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Written by:
Lynne Collis CEng, System Safety Engineer, RSSB

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Main cover image courtesy of RAIB report 21/2014 [18], noted in that report as courtesy of Network Rail
Executive summary

Introduction

Whilst the overall risk of freight derailment is very low, the industry has expressed concern about a number of freight derailments due to combinations of track condition, vehicle sensitivity to track geometry or vehicle faults and asymmetric loading of wagons. In some cases, each of these were not necessarily outside thresholds defined by standards, but the combination of them had led to derailment.

On 5 December 2014 Ian Prosser, HM Chief Inspector of Railways, sent a letter to several key companies in the rail industry [1] requesting that the industry work collectively to address concerns about freight train derailment relating to the combinational effects.

The Cross-Industry Working Group on Freight Derailment (XIFDWG) was set up and a number of actions were agreed. These included that the industry should:

- Review its understanding of the hazards and risk associated with container freight train derailments.
- Ensure a common understanding of the effectiveness of current risk control measures.
- Identify improvements to reduce the risk as low as reasonably practicable.

Whilst the initial concern focussed on container wagons, the scope of the risk assessment was agreed to be extended to cover wagons carrying bulk-loaded products such as hopper wagons, to include the derailment at Angerstein Junction [19].

The working group was invited to consider whether the type of track fault known as cyclic top should be considered under this remit. After discussion, the group decided firstly to complete the work evaluating combinations of track twist, wagon sensitivity to track geometry or wagon faults and asymmetric loading of wagons and later to re-evaluate whether developing knowledge gained could be transferred. Accordingly, cyclic top is excluded from the scope of this report.
Method

The XIFDWG needed a mechanism to assess the risk of freight derailment due to combinations of track twist, wagon or bogie sensitivity to derailment and offset loads.

The mechanism was needed to assess the strength of current risk controls, and to identify and prioritise improvements in the management of the risk of derailment of freight trains. The RSSB Risk Team defined the process as a filtering mechanism, going from understanding of the overall risk and all existing and potential safety measures, down through understanding of risk controls requiring improvement to those on which the industry could best focus its efforts. The detailed steps required are illustrated in Figure 4. They can be summarised as:

1 Bowtie workshops to understand current risk, to assess strength of controls and identify new controls.

2 Priority workshops to:
   a Define the improvement needed for each poor performing control (those whose effectiveness was currently classed as inadequate, uncontrolled, potential or unknown via the bowtie workshops).
   b Assess the effort required for each improvement.
   c Estimate the safety benefit derived from each improvement.
   d Reach agreement on the control measures providing the best focus for the industry’s efforts.

3 Agreement on the detailed studies to be undertaken for improvement, including detailed risk assessment and cost-benefit analysis, reached through review of this report and by consultation.

4 Detailed studies by industry of the chosen areas for improvement.

5 Review of studies and implementation of chosen risk control improvements by industry.

6 Monitoring of effectiveness and assessment of residual risk as a result of the changes.

This report covers the first two steps of this process, and facilitates the consultation under step 3.

The rationale for the methods chosen was that the large populations of data required to undertake a customised quantified risk assessment to supplement
that of RSSB’s Safety Risk Model were not currently available and would require a long process of collection and analysis. The RSSB Risk team therefore proposed a qualitative method, to make best use of the industry experience in the XIFDWG.

As the ORR had provided a draft bowtie risk assessment [1], the team chose bowtie risk analysis as the way forward, supported by representative expertise from industry stakeholders, including the ORR. This provided a means of understanding the level of risk under current operations, describing the current controls and assessing their effectiveness as implemented by the single duty holders. As these workshops identified a number of potential risk control measures that could be employed, as well as means of strengthening current controls, a method of prioritising those controls was needed. Using criteria developed from RSSB’s Taking Safe Decisions guidance [2], the Risk Team developed a prioritisation method, to assess controls by both effort and safety benefit measures, and to permit ranking in order to select the most effective measures on which the XIFDWG should focus its efforts.

Results

From over 180 risk control measures identified in the bowtie workshop and priority workshops, 94 controls were assessed, either because their strength today could be improved, or because they were new potential controls not yet in use. The working group ranked these controls, and a list of top ranked controls was agreed. An initial top 10 was expanded to a top 11 following review as positions 10 and 11 had the same score. The measures are described in the Results section of this report, along with outlines of the requirements for detailed study.

Within the top ranked controls, the group identified three as key enablers. These were agreed to be urgent pieces of work to improve understanding of current risk. The group recommended that these be implemented as quickly as possible, to gain the intelligence necessary as inputs to the other top ranked risk control measures. They are:

- Use of Offline GOTCHA to check for wagon/bogie twist and for offset load (scored as two measures in the priority workshops).
- The port survey of offset container loads.
- Simulation of wagon sensitivity to derailment due to offset load and track twist.
As described in Section 3.3.1, the use of offline GOTCHA is subject to confirmation that the Network Rail implementation is suitable for this control. That assessment is underway.

It is recognised that the wagon sensitivity modelling may need to go through an open procurement exercise.

At the meeting on 7 October, 2016, the XIFDWG agreed the leaders and support for the key enablers, and felt that other studies in the top 10 should be agreed at the output of the key enabler studies. Once those have been decided, it will be necessary to:

- Agree the detailed scope of each measure.
- Make any necessary arrangements with external bodies.
- Agree funding sources and mechanisms.
- Identify relevant data sources.

The bowtie risk analysis and associated priority workshops have provided a systematic, structured, transparent and repeatable means of assessing where the industry can best direct its efforts to reduce the risk of flange climb derailments of freight trains, having identified over 180 existing and potential freight derailment risk control measures.

It is thanks to the considerable expertise, effort and engagement of all the participants that the XIFDWG now has a significantly improved understanding of risk areas, the strength of current controls and the potential improvements in controls which could be put in place.

Now that the priorities for further improvement have been decided, implementation should progress as quickly as possible, to put into effect the risk control reductions described in this report.
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1 Background and requirements

On 5 December 2014 Ian Prosser, HM Chief Inspector of Railways, sent a letter to several key companies in the rail industry [1] requesting that the industry work collectively to address concerns about freight train derailment relating to the combinational effects of track condition, vehicle sensitivity to track geometry and asymmetric loading of container wagons.

1.1 The Cross-Industry Freight Derailment Working Group

In response to the ORR letter [1], Freight Technical Committee proposed a cross-industry working group should be set up to oversee the work needed. The cross-industry freight derailment working group (XIFDWG) was therefore set up to respond to the ORR’s request and to consider this topic area and issues such as related RAIB recommendations. The group is facilitated by RSSB, with representatives from: Network Rail, freight operators, SNC Lavalin (formerly Interfleet Technology), the Institute of Rail Research (IRR) at the University of Huddersfield, Ricardo Rail (formerly Lloyds Register Rail), ORR and RSSB. A representative from Aggregate Industries also joined the group to help cover issues relevant to the Angerstein Junction derailment. The working group has defined its purpose and role in the Terms of Reference for the Cross-Industry Freight Derailment Working Group (XIFDWG) [3].

1.2 Objectives from meeting with ORR

At the ORR-hosted meeting on 6 March 2015, six actions for the XIFDWG were agreed [4]. The first of these concerns the risk analysis work stream:

**Action 1**: The industry to review its understanding of the hazards and risks associated with container freight train derailments to ensure a common understanding of the effectiveness of current risk control measures, and identify improvements to reduce the risk as low as reasonably practicable.

- **i.** This review to be approached from a first principles system perspective.

- **ii.** The review should be based on detailed risk analysis supported by bow tie assessment. The existing SRM/PIM provides information
that can form part of this review. The initial basic bow tie analysis presented in ORR’s paper is a potential starting point [1].

iii. The review should include consideration of what has changed/is changing on the railway that could change the industry understanding of the way in which these types of derailment can occur and the way they are modelled/assessed.

iv. The risk analysis work should take account of views and inputs from organisations outside the rail sector with responsibilities for forwarding, loading and handling of freight containers

v. This links to the cross-industry working group (XIFDWG) proposals described in the Cross-Industry Freight Derailment Working Group Interim Progress Report [5].

This report covers the elements planned to undertake the risk assessment aspects of the XIFDWG work, based on the ‘Analysing and selecting options’ section of the Taking Safe Decisions framework [2].

To summarise, the safety analysis work involves:

a Scoping the safety concern raised by the ORR and considered by the XIFDWG in terms of nature, size and complexity.

b Identifying and analysing potential options available to address areas of risk associated with the safety concern.

c Preparing evidence to allow suitable consideration of which options industry might consider for implementation.

1.3 Risk profile

The RSSB Safety Risk Model (SRM) calculates an estimate of risk for the whole of the GB rail network, in the form of cause and consequence analysis. Most of the data used to populate the SRM comes from the rail industry’s accident reporting into the Safety Management Information System (SMIS), a national reporting system provided and maintained by RSSB. This risk model has been developed over 15 years, as an evidence-based national risk analysis tool.

The SRM (v8.1) [6] assesses the total network risk as 139 Fatalities and Weighted Injuries per year (FWI/yr). Of this, total train accident risk is 8 FWI/yr and total derailment risk is 2.1 FWI/yr. Derailment of non-passenger trains represents 0.53 FWI/yr, which is 0.38 % of total GB rail network risk, as shown in Figure 1.
When this is broken down to exclude empty coaching stock, trains in possessions, and yards, depots and sidings, freight train derailment risk is 0.242 FWI/yr. This represents 11% of total derailment risk, or 0.17% of total network risk (ie the total risk in the SRM V8.1), shown as ‘other risk’ in Figure 1.

At the 2015 rate of Value of Preventing a Fatality of £1,889,000, this suggests that it would be reasonably practicable to spend £458,000 per year to eliminate completely the total network risk of freight train derailment. However, this does not take into account other safety benefits of such work, nor does it take into account the reputational cost of derailments.

In addition, the joint RSSB and TRL report, ‘Potential risks to road and rail transport associated with asymmetric loading of containers’ [7] suggests that the average, indicative cost of a derailment, excluding safety was £138,500 per derailment, when averaged over major and minor (unclassified) derailments between 1 January 2005 and 31 December 2010. The average of the classified major derailments where track twist was the major contributory factor was £661,073, and the major derailment where improper loading of container wagons was the major factor had an indicative cost of £353,532. It was also noted that a single derailment cost as much as £6.5m, taking into account infrastructure damage and operational delay costs.

Although the overall risk is low, as illustrated by Figure 1, the topic nevertheless merits further assessment to enhance industry’s understanding of where efforts should best be directed.
Analysis of the factors leading to freight train derailment also shows that a key component of freight train derailments on the GB mainline railway is the combination of factors which, in themselves, may not exceed current standards. These are considered to be track twist, wagon faults and offset loads. As shown in Figure 2, there is a significant number of derailments caused by the combination of factors. Figure 2 includes examples of derailments with these combinations of causes. In addition to the derailment totals above, where single major causal factors were reported, there were:

- 5 derailments in the period due to a combination of offset loads and track faults.
- 2 derailments in the period due to a combination of offset loads, wagon faults and track faults.
- 10 derailments in the period due to a combination of wagon faults and track faults.

The chart in Figure 2 includes some combinations which were not taken forward into the study at this stage, for example the Gloucester derailment, which was due to a combination of the cyclic top track fault and a wagon sensitivity to that track defect.
2 Risk management activities

The risk management activities described in this report follow the structure of risk assessment as set out in the common safety method for risk assessment and evaluation (CSM RA) [9]. Equally, the methodology follows the framework described in Taking Safe Decisions [2]. The work being carried out prepares material for the decision making process involved in selecting and implementing potential future changes to control freight derailment risk.

2.1 Roles and responsibilities

The Safety Lead is Lynne Collis, supported by Ben Gilmartin.

Independent assessment is by Dave Griffin.

The work is directed overall by George Bearfield (Chair of XIFDWG).

Technical support is provided as required by members of the XIFDWG and wider industry stakeholders.

2.2 System definition

The system being considered is defined by the scope of the ORR letter [1] and by subsequent discussions by the XIFDWG which are recorded in meeting minutes [10].

In summary, the scope of the safety analysis is the hazards associated with track twist, rolling stock faults, and offset loading of freight container, hopper and box wagons, leading to freight train derailments, and also the combined effects of more than one of these causal factors.

2.3 Taking Safe Decisions

The work of the cross-industry group is being undertaken following a structured process in accordance with the industry guidance on safety-related decision making and risk management, Taking Safe Decisions [2]. Taking Safe Decisions is built around key regulatory requirements with which that duty holders must comply, in particular the common safety method for monitoring and the common safety method on risk evaluation and assessment (CSM RA) [9].
Figure 3 - The Taking Safe Decisions risk management framework, mapped to the XIFDWG risk processes
The Taking Safe Decisions process sets out the industry consensus view of how safety is taken into account during decision making. It describes the principles that companies apply to protect people’s safety, satisfy the law, respect the interests of stakeholders and meet commercial objectives.

According to that process when a safety concern has been identified, analysis is required to understand the nature of the problem, and identify options that can be considered to reduce any identified risk. Appropriate application of risk acceptance criteria is necessary in order to understand whether there are any measures which are necessary.

Following the identification of options to progress, any necessary changes to the railway and its operation are made, and necessary monitoring arrangements put in place to monitor the impact of the change. This process is consistent with the ORR request for industry activity.

Figure 3 maps steps of the XIFDWG risk work to the Taking Safe Decisions management framework. The steps are:

1. Bowtie workshops to understand current risk, to assess strength of controls and identify new controls,
2. Priority Workshops to assess the effort required for each improvement and the safety benefit derived from each, and to reach agreement on the control measures providing the best focus for the industry’s efforts,
3. Agreement reached through review of this report and by consultation on the detailed studies to be undertaken for improvement, including detailed risk assessment and cost-benefit analysis,
4. Detailed studies by industry of the chosen areas for improvement,
5. Review of studies and implementation of chosen risk control improvements by industry,
6. Monitoring of effectiveness and assessment of residual risk as a result of the changes.
2.4 Risk analysis overview

The overview of the risk analysis process used for the XIFDWG is presented in Figure 4.

The diagram above shows how the XIFDWG firstly uses bowtie risk analysis to understand the current risk, the current and potential risk controls and their effectiveness. The Priority Workshops are then used to determine which controls would most merit improvement, and these lead to more detailed studies. The outputs of the Bowtie risk analysis and the Priority workshops are attached in Appendix C.
Once the output of these studies has been considered, measures to improve risk control can be implemented, if they are proven to be needed. The effectiveness of the changes made is monitored to check their effectiveness, and the residual risk is assessed. The process includes steps for the financing and procurement of studies and implementation projects where appropriate.

2.5 Understanding current risk

2.5.1 Preliminary risk analysis

Previous RSSB safety risk work on derailment, undertaken prior to the XIFDWG risk analysis, was reviewed by the RSSB Safety Lead as background to the scope of the risk analysis and was accepted by the XIFDWG. This has included:

- Output from the European FP7 D-Rail Project (a consortium programme of work investigating methods of reducing freight derailments) [28].
- RSSB/TRL assessment on container freight offset loading risk [7].
- Freight derailment incident data, studied by The IRR at the University of Huddersfield.
- A preliminary tailored risk profile, developed, based on the RSSB Safety Risk Model [6].

This preliminary safety risk analysis was used to frame discussions of the XIFDWG and also as input to the bowtie workshops.

2.6 Bowtie risk analysis

The systems supporting the SRM assign derailments to a single causal factor and do not allow customised combinations of causes to be assigned. In addition, large populations of data would be required to undertake a further quantified risk assessment of the risk of freight derailment due to combinations of the causal factors identified. The RSSB Risk Team therefore decided that a qualitative risk analysis method would be more practicable, and as the ORR had provided a draft bowtie risk analysis, the working group chose this as the way forward.

The working group undertook the bowtie risk analysis through specifically-constituted workshops, described below.

2.6.1 Defining a competent group

To validate and further develop the bowtie provided by ORR, it was clear that it would be necessary to constitute a competent group that would be representative of the various stakeholders in the rail freight industry.
Table 1 - Companies invited to the workshops

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Note 1: Company names in **bold** show attendance at the workshops.

Note 2: DB Schenker’s name was changed to DB Cargo during the bowtie risk process.

The Risk Team drafted a skills, knowledge, and experience (SKE) matrix and sent it to the group for review, and for members to be proposed. Doodle polls were sent out to find dates for each workshop, taking into account the best range of attendees according to the SKE matrix. The working group checked the quorum at each workshop, and attendance sheets were completed. Invitees unable to attend were included in review of the outputs and offered meetings to discuss the output, if required. The SKE matrix is attached in Appendix B. Invitees were from the companies shown in Table 1.

A ‘skills, knowledge and experience matrix’ (SKE matrix) defines each aspect of the competence needed for a workshop. The SKE matrix first defines the competences required and then requests attendees to represent each of the skills, knowledge and experience required. The objective is to ensure that the workshops are quorate, so that the participants will not be faced, as far as can be predicted, with gaps in the knowledge required to meet the workshops’ objectives.
2.7 Scope

The focus of the assessment was freight derailments on the GB mainline railway, caused by loss of wheel-rail interface where the flange of the wheel climbs up and over the rail head due to combinations of track twist, wagon faults and offset loads.

2.7.1 Flange climb derailments

Derailment by flange-climb can occur when the vertical load on a wheel is insufficient to prevent the lateral forces pushing the wheel up the sloping interface between the wheel flange and the rail, as shown in Figure 5. A reduction in load on a wheel, for example due to a combination of track twist, wagon or bogie twist and offset load, will therefore tend to increase the likelihood that lateral forces will cause the wheel flange to climb the rail. [19]. It should also be noted that the risk of this type of derailment can increase at slow speed on canted curves because of the load transfer, and because the lateral loads increase on curves.
2.7.2 Scope details

The scope of the study therefore included combinations of:

- Track condition, particularly track twist.
- Wagon condition, including containers, 2-axle and bogied wagons. Hoppers and box wagons were included from bowtie workshop 2 as a result of analysis of the Angerstein Junction derailment [19].
- Load conditions, including offset loads, overloads, and incompletely unloaded bulk products.

Exclusions included:

- Derailments in yards, depots and sidings.
- Buffer locking leading to freight train derailment.
- Environmental conditions leading to freight train derailment.
- Miscellaneous mechanical fault leading to freight train derailment.
- Movement of points under train (equipment fault) leading to freight train derailment.
- Miscellaneous/unknown causes on plain line leading to freight train derailment.
- Points in the wrong position and not detected leading to freight train derailment.
- On-track plant derailments.
- Other driver or train crew error at switches and crossings leading to freight train derailment.
- Runaways leading to freight train derailment.
- Running into landslip leading to freight train derailment - from cutting.
- Running into a vehicle which has come through boundary fence leading to freight train derailment.
- Severe braking/snatch leading to freight train derailment.
- Signaller/crossing keeper error leading to freight train derailment.
- Signal passed at danger at switches and crossings leading to freight train derailment.
- Cyclic top track faults, as the applicable risk control measures were considered to be different from those required for track twist.

2.8 Bowtie analysis

The objectives of the bowtie workshops involved:

- Gaining an understanding of what can go wrong with freight transport.
• Identifying likely causes of the hazards.
• Identifying what the potential consequences of the hazards might be.
• Identifying existing and additional mitigations (barriers) and assessing their effectiveness. This included risk controls both to prevent the loss of wheel-rail interface, and to mitigate the consequences. (See the bowtie diagram in Figure 7, Section 3).
• Identifying any escalation factors which can cause the barriers to fail.
• Assessing the residual risk of the consequences.

The Briefing Note, including the scope of the workshop and the methodology, was sent out to participants for review.

2.8.1 Effectiveness of risk controls

The group assessed risk controls by effectiveness, as a qualitative measure, using the same categories as those in the draft ORR bowtie to enable comparison, albeit that ‘uncontrolled’ was used instead of ‘unacceptable’. The categories are as shown in Figure 6.

The objective was to gain a picture of the current state of risk management, of the strength of current controls and to identify any future controls which could be applied to the risks.

<table>
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<tr>
<td>A: Excessive</td>
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<tr>
<td>B: Optimal</td>
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<tr>
<td>C: Adequate</td>
</tr>
<tr>
<td>D: Inadequate</td>
</tr>
<tr>
<td>E: Unacceptable/Uncontrolled</td>
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<tr>
<td>Potential</td>
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All controls were assessed in relation to the threat line under consideration. The effectiveness categories above relate only to the strength of each control in managing specific, defined risks and should not be considered as having any other significance.

2.9 Prioritisation process

2.9.1 Filtering

Once the bowtie risk controls were all categorised according to effectiveness, and comments were taken into account, the Risk Team undertook a filtering exercise (shown in Appendix C1) to define a list of ‘poor’ controls: those which were in scope, and not already optimal or adequate.

This allowed the group to consider which controls would most merit further study regarding the improvement of each, to bring them up to an adequate level of effectiveness.

2.9.2 Scoring process

In the prioritisation workshops, members were asked to:

- Describe the potential improvement or safety benefit achieved by enhancing each control measure to an adequate level.
- Effort: Define (as High, Medium or Low) the effort required to implement each control in terms of cost, complexity and timescales, ease of implementation, and ease of monitoring the improvement. The criteria are shown in Table 2.
- Safety Benefit: By how much would this control, in isolation, reduce this risk of a specific threat? This was done by defining the percentage reduction in risk per threat or improvement in understanding for key enablers. The benefits are shown in Table 3.

<table>
<thead>
<tr>
<th>Table 2 - Effort scoring criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Criterion</strong></td>
</tr>
<tr>
<td>Cost per year</td>
</tr>
<tr>
<td>Complexity</td>
</tr>
<tr>
<td>Timescales</td>
</tr>
<tr>
<td>Ease of implementation of change</td>
</tr>
</tbody>
</table>
### Table 2 - Effort scoring criteria

<table>
<thead>
<tr>
<th>Ease of monitoring effectiveness of change</th>
<th>New monitoring</th>
<th>Adapted monitoring</th>
<th>Existing monitoring</th>
</tr>
</thead>
</table>
The Risk Team added scoring for key enablers, as research projects can score as low safety benefit if implementation of the project is not included, as they have a low individual impact. However, the group felt that certain projects are critical to understanding the detail of the threats. Scores for how much each of these contributes to understanding of each threat, as enablers for potential safety benefit, were therefore added. The criteria for safety benefit scoring are shown in Table 3.

Voting cards were made available to workshop members so that differences in scoring could be recorded where necessary, but the cards were very rarely used, the members coming to an agreement on scores.

### 2.9.3 Post-processing

Following the workshops, the Risk Team converted the workshop conclusions to scores, and weighted them. (Detailed in the Post-Processing section of Appendix C2.)

The Risk Team then undertook further assessment via a narrative search of the Safety Management Information System (SMIS) for in-scope derailments. Whilst the SRM assigns a single causal factor to events, the analysis evaluated the contribution of combined causal factors in accordance with the threat lines defined in the bowtie workshops, and added a proportional percentage to each, in accordance with the RAIB reports for each derailment [see, for example, references 19-21]. The total percentage was then applied to the total in-scope FWI of 0.242 FWI/yr to derive a risk per threat line.
Rankings for each measure were derived in terms of the following equation:

\[
\text{Scoring Ratio} = \frac{\text{Safety Benefit}}{\text{Effort}} \times 100.
\]

Combining the FWI per threat line with the individual safety benefit scores from the workshops enabled the Risk Team to define a risk reduction level per control measure. The caveat on this score is that it was generated from a mix of workshop scores, expert judgement and SRM FWI/yr scores, and so is not comparable with fully quantified risk analysis or other forms of risk assessment.

2.9.4 Chart output

The issues list with the effort and safety benefit scores from the workshops, combined with the post-processing as described in Appendix C2, was converted into charts for ease of review. Once the review comments were collected, further workshops were then held to agree the review output. The group agreed a Top Ten chart (in fact, a top 11, as two scores at position 10 and 11 were equal), of those measures deemed most worthy of further study. The Top 10 control measures will be presented in the results section. The other charts are attached in Appendix C3.
3 Results of bowtie analysis

During the bowtie workshops, participants were invited to propose and reach agreement on, firstly, the hazard and top event, as shown in Figure 7.

The hazard was updated from the ORR draft [1] from ‘Freight Train’ to ‘Carriage of rail freight’, as more specific, whilst the top event remained unchanged as ‘Loss of Wheel/Rail Interface’. This is beneficial as it permits a range of consequences and mitigating controls to be considered, as shown below, rather than selecting ‘derailment’ as the top event.

Figure 7 - Bowtie hazard and top event

Threats, or risk causes are defined on the left hand-side of a bowtie, and lead to the top event. Controls are defined along each threat line to mitigate or prevent the top event from occurring. Consequence lines radiate out on the right hand side of a top event, with controls along each which mitigate against the top event reaching the defined consequence. The full list of bowtie terminology is provided in Appendix C5.

The workshop was asked to consider threats, the causes of the top event, and the consequences arising from it. A comparison between the threats and consequences chosen by ORR and the XIFDWG workshops is provided in Appendix A. The threats and consequences chosen were:

Threat 1. Plain line track twist
Threat 2. Track twist over switches & crossings (S&C)
Threat 3. Combination track geometry fault
Threat 4. Poor rolling stock design
Threat 5. Vehicle frame and or bogie twist
Threat 6. 2 axle wagon defects
Threat 7. Bogie wagon defects
Threat 8. Asymmetric loading of container
Threat 9. Asymmetric loading of container wagon longitudinal
Threat 10. Asymmetric loading -bulk loaded hopper wagons
Threat 11. Interaction between wagons
Threat 12. Asymmetric loading of box wagons
Threat 13. Combination of within tolerance track geometry fault, rolling stock specification at tolerance and load
Consequence 21. Derailment and catastrophic railway accident
Consequence 22. Derailment container ejected into public area
Consequence 23. Derailment container ejected into non-public area
Consequence 24. Derailment wagon/load ejected into public area
Consequence 25. Derailment wagon/load ejected into non-public area
Consequence 26. Derailment resulting in catastrophic environmental impact
Consequence 27. Derailment railway damage
Consequence 28. No derailment or de-rail/re-rail

In general, the XIFDWG bowtie followed the same structure as that of ORR, except where the workshops found a reason to change. Differences of note included:

- The addition of a threat line for track twist across switches and crossings (S&C) as the challenges of measuring all routes via each possible path through each S&C were highlighted by workshop members as being different from the task of assessing track twist on plain line track. Specific controls were identified along that threat line, with a number of controls which either are challenged by emerging operating conditions or are potential controls for consideration.
- The addition of threats, consequences and controls for bulk-loaded hoppers and box wagons.
As illustrated by Figure 8, the workshops identified over 180 risk controls, compared with the ORR draft bowtie, which had 66 controls. The key differences are:

- There was a significant reduction in ‘unknown’ controls.
- There were many more existing risk controls identified.
- There were many more potential controls identified which do not exist today. (These were then part of the priority workshop assessments to determine benefit and effort, and, if chosen as top 10 controls, would then be subject to detailed studies to determine if they would be practicable.)
Figure 8 - Evolution in understanding of risk controls
- There was a significant increase in the number of controls relating to track twist and to offset loads.
- There was a small increase in the number of controls on the risk of wagon faults; this is because a key risk control identified was the simulation of wagon sensitivity to offset loads and track twist, discussed in more detail below.
- It was agreed in the priority workshops that Threat 11 was out of scope, as the buffer-locking type of interaction between wagons typically occurs in yards, depots and sidings only. This resulted in a reduction in the number of load controls.
- Conversely, new controls were identified, and the total is therefore slightly higher than in the second bowtie workshop.

The link to the bowtie diagram is provided in Appendix C4. It should be noted that the full bowtie needs an A0 paper size for full readability. The controls were also exported into an Issues list for comment. This issues list was used as the input for the prioritisation workshops. It is attached in Appendix C6.1.

### 3.1 Prioritisation workshops

The prioritisation workshops, as well as evaluating the effort and safety benefits associated with each control, served to foster further discussion and clarification of each improvement measure.

Some ideas from the bowtie workshops were considered in further detail and as a result were no longer considered in scope, in particular, Threat 11, the threat concerning derailment risk due to the buffer-locking interaction between wagons. It was decided that this threat was relevant only to marshalling derailments in yards, depots and sidings and thus was out of scope. Where individual risk controls were deemed by the workshop members not to be effective for the threat line under consideration, the safety benefit score was marked as 0.

The prioritisation workshops also resulted in new controls being identified, compared with the first XIFDWG bowtie, such as the need for reliable pathing of the Track Recording Vehicle (TRV) to avoid them being stopped or diverted) from their booked routes mid-recording. This measure is intended to reduce aborted track recording runs and enable greater network coverage with the same fleet.
The results were summarised in charts with associated live tables, permitting users to change the scores dynamically on review. Charts were generated from the bowtie issues lists for:

- Track, representing Threats 1, 2, 3
- Wagons representing Threats 4, 5, 6, 7
- Loads – container representing Threats 8 and 9
- Loads – bulk loaded representing Threat 10
- Loads – box wagons representing Threat 12
- Combinations representing Threat 13
- Consequences representing in-scope controls from all consequence lines

In some cases, a control repeated across a number of threat lines. Where the same risk control was applicable, with equal effort scores, the Risk Team combined the scores from repeats. Apart from the Top 10 chart, which was created manually using the scoring ratio, above, individual control measures can only feature in one chart. Where they cross chart boundaries, they have been included in the chart for Threat 13, the combination of track twist, wagon faults and offset load.

3.2 Top 10 chart

The top 10 chart was derived manually from analysis of the scoring ratios (see equation in Section 2.9.3). As the controls at positions 10 and 11 had identical scores, there are, in fact, 11 top control measures. The scatter chart in Figure 9 is annotated in Table 4. Further detail is provided on each of the measures selected, based on discussions from the workshops and further development of each.

The objective is to define the controls warranting further study. It is envisaged that the nominated industry leaders and support for each measure would undertake a detailed cost-benefit analysis, including a detailed risk assessment of each measure, to enable further choices to be made regarding implementation, and to contribute to the overall risk picture.
Figure 9 - Top 10 chart
<table>
<thead>
<tr>
<th>Top 10 Chart Table</th>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Threat / Consequence</th>
<th>Feasibility / cost</th>
<th>Timeliness</th>
<th>Ease of Implementation</th>
<th>Safety Benefit Score</th>
<th>Effort Score</th>
<th>Safety Score</th>
<th>Ratio for scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T5,6,7 Offline GOTCHA check wagon twist</td>
<td>Tht. 5.</td>
<td>2</td>
<td>0.026</td>
<td>2</td>
<td>0.016</td>
<td>9.9</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Tht. 6.</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>2</td>
<td>0.017</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tht. 7.</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>2</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Offline use of GOTCHA for problem loads</td>
<td>Tht. 8.</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>Tht. 9.</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Tht. 10.</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Tht. 11.</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Port survey for offset loads</td>
<td>Tht. 12.</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>Tht. 13.</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>S&amp;C use MPVs (T2)</td>
<td>Tht. 14.</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Tht. 15.</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>2</td>
<td>0.056</td>
</tr>
<tr>
<td>5</td>
<td>Add twist equipment to freight locos (T2)</td>
<td>Tht. 16.</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Tht. 17.</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>1</td>
<td>0.056</td>
</tr>
<tr>
<td>6</td>
<td>Simulate container wagon sensitivity to derailment with combinations of longitudinal &amp; lateral offset load</td>
<td>Tht. 18.</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>Tht. 19.</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Future Online use of GOTCHA for offset loads with practicable procedures</td>
<td>Tht. 20.</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Tht. 21.</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>2</td>
<td>0.008</td>
</tr>
<tr>
<td>8</td>
<td>Longer /alt. wavelength monitoring (T2)</td>
<td>Tht. 22.</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Tht. 23.</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>3</td>
<td>0.056</td>
</tr>
<tr>
<td>9</td>
<td>Set limits and guidelines for rejecting wagons with retained loads - wagon dependent</td>
<td>Tht. 24.</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Tht. 25.</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>2</td>
<td>0.008</td>
</tr>
<tr>
<td>10</td>
<td>T8 At loading onto rail check container for offset load</td>
<td>Tht. 26.</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Tht. 27.</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>1</td>
<td>0.016</td>
</tr>
<tr>
<td>11</td>
<td>Identify offset loads at start of UK journey</td>
<td>Tht. 28.</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Tht. 29.</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>1</td>
<td>0.016</td>
</tr>
</tbody>
</table>
3.3 Top ten control measures

The roadmap in Figure 10 shows dependencies between the control measures. Each control is shown in the context of its required inputs and outputs. For example, the port survey provides data needed to inform the development of thresholds for offset loads, along with output from offline GOTCHA, and other considerations of safe margins. Such thresholds would then feed into control measures related to checking of offset loads, at the start of the UK journey, at loading onto rail and by trackside assessment via online GOTCHA.

The control measures are described in detail below in that context, as shown in the roadmap. Where appropriate, (where there is not already a scope or specification being developed) outline draft work stream notes and a list of draft data sources are provided. These are intended to inform the detailed scope to be developed by the nominated leaders and support, but would be subject to review by them, in accordance with the filter diagram in Figure 4. Their ranking in the top 10 is given in brackets after the title of each control. The workshops identified four key enabler control measures. These were agreed to be urgent pieces of work to improve understanding of current risk. These are:

- Use of offline GOTCHA for wagon twist data
- Use of offline GOTCHA for offset loads data
- The port survey of offset container loads
- Simulation of wagon sensitivity to offset load and track twist

Implementation of these key measures is intended to proceed as soon as possible, in accordance with the specifications developed for their work.
3.4 Key enablers

3.4.1 Use of offline GOTCHA to check wagon twist (1).

GOTCHA is a trackside monitoring system used for measuring the dynamic wheel forces imposed on the infrastructure by passing trains. It is set up with sensors under the track as shown in Figures 11 and 12. It is left permanently in place, transmitting data to remote terminals for analysis. GOTCHA has been brought into use on the GB mainline railway by Network Rail, initially to replace the Wheelchex system for wheel impact load detection. It can also be used for weighing in motion, dependant on the configuration.

The workshops proposed investigating whether GOTCHA [24] could be used to collect data on wagon faults such as frame and bogie twist, so that the extent of the problem with these faults can be assessed. The scores from this control in threats 4 to 7 were grouped, as they refer to the same measure. The workshop distinguished offline use of the system, where the data is used for analysis only, from online use of the system as a real-time control measure used to alert railway undertakings to rolling stock which is outside current wheel impact limits and to require operational measures to control the risk.
Offline GOTCHA could provide data on wagon faults but it was suggested by workshop members that it would need to be initially undertaken via trending, as the system itself would be unable to distinguish wagon faults leading to wheel unloading from wheel impact or offset load for a single measurement. However, repeated readings outside thresholds over time and in several locations and with a variety of wagon load conditions could indicate such a wagon fault. It was highlighted in the workshops that this measure could involve the analysis of large volumes of data, which informed the choice of effort scores. To ease identification of wagons within the data, the use of AVI tags on wagons was discussed.
3.4.1.1 Work stream draft notes

The XIFDWG agreed that the University of Huddersfield should peer review the data with the Network Rail team to clarify whether Network Rail’s implementation of GOTCHA can support the research aspirations of the XIFDWG, and can clearly distinguish such issues as wheel flats from those leading to wheel unloading, such as wagon or bogie twist. At the time of drafting this report, those discussions are underway.

Further study of this work stream would be developed by Network Rail, co-operating with FOCs such as Freightliner and DRSL.

3.4.1.2 Output

Data from this analysis would be an essential input to review of the standards for wagon tests, principally GMRT2141, Resistance of Railway Vehicles to Derailment and Roll-Over [13]. It is also a precursor to online use of GOTCHA with practicable procedures, discussed below.

3.4.2 Use of offline GOTCHA to check for problem loads (2)

Workshop members reported that the checking of container loads directly presents a number of problems for freight operating companies:

- Containers may be Customs sealed and thus could only be opened in the presence of the client or with HM Revenue and Customs (HMRC) support.
- They are designed for inter-modal transport and are thus sensitive to modal switch if rail freight becomes too onerous, too slow, or too expensive.
- They could contain hazardous materials, although this should be stated in the manifest.
- An additional issue that would be faced is that many loads are loose-loaded, such as grain or fragmentised scrap. In such cases, opening of the container by the FOC may present hazards due to issues including loss of load.
- Visual checks either of containers, box wagons or hoppers would not determine mass, and therefore could not necessarily identify an offset load.

Use of offline GOTCHA to check for problem loads is intended to quantify the problem of offset loads without opening containers or wagons. It groups threats from all load categories (Threats 8, 9, 10, 12) and Threat 13.

Again, large amounts of data would be generated, which would need to be analysed via trending.
3.4.2.1 Work stream draft notes

It has been agreed that the University of Huddersfield should peer review the data with the Network Rail team to clarify whether Network Rail’s implementation of GOTCHA can support the research aspirations of the XIFDWG, and can clearly distinguish such issues as wheel flats from those leading to wheel unloading, such as offset loads. Those discussions have started at the time of drafting this report.

3.4.2.2 Output

Along with the port survey, below, this is a key input to the data required to inform the setting of thresholds for offset loads, which in turn is a required input to the controls for identifying offset loads at the start of their UK journey or at loading of containers onto rail. It is also an input to use of online GOTCHA with practicable procedures.

3.4.3 Port survey of offset container loads (3)

The port survey of offset container loads is designed to scope the size of the problem of offset container loads (import and export) at ports, regardless of the land transport mode used, and to distinguish certain factors which could inform the practicable control measures.

3.4.3.1 Work stream draft notes

In considering the derailment risk of container wagons due to offset loads (lateral and longitudinal), it is important to understand how containers are loaded in practice. A number of questions can be asked about container loading, for which the answers could provide a baseline for the results of the sensitivity analysis for derailment (Item 4):

- How many 20ft and 40ft containers are tare (no contents)?
- How many 20ft and 40ft containers are overloaded (and to what extent)?
- Percentages of 20ft and 40ft containers with eccentric (offset) load – lateral, longitudinal and combined.
- Are there any trends exhibiting changes in the above with time?
- Are there more eccentric loads in import or export containers?
- What type of freight flows are more susceptible to eccentric loading?

A first step of analysing existing data provided by a workshop member will be undertaken, to provide preliminary results.

If warranted by these results, the working group proposed that a project be set up whereby either existing port data would be analysed or additional sensors would be added to port cranes at a busy container port. It is likely that the question of whether
import or export containers display more offset loads would need to be undertaken in this second phase. Should the answer to this question indicate a significant problem with export containers, other control measures proposed for multi-modal loading risk management could become more significant. These are discussed under the control ‘Identify offset load at start of UK journey’ in Section 3.3.5.1.

3.4.4 Simulate container wagon sensitivity to offset loads and track twist (6)

When presented for acceptance, wagons are statically tested on a 1:300 long wavelength twist with a superimposed 6m long 1:150 twist fault applied at a worst case position (as defined in GMRT2141 [13]) with a resulting maximum allowable wheel unloading limit of 60%.

The recent focus on combined twist, offset loading, and wagon fault derailments has led to the need to improve understanding of the margin of safety provided by this test, specifically in order to determine whether any further controls are necessary to ensure that the railway controls this risk adequately. This is of particular relevance to container carrying wagons, as the load in the container can vary significantly anywhere between the container tare mass to the container’s full loading capacity, with variation in the amount of eccentricity in the loading of individual containers. A specification is being developed for this study. The study aims to:

- Improve the understanding of the extents of the margin of safety which results from the GMRT2141 assessment of wheel unloading and resistance to flange climb derailment on twisted track [13].
- Investigate whether an additional test is required to quantify the performance of intermodal vehicles with offset load on twisted track (and, if so, what alternative limits should be applied).

The envisaged scope of work will be delivered by means of a desktop study for derailment risk via multi-body vehicle dynamics simulation, using previously-validated Vampire® vehicle models. It is proposed to start this study using vehicle models of the most widely used container wagons, FEAs and FSAs/FTAs as shown in Figure 13. (There are currently 920 FEA wagons and 694 FSAs/FTAs wagons in the GB fleet). Initially, it is envisaged that the original type test reports for the vehicles will be reviewed (where available), and a comparison made to a simulation of the test to determine the effectiveness of the model-matching. In parallel, the derailment history of the wagon will be reviewed to seek any correlation with the type test results, particularly if those results were close to the limit values.
A matrix of calculation cases will be developed for loaded and unloaded vehicles (in various permitted arrangements), including ‘nominal’ and unevenly-loaded cases in various combinations of lateral and longitudinal offset load.

### 3.4.4.1 Output

The results of this study are envisaged to feed into:

- Definitions of thresholds for offset loads
- Review of standards for wagon tests
- Simulation of hopper wagon sensitivity to derailment
- Review of standards for management of risk relating to potential combinations of lateral and longitudinal offset loads. [16].

![Figure 13 - FEA Wagons and FSA /FTA wagons](image)

At the time of drafting this report, the specification for this study has been written, and the project is being processed by RSSB R&D department prior to procurement being undertaken. Once the procurement exercise is complete, it is expected that this represents approximately 3 months’ work.
3.5 Other wagon and load measures in the top 10

Other wagon and load controls in the top 10 are discussed below.

3.5.1 Check load at the start of UK journey (10)

This control would be to identify and correct offset loads at the start of a container’s UK journey, for example on port terminal or consignee packing container handling equipment. It is intended to be multi-modal, improving loading regardless of whether the container will be carried by road or rail and therefore could reduce the risk of either derailment or road lorries overturning.

The port survey and offline analysis of GOTCHA data are key inputs to this work, to show the extent of the issue, and to help influence the implementation of this control, as it requires measures outside the direct mandate of the rail industry. It was highlighted in the bowtie workshops that it is believed that this control could focus on delivering compliance with the IMO (International Maritime Organisation) container packing guidelines [17]. Legal enforcement would currently require UK legislation, which could be difficult to negotiate, given its possible impact on international trade agreements, diverse stakeholder interests and international traffic. Implementation costs would also need to be assessed in the study, both to add equipment to facilitate measuring containers for offset loads and to provide processes and space to handle rejected containers.

Whilst it was mentioned by workshop members that delay damages might be sought by customers for rejected containers, it may be feasible to strengthen clauses requiring loading to be compliant with the IMO loading guidelines to mitigate this.

The benefit of a multi-modal control is that it potentially avoids the transfer of risk from rail to road, which could occur if stronger controls on offset container loads were applied unilaterally to rail.

The working group identified that there are parties external to the GB rail industry who could significantly assist in the minimisation of export of risk to the rail network. These controls include:

- ORR to continue to explore options with other enforcing authorities to help manage risks.
- Inspection and enforcement of container packing guidelines at UK source by HSE and other enforcing authorities.
- The police collecting data on offset container loads and failed securing mechanisms, when they inspect lorries, and on containers involved in accidents where lorries overturn.
- Roadside controls by the Driver and Vehicle Standards Agency (DVSA) using mobile 4-corner weighbridges to check for offset loads.
This control would apply both to imports and to UK-loaded containers. Consideration would need to be given in the study to containers starting their journey at UK freight handling depots. Examples of the impact of poor load securing are shown in Figures 14 and 15.

Figure 14 - Example of poor load securing – road transport [22]

Figure 15 - Example of an offset load in a rail container which derailed [18]
3.5.1.1 Draft work stream notes

It is assumed for the purposes of the study into the checking of loads at the start of their UK journey that:

- The port survey will provide suitable quantification of the number and variation of offset loads for the study.
- Suitable ‘sample’ ports and terminals can be found for the study, for example a container port such as Felixstowe or Southampton, and a smaller terminal such as a container loading terminal, included as an example of a UK-originating container load.

Data which could be needed for the detailed risk and cost-benefit analysis of this potential control is included in Table 5.

Table 5 - Sample data for study - checking containers at UK origin

<table>
<thead>
<tr>
<th>No</th>
<th>Source</th>
<th>Factor</th>
<th>Reason for analysis</th>
<th>Costs for CBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RSSB Safety</td>
<td>Freight derailment data from SRM</td>
<td>To factor in existing FWI/yr from offset load derailments (rail only, not segregated to containers)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>R&amp;D Port survey output</td>
<td>Port survey output</td>
<td>Quantification of problem</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Network Rail/FOCs</td>
<td>Output from offline GOTCHA on offset loads</td>
<td>Quantification of problem</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Study lead</td>
<td>Literature survey – much literature exists on delays in container ports</td>
<td>May provide input on delay costs over wider range than sample terminals</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sample port terminal</td>
<td>Container traffic numbers per day</td>
<td>Baseline of traffic</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sample port terminal</td>
<td>Method of checking containers today (such as for SOLAS verified weight)</td>
<td>To determine current container rejection reasons</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Sample port terminal</td>
<td>Number of containers rejected today</td>
<td>Baseline of rejected containers</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Sample port terminal</td>
<td>Reasons for containers rejected today</td>
<td>To avoid double-counting</td>
<td></td>
</tr>
</tbody>
</table>
Table 5 - Sample data for study - checking containers at UK origin

<table>
<thead>
<tr>
<th>No</th>
<th>Source</th>
<th>Factor</th>
<th>Reason for analysis</th>
<th>Costs for CBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Sample port terminal</td>
<td>Space needed to process rejected containers today</td>
<td>Baseline for infrastructure</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Sample port terminal</td>
<td>Time taken to process rejected containers today and any damages</td>
<td>Baseline for time taken to process /costs of processing rejected containers today</td>
<td>✔</td>
</tr>
<tr>
<td>11</td>
<td>Sample port terminal</td>
<td>Additional infrastructure needed to process rejected containers from offset load check (based on port survey output)</td>
<td>To assess costs of additional infrastructure</td>
<td>✔</td>
</tr>
<tr>
<td>12</td>
<td>Sample port terminal</td>
<td>Details of whether reachstackers or cranes have systems to measure offset load today</td>
<td>To assess whether additional equipment or only the collection or analysis would need to be factored in</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Supplier</td>
<td>Cost of reachstackers with weighing system</td>
<td>Cost of equipment</td>
<td>✔</td>
</tr>
<tr>
<td>14</td>
<td>Study project</td>
<td>Cost and resources to collect and analyse data</td>
<td>Cost of data collection and analysis</td>
<td>✔</td>
</tr>
<tr>
<td>15</td>
<td>Container loading terminal</td>
<td>Container traffic numbers per day</td>
<td>Baseline of traffic</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Container loading terminal</td>
<td>Method of checking containers today (for SOLAS verified weight)</td>
<td>To determine current container rejection /reloading reasons</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Container loading terminal</td>
<td>Number of containers rejected/reloading today</td>
<td>Baseline of rejected/reloading containers</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Container loading terminal</td>
<td>Reasons for containers rejected /reloading today</td>
<td>To avoid double-counting</td>
<td></td>
</tr>
</tbody>
</table>
3.5.2 At loading onto rail, check container for offset loading (11)

This control measure would be rail-specific, and covers the identification and management of offset container loads in rail terminals, yards, depots and sidings. Key inputs would again be the port survey and offline analysis of GOTCHA data on offset loads. Costs would need to be assessed in the study, both to add equipment to facilitate measuring containers for offset loads and to provide processes and space to handle rejected containers.

Examples of potential means of weighing for offset load include load cells with appropriate software on gantry cranes, straddle carriers, or reachstackers, such as those shown in Figure 16.
During the workshops FOC representatives mentioned that use of X-rays had apparently been tried in the USA, but had been rejected as impractical because of their limitations, in that X-rays cannot assess the weight of an offset load, the high capital costs and the time required for scanning.

Whilst it was mentioned by workshop members that delay damages might be sought by customers for rejected containers, it was suggested by others that it may be feasible to strengthen clauses requiring loading to be compliant with the IMO loading guidelines to mitigate this.

Workshop members stressed that if this control measure were implemented without corresponding control on offset loads for road vehicles, there could be a strongly detrimental effect on the rail freight market, should clients find it cheaper to use a less regulated market such as road transport. The risk would thus be transferred to road, rather than providing an overall societal response.

Other risk controls that may help reduce the number of offset loads arriving at rail depots were discussed, including:

- Audit and inspection regimes based on the number of offset loads found. This may be more effective on large contracts, and depends on commercial drivers, including reputational value. If applied to spot (one-off contract) loads, workshop members
believed such clients could be less likely to maintain traffic on rail. It could also be impractical in cases with complex supply chains.

- For domestic traffic, categorising palletised loads to ensure even loading and controlling distribution. Where this is possible, workshop members highlighted that it could promulgate best practice. They believed to be more practicable for large contracts (a major supermarket chain was given as an example).

- FOCs educating domestic customers on best practice in loading. This would potentially have a large audience. Some simple material may be more easily produced (made available online), but it was believed by workshop members that more targeted, higher cost versions would be more effective.

- The inclusion by FOCs of contractual requirements for shippers to comply with the IMO loading guidelines. This is understood to have been implemented by some FOCs.

- Overseas measures were discussed, such as overseas enforcement by the IMO of their loading guidelines, or the training of loading staff at overseas sources, but these were felt to be beyond the scope of the XIFDWG.

- The UIC loading guidelines were also discussed, but are understood by workshop members only to be available to UIC members (ie not shippers) and thus may be of limited efficacy.

### 3.5.2.1 Work stream draft notes

The detailed study would be similar in scope to that for checking of containers at the start of their UK journey, except that this study would be rail-based. Sample data which could be collected to support the study is found in Table 6.

<table>
<thead>
<tr>
<th>No</th>
<th>Discipline</th>
<th>Factor</th>
<th>Reason for analysis</th>
<th>Costs for CBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R&amp;D</td>
<td>Port survey output</td>
<td>Quantification of problem</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Network Rail/FOCs</td>
<td>Output from offline GOTCHA on offset loads</td>
<td>Quantification of problem</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>FOC - Container terminal</td>
<td>Container traffic numbers per day</td>
<td>Baseline of traffic</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>FOC / Container terminal</td>
<td>Number of containers rejected today</td>
<td>Baseline of rejected containers</td>
<td></td>
</tr>
</tbody>
</table>
Table 6 - Sample data for study of checking container at loading onto rail

<table>
<thead>
<tr>
<th>No</th>
<th>Discipline</th>
<th>Factor</th>
<th>Reason for analysis</th>
<th>Costs for CBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>FOC / Container terminal</td>
<td>Reasons for containers rejected today</td>
<td>To avoid double-counting</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>FOC / Container terminal</td>
<td>Space needed to process rejected containers today</td>
<td>Baseline for infrastructure</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>FOC / Container terminal</td>
<td>Time taken to process rejected containers today and any damages</td>
<td>Baseline for time taken to process /costs of processing rejected containers today</td>
<td>✓</td>
</tr>
<tr>
<td>8</td>
<td>FOC / Container terminal</td>
<td>Additional infrastructure needed to process rejected containers from offset load check (based on port survey /offline GOTCHA output)</td>
<td>To assess costs of additional infrastructure</td>
<td>✓</td>
</tr>
<tr>
<td>9</td>
<td>FOC / Container terminal</td>
<td>Details of whether reachstackers or cranes have systems to measure offset load today</td>
<td>To assess whether additional equipment or only the collection or analysis would need to be factored in</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Supplier</td>
<td>Cost of reachstackers with weighing system</td>
<td>Cost of equipment</td>
<td>✓</td>
</tr>
<tr>
<td>11</td>
<td>Study project</td>
<td>Cost and resources to collect and analyse data</td>
<td>Cost of data collection and analysis</td>
<td>✓</td>
</tr>
<tr>
<td>12</td>
<td>RSSB Safety</td>
<td>Freight derailment data from SRM</td>
<td>To factor in existing FWI/yr from offset load derailments</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>FOC / Container terminal</td>
<td>Estimate of business lost to road transport if measure introduced for rail only, by number of containers and cost</td>
<td>Risk identified of modal shift</td>
<td>✓</td>
</tr>
</tbody>
</table>
3.5.3 Online GOTCHA with practicable procedures (7)

Use of GOTCHA as a near real-time operational control was discussed.

3.5.3.1 Work stream draft notes

It is assumed that the study for this measure would involve assessment of:

- Specific thresholds being set for wagon twist and offset loads (including retained loads in bulk wagons), as distinct from the threshold set for wheel impact detection, with factors filtered out which could cause false positive readings. Such thresholds could be an output of the simulation of container wagon sensitivity to derailment study, the simulation of hopper wagon sensitivity to retained/offset loads and of the output from offline GOTCHA.

- Automatic Vehicle Identification to enable the affected wagons to be identified quickly.

- Connection of the system to systems such as NR TRUST and TOPS systems, and any required FOC systems, to aid identification.

- Alarms being sent directly to the FOC concerned and in a timely manner to permit real time management.

- Practicable processes being created and agreed with all railway undertakings for the management of any rail vehicles identified with problem loads, eg requiring removal from the mainline railway.

- Infrastructure being created to permit any rail vehicles requiring removal from the mainline railway to be stabled, and then to be transported in a safe, cost-efficient and timely manner to an appropriate terminal.

The need for practicable processes and infrastructure was much discussed in the workshops. The British railway network today has few locations where a wagon exceeding agreed thresholds could be managed without causing costly delays to other trains. In addition, workshop members highlighted that infrastructure would be needed to permit the FOC to fulfil its contractual obligation of delivery. Workshop members also noted that permission to open Customs-sealed containers to tranship the loads could require HMRC and the customer’s presence, processes and infrastructure to manage any dangerous goods, or substantial civil engineering to support reachstacker usage to transfer a container from one wagon to another.

It should further be noted that in the cases of flange-climb derailment risk discussed in this report, it is not helpful to permit the train to proceed at a slower speed, since slow speeds can increase, rather than decrease, the risk of flange climb derailment on curves. This is due to the interaction of vertical and lateral forces in flange climb derailments (see Section 2.7.1) where the excess cant at slow speed reduces the vertical load on the outer wheel on the curve thus reducing the force that resists flange climb.
The details of what would be required for a study of the risks and cost-benefit analysis for online GOTCHA would be the responsibility of Network Rail under the Network Change Notice process and associated impact assessments.

Since the workshops concluded, the Network Rail GOTCHA project has provided the following update [27]: GOTCHA can record every wheel passage. Train operators will be able to use this data to help apply condition-based maintenance, allowing the wheelset defect to be addressed before it reaches alarm level. This will be most effective when coupled with vehicle identification provided through the use of AVI tags on vehicles. The GOTCHA project will install RFID readers at each GOTCHA location (subject to track access, these installations will take place Nov 2016 – March 2017). NR will be discussing this approach with train operators over the next few months. The RSSB work on cross industry remote monitoring (T1010) is likely to form the basis of this discussion.

Additionally, as the RAIB reports into Angerstein, Ely Dock Junction and King Edward Bridge state, work is starting to assess whether GOTCHA can provide useful information on asymmetric loading. On current plans, testing will take place in early 2017; this will allow the industry to understand the system capability and how to make best use of this.

Network Rail is working with the GOTCHA Working Group (a subgroup of the Freight Technical Committee) to determine the thresholds for offset loads, taking into account a draft European standard [29] concerning on-track measurement for vehicles in service for guidance on determining accuracy and appropriate methodologies.

3.5.4 Set limits and guidelines for retained load – hopper wagons (9)

The derailment at Angerstein Junction on 2 April 2014 highlighted that incompletely unloaded hopper wagons (wagons with retained loads) can contribute to derailment risk [19]. The hopper wagon type concerned is shown in Figure 17.

Whilst Railway Group Standard GORT 3056C requires, as part of the pre-departure check that 'loaded vehicles appear to have their weight correctly distributed' [24], it does not include any requirement to check for incompletely unloaded products, nor does it propose any thresholds for retained loads.
The bowtie workshops discussed various methods of controlling the risk of loads being retained. Existing weighbridges were held by workshop members to be insufficiently accurate: ‘good only at trainload level’, while visual inspection (either directly or via CCTV) cannot determine the weight of any retained load. Inline rolling weighbridges for offset loads could be used, but they were believed to have high costs and would need processes and infrastructure to deal with rejected wagons.

3.5.4.1 Work stream draft notes

The working group felt that the principal control was the development of guidelines and setting limits for retained loads. This was felt to warrant simulation modelling as the limits would be wagon dependent: a 10 tonne offset retained load on a 102 tonne wagon would be considerably less significant than a similar offset retained load on a lighter wagon. The effect of the offset will also be highly dependent on design features such as the wagon bogie (suspension) design and wagon length. It is proposed that Vampire simulation be undertaken following the work on the container wagon modelling, via an adaptation of the work on the container wagons. The work may also benefit from analysis of offline GOTCHA data.
Once the sensitivity to derailment has been modelled, further work would be required to determine the relevant processes and supporting infrastructure required. Suggestions were made, for example, that retained loads up to a certain threshold may be permitted to return for one cycle of reloading and unloading, as the loading/unloading cycle may dislodge a retained load. In addition, if loads are required to be removed manually, diggers and infrastructure to permit unloading were believed to be required, as well as space to stable rejected wagons.

3.6 Track twist control measures

The risk control measures identified by the workshop concerning track twist fell principally into the area of measurement of track twist.

The track system is inspected and measured in accordance with intervals depending on the construction of the track, tonnage, and line speed, as specified in the Network Rail Track standard, NR/L2/TRK/001 [25]. The requirements are risk-based, and so further inspections or actions may be required to control the risks associated with poor track conditions, such as faults that are deteriorating rapidly, limited access or environmental conditions affecting track stability.

Track twist inspections are most effective when measured in loaded condition or are observed under load as part of a manual measurement cycle. Track twist may be measured by Track Recording Vehicles (TRVs), by hand-pushed recording equipment trolleys or manual gauges. It was reported in the workshops that concerns over track worker safety and the drive to separate operatives from the ‘live’ railway have led to increased challenges in gaining track access for inspections and proactive intervention within specified timescales.

A key output from the first bowtie workshop was to identify risks concerning the inspection and measurement of track twist over switches and crossings. Planning and undertaking loaded measurements was reported by workshop members as being more challenging for several reasons:

- Freight trains often have to use paths across switches and crossings to slower or freight-only lines to avoid delaying passenger trains.
- TRVs runs may prioritise the main routes, rather than those used most frequently by freight trains.
- TRV paths may be changed for operational reasons.
- TRV runs may be aborted for operational reasons.
- The records from slow speed measurements of switches and crossings by track recording vehicles can be unrepresentative at slow speeds but twist measurements are considered sufficiently accurate to use.
Alternative methods for confirming compliance by inspection and maintenance are permitted in NR/L2/TRK/001. Possessions of junctions to undertake measurement by hand-pushed trolley-type devices may be difficult to achieve if it is necessary to maintain alternative routes open. Such trolleys are not able to measure dynamic track twist, only static twist, so any voiding below the sleepers/bearers needs to be measured separately. In-service trains and locomotives are used for some types of visual cab inspection, but track twist cannot reliably be identified from a cab viewpoint and cannot be measured to enable proactive intervention.

Workshop members discussed other measures related to the potential for repeat faults at the same location and the assurance that a fault has been rectified.

The action which was recorded for these risks was for observation or measurement of loaded track performance after repairs. Whilst not themselves scoring in the Top 10, these are controls which could also benefit from improved track twist measurement.

3.6.1 Longer or alternative wavelength track twist monitoring (8)

The study of whether track twist should be measured only over a 3m wavelength, or whether longer or alternative wavelengths should be considered, was included in the assessment as it had been agreed as a work stream with ORR and was recommended in several RAIB reports [see, for example, references 18-21].

The normal limit for design cant transitions is 1:400. Track faults are defined as twists exceeding 1:200 over a 3m base. Once discovered, a track twist between 1:90 and 1:200 may remain in track for a period of time specified by the appropriate alert and immediate action intervention limits. Lines must be closed to traffic immediately for faults greater than 1:90. These values are consistent with those in the Infrastructure TSI [30].

Track twist faults are currently measured over 3m base [14]. Current track twist limits and the required intervention are shown in Table 7.
The XIFDWG has discussed the potential benefits that could be gained from adding an alternative track twist measurement base length (or wavelength) for assessing track twist. Network Rail has undertaken a study of track data to identify the wavelength content of twist defects on their network. That study will need the output of the modelling of sensitivity to offset loads and track twist to be completed, but the work to date has been presented to the XIFDWG. This work is due to be peer reviewed by the University of Huddersfield and may need input from the modelling of sensitivity of wagons to derailment.

This work stream is shown in Figure 10 as being a precursor to the other track twist measurement work streams as assessment of these controls could be affected by the results of this study, for example if it were decided to monitor other wavelengths.

### 3.6.2 Add twist recording equipment to freight locomotives (5)

Adding track twist recording equipment to in-service freight locomotives was discussed in the workshops as a means of improving coverage of the rail network with on-board dynamic track twist recording, particularly at S&C, on freight only routes and at locations where static measurement only is made by hand.

<table>
<thead>
<tr>
<th>Curve radius</th>
<th>Twist fault over 3m</th>
<th>Speed Range</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>&gt;33mm (1 in 90 or worse)</td>
<td>All speeds</td>
<td>Stop all traffic immediately and correct fault</td>
</tr>
<tr>
<td>All</td>
<td>33mm to 24mm (1 in 91 to 1 in 125)</td>
<td>Up to 75mph</td>
<td>Correct fault within 36 hours</td>
</tr>
<tr>
<td>All</td>
<td>33mm to 21mm (1 in 91 to 1 in 143)</td>
<td>80mph to 125 mph</td>
<td></td>
</tr>
<tr>
<td>Curve Radius ≤400m</td>
<td>&lt;24mm to &gt;15mm (1 in 126 to 1 in 199)</td>
<td>Up to 65 mph</td>
<td>Correct fault within 7 days</td>
</tr>
<tr>
<td>Curve Radius ≥400m</td>
<td>&lt;24mm to &gt;15mm (1 in 126 to 1 in 199)</td>
<td>Up to 75 mph</td>
<td>Correct fault within 14 days</td>
</tr>
<tr>
<td>Curve Radius ≥400m</td>
<td>&lt;21mm to &gt;15mm (1 in 144 to 1 in 199)</td>
<td>80 to 125mph</td>
<td></td>
</tr>
</tbody>
</table>
The main objectives included:

1. Examining track data to see how often track twists are likely to happen and where.
2. Assessing whether longer wavelengths identify problems or only known areas like transitions.
3. Studying the implication of short and long wavelength twist occurring on curve transitions.
4. Analysis of different combinations of track twist lengths to see if this will identify as yet unknown opportunities.

A total of 251 miles of track geometry data were assessed, against the Network Rail Track Inspection limits mandated within NR/L2/TRK/001 [25], from:

- 126 miles between Felixstowe Beach and Mossend (Freight dominant route).
- 125 miles between Inverness Station and Wick (Lower track category).

A full report discussing the analysis process and key findings is being completed within the XIFDWG but is not published at the time of drafting this report. The main conclusions are outlined below.

### 3.6.2.1 Outcomes of the study

The following major outcomes were presented to the XIFDWG on 7 October 2016 [10]:

- Reducing the track twist base length significantly increased the sensitivity of the track twist measurement. For example, reducing to a 2.0m base length increased the number of Intervention Limit (IL) alerts by approximately 1550%.
- Introducing a reduced base length track twist measurement would therefore significantly increase the maintenance effort requirement for managing track twist.
- Only one long wavelength (>3m) track twist was identified as an IL alert and only when assessed against the stricter twist intervention limit proposed by the ORE B55 committee [31], which introduces a reducing allowable twist gradient with increasing measurement base length. This equated to only 0.1% of the total IL alerts identified within the entire study.
- All longer wavelength track twists, which included those that were close to but did not exceed the alerts limits, were associated with curve transitions.
- The derailment risk associated with alternative twist base lengths was assessed using GMRT2141 Appendix C [13] using a validated JHAI Hopper Wagon model. For all existing IL limit twists (ie at the point in which Network Rail would initiate a maintenance activity):
a. The derailment quotient remained substantially unchanged for <3m twist base lengths.
b. The derailment quotient reduced for >3m twist base lengths.
c. The derailment quotient only marginally increased for >3m twist base lengths upon application of an artificial bogie yaw torque (applied on the approach to the track twist to further promote flange contact).
d. The degree of wheel unloading \( (Q/Q, \text{defined in [13]}) \) remained well within the 0.6 acceptance limit (ie 60% wheel unloading) for all alternative twist base lengths.

- Zero combinations of short and long wavelength twists were identified using the NR/L2/TRK/001 [25] limits.
- Only 1 short and long wavelength twist combination was identified when using the ORE B55 system [31], which was again associated with a known curve transition.

This study therefore concluded that no significant evidence has been identified to suggest that an alternative or additional track twist base length measurement would provide any further benefit to the industry.

The IRR at the University of Huddersfield have also completed a sensitivity study for the derailment risk of wagons with offset loads (report also being compiled for the XIFDWG). Working independently, both the Network Rail and University of Huddersfield studies draw up the same, complementary conclusions.

The XIFDWG have collectively agreed that completion of this work package has adequately demonstrated that no further work is required and that the existing, 3m track twist base length is indeed an effective measure for track twist identification.

This work stream is shown in Figure 10 as being a precursor to other track twist measurement work streams, in that any proposed change to monitoring standards would affect those studies. It can now be confirmed that the 3m existing wavelength is the measurement to include in those studies.
3.6.2.2 Draft work stream notes

The advantages presented by workshops members are that:

- These locomotives may cover parts of the network that the TRV runs cannot effectively accommodate.
- The routes taken by the freight locomotives replicate service patterns taken by the rolling stock at risk of flange-climb derailment.
- Measurement by locomotive could reduce the number of trackside worker interventions to measure track twist, although asset inspection is still required.
- Specific rolling stock is not required.

Several challenges affecting the potential benefit of this control were raised at the workshops. These include:

- The complexity of responsibility between the infrastructure manager (IM) and the railway undertaking (RU) for the procurement, installation and maintenance of recording, analysis and transmission equipment to be installed.
- Space or weight constraints it could be impracticable to find additional space for track twist recording, power and transmission equipment in rolling stock, or to add that equipment whilst keeping within weight and gauge constraints.
- Data collection and transfer for analysis could be challenging as large amounts of data would be collected and need to be transferred.

The safety benefit of this potential control was reduced from 1 to 2 in the priority workshops, as the measure would not reduce the risk of derailments due to twist faults already identified, but still within their intervention period.

The assumptions for this study were that:

- The recording would be undertaken by multiple locomotives.
- They would be capable of recording at low speed.
- The runs would use normal commercial paths for those locomotives, rather than specially created paths.

The detailed risk analysis and cost-benefit analysis needed for the detailed study of this control would need data from various sources, for example, as shown in Table 8.
### Table 8 - Sample data for detailed study of adding track twist to locomotives

<table>
<thead>
<tr>
<th>No</th>
<th>Discipline</th>
<th>Factor</th>
<th>Reason for Analysis</th>
<th>Costs for CBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RSSB Safety</td>
<td>Freight derailment data from SRM</td>
<td>To factor in existing FWI/yr from track twist derailments</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Track</td>
<td>Existing track twist lists with location – from hazard log</td>
<td>To assess the potential for risk reduction due to freight loco recording</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Track</td>
<td>Method of measuring track twist today by track type, category, route with frequency each year</td>
<td>Baseline needed to assess safety benefit of track recording by locomotive</td>
<td>✓</td>
</tr>
<tr>
<td>4</td>
<td>Track</td>
<td>Numbers of track worker interventions pa to inspect/measure twist and possession type</td>
<td>Baseline needed to assess the potential benefit of moving from trackside worker inspection to recording via rolling stock</td>
<td>✓</td>
</tr>
<tr>
<td>5</td>
<td>Rolling Stock</td>
<td>Locomotive types proposed</td>
<td>To feed into information below</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Rolling stock operations</td>
<td>Commercial pathing patterns of rolling stock, including precise routes</td>
<td>To check that the rolling stock actually traverses the sections of track needed from 1.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Track</td>
<td>Outline interface specification for track twist recording equipment, such as dimensions, weight, heat output and cooling requirements, power supply and cabling requirements.</td>
<td>To check that the equipment could fit within the space available</td>
<td></td>
</tr>
</tbody>
</table>
3.6.3 Use MPVs to measure twist on S&C (4)

One solution to the difficulty of measuring track twist over the approximately 22,000 switches and crossings on the GB rail network is to measure the track twist intensively on complex junctions using Network Rail’s multi-purpose track recording vehicles (MPV).

3.6.3.1 Draft work stream notes

Whilst this can be an effective measure for identification of track twist faults on S&C for complex junctions, possessions are required. The introduction of more MPVs would be an internal decision for Network Rail, rather than a cross-industry proposal, but it is recommended that the costs of this measure be used as a comparator for the study into adding twist recording equipment to freight locomotives, above.

3.7 Leaders and support for the studies

At the meeting on 7 October, 2016, the XI FDWG agreed the leaders and support for the key enablers, and felt that other studies in the top 10 should be agreed at the output of the key enabler studies. Once those have been decided, it will be necessary to:

- Agree the detailed scope of each measure.
- Make any necessary arrangements with external bodies.
- Agree funding sources and mechanisms.
Identify relevant data sources.

Table 9 records the agreements made on leaders and support, taking into account where work has already started, and where the work would be subject to procurement rules.

<table>
<thead>
<tr>
<th>No</th>
<th>Study</th>
<th>Status</th>
<th>Leader</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>Offline GOTCHA trending of wagon twist and offset loads</td>
<td><strong>Key enabler</strong>&lt;br&gt;Discussions started, UoH and NR</td>
<td>Phase 1: IRR, University of Huddersfield (UoH) &lt;br&gt;Phase 2: Network Rail</td>
<td>Network Rail (NR), Freightliner, DRSL, UoH</td>
</tr>
<tr>
<td>3</td>
<td>Port Survey</td>
<td><strong>Key enabler</strong>&lt;br&gt;R&amp;D</td>
<td>Phase 1 ETS Consulting &lt;br&gt;Phase 2 RSSB, Procurement tba</td>
<td>UoH / RSSB/ETS</td>
</tr>
<tr>
<td>4</td>
<td>Use MPVs to measure twist on S&amp;C</td>
<td>Use as comparator for 5</td>
<td>Network Rail</td>
<td>tba</td>
</tr>
<tr>
<td>5</td>
<td>Add twist equipment to freight locomotives</td>
<td>To be proposed</td>
<td>Network Rail</td>
<td>FOC tba</td>
</tr>
<tr>
<td>6</td>
<td>Simulate Container Wagon sensitivity to derailment to offset load/track twist</td>
<td><strong>Key enabler</strong>&lt;br&gt;R&amp;D</td>
<td>Lead HON Procurement tba</td>
<td>FOC</td>
</tr>
<tr>
<td>8</td>
<td>Longer/alternative wavelength track monitoring</td>
<td>Project completed subject to report</td>
<td>Network Rail</td>
<td>UoH</td>
</tr>
</tbody>
</table>
### 3.8 Output from the studies

Once the studies above are complete, they should be submitted for review by XIFDWG and the relevant governance bodies so that decisions can be made on which of the studies should be carried forward for implementation funding sourcing, procurement and projects, as shown in Figure 4.

It is also envisaged that the output of the studies will provide sufficient risk assessment to satisfy the action agreed with ORR [12] on risk analysis, as described in Section 1.2 of this report.

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**Table 9 - Proposals for study leaders and support**

<table>
<thead>
<tr>
<th>No</th>
<th>Study</th>
<th>Status</th>
<th>Leader</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Set limits and guidelines for rejecting hoppers with offset retained loads</td>
<td>To be proposed</td>
<td>tba</td>
<td>RSSB Freightliner</td>
</tr>
<tr>
<td>10</td>
<td>Identify offset load at start of UK journey</td>
<td>To be proposed</td>
<td>tba</td>
<td>tba</td>
</tr>
<tr>
<td>10</td>
<td>At loading onto rail, check container</td>
<td>To be proposed</td>
<td>tba</td>
<td>tba</td>
</tr>
</tbody>
</table>
4 Recommendations

4.1 Key enablers

The working group recommends that the controls identified as key enablers be implemented as quickly as possible, to gain the intelligence necessary for study of further risk control measures. These measures are:

- Use of offline GOTCHA to check for wagon/bogie twist and for offset load.
- The port survey of offset container loads.
- Simulation of wagon sensitivity to derailment due to offset load and track twist.

It is recognised that the wagon sensitivity modelling may need to go through an open procurement exercise.

4.2 Overall recommendations

The bowtie risk analysis and associated priority workshops have provided a systematic, structured, transparent and repeatable means of assessing where the industry can best direct its efforts to reduce the risk of flange climb derailments of freight trains.

Now that the priorities for further improvement have been decided, the XIFDWG recommends that the studies should progress as quickly as possible, to enable the risk control reductions described in this report to be put into effect.

It is thanks to the considerable expertise, effort and engagement of all the participants that the XIFDWG now has a significantly improved understanding of risk areas, the strength of current controls and the potential improvements in controls which could be put in place.
5 References

1 Letter from Ian Prosser to Network Rail, Freightliner, GBRF, DB Schenker, DRS, Colas, RSSB, RAIB and HSE, titled 'Recent freight derailment: The interaction of track, vehicles and freight container loads, and potential areas for improvement', 5th December 2014.


7 PPR691 ‘Potential risk to road and rail transport associated with asymmetric loading of containers’, RSSB and TRL 2014


10 XIFDWG Minutes of Meeting for 29 January, 23 February, 10 April, 3 June, and 23 September 2015, 2 February, 2016, 16 May, 2016, 7 October, 2016.

11 Maritime and Coastguard Agency MG530 Guidance on the implementation of the SOLAS VI Regulation 2 amendment requiring the verification of the gross mass of packed containers, 2015

12 Note of ORR/RSSB meeting about safety decision making, 14 May 2015

13 GMRT2141 Resistance of Railway Vehicles to Derailment and Roll-Over, Issue 3, RSSB, 2009
14 GCRT5021 Track System Requirements, Issue 5, RSSB, 2011
15 T1119 Specification for research project Quantifying Offset Loading of Container Wagons (Draft)
16 R698 Specification for research project Container wagons on twisted track (Draft)
18 RAIB report 21/2014 Derailment at Primrose Hill / Camden Road West Junction, 15 October 2013 © Crown Copyright
19 RAIB report 11/2015 Freight train derailment at Angerstein Junction, 2 April 2014 © Crown Copyright
20 RAIB Report 02/2013 Freight train derailment at Reading West Junction, 28 January 2012 © Crown Copyright
21 RAIB Report 20/2014 Freight train derailment near Gloucester 15 October 2013 © Crown Copyright
22 CTU Packing Under the New Code, Mike Yarwood, TT Club, UIC Workshop on Safe Loading, 11 June 2015
24 GO/RT3056C Principles of Safe Freight Train Operation, RSSB, 2013
25 NR/L2/TRK 001 Inspection and Maintenance of Permanent Way, Issue 9, Network Rail, 2015
29 prEN 15654-1:2015 (E) Railway applications — Measurement of vertical forces on wheels and wheelsets — Part 1: on-track measurement sites for vehicles in service
30 TSI INF: Technical specification for interoperability relating to the infrastructure subsystem of the rail system in the European Union (Decision 1299/2014 of 18 Nov 2014) European Union Agency for Railways

Note 1: ‘α’ denotes: available to XIFDWG members, including ORR. Other references are published unless otherwise stated.

Note 2: Permission has been obtained from copyright holders of all photographs used.
6 Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASPR</td>
<td>(RSSB) Annual Safety Performance Report</td>
</tr>
<tr>
<td>CSM RA</td>
<td>Common Safety Methods for Risk Evaluation and Assessment</td>
</tr>
<tr>
<td>DB</td>
<td>Deutsche Bahn</td>
</tr>
<tr>
<td>DRSL</td>
<td>Direct Rail Services Ltd</td>
</tr>
<tr>
<td>DVSA</td>
<td>Driver and Vehicle Standards Agency</td>
</tr>
<tr>
<td>ERA</td>
<td>European Railway Agency</td>
</tr>
<tr>
<td>FOC</td>
<td>Freight operating company</td>
</tr>
<tr>
<td>FWI/yr</td>
<td>Fatalities and Weighted Injuries per year</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organisation</td>
</tr>
<tr>
<td>MPV</td>
<td>Multi-purpose vehicle</td>
</tr>
<tr>
<td>NR</td>
<td>Network Rail</td>
</tr>
<tr>
<td>ORE</td>
<td>Office of Research and Experiments, UIC</td>
</tr>
<tr>
<td>ORR</td>
<td>Office of Rail and Road</td>
</tr>
<tr>
<td>PHRTA</td>
<td>Potentially higher risk train accident</td>
</tr>
<tr>
<td>RAIB</td>
<td>Rail Accident Investigation Branch</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and development</td>
</tr>
<tr>
<td>RSSB</td>
<td>Railway Safety and Standards Board</td>
</tr>
<tr>
<td>S&amp;C</td>
<td>Switches and crossings</td>
</tr>
<tr>
<td>SKE</td>
<td>Skills, Knowledge and Experience Matrix</td>
</tr>
<tr>
<td>SMIS</td>
<td>Safety Management Information System</td>
</tr>
<tr>
<td>SOLAS</td>
<td>Safety of Life at Sea [IMO Regulations]</td>
</tr>
<tr>
<td>SRM</td>
<td>Safety Risk Model</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>TRL</td>
<td>Transport Research Laboratory</td>
</tr>
<tr>
<td>TRV</td>
<td>Track Recording Vehicle</td>
</tr>
<tr>
<td>TRUST</td>
<td>Train RUnning Systems on TOPS</td>
</tr>
<tr>
<td>TOPS</td>
<td>Total Operations Processing System</td>
</tr>
<tr>
<td>UIC</td>
<td>Union Internationale des Chemins de Fer (International Union of Railways)</td>
</tr>
<tr>
<td>XIFDWG</td>
<td>Cross-Industry Working Group on Freight Derailment</td>
</tr>
</tbody>
</table>