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Scenario Description, Barrier Model and Human Factor Classification to Analysis Freight Train Derailments, Part II: Case study

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Abstract: The background part of this work was firstly to learn the history of incident data at the SMIS and AEAT Rail derailment database, attributed to the causal factors analysis and the preliminary statistics process.

The review of the vehicle acceptance test included the Y/Q derailment criterion and the bogie rotation inspection demonstrated the major technical reason; The track geometry deterioration model was calculated in the Markov Chain transition probabilistic model.

The work explained the case analysis in the Porthkerry derailment: the track Vertical Longitudinal Split (VLS) failure mechanism study; the Heworth derailment: the track geometry degradation and Human Reliability Analysis (HRA); the Camden derailment: the freight train unevenly loading derailment compliant to the standard intervention.

Keywords: System Theory; Track Geometry Deterioration; Barrier Model; Performance Shaping Factor; HEART

1 Introduction

In the RAIB reports, there were at least 10 incidents due to the defective switch and crossing; and 12 derailment incidents at the S&C due to the vehicle exposed to the poor track geometry, if the RAMS standards and practical data analysis be the consequence? (according to the RAIB original investigation).

From 1992 to 2001, the RSSB T357 (2006) reported that in the derailment risk analysis in statistics, poor loading was the most common principal factor, but the rapid deterioration of track quality was a causal feature. If the author could learn from the incident, for:

1) Perform the operational integration and human response audit.

2) Large-scale experimental focus on the track geometry deterioration model.

2 Aim and Key objectives

The research aim of the work was: to analyse the causes of freight train derailments using the scenario method, barrier description and performance shaping factors evaluation.

1.To quantify the failure probability of individual barriers and understand each barriers' system reliability through the generic task unreliability and error-producing condition (EPC).

2.To use a traditional probabilistic model (Markov Chain) to predict the railway geometry system deterioration and the impact on safety.

3 Case study

1) Porthkerry derailment

A loaded coal train derailed at Porthkerry on 2 October 2014, in South Wales on the Vale of Glamorgan line. Train loaded with coal at Avonmouth Docks, and then the train passed over a wheel load monitoring installation at Marshfield; data showed the wagon has unevenly loaded. However, the front train passed the site at 16.5 mph, the first 19 wagons passed over the defective rail; therefore, the 20th wagon ran onto the defective left rail when the field side of the rail head broke.

• The cause of the derailment was the failure of a section of the left-hand side rail due to a metallurgical defect within that rail. The defect arose due to impurities within the steel which had been present since manufacture;

• The track repair actions could improve the track quality;

• The RCF site investigation play key role in the Porthkerry derailment;

• The UTU and verification as the latent failure in the functional barrier system.

The precursor indicator model broken track subsection demonstrated that the annual FWI due to the broken fishplates, broken rails, buckled rails, gauge faults, switches and crossing faults, and track twist & geometry faults. The broken rails (in the Porthkerry derailment), the S&C faults and track twists are the most severe factors from April 2010 to April 2016 listed below (RSSB).

To learn the failure mechanism: the critical defects could lead to the rail being broken: Banverket (1998) established that the transverse fracture occupied 44.1%, vertical split 19.4%, welded joint 19.4% and horizontal defect 17.2% (Kumar, 2006).

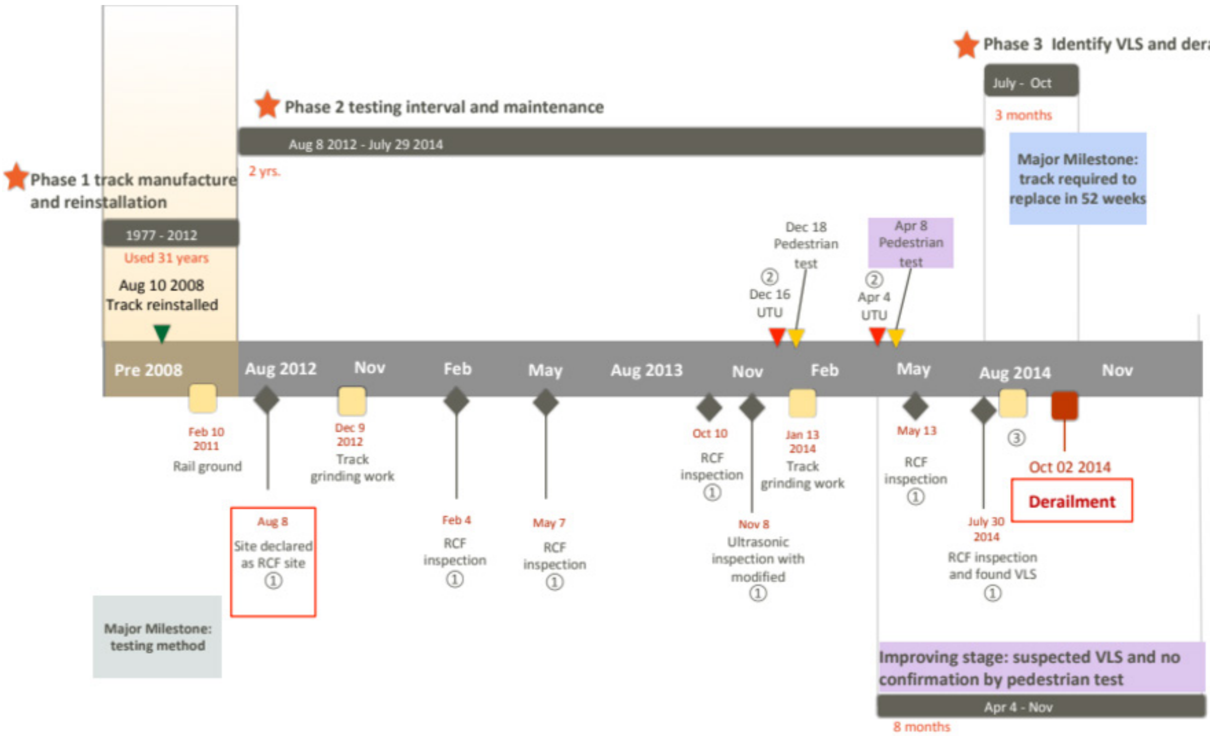

FIGURE 1 Porthkerry Derailment Timeline

2) Heworth Derailment

23 October 2014, the accident happened when a train travelling at 51 mph passed through Heworth station. The derailment was caused by wagon worn suspension component, the track geometry deterioration and human unreliability to prevent the incident consequence. There are barrier model and timeline descriptions including the Plain time Pattern Recognition (PLPR), the basic visual inspection, track geometry recording train, track maintenance engineering (TME), Vehicle inspection and Brake Test (VIBT), speed restriction, and track drainage improvement.

In the study of the track degradation analysis, following 50-55 mph of train speed, the measurements of the SD value and track geometry quality are:

i. Top = 3.5 (mm) good

ii. 3.5 to 5.0 satisfactory

iii. 5.0 to 5.9 poor

iv. 5.9 to 6.3 very poor

v. 6.3 maximum = super-red level TSM inspection in 14 days, immediate 30 mph emergency speed restriction and correct within 36 hours.

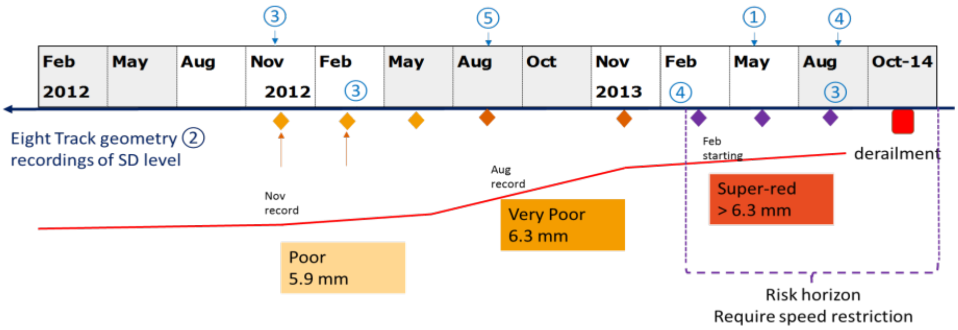

FIGURE 2 Track geometry deterioration in the Heworth derailment

The standard deviation stated in the GC/RT 5021: The Standard Deviation (SD) is the universally used scientific measurement of the variation of random processing. The vertical and horizontal track profile data have been found similar to the statistical calculation of the magnitude of track irregularities by obtaining the SD measurement level.

$$Standard\ Deviation\ \sigma = \sqrt{1/n \sum_{j-1}^{n} x_{ij}^2 - \bar{x}_i^2}$$

$$TQI = \sum_{i=1}^{7} \sigma_i$$

The track quality index (TQI) combined seven the deviation levels for the track alignment (1), the twist measurement (2), the gauge (3), the left/right longitudinal (4-5), the left/right alignment (6-7), and the cross-level.

According to the accident report 16/2015, the track geometry recording train on the Down Sunderland line recorded the standard deviation (SD) for the vertical value in each eight-mile section. In the historical record, from the 99 miles 220 yards to 99 miles 440 yards, the track had fallen into 'very poor' from August 2013. In 2014 Feb, the record shown the track geometry was 'super-red' level (Figure 3).

From the year of 2011/12 to the 2014/15 financial year, the track geometry recording train identified track geometry faults on the LNE route, the number of defects requiring correction: Newcastle route (about 500 defects), Doncaster route (about 300) and Sheffield route area (about 200) respectively. Three percentages of eighths in the one-mile section of track fall in the 'super-red' level in the Newcastle area.

3) Camden Derailment

The derailment accident happened on 15 October 2013; the train 4L77 was travelling from Birmingham Lawley Street to Felixstowe freight port derailed at Camden road west junction. The accident reasons were the vehicle's lateral and longitudinal imbalance leading to asymmetric loading negotiated with track twist conditions. The combination of the vehicle and track conditions caused reducing the vehicle's resistance to flange climb.

According to the accident report, for the load condition of the derailed wagon, 'the 20ft container was loaded with scrap electrical machines and had a gross weight of 28.83 tonnes; the empty 40ft container on the rear of the wagon weighed 3.88 tonnes.' The information was shown that 'the offset in the centre of gravity of the 20ft container towards the front of the wagon, with the longitudinal eccentricity 3-4\%'. Concerning the analysis report, there was a longitudinal weight ratio of 2.7:1.

4 Discussion

The large scale experimental: example of the SD level calculation based on the track geometry recording data (2013-2014, 70 mileages, at LEC1 2100). The Markov Chain transition matrix could be established the track deterioration probability from the slightly, medium to the severe deterioration state.

In order to understand the track geometry monitoring, the first step is trying to calculate the track standard deviation, and based on the transition matrix to assess the feasibility of the model through the comparison between prediction value and accurate track geometry recording:

$$\begin{bmatrix} S_1 \\ \vdots \\ S_n \end{bmatrix}^k = \begin{bmatrix} P_{11} & \cdots & P_{1N} \\ \vdots & \ddots & \vdots \\ P_{n1} & \cdots & P_{nn} \end{bmatrix} \begin{bmatrix} S_1 \\ \vdots \\ S_n \end{bmatrix}^{k-1}$$

and

$$P_{ij} = P(S^k = i | S^{k-1} = j)$$

$$\sum_{i=1}^{n} P_{ij} = P_{1j} + P_{2j} + \cdots + P_{nj} = 1, (j = 1, 2 \ \ldots n)$$

The track irregularities (track twist) were derived from the characterization, the track recording vehicle, the specification for the measuring device, and the geometric quality assessment (EN 13848-1). The twist measurement was taken simultaneously at the fixed distance; it showed the different gradients between the two points. The algebraic difference between the defined distance of the two cross-levels, which specify equivalent to the wheel-base distance, and the consecutive measurement of the cross-level were calculated. The probabilistic transitions model based on the matrix is illustrated.

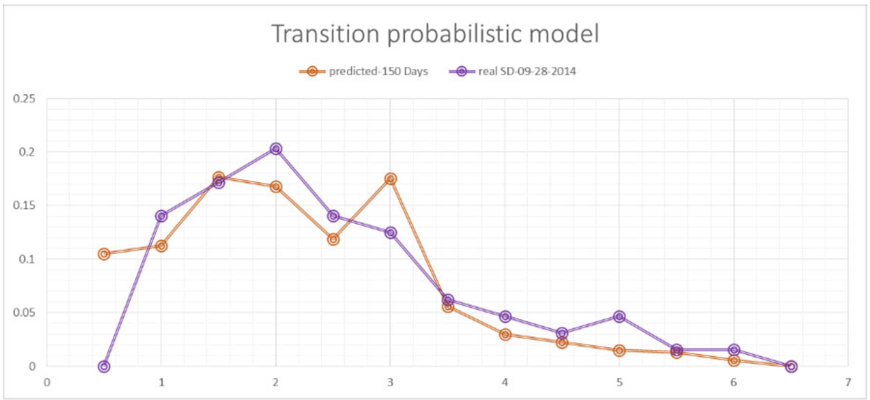

FIGURE 3 Track geometry deterioration model

The iterations shown above for the transition for the standard deviation depicted the comparison between predicted degradation and real-time recorded Standard Deviate (SD) value.

With respect to the Low Carbon Freight Modelling strategy from 2023 to 2050, the author basically surveys the technical reasons, firstly through the understanding of physical experiments, such as, compilation of the track geometry degradation model, the fatigue reliability prediction methods and the survival analysis. The main failure modes of the system are identified and the system failure probabilities could be calculated.

5 Conclusion

Firstly, there are investigations of the derailment mechanism, for instance, the track geometry deterioration, the track twist, the degradation at switches and crossing, the track void, the vehicle frame twist, the suspension characteristics, the friction liner performance and case studies to learn the technical reasons.

Secondly, the work concluded the quantitative analysis based on the state transition model (track geometry recording data), and the qualitative analysis to demonstrate HEART and cognitive reliability understanding of the performance shaping factors in the normal vehicle/track maintenance regime.

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