Cross Industry collaboration to control the risk of freight wagon derailment

Dr Gareth Tucker
9/11/17
Institute of Railway Research

- Have a strategic partnership with RSSB (currently in contract until 2020)
- Based in University of Huddersfield
- Established 2012
- 35 fulltime staff
- Research and industry consulting:
  - Vehicle and track dynamics
  - Civils and track structure
  - Big data analytics and RCM
  - Railway Safety and Risk
  - Technology Development and Innovation
  - Advanced testing facilities
Container wagons and twisted track

Oct 2008 Duddeston Jn
Feb 2009 Ditton
Jan 2012 Reading West
May 2012 Felixstowe South

2012 RSSB/TRL Risk assessment container traffic
2012 FTC GOTCHA working group
October 2013 Camden Road Derailment
October 2014 Camden RAIB report published
December 2014 ORR Letter to industry
January 2015 XIFDWG established
March 2015 ORR seminar on container traffic derailment risk
August 2017 Ely derailment
18 August 2017 at 6:08pm

Cost of freight train derailment could top £1 million

Rail experts say the cost of the freight train derailment near Ely could top £1 million. Credit: ITV News Anglia
Cross Industry Freight train Derailment Working Group (XIFDWG)

Freight Technical Committee/National Freight Safety Group

↓

XIFDWG
ISO shipping containers
60 foot container wagon
RAIB recommendations being address by XIFDWG (summarised)

RAIB report 21/2014 (Camden Road)
Freightliner and Network Rail should request that RSSB:

a) Researches factors that increase the probability of derailment when container wagons are asymmetrically loaded

b) updates and amends the risk assessment in RSSB/TRL report on container wagon risk

c) evaluates and promotes adoption of any reasonably practicable mitigations

RSSB should amend GM/RT2141 to refer to asymmetric loading

RAIB report 11/2015 (Angerstein Junction)
Network Rail should liaise with RSSB to review whether a 3 m base for measuring track twist is sufficient

Network Rail should review the potential to use WIM (GOTCHA) to monitor uneven loads
Risk controls

Container Packing Rules

£?
Taking safe decisions
Control measures: track

• GCRT5021
  – Cant gradient (i.e. design twist) limit – 1:400
  – Track twist maintenance intervention limit (3m) – 1:200 (within 7 days)
  – Twist absolute limit 1:90

Camden Road twist: 1:160
Control measures: vehicle

- GMRT2141 Appendix A Wheel Unloading on twisted track test
  - Wheel unloading ($\Delta Q/Q$) limit of 0.6 when subject to specified twist
  - Load case not specified

Tare FEA $\Delta Q/Q = 0.44$
Control measures: container load

- IMO/ILO/UNECE Guidelines for packing of Cargo Transport Units (CTUs)
- BS 5073
  - Loads shall be evenly distributed inside containers
  - Loads shall be secured within the containers
RSSB bowtie work shop

XIFDWG priorities

• Do we really understand the residual risk of flange climb derailments due to laterally offset loads and track twist? Are some wagon designs more susceptible?
  - IRR/110/125 Wagon Derailment Frequencies
  - IRR/110/126 Body Torsional Stiffness Study

• How often are containers loaded with non-central CoG, and how severe is the offset?
  - IRR/110/153 Review of GOTCHA outputs
  - NR GOTCHA review
  - T1112 Port container survey

• Is there a benefit in changing track maintenance standards?
  - IRR/110/139 Track twist baselength assessment

• What is the margin of safety built into vehicle acceptance standards?
  – Is there a benefit in changing vehicle acceptance standards?
  - IRR/110/159 GMRT2141 results vs derailment propensity
  - T1119 Simulation of wheel unloading
How to assess risk?

Risk = likelihood x consequence
- Safety risk
- Risk of damage to assets

Historic data?

Assessment of causal factors?
# Probability – can you predict the future?

<table>
<thead>
<tr>
<th>Date</th>
<th>Balls Selected</th>
</tr>
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<tbody>
<tr>
<td>19/11/2016</td>
<td>5 7 8 16 28 37</td>
</tr>
<tr>
<td>26/11/2016</td>
<td>1 2 28 40 48 49</td>
</tr>
<tr>
<td>03/12/2016</td>
<td>3 8 9 19 21 54</td>
</tr>
<tr>
<td>10/12/2016</td>
<td>11 26 31 32 33 46</td>
</tr>
<tr>
<td>17/12/2016</td>
<td>2 11 18 32 40 54</td>
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<tr>
<td>24/12/2016</td>
<td>16 19 29 46 54 58</td>
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<tr>
<td>31/12/2016</td>
<td>10 17 35 41 51 54</td>
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<tr>
<td>07/01/2017</td>
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<td>21/01/2017</td>
<td>4 13 37 40 52 58</td>
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<td>28/01/2017</td>
<td>5 21 23 34 43 45</td>
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<td>04/02/2017</td>
<td>6 9 27 30 40 50</td>
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<td>04/03/2017</td>
<td>24 38 39 40 49 56</td>
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<td>11/03/2017</td>
<td>6 15 23 29 55 57</td>
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<td>18/03/2017</td>
<td>12 20 22 25 44 59</td>
</tr>
<tr>
<td></td>
<td>8 16 23 38 40 54</td>
</tr>
</tbody>
</table>

- **Pick 6 balls from 49**
  - 1:13,983,816
  - Probability of winning: 0.0000000222
  - Typical win: £10,000,000
  - Value of (positive) risk: £0.22
  - Cost of investment: £2

- **Pick 6 balls from 59**
  - 1:45,057,474

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**Unseen:**

- 26/11/2016 1 2 28 40 48 49
- 03/12/2016 3 8 9 19 21 54
- 10/12/2016 11 26 31 32 33 46
- 17/12/2016 2 11 18 32 40 54
- 24/12/2016 16 19 29 46 54 58
- 31/12/2016 10 17 35 41 51 54
- 07/01/2017 8 16 33 36 45 51
- 14/01/2017 14 19 21 36 53 54
- 21/01/2017 4 13 37 40 52 58
- 28/01/2017 5 21 23 34 43 45
- 04/02/2017 6 9 27 30 40 50
- 11/02/2017 15 18 23 42 43 52
- 18/02/2017 17 23 28 38 47 56
- 25/02/2017 18 24 34 38 41 49
- 04/03/2017 24 38 39 40 49 56
- 11/03/2017 6 15 23 29 55 57
- 18/03/2017 12 20 22 25 44 59
- 8 16 23 38 40 54
• Safety Management Intelligence System (SMIS)
  – Database of safety related incidents
  – Updated with ~75,000 events pa
  – Includes all record of all derailments since 2000
    • Contains ‘Immediate Cause’ and ‘Secondary Cause’ fields for each incident

• Safety Risk Model
  – Quantitative representation of potential incidents
  – Uses SMIS as an input
  – Includes ‘expert judgement’ for risk of high severity low frequency events
Safety Risk Model

- 140 FWI pa
- Train accidents (collisions and derailments) 3.5 FWI pa
- Average safety consequence due to 1 freight train derailment:
  » 0.025 FWI
### Cost of damage due to derailments

**Data from D-Rail analysis 2005 - 2010**

<table>
<thead>
<tr>
<th>MAJOR COST DERAILMENTS:</th>
<th>events count</th>
<th>Infrastructure &amp; assets costs</th>
<th>Operational delay costs</th>
<th>Non-infrastructure manager costs (e.g., train operating companies, etc.)</th>
<th>total cost</th>
<th>average cost per derailment</th>
</tr>
</thead>
<tbody>
<tr>
<td>b. Spring &amp; suspension failure</td>
<td>2</td>
<td>£9,500,000</td>
<td>£3,500,000</td>
<td>£0</td>
<td>£13,000,000</td>
<td>£6,500,000 *</td>
</tr>
<tr>
<td>Cause not established</td>
<td>12</td>
<td>£4,844,481</td>
<td>£2,509,891</td>
<td>£1,626,516</td>
<td>£8,806,988</td>
<td>£748,416 *</td>
</tr>
<tr>
<td>f. Other or unspecified track geometry causes</td>
<td>2</td>
<td>£3,922,415</td>
<td>£795,774</td>
<td>£2,058,684</td>
<td>£7,776,873</td>
<td>£3,888,737 *</td>
</tr>
<tr>
<td>a. Excessive track twist</td>
<td>3</td>
<td>£712,945</td>
<td>£1,195,273</td>
<td>£75,000</td>
<td>£1,983,219</td>
<td>£661,073 *</td>
</tr>
<tr>
<td>Failure to carry out Rules/Instructions/SSOW</td>
<td>5</td>
<td>£254,097</td>
<td>£895,069</td>
<td>£120,000</td>
<td>£1,233,166</td>
<td>£246,632 *</td>
</tr>
<tr>
<td>d. Failure of rail support and fastening</td>
<td>2</td>
<td>£14,336</td>
<td>£521,549</td>
<td>£0</td>
<td>£535,895</td>
<td>£267,993 *</td>
</tr>
<tr>
<td>e. Excessive track width</td>
<td>2</td>
<td>£360,955</td>
<td>£55,263</td>
<td>£70,000</td>
<td>£442,218</td>
<td>£221,109 *</td>
</tr>
<tr>
<td>2. Improper loading of wagon</td>
<td>1</td>
<td>£106,255</td>
<td>£247,277</td>
<td>£0</td>
<td>£753,532</td>
<td>£753,532 *</td>
</tr>
<tr>
<td>Inadequately performed maintenance task - other</td>
<td>1</td>
<td>£8,405</td>
<td>£123,333</td>
<td>£0</td>
<td>£130,738</td>
<td>£130,738 *</td>
</tr>
<tr>
<td>4. Other infrastructure failure</td>
<td>1</td>
<td>£104,250</td>
<td>£5,000</td>
<td>£0</td>
<td>£109,250</td>
<td>£54,625 *</td>
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<tr>
<td>c. Switch component structural failure</td>
<td>1</td>
<td>£79,000</td>
<td>£20,314</td>
<td>£0</td>
<td>£99,314</td>
<td>£99,314 *</td>
</tr>
<tr>
<td>7. Other operational failure</td>
<td>1</td>
<td>£0</td>
<td>£97,013</td>
<td>£0</td>
<td>£97,013</td>
<td>£97,013 *</td>
</tr>
<tr>
<td>b. Other mishandling of train including driver caused SPAD</td>
<td>1</td>
<td>£17,695</td>
<td>£77,020</td>
<td>£0</td>
<td>£94,715</td>
<td>£94,715 *</td>
</tr>
<tr>
<td>a. Axle ruptures</td>
<td>1</td>
<td>£20,000</td>
<td>£2,527</td>
<td>£0</td>
<td>£22,527</td>
<td>£22,527 *</td>
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<tr>
<td><strong>TOTAL Major cost derailment events</strong></td>
<td><strong>36</strong></td>
<td><strong>£19,960,834</strong></td>
<td><strong>£10,018,403</strong></td>
<td><strong>£3,950,300</strong></td>
<td><strong>£33,869,537</strong></td>
<td><strong>£940,820</strong></td>
</tr>
</tbody>
</table>

#### LOW COST DERAILMENTS:

Cost data for low cost derailments are not recorded separately so cannot be matched to cause types.

We can assume that these are all below £78,000, based on initial estimates (this is the threshold for cost recording).

We assume that the average for these is £37,500 and that the costs are split in the same proportions as for major derailment events.

<table>
<thead>
<tr>
<th>TOTAL Low cost derailment events</th>
<th>286</th>
<th>(£3,341,272)</th>
<th>(£1,272,390)</th>
<th>(£625,887)</th>
<th>(£37,500)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(estimated)</td>
<td></td>
<td>(estimated)</td>
<td>(estimated)</td>
<td>(estimated)</td>
<td>(assumed)</td>
</tr>
<tr>
<td>TOTAL events (Major and low cost events)</td>
<td>322</td>
<td>(£26,262,587)</td>
<td>(£13,190,793)</td>
<td>(£5,201,187)</td>
<td>(£44,594,537)</td>
</tr>
</tbody>
</table>
Risk of derailment for container wagons with asymmetric load

**NB RSSB are now updating this analysis**

Safety risk = $0.7 \times 0.025 \times 1748000 = £24472$

Risk of damage = $0.7 \times 661,073 = £462,750$

Total risk = £487,000 pa?
• Survey of container load eccentricity from port cranes
• 240,000 containers measured
• 22,700 20’ with a mass > 20t

0.01% of 20’ container with a mass > 20 tonnes lateral offset worse than Camden Road
Is an additional track twist baselength required?

- Track twist is a relative change in the cross level between two running rails along the length of the track
  - It can be measured as the variation in cross level between two locations a fixed distance apart (i.e. the twist measurement base length)
  - The measured twist can be specified as either the absolute difference in cross level, or a twist gradient.
- GCRT5021 and NR/SP/TRK/001/C01 specify track twist intervention limits based on gradients measured of a 3m base length
- Is there any benefit in adding an additional twist assessment base length?
Measuring twist over a different baselength?

**Twist intervention limits in EN13848-5 (twist gradient)**

- **Twist gradient (mm/m)**
  - Measurement baselength (m)
  - Graph showing twist gradient changes over baselength.

**Twist intervention limits in EN13848-5 (total twist)**

- **Total twist (mm)**
  - Measurement baselength (m)
  - Graph showing total twist changes over baselength.

Localised dip on cant gradient (design cant gradient 1:400)

- **Z_{0R} = -22.5mm**
  - **T_3 = 1:200, T_6 = 1:267**

- **Z_{OR} = -15mm**
  - **3m twist = 1:200**
  - **2m twist ≈ 1:130**
Primrose Hill / Camden Road track geometry

Curvature

Cross Level

2m Twist Wavelength

3m Twist Wavelength

13.94m Twist Wavelength
Duddeston Junction track geometry
Conclusion on track twist monitoring

- At the two derailment sites, assessment over 3m identified the risk
  - Also identify an exceedance in twist over a longer baselength is not particularly useful
- Risk is dependent on total difference in cross level over a vehicle, not twist gradient for part of the length of the vehicle
• 4 wagon types have been modelled with a range of asymmetric loading conditions
• Derailment risk has been assessed using method in GMRT2141 and simulations on measured track from derailment sites
• All wagons can accommodate a certain degree of asymmetric loading
• A notional limit has been proposed
Initial findings

- We now have more information on probability of containers being loaded asymmetrically and how severely
- The 3m baselength for assessing track twist appears to be adequate
- A notional limit has been proposed for combined longitudinal and lateral CoG offsets on a vehicle
  - These limits could be used to inform monitoring using GOTCHA
  - The limits could be considered in a revised version of GMRT2141