls and management by each business unit.

Objectives

To demonstrate the application of simple-yet-structured BOWTIE risk diagram to effectively manage and visualize the underlying causes and multiple consequence scenarios of highly complicated railway major risk scenarios, and most importantly to drive regular risk reviews and inspire continuous improvement in risk control measures.

The train derailment scenario will be used for illustration of the application of BOWTIE risk diagram and also the latest innovation and technologies to effectively manage this top-risk, which is a common and tremendous safety challenge for all railway operators.

Methods / Approach

The BOWTIE method to construct risk diagram will be illustrated in the paper to demonstrate the ability of this methodology to document and visualise all types of causes and consequences of a highly



complicated risk scenario. It also demonstrates that this is a useful knowledge management tool to capture and assimilate all lessons learnt from internal and external incidents and near-misses.

Results / Findings

The integral “Five trackside and trainborne real-time train safety assurance systems” based on sound, vibration and temperature detection technologies and AI have enabled effective and collective monitoring of critical underframe equipment conditions for the entire train fleet thereby enabling early detection of equipment anomalies well in advance of its failure and thus effectively avoid major catastrophic failure due to hot or damaged axle-bearing etc. This has also enabled optimisation of maintenance strategy resulting in cost optimisation for wheel/rail interface related maintenance tasks.

Conclusions

The application of BOWTIE risk diagram as a core part of the Operations Safety Management and Risk Register System will enable effective integration and management of risks and control measures thereby enabling effective risk control review and efficient risk management process. The benchmarking of risk control measures has become an instrumental process in our safety meeting and recommended to be adopted as a tool for review of relevant safety and technical standards.

The use of “Five trackside and trainborne real-time safety assurance systems” has proven to be effective in safeguarding the health status of the train fleet and reducing the risk of train derailment to As Low As Reasonably Practicable (ALARP).



三 举措 Actions

第2步：引入智能化新技术——轮轨风险管控5宝

Step 2: Introduce intelligent new technology - 5 treasures of wheel rail risk control

TS – Trackside 轨旁
T – Trainborne 车载

<p>TS1 轨旁式轴承声学诊断系统 TS1-Acoustic diagnostic system for trackside bearings</p> 	<p>TS2 轨旁式温度成像检测系统 TS2-Trackside temperature imaging detection system</p> 	<p>TS3 车辆360°检测系统 TS3-Vehicle 360 ° Detection System</p> 
<p>T1 车载式振动/冲击/温度检测系统 T1-Vehicle mounted vibration and temperature detection system</p> 	<p>T2 车载式轨道几何尺寸检测系统 T2-Vehicle mounted track geometry dimension detection system</p> 	



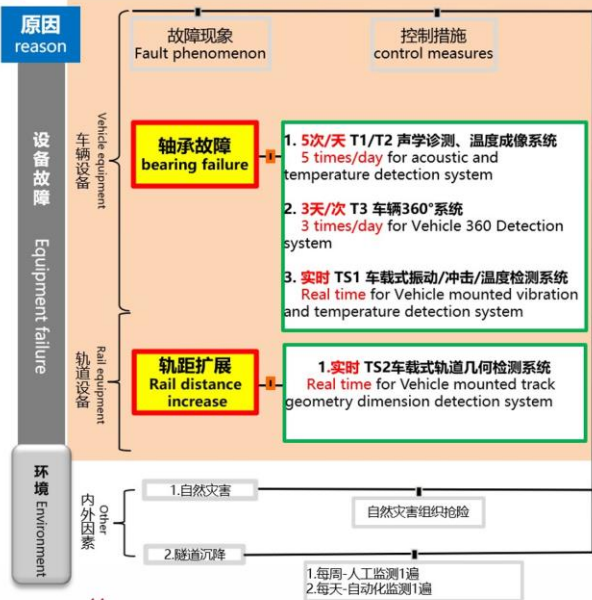
三 举措 Actions

第3步：优化维修体系

Step 3: Optimize the maintenance system

以“列车脱轨Bowtie分析图”为例，通过5宝进行故障排查、分析、运营联动：

Adoption Bowtie diagrams to demonstrate the advantage of the 5 Treasures in reduce at the risk of derailling.



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