AI-Powered Prescriptive Track Maintenance Decisions From Ore Car Performance Measurement

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Introduction

Track geometry faults have a direct impact on safe passage of rolling stock through heavy haul networks. Track geometry standards of each network provide guidelines for maintenance and operational interventions to control the risk borne from the track geometry faults. They inform inspection, speed restriction and maintenance on the network based on track geometry amplitude thresholds. However, there have been numerous cases where this has proved ineffective in controlling derailment risk. A number of derailments in the past have occurred where the track geometry thresholds have not been exceeded.

This indicates the complexity in how the track geometry drives derailment risk. Derailment risk is not a mere function of track geometry amplitude, also depends on the wavelength, combination with other faults and specifically the dynamic characteristics of the rolling stock. In recognition of this shortfall a number of railway operators utilise performance based measurement from instrumented ore cars (IOC) to assess risk (Reichl, Ribeiro and Santos 2015) . This has resulted in the operators having a voluminous source of track geometry and vehicle performance data.

This research explores the possibility of the using the two data sources to build an AI model to understand the key track geometry characteristics that drive derailment risk. The objective of the research was to develop a model which takes in track geometry vehicle (TGV) measurements and operational speed to predict the sections at which the wagon would be at risk due to high vehicle dynamics. The research also aims to get the model to prescribe the required speed restriction to pass through the section safely and also the geometry corrections required to not impose speed restrictions.

Experimental work

Figure 1 shows the key steps in building a prescriptive model (Mehranfar, Adey et al. 2025)from the measured track geometry and instrumented ore car data. Figure 2 shows spatially aligned IOC and TGV data. The key step was to develop features from the measured geometry data. This was informed from the vehicle track interaction understanding. In addition to track geometry amplitude, the model also used wavelength of the faults, the phase difference between faults and the energy accumulated at different frequencies over a length of track as input features.

A decision tree model was trained with different features as inputs and vehicle dynamic response as the output. In particular, the bounce measurement was used as the vehicle dynamic response to be predicted.

Results

The model performance was evaluated against data from a 50 km section of track. Figure 3 shows the key inputs to the model, namely, top geometry (and associated features and desired operational speed. The model predicted 4 sections in the region where the bounce amplitude would be greater than the safety threshold (see figure 4 (a). Comparing this to the IOC data, showed that 1 of the prediction section did in fact result in an IOC bounce measurement above the safety threshold. The other 3 regions were within 10% of the safety threshold, proving the models reliable and adequately conservative nature. The model also prescribed the recommended speed profile over the region to contain the vehicle dynamics withing the region to safe limits. The recommended speed profile was used in a multi-body dynamic simulation to verify that it did in fact reduce the wagon bounce response to less than 80% of the safety threshold.

Conclusions

This research demonstrates how valuable track geometry and wagon dynamics data available to heavy haul operators can be used to build a prescriptive model to recommend safe operational speeds and track geometry corrections to ensure safety and productivity of the networks.

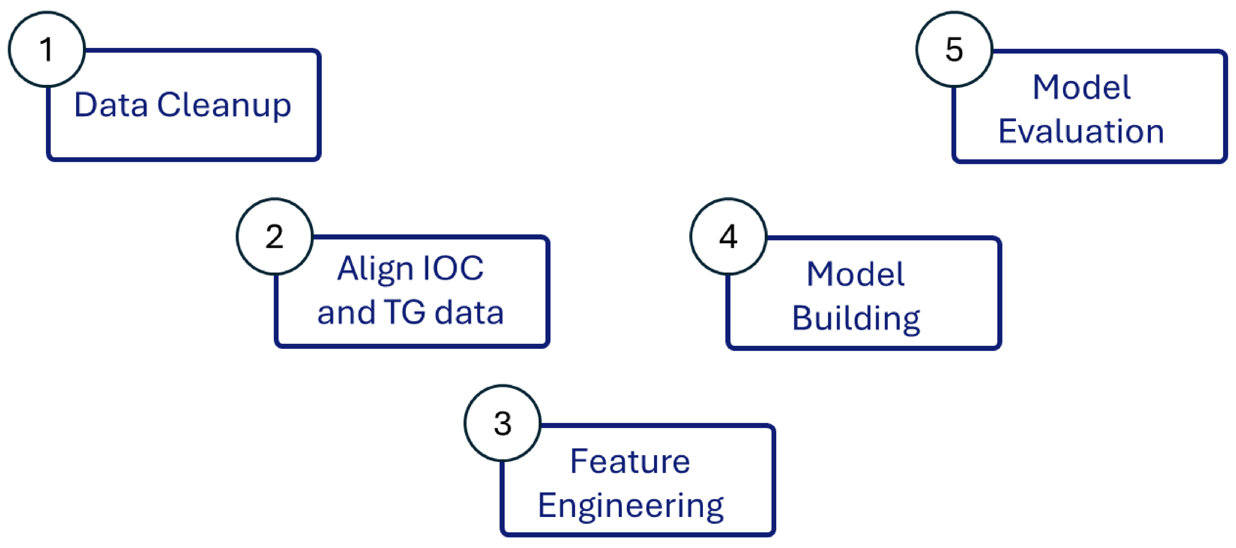

Figure 1. Steps in building a prescriptive model

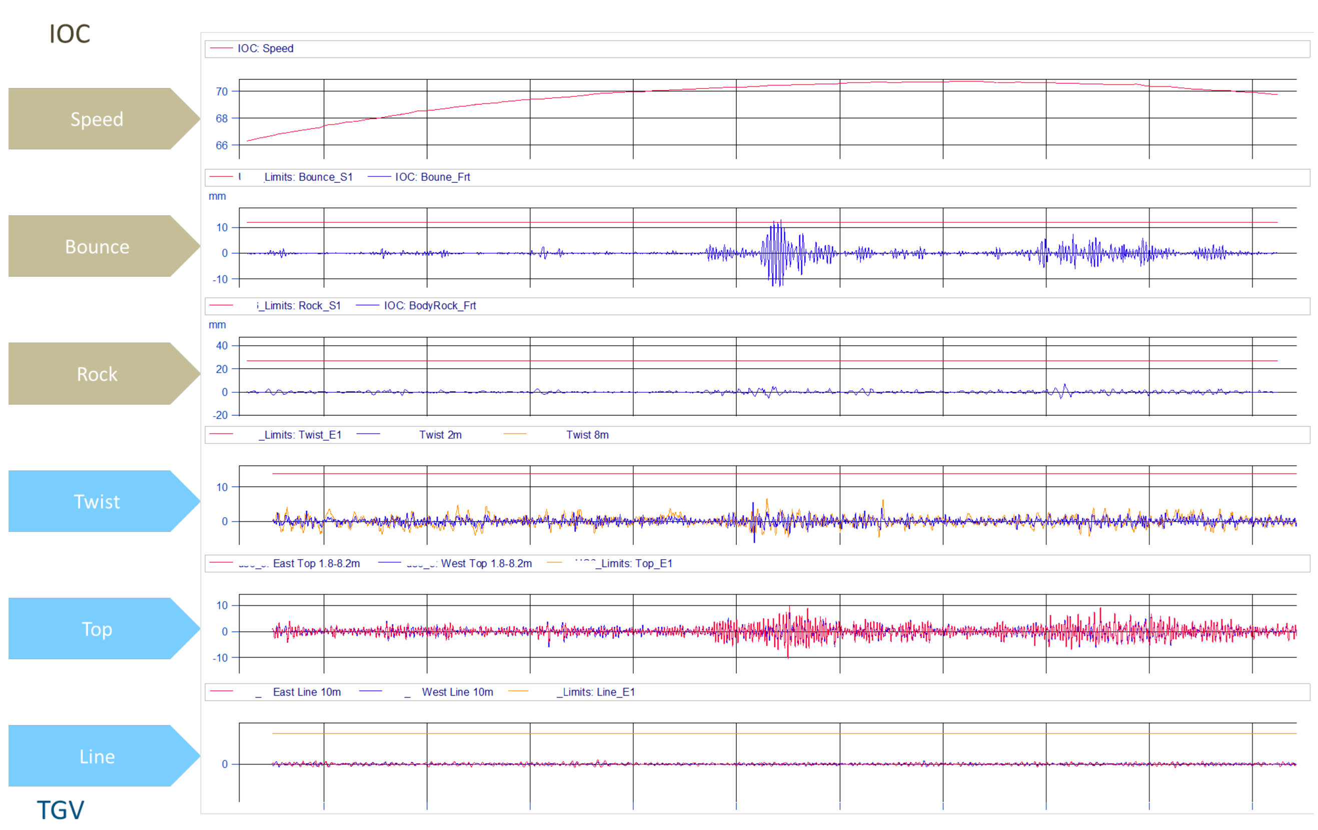

Figure 2. Aligned TGV and IOC data

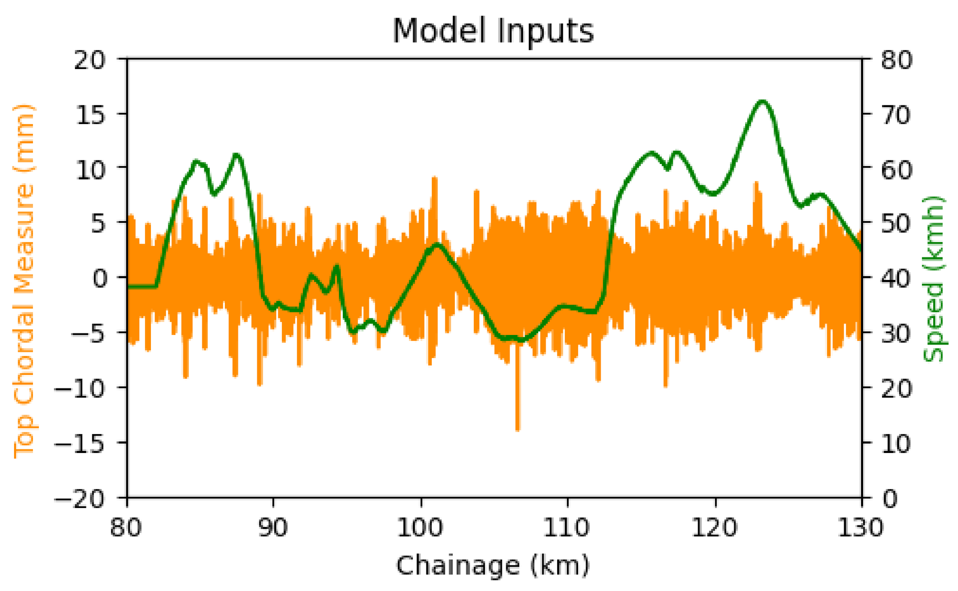

Figure 3: Inputs to the prescriptive model

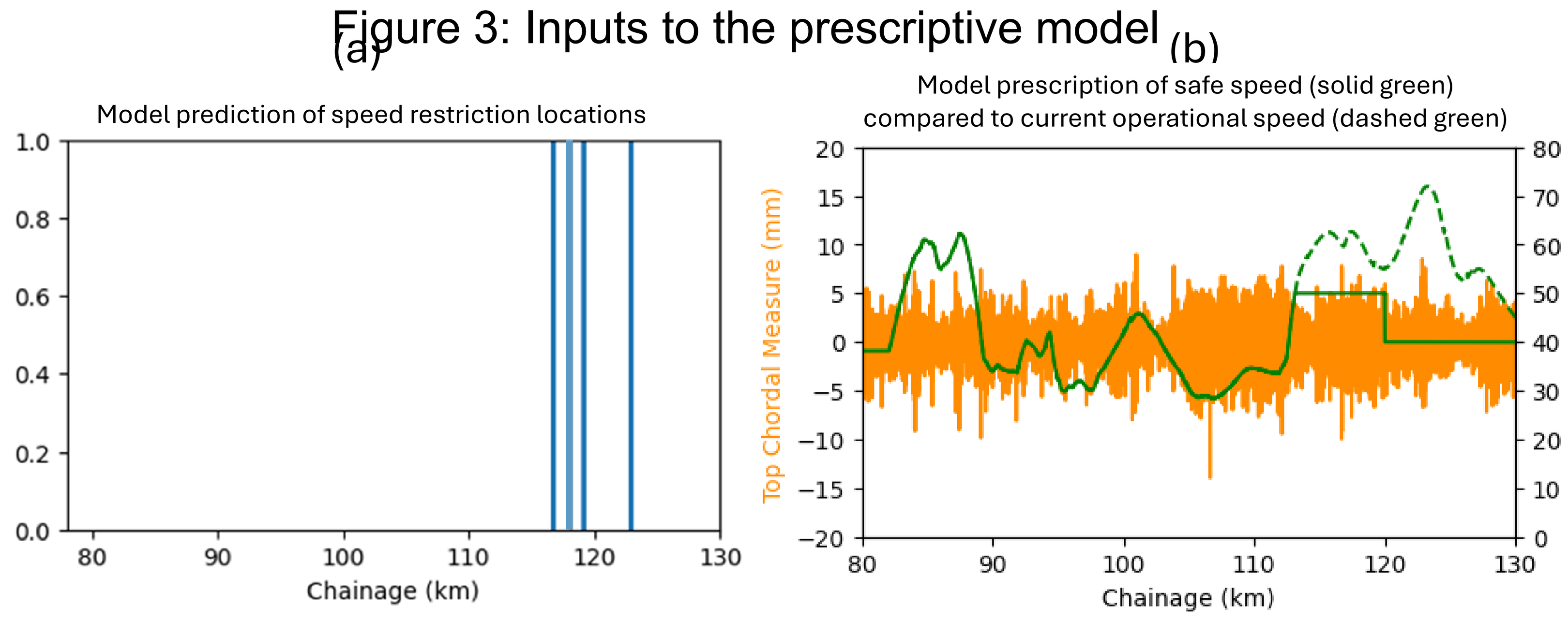

Figure 4: Prescriptive model outputs of sections requiring speed restriction and prescribed speed through the section of track

References

Reichl, P., et al. (2015). Improving the Efficiency of Vale's EFC Line Through the Use of Continuously Measured Operational Data, IHHA.

Mehranfar, H., et al. (2025). "Enhancing Railway Track Intervention Planning: Accounting for Component Interactions and Evolving Failure Risks." Infrastructures (Basel) **10**(5): 126.

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