Rail Standards Safety Board

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PUBLISHED PROJECT REPORT PPR691

Potential risks to road and rail transport associated with asymmetric loading of containers

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Transport Research Laboratory
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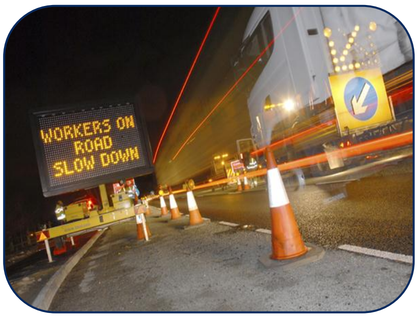


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Contents amendment record

This report has been amended and issued as follows:

Version	**Date**	**Description**	**Editor**	**Technical Referee**

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1 Introduction

This report considers the risks associated with transporting ISO Containers by road and rail. Each year millions of these containers are moved around the world by road, rail and sea, 4.8 million being handled at UK ports in 2012. Containers offer an efficient, secure and safe means of transporting goods over long distances and between different modes of transport.

Shipping containers are loaded at the point of origin, where they are secured and then shipped, usually by a number of transport modes. Despite guidance on the loading of containers, they can be overloaded or unevenly loaded. In addition, containers from overseas will have been handled a number of times, each introducing risk of poorly secured contents moving. These factors can lead to asymmetric loading of the container, the load being concentrated at one end or side. Typically containers are 'customs sealed' and not opened between the point of origin and their destination so there is no opportunity for freight operators to inspect the distribution of load inside a container.

On the railway, asymmetric loading / a high centre of gravity increases the potential for wheel unloading leading to a derailment. There are similar risks for road transportation, with an increased risk of instability and overturning. In practice, emphasis is placed on the speedy and accurate transfer of containers between transport modes rather than the assessment of load distribution which could impact on efficiency and productivity of the interchange.

Whilst tens of thousands of containers are transported throughout Great Britain safely and reliably each day, accident investigations have identified that a small number of asymmetrically loaded containers could introduce a risk of rail vehicle derailment or road vehicle overturning.

The aim of this project was to improve understanding of the nature and size of any risks of damage to infrastructure and societal harm (including casualties), related to inappropriately loaded containers, and to identify potential mitigating actions.

The objectives of the project are to:

- Review current knowledge about the loading of containers and associated risks
- Identify the risks associated with transporting asymmetrically loaded containers by road and rail
- Identify technologies for determining whether containers are asymmetrically loaded
- Examine the feasibility of reducing the carriage of asymmetrically loaded containers

2 Use of ISO containers

2.1 Types of container

This report considers the risks associated with transporting ISO containers. Other types of intermodal units are not specifically considered.

2.1.1 ISO Containers

ISO containers are designed for carriage by sea, rail and road. They are therefore designed to be robust, to be stacked (on board ship and on land) and to be top lifted. Their design is regulated by the International Organization for Standardization (ISO) to ensure that there is worldwide compatibility with ships, road vehicles, rail vehicles and handling equipment. The use of ISO containers has become firmly established for the international carriage of goods over the last fifty years and they have been a major technological advance in the handling of general cargoes.

Originally the ISO container designs had external dimensions of 8 feet (2.44 m) wide, 8 feet high and 20 feet (6.06 m), 30 feet (9.13 m) or 40 feet (12.19 m) long. However, experience with use has led to a height increase to 8 feet 6 inches (2.59 m) which has become the most common size. There is also an increasing demand for high-cube containers which are 9 feet 6 inches (2.90 m) high and up to 49 foot (14.94 m) long.

Container capacity is often expressed in twenty-foot equivalent units (TEU) which is a unit of capacity equal to one standard 20 foot long container.

2.1.2 Other types of Intermodal Unit

A range of other types of intermodal units are used where there is no requirement for carriage by sea:

- Swop bodies are similar to ISO containers but are generally non-stackable (and therefore lighter), bottom lifted and used mostly in road/rail movements. They are fitted with bottom corner castings (similar to the corners of ISO containers) which generally conform to ISO dimensions. These give compatibility with the twistlocks on road and rail vehicles that are used to carry maritime containers. Their overall dimensions are generally determined by road vehicle regulations (for example, 13.6 metres long for carriage by European articulated vehicles).
- Air portable containers are designed and built to standards laid down by the International Air Transport Association (IATA). The variety of aircraft types and the nature of aircraft stowage (curved fuselage walls) have led to a variety of dimensions and shapes.

2.2 Port Statistics

The Department for Transport (DfT) publishes statistics on freight traffic at UK ports. In 2012, 4.8 million containers were moved on Lo-Lo (Lift-on, Lift-off) shipping services, accounting for 55.1 million tonnes of goods (11% of all goods through UK ports).

Table 1 shows that 92% of inward containers are loaded whilst only 54% of outward containers are loaded. This reflects the balance of UK trade. However, the average load on laden outward units (18.3 tonnes) is greater than that of inward units (14.3 tonnes).

Table 1: Container traffic at UK major ports (2012)

	Containers (thousand)			% loaded	Weight of goods (thousand tonnes)	Average weight of goods – loaded units (tonnes)
	Loaded	Empty	Total			
Inward traffic	2,202	193	2,395	91.9%	31,542	14.3
Outward traffic	1,287	1,087	2,374	54.2%	23,511	18.3
Total	**3,488**	**1,280**	**4,769**	**73.1%**	**55,053**	**15.8**

Source: DfT Port Freight Statistics (PORT0205)

Between 2005 and 2012, the number of containers handled by UK Ports has generally been between 4.7 and 5.0 million (see Figure 1), with over 5.2 million in 2007 and 2008, and less than 4.5 million in 2009 following the economic downturn.

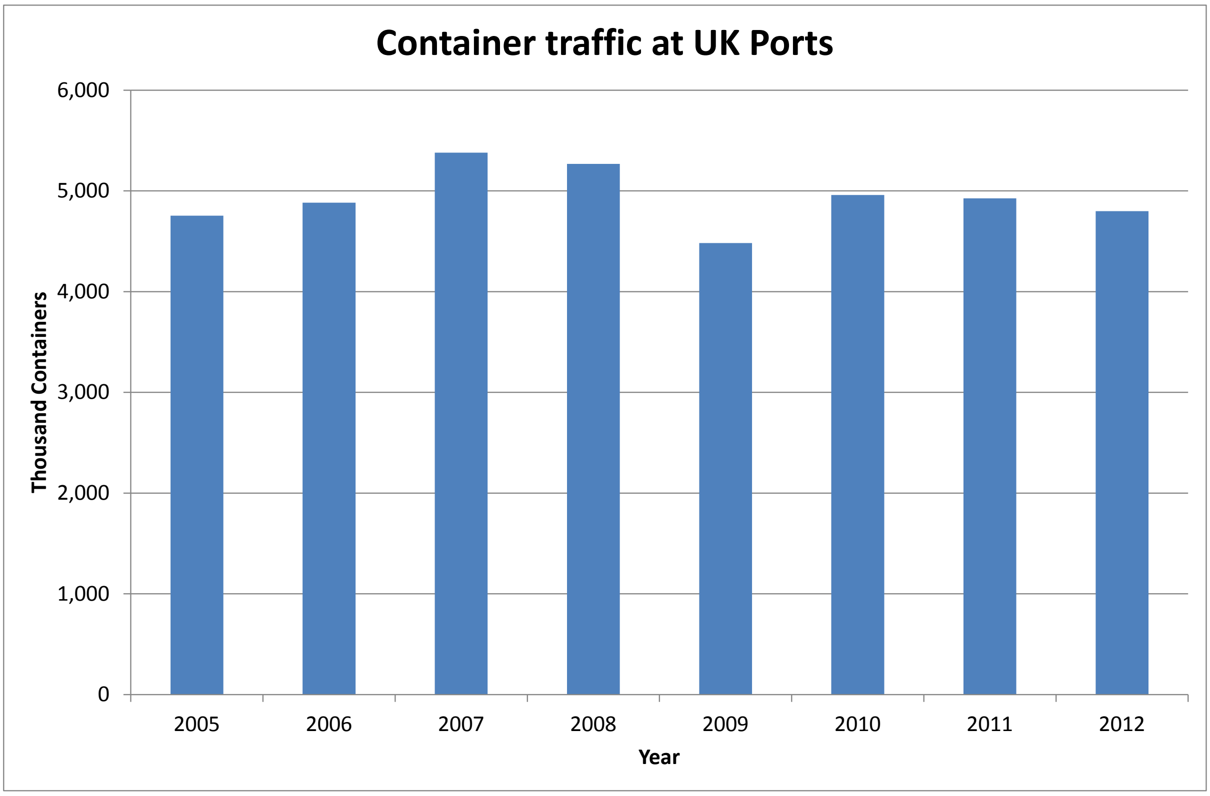

Figure 1: Container traffic at UK ports (2005 - 2012)

Source: DfT Port Freight Statistics (PORT0203)

The main UK container ports are Felixstowe and Southampton (see Table 2). These two ports accounted for 62% of units and 58% of the weight of goods transported through UK ports.

Table 2: Main Container ports (2012)

Port	% of units	% of weight of goods
Felixstowe	42.9%	43.3%
Southampton	18.6%	14.6%
London	8.2%	9.7%
Liverpool	8.1%	8.5%

Source: DfT Port Freight Statistics (PORT0202)

The majority of containers passing through UK ports are either 20 or 40 feet long (see Table 3). Inward, 20 foot containers are more heavily loaded than are 40 foot containers, but a lower percentage are loaded. Outward, these trends are reversed.

Table 3: Average load and % loaded by Container size (2012)

Container size (length)	% of containers at UK ports	Average Load (tonnes)		% Loaded	
		Inward	Outward	Inward	Outward
20 foot	33.1%	14.9	17.1	89.7%	59.0%
40 foot	58.6%	13.5	19.1	92.9%	53.1%

Source: DfT Port Freight Statistics (PORT0205)

Some containers are transhipped from one ship to another (for example, from deep-sea to coastal shipping). In 2004, transhipment accounted for 13% of container activity at Felixstowe and 5% at Southampton[1].

2.3 Road freight statistics

Great Britain's road freight statistics are based on data from the Continuing Survey of Road Goods Transport (CSRGT). This is a statutory survey completed by operators for a week's activity of samples of vehicles.

The CSRGT questionnaire includes two particularly relevant questions for each journey:

- Mode of appearance[2]: the options include "Large Freight Containers, incl. ISO Containers"; and
- Intermodal journeys: the options include "Docks – container: when a container is collected or delivered at the docks" and "Rail – container: when a container is collected or delivered at a railhead".

CSRGT data for goods carried by articulated vehicles in 2010 have been analysed (almost all maritime containers are carried by articulated vehicles at some point in their journey). Trips were classified as intermodal if either end was at an intermodal terminal.

[1] Woodburn, A. (2011). An Investigation of Container Train Service Provision and Load Factors in Great Britain. Transport Studies Department, University of Westminster, United Kingdom, EJTIR Issue 11(2), pp. 147-165.

[2] i.e. type of traffic

Table 4: Goods lifted (million tonnes) by articulated vehicles in 2010

Type of journey	Large Freight Containers	All articulated vehicles
Docks – container, or rail – container journeys	9.1 (1.0%)	10.5 (1.2%)
Other intermodal journeys	4.0 (0.5%)	23.3 (2.6%)
All intermodal journeys	***13.1 (1.5%)***	***33.8 (3.8%)***
Non-intermodal journeys	31.2 (3.5%)	847.4 (96.2%)
All journeys	**44.3 (5.0%)**	**881.2 (100.0%)**

Source: CSRGT

Table 4 shows the weight of goods lifted by mode of appearance and intermodal journey.

The weight of goods shown as lifted for "Docks – container, or rail – container" journeys (10.5 million tonnes) is much smaller than the weight of containerised goods at ports. However, the figure for goods lifted for all "large freight container" journeys (44.3 million tonnes) is much closer to the weight of goods lifted at ports (but may include other types of container).

It was expected that the majority of containers travelling through UK ports would be carried by road for some part of their journey (even if the journey to / from the port used an alternative mode, it is likely that the initial / final legs of the journey would be by road). However, a number of factors would lead to the weight of containerised goods carried by road being different from the weight of containerised goods at ports:

- The CSRGT figures are for Great Britain (GB) whilst the port statistics are for the United Kingdom (UK) – in 2012 53.2 million tonnes of goods was carried by container through GB ports (97% of the UK total)
- The latest CSRGT figures are for 2010 whilst the port statistics are for 2012 – the weight of containerised goods carried though UK ports declined from 56.7 million tonnes in 2010 to 55.1 million tonnes in 2012 (3% decline)
- Some containers will be unpacked at the ports
- Some containers will arrive and depart by ship (for example, being transferred from a deep-sea ship to a smaller ship for onward travel to Northern Ireland)
- The definitions of container may be different – the port statistics will be for ISO maritime containers whilst the CSRGT statistics may include other containers, some of which may not be suitable for maritime carriage

These factors could account for the difference between the port and "large freight container" statistics, but are unlikely to be large enough to account for the differences between the port and "all intermodal journeys" statistics. It therefore appears that the coding of intermodal journeys is unreliable and that the figures for "large freight containers" are more likely to be a measure of ISO container carriage.

Table 5: Goods moved (million tonne-kms) by articulated vehicles in 2010

Type of journey	Large Freight Containers	All articulated vehicles
Docks – container, or rail – container journeys	1,408 (1.3%)	1,575 (1.5%)
Other intermodal journeys	649 (0.6%)	3,629 (3.4%)
All intermodal journeys	***2,057 (1.9%)***	***5,205 (4.8%)***
Non-intermodal journeys	3,558 (3.3%)	102,690 (95.2%)
All journeys	**5,615 (5.2%)**	**107,895 (100.0%)**

Source: CSRGT

Table 5 shows the amount of goods moved (in tonne-kilometres) by articulated vehicles by mode of appearance and intermodal journey and Table 6 shows the equivalent loaded kilometres. In 2010, large freight containers accounted for 5.2% of articulated vehicle tonne-kilometres and 5.8% of loaded kilometres.

Table 6: Loaded kilometres (million) by articulated vehicles in 2010

Type of journey	Large Freight Containers	All articulated vehicles
Docks – container, or rail – container journeys	104 (1.5%)	114 (1.7%)
Other intermodal journeys	41 (0.6%)	204 (3.0%)
All intermodal journeys	***145 (2.1%)***	***318 (4.6%)***
Non-intermodal journeys	251 (3.7%)	6,530 (95.4%)
All journeys	**395 (5.8%)**	**6,849 (100.0%)**

Source: CSRGT

From these figures, it was calculated that for Large Freight Containers the:

- Average length of haul is 127 km (tonne-km divided by tonnes); and
- Average load is 14 tonnes (tonne-km divided by loaded km)

2.4 Rail freight statistics

The rail freight statistics include a category “domestic intermodal”, the majority of which are port-based container flows[3]. Between 2002/3 and 2012/3, domestic intermodal rail

[3] There is also a clategory “international” which is freight that travels through the tunnel, this has been on average 0.4 billion net tonne-kms since 1999/00, and may also include a small amount of container traffic.

freight increased by 86% (from 3.4 to 6.3 billion tonne-kms, see Figure 2), and from 18% to 30% of all rail freight (the published figures do not include the weight of goods lifted). The figure for 2010/1 (5.7 billion tonne-kms) is similar to that for large freight containers by road (5.6 billion tonne-kms). In practice, the lengths of haul by rail are likely to be much longer than those by road and therefore the tonnages of goods lifted would be significantly less than by road.

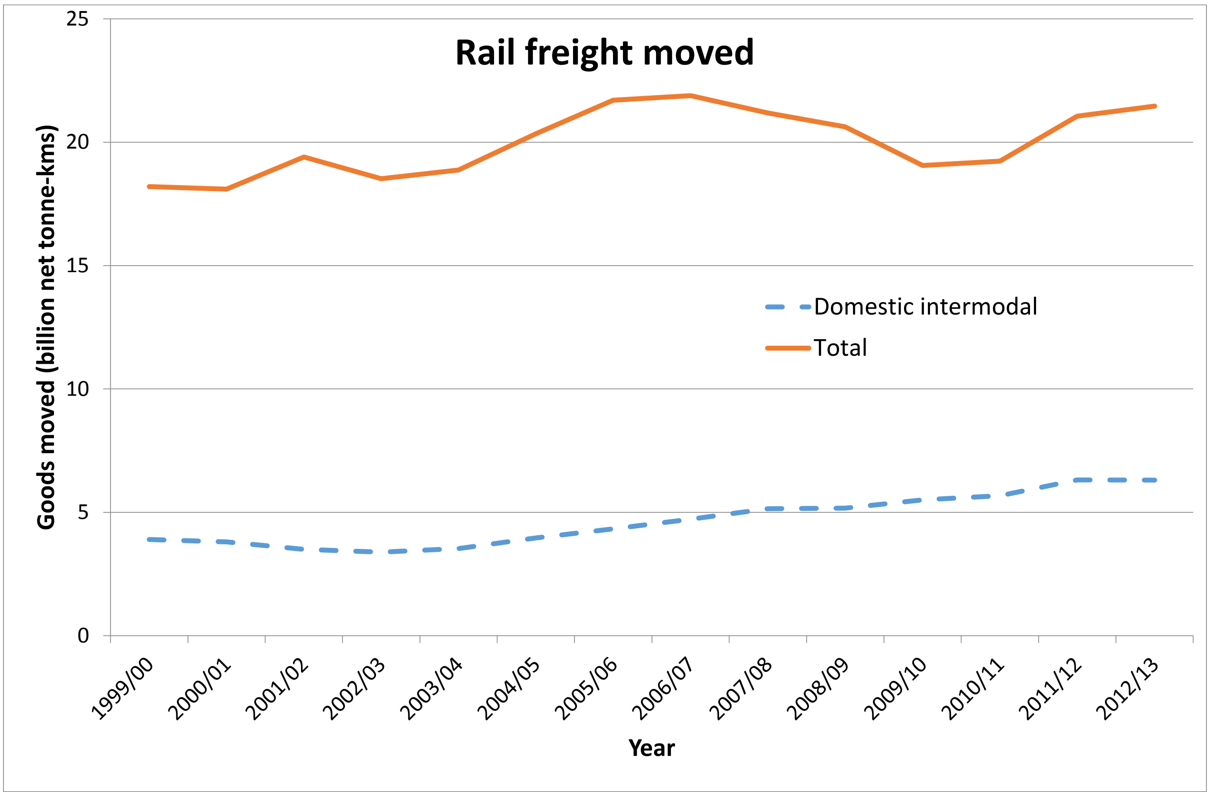

Figure 2: Rail freight (1999/0 – 2012/3)

Source: Office of Rail Regulation

3 Standards and guidelines for the packing of containers

3.1 Packing of containers

There are a number of standards and guidelines for the loading of shipping containers, including:

1. BS 5073
2. IMO/ILO/UNECE Guidelines for packing of Cargo Transport Units (CTU)
3. ICHCA Stow it right leaflet

3.1.1 BS 5073

BS 5073:1982, Guide to Stowage of goods in freight containers, covers a range of guidance on the packing of containers, including condition inspection, stowage plans, securing of cargo and checking of the load.

The clauses covering load distribution are:

5.4.5 *'Cargo mass should be as evenly distributed over the length and breadth of the container as may be practicable'*… *'the stow should be arranged and secured so that the approximate centre of gravity of the cargo is close the mid length and mid width of the container'*.

5.4.6 *'In no case should more than 60% of the load be at one end'*

5.4.7 *'wherever possible, the centre of gravity of the loaded container should be below the mid-point of its height'*

The standard also states that: *'it is essential to make the cargo in the container secure against any reasonably foreseeable movement'*.

3.1.2 IMO/ILO/UNECE Guidelines for packing of Cargo Transport Units (CTUs)

The International Maritime Organisation's (IMO) Guidelines for packing of cargo transport units appear to be the most comprehensive set of instruction for the packing of shipping containers. The guidelines include a discussion of the accelerations a container is likely to experience during different modes of transport and guidance on visual inspections of containers as well as packing and securing of cargo.

The clauses most pertinent to distribution of load inside a container are:

3.1.7 '*Stowage planning should take account of the fact that CTUs are generally designed and handled assuming the cargo to be evenly distributed over the entire floor* *area. Where substantial deviations from uniform packing occur special advice for preferred packing should be sought'*[4]

3.1.10 '*The centre of gravity of the packed cargo should be at or near the longitudinal centreline of the CTU and below half the height of the cargo space of the unit*'

3.1.13 '*When packing a CTU, the shipper and persons responsible for packing should bear in mind that any failure to pack and secure the cargo correctly may result in additional costs that they will have to bear. If, for example in railway transport, a unit is found not to be properly packed and secured, the rail-car may be marshalled out of the train into a siding and the transport can only be continued once the cargo has been properly secured. The shipper may have to pay for this work, especially for the repacking and re-securing operation, as well as for the additional time during which the rail-car has been used. In addition, he may be held responsible for any delay of the transport operation.*'[5]

3.2.1 '*It is essential to make the cargo in a CTU secure to prevent cargo movement inside the unit*'

3.2.5 '*In no case should more than 60% of the load be concentrated in less than half the length of a container measured from one end. For vehicles, special attention should be paid to axle loads.'*

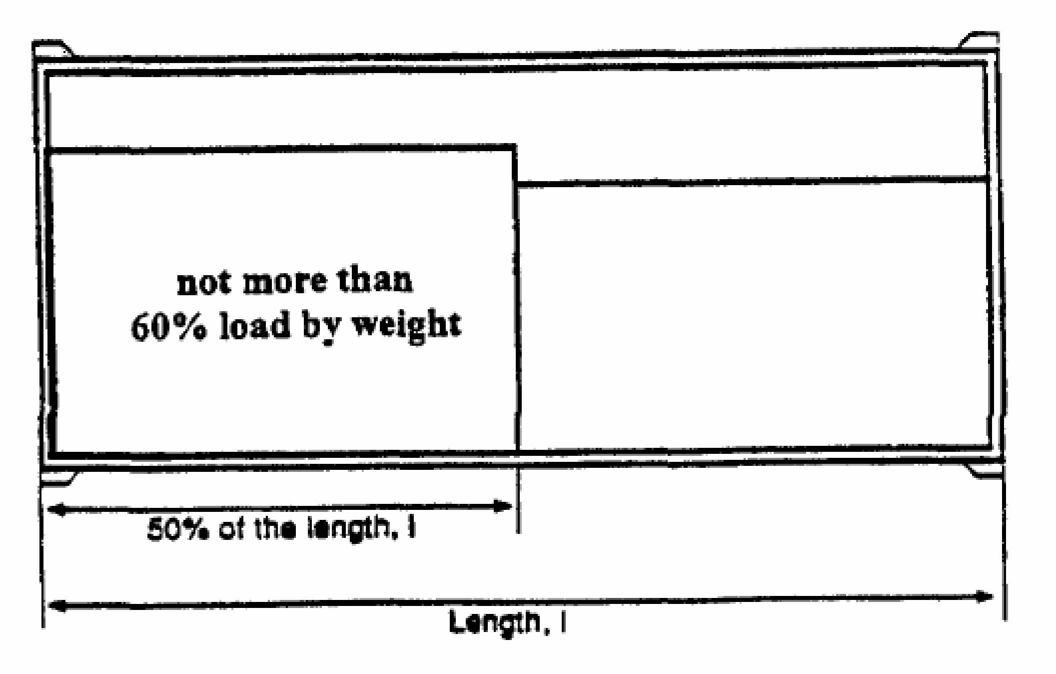

Figure 3: Load distribution in the container

[4] Though there is no guidance on where this special advice should be sought

[5] The practicalities of enforcing this for international transport are not mentioned in the guidelines

The guidelines also mention the need for training of staff who will pack containers, stating:

7.1.1 *'The regulatory authority should establish minimum requirements for training and, where appropriate, qualifications for each person involved, directly or indirectly, in the packing of cargo in CTUs, particularly in relation to dangerous cargos'*

However, it is unclear who that 'regulatory authority' might be or how the requirement for training could be enforced.

3.1.3 ICHCA Stow it right

The International Cargo Handling Coordination Association's (ICHCA), Stow it Right pamphlet does not give any specific limits on asymmetric loading; however, it does state in the preface that it is recommended '*for rail carriage of a laden container, that the weight of the load be evenly distributed from side to side and end to end of the container and to a uniform height of loading (insofar as loading permits)*'.

The pamphlet includes a lot of detail about securing the load, some pertinent clauses are:

4.2.2 '*The cargo should be restrained from moving fore and aft and side to side'*

5.3.1 *'It is important that the merchandise does not move within the carton, box, or other receptacle in which it is packed. In order to immobilise the contents, it is necessary to provide adequate cushioning within the packaging and/or block and brace the contents'*

6.1 *'If a shipment is moved by rail there should always be adequate bracing in the front and rear of a container utilising the corner posts as restraints'*

7.1.1 *'For rail movement, the cargo should be squared and a bulkhead constructed at the rear of the load'*

The pamphlet encourages even distribution of loads in containers, and includes a number of diagrams giving recommended packing layout for different types of load. It focuses on methods of securing loads, load layout and use of dunnage (inexpensive or waste material used to protect and secure cargo during transport).

However, there is no guidance on how to measure how evenly a load is distributed in a container or what the limits on uneven loading might be.

The pamphlet does give specific clauses for containers being transported by rail, highlighting the need for additional longitudinal restraint (in clause 7.1.1). However, it is not clear how the original packer of the container (which could be anywhere in the world) will be informed that their goods may be transported by rail for part of their onward journey after being shipped. As a rail freight operating company receiving containers in the UK will not open them, there is no way for that operator to know if this clause has been met.

3.1.4 How effectively do packing guidelines control uneven loading?

The three documents reviewed in this section all contain a general requirement that loads should be distributed evenly with the centre of gravity at the centre of the container where possible. BS5073 and the IMO Guidelines for packing of cargo transport units also give a limit for the front to back uneven loading of no more than 60 % of the load to be at either end of the container; none of documents reviewed contained a fixed limit for side to side uneven loading (further than the general requirement to distribute loads evenly).

Another theme is the need to suitably secure loads in containers so they don't move during transit, which is especially likely when exposed to the high accelerations experienced during sea travel.

The IMO guidelines also highlight the need for packing staff to be suitably trained.

All of these guidelines are not legally enforceable and whilst a freight haulier (either road or rail) may specify the need to pack containers in line with these requirements, they are difficult to enforce; especially as the freight company has no right to open the containers it is transporting.

3.2 Loading of containers onto rail vehicles

The Railway Group Standard affecting the operation of freight trains is, GO/RT3056 Working Manual for Rail Staff, Freight Train Operations.

Section C3 of GO/RT3056 details the required operational pre-departure check for a freight train. This includes the requirement that a physical examination should be carried out, to ensure that:

- loaded vehicles appear to have their weight correctly distributed

This is an opportunity to identify asymmetrically loaded containers; however, it is a visible inspection based on looking at suspension deflections which is not a particularly thorough method.

The standard also states that the examination should ensure that:

- additional checks required by company instructions have been carried out

Each freight operating company will have their own pre departure inspection methods which will include taking into account the weight of each container but at the moment they do not have the facilities to measure if a container is unevenly loaded

3.3 Loading of containers onto road vehicles

DfT has produced a **Code of Practice on Safe Loads on Vehicles**. A number of sections refer to the carriage of ISO Containers:

5.9 '*ISO freight containers are secured to vehicles by means of special container locks commonly known as twist locks. (ISO 1161/BS 3951 covers the specification for corner fittings for series 1 freight containers) In most cases twist locks will be fitted to the vehicle during manufacture but where they are fitted at a later date then modifications* *to the chassis/structure should be carried out in accordance with the recommendations of the vehicle manufacturer. Twist locks should be inspected regularly for wear, damage and correct operation. Locking devices, which are intended to prevent the operating levers from moving during transit, should be given special attention. The "Freight Containers (Safety Convention) Regulations 194" deal with the examination and plating of freight containers in general. A minimum of four twist locks should be provided for each container carried.'*

12.2 *'The majority of containers in use are constructed to International (ISO 1496) or British (BS 3951) standards. A common feature in the construction of these containers is that specially designed corner castings are incorporated which can be used. In conjunction with twist locks fitted on the vehicle, to provide a simple and positive means of restraint (see fig 28).'*

12.3 *'This type of container should only be carried on vehicles fitted with twist locks. Twist locks must be maintained in serviceable condition and a minimum of four used for each container carried (see Section 5.9). Provided that the twist locks are fully engaged and locked in position, the container will be adequately secured and no further restraint will be necessary.'*

12.4 *'The operator is confronted with a number of problems when attempting to carry ISO containers on vehicles not equipped with twist locks. Unlike normal box type loads that spread their weight over a large area, containers are designed to stand on the twist lock sockets or feet that protrude down at each corner. With heavy containers this produces high point loading that could over-stress a normal platform floor. Other platform vehicles may have raised or wide section side ledges which would prevent the container from resting on the platform floor. The resultant interface between the side ledges and the container feet would offer little frictional resistance making it virtually impossible to secure the container on to the vehicle safely and the practice should be avoided. If carried on a vehicle not fitted with twist locks, a retention system must be used that fulfils the requirements set out in Sections 3-7.'*

It also covers the stowage of goods in containers:

12.9 *'Incorrect loading of a container may result in dangerous situations occurring when the container is handled or transported; which could adversely affect the stability of the vehicle. In addition serious damage may be caused to the goods carried. In many instances the driver will have no control over the packing of a container nor be able to inspect its contents when he accepts it for carriage. If it is apparent that the container has not been safely loaded then it should not be accepted.'*

12.10 *'The following general stowage rules that affect road safety should always be observed:*

a. The load should not exceed the permitted payload of the container;

b. The load should be evenly distributed across the floor area of the container. In no case should more than 60% of the load be in less than half the length of the container which could lead to an axle been overloaded;

c. Heavy goods should not be stowed on top of lighter goods and wherever possible the centre of gravity of the loaded container should be below the mid-point of its height;

d. The load should be secured in the container against any reasonable forces that might be expected to occur during the journey. A tightly packed load will be less likely to move than one that has spaces between parts of the load.

e. After the packing of the container is completed, steps should be taken to ensure that the load and dunnage will not fall out when the doors are opened. Webbing lashings or nets are often suitable for this purpose, alternatively a timber or metal gate can be constructed.

f. Always make certain that the doors are locked and that the locking mechanisms are in good condition.'

12.11 *'More detailed information on the stowage of goods in containers can be found in British Standard BS 5073.'*

Vehicle operators and drivers have legal duties to ensure that vehicles and axles are not overloaded:

The **Road Traffic Act 1988** requires "vehicle users" to ensure that vehicles are not overloaded. If a vehicle is found to be overloaded both the driver and operator could be prosecuted or cautioned. Legislation imposes fines of up to £5,000 for each offence. That means a fine for each overloaded axle plus any overloading on the total weight. Also, if a vehicle is dangerously overloaded the driver could face a charge of Dangerous Driving which carries a maximum penalty of two years in prison.

The **Road Vehicles (Construction and Use) Regulations 1986** require that "all parts and accessories and the weight distribution, packing and adjustment of their loads shall be such that no danger is likely to be caused to any person in or on the vehicle or trailer or on the road." Additionally, "no motor vehicle or trailer must be used for any purpose for which it is unsuited as to cause or be likely to cause danger or nuisance to any person."

4 Risks associated with transporting asymmetrically loaded containers

4.1 Risks associated with rail transport

4.1.1 Frequency of derailments due to uneven loading of containers

The rail industry has a national database, the Safety Management Information System (SMIS)[6], managed by RSSB, to record safety related events that occur on Network Rail managed infrastructure. SMIS includes a record of derailments since 2000. These records have been searched to identify derailments of container wagons between January 2000 and December 2012.

Table 7 gives a summary of the findings. There were on average 71 derailments per year recorded during the period under analysis. Of these, 8% (6 per year) involved container wagons and 5% (the four listed in Section 4.1.2) of those container wagon derailments were attributed to uneven loading (0.3 per year).

Table 7: Freight wagon derailment figures

All freight derailment records 2000-2012	920 incidents	71 per year
All container[7] freight derailment	73 incidents	6 per year
All freight incidents with 'uneven loading'[8] cited as cause	21 incidents	2 per year
Incidents with 'uneven loading' cited as cause involving container freight wagons	4 incidents	0.3 per year

These figures suggest that, whilst the frequency of derailments due to uneven loading is not insignificant, it may not represent the substantial risk that it is currently considered by the industry.

However, the SMIS database relies on the cause attribution being correctly input after an incident. Unfortunately, uneven loading is difficult to identify post incident because loads shift during a derailment making it difficult to know if a container was already unevenly loaded and caused the derailments or if the load as shifted as a result of the derailment. There may be more 'hidden' derailments that were caused by uneven loading with the cause not correctly attributed in the SMIS database.

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[6] http://www.rssb.co.uk/SPR/Pages/SMIS.aspx

[7] Based on wagon codes: FAA, FBA, FCA, FEA, FFA, FGA, FHA, FIA, FJA, FKA, FLA, FPA, FRA, FSA, FTA, FUA, FWA, FXA, FYA, IDA, IFA, IJA, IKA, INA, KAA, KFA, KGA, KHA, KJA, KQA, KWA, KYA, & PFA.

[8] SMIS Immediate Cause level 1 "Inappropriate loading/securing of load or vehicle" or Immediate Cause level 2 "Badly stowed/loaded items".

4.1.2 Derailments due to uneven loading of containers

The four derailments due to uneven loading of containers shown in Table 7 were:

1. Duddeston Junction, 10/08/2007
2. Reading West Junction, 28/01/2012
3. Ditton, 20/02/2009
4. Felixstowe South, 02/05/2012

Appendix A gives incident reports and extracts from accident investigations for these derailments. All of these derailments involved the same wagon type, an FEA (a 60 foot wagon that can carry up to three 20 foot containers or one 20 foot container and one 40 foot container). Typical factors involved in these derailments include: the unevenly loaded container, a wagon carrying a heavy container at one end and a light (or empty) container at the other end, and the presence of a track twist. The unevenly laden container on its own was not enough to cause a derailment; a number of factors had to combine to cause the derailments.

4.1.3 Camden derailment 2013

In October 2013 there was an additional derailment of an FEA wagon carrying containers which is not included in the statistics shown in Table 8. At the time of writing, the Rail Accident Investigation Branch (RAIB) has not published a report on the cause of this derailment. However, it appears this was another derailment due to uneven loading (again involving a wagon carrying one empty 40 foot container and one asymmetrically loaded heavy 20 foot container).

4.1.4 Safety risk due to uneven loading

The Safety Risk Model[9] is a collection of models that describe the safety risk profile of the rail industry it is managed by RSSB. Based on the frequency of derailments given in 4.1.1 a safety risk has been calculated as shown in

Table 8 (FWI – Fatalities and Weighted Injuries[10]).

[9] http://www.rssb.co.uk/SPR/Pages/SAFETYRISKMODEL.aspx

[10] fatalities and weighted injuries (FWI) — The aggregate amount of safety harm. One FWI is equivalent to:

- one fatality, or
- 10 major injuries, or
- 200 RIDDOR-reportable minor injuries

Table 8: Safety risk associated with uneven loading of containers[11]

Derailment due to uneven loading of container freight	Estimated risk (FWI/year)
Total Risk	**0.0075**
Passenger Risk	**0.0049**
Fatalities / year	0.0041
Major injuries / year	0.0079
Rep. minor injuries / year	0.0170
Workforce Risk	**0.0015**
Fatalities / year	0.0011
Major injuries / year	0.0040
Rep. minor injuries / year	0.0277
Public Risk	**0.0011**
Fatalities / year	0.0008
Major injuries / year	0.0030
Rep. minor injuries / year	0.0032

4.1.5 Cost of damage due to derailments

The cost of damage to infrastructure and rolling stock along with the cost of operational delays due to derailments between 1 Jan 2005 and 31 Dec 2010 has been collated[12], during this time there were 322 freight train derailments. A summary of the cost of these derailments is shown in Table 9.

Specific cost data was only recorded for the 36 ‘major cost’ derailments; for the remaining 286 ‘minor cost’ derailments an average cost of £37,500 has been assumed (which is half of the recording threshold of £75,000).

The average cost of a derailment was £138,492; whilst the cost a single derailment can be as high as £6.5million.

4.1.6 Risk exposure due to uneven loading of containers

Based on the figures found in this study, the risk exposure of damage to assets on the railway of uneven loading to containers is £42,000 per year[13]. In addition the safety risk of 0.0075 FWI/year can be equated to a risk exposure cost of £13,100 per year[14]. This gives a total risk exposure of £55,100 per year.

This figure, when viewed in isolation does not appear to be a significant risk to the railways as a whole; however, a single derailment has caused damage and operational delays to a value of £6.5 million and there is a risk that a derailment where an unevenly

[11] Care should be taken in using these figures as they are based on analysis of very low frequency events and there is limited data for analysis.

[12] The data was originally collected as party of the RSSB research project T974 D-Rail

[13] Based on the average cost of a derailment and the average number of derailments per year

[14] Based on a value of preventing a fatality of £1,748,000, http://www.rssb.co.uk/safety/Pages/default.aspx [accessed 29/1/14]

loaded container is a contributatary factor, could cause damage on this scale or greater. At present it is difficult to detect unevenly loaded containers and therefore difficult to manage this risk.

When looking at the period 2000 to 2012, there were four derailments. However, all four of these derailments occurred between 2007 and 2012. When including the Camden Road derailment in 2013; there have been five derailments where uneven loading was a contributory factor in the last seven years (or 0.7 per year). A distribution of these events is shown in Figure 4. From these figures it appears as though the problem has been growing since 2007 and it is possible it may continue to grow (although this increase may be because the issue is now more commonly recognised and more likely to be correctly attributed when incidents do occur).

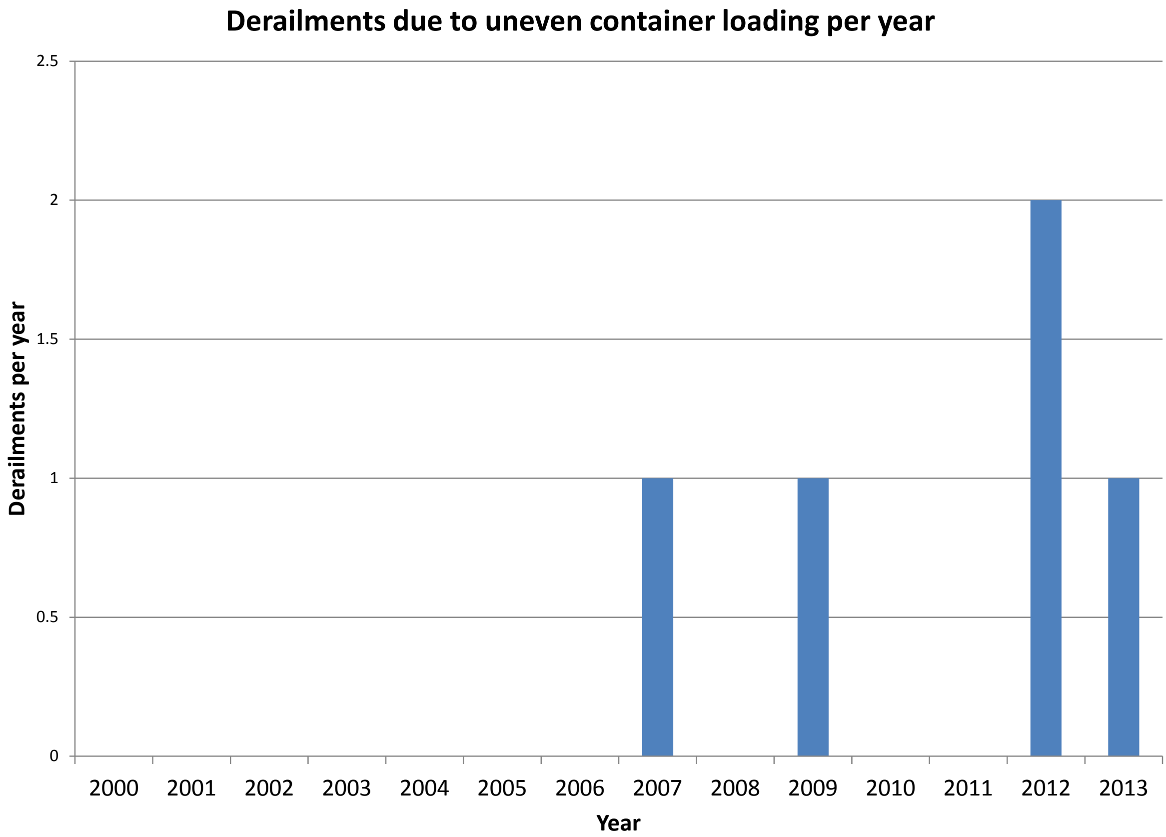

Figure 4: Distribution of derailments due to uneven container loading

Table 9: GB Freight Derailment Data from SMIS and limited supplied cost data, Six year data period: 1 Jan 2005 to 31 Dec 2010

	events count	Infrastructure & assets costs	Operational/ delay costs	Non-infrastructure manager costs (eg. train operating companies, etc.)	total cost	average cost per derailment
MAJOR COST DERAILMENTS:						
b. Spring & suspension failure	2	£9,500,000	£3,500,000	£0	£13,000,000	£6,500,000
Cause not established	12	£4,844,481	£2,509,891	£1,626,616	£8,980,988	£748,416
f. Other or unspecified track geometry causes	2	£3,922,415	£795,774	£2,058,684	£6,776,873	£3,388,437
a. Excessive track twist	3	£712,945	£1,195,273	£75,000	£1,983,219	£661,073
Failure to carry out Rules/instructions/SSOW	5	£254,097	£859,069	£120,000	£1,233,166	£246,633
d. Failure of rail support and fastening	2	£14,336	£521,649	£0	£535,985	£267,993
e. Excessive track width	2	£306,955	£65,263	£70,000	£442,218	£221,109
2. Improper loading of wagon	1	£106,255	£247,277	£0	£353,532	£353,532
Inadequately performed maintenance task - other	1	£8,405	£122,333	£0	£130,738	£130,738
4. Other infrastructure failure	2	£104,250	£5,000	£0	£109,250	£54,625
c. Switch component structural failure	1	£79,000	£20,314	£0	£99,314	£99,314
7. Other operational failure	1	£0	£97,013	£0	£97,013	£97,013
b. Other mishandling of train including driver caused SPAD	1	£17,695	£77,020	£0	£94,715	£94,715
a. Axle ruptures	1	£30,000	£2,527	£0	£32,527	£32,527
TOTAL Major cost derailment events	**36**	**£19,900,834**	**£10,018,403**	**£3,950,300**	**£33,869,537**	**£940,820**
		59%	**30%**	**12%**		
LOW COST DERAILMENTS:						
Cost data for low cost derailments are not recorded separately so cannot be matched to cause types.						
We can assume that these are all below £75,000, based on initial estimates (this is the threshold for cost recording)						
We assume that the average for these is the median £37,500 and that the costs are split in the same proportions as for major derailment events.						
TOTAL Low cost derailment events	**286**	**£6,301,723**	**£3,172,390**	**£1,250,887**	**£10,725,000**	**£37,500**
		(estimated)	(estimated)	(estimated)	(estimated)	(assumed)
TOTAL events (Major and low cost events)	**322**	**£26,202,557**	**£13,190,793**	**£5,201,187**	**£44,594,537**	**£138,492**

4.2 Risks associated with road transport

Vehicle stability is one of the main risks associated with articulated Heavy Goods Vehicles (HGVs) and can involve either directional instability, where at least one part of the combination starts to follow a path different to that demanded by the driver, or roll instability where at least one part of the combination begins to rollover. Each of these modes has a strong potential to cause serious accidents, although for current HGVs roll stability is considered to be a bigger problem than directional stability.

Commercial vehicles have a low level of basic roll stability compared with light vehicles. This is a significant contributing cause of HGV rollover accidents. Most passenger cars have a rollover threshold of greater than 1g, light trucks and vans range from 0.8g to 1.2g, but the rollover threshold of fully laden HGVs often lies well below 0.5g.[15]

Vehicles rollover when the rollover threshold has been reached. When a vehicle combination is cornering and the semi-trailer axles lift, rollover will occur if the axles that are still in contact with the ground cannot provide any further resistance to the increasing roll angle of the trailer. The vehicle combination becomes incredibly unstable and rollover occurs. Articulated vehicles, where the semi-trailer is connected to the tractive unit via a fifth-wheel coupling, will rollover as connected units and the driver has little warning of semi-trailer axles lifting. This is illustrated in Figure 5.

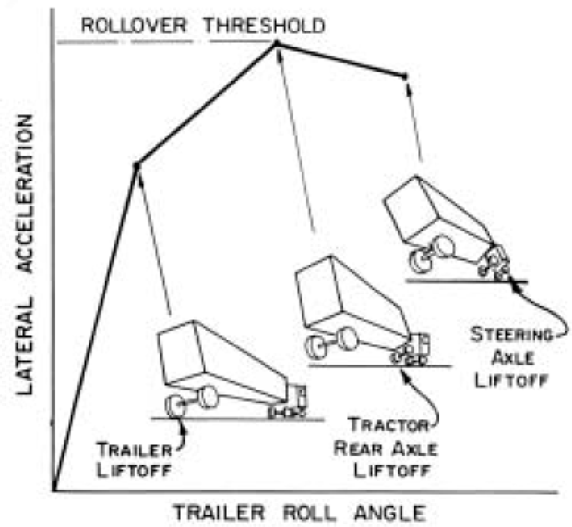

Figure 5: Typical axle lift off sequence and rollover threshold for a tractor unit and semi-trailer. Source: Ervin et al, 1986

Qualitatively, two destabilizing (overturning) moments act on the vehicle:

- A moment due to the lateral force acting through the centre of gravity as a result of the external imposition of lateral acceleration. Factors include the height of the centre of gravity and the lateral acceleration.

[15] Chrstos, J. P. (1991). An evaluation of static rollover propensity measures. Interim final report. Sponsor: National Highway Traffic Safety Administration, Washington, D.C. Report No. VRTC-87-0086/DOT/HS807 747. National Highway Traffic safety Administration, Vehicle and Research Test Centre, East Liberty, Ohio.

- A moment due to the weight of the vehicle acting at a position that is laterally offset from the centre of the track.

4.2.1 Reported road casualty data for Great Britain (STATS19)

The main source of road casualty data for this study is the national STATS19 injury accident data for 2005 to 2012[16]. STATS19 is the national database of records of road accidents that occur on the highway involving personal injury reported to and by the police. Typically over 60 fields are recorded for each collision, including details of their circumstances, vehicles involved and the resulting casualties (details of what information is recorded is given in STATS20, DfT, 2004). Driver/rider and passenger casualties are linked to the vehicle they were in/on at the time of the collision, so it is possible to analyse those collisions where a casualty resulted from an articulated lorry rollover.

4.2.1.1 STATS19 and contributory factors

Contributory factor data has been recorded nationally as part of the STATS19 system since 2005. Contributory factors are reported by the police officer and represent their view of the key factors leading to the collision. Whilst they give a good indication of the causal factors, they should be treated with caution: many rely on a subjective assessment rather than hard facts and they are inevitably determined after the accident occurred. There are 77 different contributory factors, and each collision can have up to six factors attributed to it. Contributory factors can be either related to the road environment, behaviour or actions of a driver, rider or pedestrian.

One of the contributory factors under 'Vehicle Defects' is code number 206 - 'Overloaded or poorly loaded vehicle or trailer'. However, this code covers a wide range of scenarios from passenger cars with inappropriate loads attached to their roofs to overloaded commercial vehicles exceeding their mandatory and safe weight limits. It must also be borne in mind that it is a difficult code to ascribe, because evidence of inappropriate loading is required and this can be difficult to differentiate after an accident, when the load may have significantly moved during the roll over.

4.2.1.2 STATS19 findings

Another difficulty is that it is not possible from the STATS19 data to determine if an articulated HGV was carrying a container. Table 10 provides an overview of the number of single vehicle accidents involving an articulated HGV over 7.5 tonnes which overturned. A proportion of these vehicles will have been carrying containers, but it is not possible to quantify how many, or compare those with and without containers to investigate any differences in their collision characteristics.

However, in the time period (2005-2012) there has been a significant reduction in the number of articulated vehicles, with all loads, that overturned and resulted in police reported injury road casualties. There were 97 reported incidents in 2012, with 22 killed or serious accidents.

[16] At the time the analyses were carried out, the 2013 data were not available.

Table 10: Number of single vehicle accidents involving an articulated HGV over 7.5 tonnes which skidded and overturned, jack-knifed and overturned or overturned

Year	Accident severity				Contributory Factor 206 "poor loading"
	Fatal	Serious	Slight	Total	
2005	4	40	204	248	24%
2006	6	49	165	220	21%
2007	9	43	183	235	17%
2008	3	37	137	177	17%
2009	1	26	114	141	19%
2010	2	37	94	133	20%
2011	3	34	96	133	27%
2012	2	20	75	97	18%

To summarise the road data:

- There is information on police reported articulated lorry rollovers that resulted in injury.
- From this data, it is **not** possible to differentiate between articulated lorries which were loaded with containers and those with all other payloads.
- One of the contributory factors used by the police is "poor loading". On average this code is used for about one fifth of single vehicle accidents involving an articulated HGV over 7.5 tonnes, which skidded and overturned, jack-knifed and overturned or overturned.
    - However, "poor loading" was not the only cause of these rollovers incidents, other contributory factors were also reported for the same incidents, often including inappropriate or excessive speed, and/or driver error or reaction.
    - The code "poor loading" is based on police officers' opinions. The intended use of the contributory factor codes is to give an overall picture of the pattern of underlying factors that lead to injury on the road.
    - The overall trends given by analysis of contributory factors often then requires further investigation to be carried out to assess a given problem more precisely and to understand how countermeasures may be applied. In this example, the nature of the "poor loading" is not known and it has been assumed that asymmetric loading would be captured, at least for some instances, by this metric.
- A measure of exposure with regards to articulated vehicle traffic in terms of tonne-km is given in Table 5 in Section 2.3. The journey data estimates that 5% of articulated vehicle traffic, by tonne-km, is container carrying lorries.

Therefore the level of uncertainty within the data is reasonably large and there are some significant unknowns, not least the number of container carrying lorries involved in injury road traffic incidents. However, it is possible to make some high-level assumptions and begin to investigate the potential size of the problem, based on:

- Assuming all articulated vehicles are equally likely to be prone to overturning as a result of overturning, an average of 1.77 overturning events have occurred on lorries carrying containers during the period 2005 to 2012.
- However, the number of events per year has significantly reduced over this period and based on the 2012 figures, the rate of over turning due to uneven loading of containers would be 0.87 per year.

These figures are based on a crude assumption, further analysis would be required to give a better understanding of the risks, but these figures can be used to give some indication of the scale of the risk. It is beyond the scope of this study, but it would be worth considering further investigations, for example:

- Investigate the location of accidents and look for trends around ports. There are very low numbers and it is unlikely that we would be able to quantify risk, because exposure data is unknown and the confounding factors, such as road type variance may have greater effects.
- Find new or existing sources of data to attempt to gain a better quantification of the risk associated with container carrying lorries.

5 Stakeholder consultation

5.1 Discussion with Freightliner Limited

On 25 November 2013, members of the project team met Freightliner Limited at the Tilbury rail container terminal. Freightliner is the UK's largest rail carrier of maritime containers, operating services from the deep-sea ports of Felixstowe, Southampton, London Gateway and Tilbury, as well as containers from Seaforth through their Garston terminal. They also operate a fleet of approximately 300 road vehicles.

Over the last few years, Freightliner has experienced three container wagon derailments on outbound journeys (Duddeston Junction in 2007, Reading West Junction in 2012, and Camden Road in 2013). The first two have been investigated, and were associated with a combination of wagon loading and excessive track twist (see Section 4.1). As stated in Section 4.1.2, all of these incidents involved 60 foot FEA wagons. Outbound journeys often involve loading these wagons with an empty 40 foot container along with a heavy 20 foot container (typically loaded with scrap metal). This loading arrangement is common (and is also used on some inbound journeys), Freightliner has loading standards which allow for this. The Duddeston Junction and Camden Road derailments involved FEA wagons with this loading arrangement (a heavily laden 20 foot container next to an empty 40 foot container), in these incidents the 20 foot laden container was asymmetrically loaded which was one of the causal factors for the derailments. The Reading West Junction involved an FEA wagon carrying one laden 40 foot container (at one end) which was asymmetrically loaded.

Freightliner's conditions of carriage require containers to be loaded in accordance with the international loading regulations (IMO guidelines) which apply to deep sea containers; however, Freightliner doesn't open the containers to check loading distribution because of safety, liability and customs issues, and has no facilities to measure the levels of offset loading.

When loading trains, Freightliner use the gross weight information of containers from the shipping documents (checks have shown that these are reasonably accurate as shipping companies refuse to take overweight containers on board). Gantry cranes at ports and lifting equipment at Freightliner terminals have weight measurement systems, but these are generally part of safety systems that prevent overloading of the crane, the actual weights are not compared with declared weights and there is no information on weight distribution.

Freightliner is keen to participate in a multi-modal review of container loading to identify any improvements that can be made to the processes used to load and identify uneven loading of conatiners before they are presented for transport

Freightliner suggested that control measures should be applied equally to road and rail transport to avoid transfering the risk from one mode to another.

Additionally Freightliner suggested the the processes to monitor and react to track twists are reviewed.

5.2 Discussion with Freight Transport Association

The Freight Transport Association (FTA) was asked for their experience, as a representative of transport companies, regarding risks to road transport caused by poorly loaded containers. The following questions were posed:

- From your experience, do lorries carrying these containers have different types of collision – including non-injury collisions?
- Are there characteristics associated with containers and their loads, that could affect the risk of their transportation?
- Do certain loads represent a greater risk? If so, why?
- Any other relevant experience/ information?

The FTA representative stressed that a shipping container to be transported on the road by an articulated lorry should be loaded with *"just as much attention to detail"* as a box lorry on a national road journey. In that respect, the aspects "*weight distribution, centre of gravity, use of the correct means of securing the cargo, block loading and use of dunnage to prevent movement of the individual cargo items inside*" were particularly emphasized. Taking into account the maritime transport of the containers, the cargo needed to be secured even better to withstand, without displacement, the higher forces a container was to experience at sea.

The fact that the "*driver has no control over the loading process and, because he will not have any access to the interior of the container, does not know how well the goods have been secured inside or whether they might have worked loose during the journey*" was called a "*significant cause of road accidents*", however without underpinning this statement with quantitative data or account of specific cases. Cargo being able to move within a container was mentioned as a mechanism causing rollover accidents at roundabouts even at slow speeds.

5.3 Discussion with Transport Police Officers

For the programme qualitative information was sought from experienced police collision investigators who had dealt with articulated vehicles that had rolled over with shipping containers attached. The questions posed were as outlined in section 0. The first point that was stressed was:

'*that most of the roll overs occur whilst the articulated vehicle is negotiating a roundabout or similarly tight curve.*'

One officer explained that it was usual, following an inspection of the tachograph to conclude that the vehicle was travelling at a speed that may not have been appropriate for the road conditions, in other words, the speed was a greater factor than any loading conditions. The same officer recalled:

'On another occasion the loss of the container was as a result of the 'twist' locks not being correctly engaged, where the driver failed to ensure security of this locking system.'

However, interestingly the officer said:

'... the ones I have witnessed the contents of the container were all insufficiently secure, i.e. the correct choice of cargo restraint was not used, thus allowing movement of the load, presumably during sea transport or loading.'

He gave an example of a series of barrels of oil which were not restrained on their pallets and free to move within the container. Another container held a large roll of steel, which had snapped its strapping and was rolling around inside the container like '*a loose snooker ball*'.

A final example involved a container with hanging sides of beef, that were free to swing around, and in so doing changed the centre of gravity, which ultimately contributed to the roll over, again on a roundabout.

Summary:

- The difference in the type of collision is that they only become apparent when the vehicle places itself in a position where the load can swing/ move and thereby allow the movement of the contents.
- Poor loading exacerbates the turning momentum of the vehicle.
- The design of the container does not generally allow the freight company/ driver to examine the contents easily without opening the rear doors and climbing over the first level they are presented with.
- In the experience of the police officers, some drivers are reluctant to inspect the inside of containers, especially if the container is company or customs sealed.

Our discussion also touched on the situation where the load can be made up of several fluid filled containers or barrels then if the fluid has room to move the centre of gravity is again open to change. Further, the method of securing is critical, but also how the container is moved in transit, if the container is swung around or tipped then the contents are relying on the restraints to hold them in place, whereas the straps are normally applied whilst the load is flat on a pallet and not for when it is swung around.

Therefore, it is recognised that poorly loaded containers can and do contribute to HGV rollovers, but it has not been possible to quantify this with regards to an annual number or similar measure.

6 Load measuring technologies for containers and vehicles

Load measuring technologies for freight containers and vehicles are commonly categorised either as compression weighing or tension weighing, based on the technical principle applied for the measurement, or as direct weighing or indirect weighing, based on whether the container mass is measured on its own or calculated from a gross mass measurement in conjunction with the carrying vehicle.

6.1 Containers

Direct weighing technologies are commonly integrated into the lifting equipment at ports, most often on ship-to-shore cranes, rubber-tyred gantry cranes or straddle carriers. Several solutions of different complexity are available, some of which can identify asymmetrically loaded containers. However, no systems that determine the vertical position of the centre of gravity of a loaded container were identified in this review.

A common solution is to determine the container mass using a strain gauge (load cell or load pin) at a single key load bearing component within the lifting equipment. This is a cost effective solution which can also be retrofitted to existing equipment. However, it only measures the overall mass of a container and does not give an indication of the weight distribution.

Other methods of direct weight determination are based on measuring the current of the hoist motor of lifting equipment while elevating a container, or the hydraulic pressure of cylinders of lifting equipment like reach stackers. These systems do not identify eccentrically loaded containers.

A more advanced and powerful solution is to integrate weighing equipment into the load spreaders of lifting equipment. This uses four strain gauged twistlocks per simultaneously lifted container (one at each corner of the container), which incurs greater cost than a single point of measurement. Strain gauges or fibre optic sensors within the twistlocks are used to estimate the lateral and longitudinal positions of the centre of gravity of the container (but not its vertical position). Measuring the load on each twistlock separately also allows an operator to determine the weight of individual 20ft containers even when two containers are lifted simultaneously (twin-mode). Strain gauged twistlocks can be retrofitted to existing equipment.

The accuracy of measurement varies between different technical solutions and different types of lifting equipment. A larger distance between the measuring point and the container introduces dynamic effects when lifting, reducing accuracy. The following ranges of accuracy can generally be expected[17,18]:

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[17] World Cargo News. (2014, 01 23). Retrieved from Container weighing - compression or tension?: http://www.worldcargonews.com/htm/w20130421.189161.htm

[18] Meurling, L. (2013, 09). Preparing for legislation on verification of container weights. Port Technology International, pp. 44-46.

- Ship-to-shore gantry cranes: load cells accurate to ±5% of full scale, subject to dynamic loads (4-5 seconds to fix weight)
- Rubber tyred gantry cranes, rail mounted gantry cranes: load cells accurate to ±3-5% of full scale, subject to dynamic loads (2 seconds to fix weight)
- Mobile harbour cranes: load cells or hydraulic pressure measuring, accurate to ±3-5% of full scale
- Straddle carriers: load cells or hoist motor current measuring, accurate to ±5% of full scale
- Reach stackers: load cells (in rotator mounting pins) or cylinder hydraulic pressure measuring, accurate to ±5% of full scale
- Fork lift trucks: load cells (in the chain anchors) or cylinder hydraulic pressure measuring, accurate to ±5% of full scale
- Measurement at spreader twistlocks: diaphragm around the twistlock or strain gauge inside it, accurate to ±0.5-1.0% of full scale

Indirect technologies for weighing vehicles can be weighbridges, weighing pads or weigh-in-motion systems. Alternatively, weighing systems can be integrated into the vehicles themselves, for example into reach stackers, fork lift trucks or articulated lorries. These systems are discussed further in the context of rail and road vehicles in Sections 6.2 and 6.3.

6.2 Rail wagons

There are a number of Weigh–in-Motion (WIM) and Wheel Impact Load Detection (WILD) systems available for use on the railways. These use load cells, accelerometers or visual displacement measurement (based on optical recognition) to measure the axle loads of passing trains. WIM systems have a low frequency output which can be used to measure the static axle load, whilst WILD systems give a more high frequency output that can be used to measure dynamic loads and assess the condition of the wheels.

Network Rail is currently in the process of replacing their Wheelchex WILD systems (a network of 25 installations around the railway system) with GOTCHA[19] WILD systems.

Gotcha has the ability to measure dynamic loads, static axle load and also individual wheel loads; which means it can be used to measure asymmetric loading (both side to side and front to back) of rail vehicles. The GOTCHA systems are placed on in-service lines on the mainline running network and can measure wheel loads at operational running speeds.

The Railway Freight Technical Committee (FTC)[20] is currently investigating the possibility of using the available functionality to measure asymmetric loading of freight wagons with proposed limits of 1:1.7 for left-to-right offset and 1:3 for front-to-back offset (based on limits currently used on the Austrian railways).

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[19] http://www.gotchamonitoringsystems.com/Gotcha.php

[20] A cross industry committee facilitated by RSSB

6.3 Road vehicles

The weight of containers loaded on road vehicles (e.g. articulated lorries) can be determined indirectly by measuring the gross vehicle weight and subtracting the tare vehicle weight. Because of the varying fuel level, driver weight and unknown other loads, the exact tare vehicle weight is usually not known, which adds a considerable level of uncertainty and potential inaccuracy to indirect measurement results. The gross vehicle weight can be measured in stationary conditions or while in motion.

Whole-vehicle weighbridges are the most widespread way of measuring static gross vehicle weights. They achieve a high level of accuracy, typically ca. ±0.2-0.5% of full scale [21]. However, the variations in tare vehicle weight add uncertainty. Some weighbridges are designed to allow individual axle loads to be measured by weighing the whole vehicle and then moving each axle at a time off the weighbridge and considering the different readings. This method is very time consuming. Individual axle load readings can be used to identify longitudinal asymmetrical load distribution.

Weigh pads placed under each wheel of a stationary vehicle are most commonly used at temporary sites to check legal loading for enforcement purposes. The readings provide information on longitudinal and transverse loading. The method however is very time consuming and prone to errors introduced during weighing.

WIM systems are a time efficient way to determine the gross vehicle weight or individual axle weights. WIM systems are generally smaller and less expensive than static weigh bridges, but do not achieve the same level of accuracy. The measurement technology is based on bending plates, load cells, piezoelectric or fibre optic sensors and can be integrated in bridges or road surfaces. Low speed WIM systems are capable of measuring gross vehicle weight or individual axle weights with an accuracy of ±2% at speeds of approximately 5 km/h (manufacturer's data[22]). High speed WIM systems, commonly used on larger roads for statistical purposes or to select vehicles for enforcement, are capable of measuring gross vehicle weight or individual axle weights but with much less accuracy (the measurement accuracy partly depending on the road surface characteristics and vehicle suspension systems).

On-board weight measurement systems for lorries rely on measurement technology either integrated into the vehicle's spring or air suspension systems or into vehicle structure supporting the loaded container. The former design can determine gross vehicle weight, axle loads and individual wheel loads; the latter can determine container weight. Individual axle and wheel load readings can identify asymmetrical load distribution of the loaded vehicle in the longitudinal and lateral directions. In practice, many outbound containers will be loaded whilst they are on a semi-trailer (rather than the loaded container being lifted onto the semi-trailer) for later collection by a tractive-unit. Any on-board weighing system would therefore need to either be free-standing on the semi-trailer or have commonality with the tractive-unit's systems.

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[21] Meurling, L. (2013, 09). Preparing for legislation on verification of container weights. Port Technology International, pp. 44-46.

[22] TDC traffic systems. (2014, 01 23). Retrieved from Low speed weigh in motion: http://www.tdcsystems.co.uk/solutions/weigh-in-motion/low-speed-weigh-in-motion

7 Feasibility of introducing asymmetric loading controls

For inbound shipping containers, the logical place to measure the longitudinal and lateral weight distribution of containers would be at ports, with a system built into ship-to-shore gantry cranes. There are a limited number of cranes and the costs of installation, maintenance and calibration would be relatively small compared with the cost of the cranes. This would also mean that unevenly loaded containers could be identified before they got on to the road and rail networks.

The limits on allowable uneven loading still need to be defined; the IMO Guidelines for packing of CTUs and BS 5073 give a longitudinal limit of no more that 60% of the load at either end of the container, but no fixed numerical limit for lateral uneven loading.

Assuming that the measuring equipment can be installed and suitable limits defined, processes would need to be developed to deal with unevenly loaded containers when they are identified. These include having: common rules for the rejection of unevenly loading containers; space to store rejected containers; and systems to ensure that the container is re-packed before being moved. Ports and rail terminals may have limited space to store "quarantined" containers.

The IMO Guidelines for packing of CTUs state that, those responsible for packing of CTUs *"should bear in mind that any failure to pack and secure the cargo correctly may result in additional costs they will have to bear".* This means that there is some precedent for allocating the cost of repacking to the originator of a container, though the practicalities of this need to be investigated.

For outbound containers (i.e. container originating in GB), the weighing point should be at or near the loading points. These are diverse. Weighing equipment could be installed on semi-trailers but there are a large number of these and the costs of installation, maintenance and calibration would be high compared with the cost of the semi-trailers. In addition, the driver collecting the semi-trailer may have limited time to check that the container is correctly loaded. Weighing at rail terminals would be more practicable, but would be after completion of the highest-risk leg of the journey (road).

Rather than trying to measure the levels of uneven loading of all outbound containers it may be more practical to control this risk through training container packers, coupled with a certification / audit system[23]. Inbound containers are packed at a variety of locations around the world, and outbound containers at a wide variety of locations ranging from individuals moving home to large companies. A risk-based approach to training / certification might be taken (for example, concentrated on those packing the heaviest 20 foot containers).

[23] RAIB Report 02/2013 also suggested this, making a recommendation that the Health and Safety Executieve should be '*making relevant parties aware of the need to pack freight containers in accordance with published guidance, and gaining assurance that this is being done*'.

8 Conclusions

8.1 Scale of risk

The movement of ISO containers is important to the UK economy. In 2012, 4.8 million containers were moved through UK ports, accounting for 11% of all goods by weight. Volumes of container traffic through UK ports have remained relatively constant for the last 8 years. However, with the opening of the new London Gateway 'super port'[24] and the beginnings of an economic recovery these volumes are likely to increase. Container traffic accounts for approximately 30% of goods moved by rail (tonne-kms, 2012/13) and 5% of goods moved by articulated heavy goods vehicles (tonne-kms, 2010). Road and rail carry similar amounts of container traffic, by tonne-km, with both modes carrying just under 6 billion tonne-km. Rail journeys tend to be longer, meaning road carries higher total tonnages but over shorter journeys.

Between 2000 and 2012, there were four recorded container wagon derailments with uneven loading cited as a cause. Based on these figures, the calculated total risk exposure (damage to assets plus safety risk) is £55,100 per year. This is small compared with number of container trains (Freightliner alone operates 100 daily services). There is some uncertainty as to the reliability of the recording of these incidents and the qualification of asymmetric loading being a factor before 2007, but this appears to be a growing problem. All four of the recorded incidents have happened since 2007 and there has been an additional derailment in 2013, in which uneven loading of a container appears to be a contributing factor (though the RAIB investigation report has not been published yet). Single derailments have caused damage up to £6.5 million and if a derailment results in a container falling in to the path of a passenger train this could result in multiple loss of life or serious injury.

There was insufficient data to calculate accident rates for road goods vehicles carrying containers , as the road casualty data does not discriminate between articulated vehicles carrying ISO containers and other articulated vehicles. Indicative results suggest that the likelihood of a rollover on a container carrying lorry is higher than the likelihood of rail vehicle derailing due to uneven loading of a container. There is a risk that the rollover of a container carrying road vehicle could affect other road users through congestion and result in loss of life or serious injury.

Safety issues concerning container transport by road have been discussed with Freightliner Limited, the FTA and police collision investigators. Freightliner and police did not consider poorly loaded containers on road vehicles to be a very urgent road safety issue. Freightliner suggested that the rollovers that occur are often attributed to drivers travelling at excess speeds around roundabouts. The police, however, recognised or recalled incidents where poor loading of the container was a significant contributory factor. The FTA pointed out that inadequately secured cargo being able to move within containers was an important contributory factor to rollover accidents at roundabouts, occurring even at slow speeds. The fact that the driver has no control over the interior loading of a container was mentioned as a safety risk.

[24] http://www.londongateway.com/about-us/

On road and rail it appears that whilst uneven loading of containers contributes to the risk of roll over or derailment, other factors also need to occur before a roll over or derailment occurs. On road these factors include inappropriate or excessive speed or driver errors or reactions such as turning too sharply; on rail these additional factors include the presence of excessive track twist and appear to be isolated to a particular wagon type and loading arrangement.

8.2 Possible solutions

Any limits on uneven loading that are introduced need to be applied equally to road and rail transport, to avoid the risk being moved between the two modes.

For inbound containers the best place to control the risks would be to measure container loading distribution on gantry cranes as they are unloaded from ships, so poorly loaded containers can be identified before they reach the road and rail networks.

There are a limited number of gantry cranes requiring instrumentation, containers are lifted by their corners, providing load-paths for measuring asymmetric loading. Uneven loading limits would need to be defined along with procedures for how to deal with any unacceptably loaded containers that are identified. There is limited space at ports and the feasibility of quarantining containers needs to be considered further.

Outbound containers are loaded at a large number of different originators at different sites around the country. Weighing all containers at their origin or through semi-trailers carrying them on the first leg of their journey is not considered practical. Uneven loading of outbound containers should be mitigated by training of the packers, at originators of container loads along with a certification scheme for those packers.

Targeting customers who pack heavily-loaded 20 foot containers for export for audit or limited container load distribution measurements should give the biggest benefits in risk.

8.2.1 Rail specific measures

As stated in Section 4.1.2 derailments where asymmetric loading of containers is a contributory factor, are often also associated with the presence of an excessive track twist. An investigation into alternative methods to measure and control track twist and the effects on existing freight vehicles would help to better understand the contribution of track twist to the risk of derailments.

Additionally the susceptibility of different vehicle types to derailment as a result of offset loading should be investigated.

8.2.1 Road specific measures

As stated in Section 4.2 it was difficult to quantify the risk of overturning of road vehicles due to uneven loading of containers, as the accident report forms do not differentiate between different types of articulated road vehicle. Adding additional codes to the accident report form to identify different types of articulated vehicle, including container carrying lorries would allow for better quantification of the size of the problem. However, the accident forms are completed by police officers and are intended to cover all road traffic injury accidents, and need to be as simple and straightforward to use as practical. As such there is an understandable resistance to add fields to the forms without removing others, and a careful balance is required especially for fields which would be rarely used. It might be more efficient to run a pilot investigation scheme near a major port with the freight operators and the police to monitor for such incidents and to capture pertinent data should they occur. The aim would be to genuinely learn more about their causes in a harmonised way. However, this would require multi-organisational cooperation and additional funding.

9 Glossary of terms

CSRGT	Continuing Survey of Road Goods Transport
CTU	Cargo Transport Unit
DfT	Department for Transport
FEA wagon	60 foot wagon that can carry up to three 20 foot containers or one 20 foot container and one 40 foot container
FTA	Freight Transport Association
FTC	Railway Freight Technical Committee
FWI	Fatalities and Weighted Injuries
GB	Great Britain
HGV	Heavy Goods Vehicle
IATA	International Air Transport Association
ICHCA	International Cargo Handling Coordination Association
ILO	International Labour Organization
IMO	International Maritime Organisation
ISO	International Organization for Standardization
Lo-Lo	Lift-on, Lift-off
RAIB	Rail Accident Investigation Branch
SMIS	Safety Management Information System
TEU	Twenty-foot Equivalent Units
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
WILD	Wheel Impact Load Detection
WIM	Weigh–in-Motion

Appendix A

Two incidents where there was a container wagon freight derailment incident, with uneven loading cited as causal factor, resulted in RAIB reports. Two other incidents resulted in Local Investigations. Relevant summary text is shown below:

Event Date	10/08/2007
Location	Lawley Street (Landor St) FLT / Duddeston Junction, Birmingham
Investigation Report	RAIB Report 16/2008
SMIS Narrative text	At 0220 the driver working train 4O84 (0243 Lawley Street to Grain) reported that the train had become derailed whilst traversing over SY715B points after departing Lawley Street towards the Up Main at Duddeston Junction. The Operations Manager was advised and went to site arriving at 0249. He reported that ywo vehicles towards the middle of the train had derailed (FEA640261 & FEA640262). FEA640261 had derailed all wheels, and FEA640261 by one bogie. One empty container had become detached from FEA640261 and was lay on its side on the Up Slow line, another empty container had shifted and was overhanging the Down Main. The S&T and Pway staff went to site. Arrangements made for a BRUFF unit and a Rail crane to go to site. RAIB staff on site at 0800 and investigations commence. Crane and Rerailing train on site at 0825. Services driverted via lichfield where possible. Arrangements made with Freightliner to take rear portion of train back to Lawley Street and front portion to Birch Coppice. Rerailing to commence when train portions clear of area. At 1758 4O84 set back to Lawley St.Pway commenced remedial work on the points. Vehicles rerailed at 1718. Remedial work to the infrasturcture to continue through the night. Lines reopened at 0604 11/8/07 A formal investigation was held and the immediate cause was found to be that the cause was due to uneven loading of a vehicle, causing it to be more susceptible to flange climbing in the presence of track twist.
RAIB report Immediate Cause	191 The immediate cause of the accident was the climbing of the front right-hand wheel flange of wagon 640 262 over the right-hand closure rail of 715B points as a result of the interaction between a combination of track twists and the unevenly loaded wagon (paragraph 144).
RAIB report Underlying Cause	64 These tests suggested that the mechanism of derailment was flange climb of the right leading wheel and that amongst the cause was still open to conjecture, it was most probably a combination of: - the combination of track twists; - uneven longitudinal wagon loading; and - possible inherent twists of the wagon body and bogie. 192 Causal factors were: c. wagon 640 262 was running loaded in a way that made it very susceptible to derailment over track twist faults (paragraph 156 & Recommendation 2); d. the uneven distribution of load placed upon the wagon was beyond that for which it was

	designed terms of derailment resistance (paragraph 157 & Recommendation 2); e. the uneven distribution of load was not detected and remedied prior to the wagon departing from Lawley Street Terminal (paragraph 157 & Recommendation 1); f. the placing of a 30.4 tonne 20 ft container next to an empty 40 ft container in contravention of the MIE 0767 limit of 24 tonnes for the 20 ft container in this configuration (paragraph 158 & Recommendation 2); and g. a probable causal factor is that the 20 ft container load was likely to have been offset to the left (paragraph 159).
RAIB report Contributory factors	193 The following factors were considered to be contributory: d. Low levels of lateral payload offset were not readily detectable (paragraph 160); e. There was a practice amongst some Freightliner loading staff of not strictly adhering to the loadings prescribed by MIE 0767 (paragraph 162 & Recommendation 2); f. Visual pre-departure checks of the train did not detect the level of uneven loading (paragraph 166 & Recommendation 1); g. Standard methods that were used for detecting uneven loading of container wagons were not always reliable (paragraph 168 & Recommendation 1); h. The computer systems used for container processing by Freightliner are not capable of detecting uneven loading beyond that allowed by standard MIE 0767 although they contain sufficient data to do so (paragraph 171 & Recommendation 1); i. The following factors were possibly contributory (paragraph 175): - VCG assumed that the wagons would be loaded reasonably evenly (as this is a 'White Pages' requirement) and thus they only required wheel unloading tests to be carried out for tare and fully laden wagons with no longitudinal or lateral load offset accounted for (longitudinal offsets were only considered as part of high speed VAMPIRE® simulations and not to the degree allowed by MIE 0767). Thus there was no independent validation of Greenbrier's assertion that the wagons were designed for all loadings on the technical specification drawing in terms of GM/RT 2141 requirements; and - Freightliner specified the FEA-B wagons' loading capacities to Greenbrier using an MIE 0767 type drawing and assumed that Greenbrier and the VAB would interpret them in the manner Freightliner intended. Greenbrier state that they did, the VAB did not (paragraph 175). (Recommendations 3, 4, 5, and 6).

Event Date	28/01/2012
Location	Reading West Jcn
Investigation Report	RAIB Report 02/2013
SMIS Narrative text	At 1345 track circuit 'OF' failed on the Up Main line at Reading West Junction after the passage of 4O02 1111 Lawley Street – Southampton MT, which had been routed from the Up Relief line to the Up Reading West Curve line. S&T staff attended and at 1402 and reported that there was damage to track cables and fishplates throughout the area of the track circuit. The MOM arrived on site and confirmed 15 damaged p/way chairs between the trailing points and the facing points on the Up Main line leading to believe that 4O02 may have derailed/rerailed whilst negotiating Reading West Junction. (It was later confirmed that the train had lifted completely off the rails before landing back on them). 4O02 which by that point was in the Wessex route area was brought to a stand on the Down Slow line at Worting Junction at 1426 where the Driver confirmed wheel flange damage on the second from rear vehicle, FEA 640166 and the third from rear vehicle, FEA 640165. RAIB were advised at 1511 (Ref 12/025). All point work in the Basingstoke area was examined with no damage reported. RAIB arrived on site with 4O02 at 1618, along with the train fitter at 1631. At 1630 P/way confirmed that the track damage at Reading West Junction was between the A and B ends of 716 points, over the fixed crossing between the Up Relief line and the Up Main line. The Up Main line was initially reopened subject to a 5mph ESR at 1630 and at linespeed from 1710.

	Following an examination by the train fitter and RAIB, 4O02 was on the move at 1739 at 40mph to destination, where the two vehicles were detached and quarantined. Arrangements were made for a download of the OTMR to be undertaken on Sunday. RAIB arrived at Reading at 1740 with all repairs work on the Up Relief line stopped to allow the site to be assessed by the RAIB inspector. A line blockage of the Up and Down Relief lines was taken at 1825 and given up at 2032, with the RAIB staff allowing repairs to be completed. 716 points were secured in the normal position, with repairs on the Up Relief line undertaken overnight. Repairs re-commenced at 0127, with base plates to replace, grinding work to be completed, stretcher bars to be replaced and lifting & packing to be completed. Normal working resumed at 0647 after repairs had been completed. 28/01/13 - The RAIB report was published. The cause of the derailment was that there was insufficient load on the front right-hand wheel of the wagon to prevent its flange climbing over the railhead. This was the combined result of the uneven loading on the wagon, specifically the lateral offset of the payload in the container, and the effect of a twist fault on the crossover. The RAIB concluded that the pallets had moved during the road journey to the freight terminal where the container was loaded onto the train. Schaeffler Automotive, the company that packed the container, had no processes at the time to ensure that the pallets would not move. The checks and handling methods used by Freightliner, the operator of the terminal, did not detect the offset load. Although the size of the twist fault did not require the line to be blocked to traffic, Network Rail's processes for track inspection and maintenance had not identified that it existed.
RAIB report Immediate Cause	59 The immediate cause of the accident was that there was insufficient load on the front right-hand wheel of the leading bogie on wagon 24 to prevent its flange climbing over the railhead as the wagon passed over crossover 3717. 63 The causes of the wheel unloading relate to: - the offset payload on wagon 24, specifically the lateral offset of the cargo in container WFHU 4147370; and - the track twist that wagon 24 encountered on crossover 3717 at Reading West Junction. Neither alone would have caused unloading on the front right-hand wheel that exceeded the criterion in GM/RT2141; in combination they did (paragraph 60). 107 The immediate cause of the accident was that there was insufficient load on the front right-hand wheel of the leading bogie on wagon 24 to prevent its flange climbing over the railhead as the wagon passed over crossover 3717 (paragraph 59).
RAIB report Underlying Cause	108 The causal factors were: a. The offset loading on wagon 24, specifically the lateral offset of the payload in container WFHU 4147370 because it was not a normal condition, significantly reduced the load on the front right-hand wheel of wagon 24 (paragraph 64, Recommendations 1, 2 and 3). The following factors relate to this: i. Schaeffler did not have a process for packing containers that ensured the pallets would not move during transit (paragraph 70, Recommendation 1). Probable factor: ii. The method that Freightliner used to handle container WFHU 4147370 at its Lawley Street terminal did not detect that it was very unevenly loaded before it loaded was onto train 4O02 (paragraph 76, Recommendations 2 and 3). Possible factor: iii. The pre-departure checks at the Lawley Street terminal rely solely on visual examination to identify unevenly loaded wagons (paragraph 79, Recommendations 2 and 3).

Event Date	20/02/2009
Location	Ditton
Investigation Report	Local Investigation Report
SMIS Narrative text	1852: Ditton Signaller advised driver of 0L71 1729 Crewe to Ditton Reception sidings reported 4L71 1844 Ditton to Felixstowe had become derailed on No. 3 reception line. Edge Hill MOM, Freightliner FOC, On call P. Way were all advised and a block put on all traffic destined for Ditton Yard . 1904: Signaller further advised that the rear part of the train had become derailed (the train was hauled out of the freight terminal by a diesel into the reception sidings, where 0L71 normally couples for the journey south). Chester Fire service advised as the train consist showed the train to be conveying dangerous goods, incident No. 2668 given, but advised that no staff would be dispatched until a leak, if any was confirmed. NOC were advised. 1926: The on call LOM called in to advise that he had already spoken with the signaller and confirmed that the train was signalled normally into No. 3 reception sidings. The Freightliner shunter on site confirmed that the leading axle of the rearmost wagon was derailed. Information on the consist showed this to be FEA 640212, not conveying dangerous goods.The on call P. Way engineer was also advised. 1940: MOM on site confirmed the wagon involved was 640212, axle off on all wheels, the point of derailment was on plain line. The front of train was trapped in the headshunt, which mean there was chance of splitting off the unaffected part of the train and running forward to Garston Yard. 1947: Freightliner advised that an OTMR download would be done on 66589 which was hauling the train. BRUFF requested to attend 2021: MOM advised that no infrastructure damage was evident, only a few flange marks to sleepers. 2104: The on call P.way engineer on site reported that the track was gauge compliant, no L2 twists, and in his opinion the condition of track was not the cause of the derailment. 2155: LOM advised a loads inspector on site from Freightliner would check the loading of the wagon and its structure when rerailed. 0016: Rerailing commenced. 0054: Rerailing completed, the rear two wagons were put back into O'Connor's freight terminal, the train then went forward to Basford Hall via Speke (to run round). Reception line No. 3 remained blocked until staff from Freightliner and NR P. Way attended for further examination later on Saturday. 0215: O'connors Sidings re-opened to traffic. Normal working resumed at 1230 hours on 23.02.09. there was no damage to repair only minor sleeper scoring. As yet no cause has been established.
Local Investigation report Immediate Cause	F1. Immediate Cause F1.1. Having considered all the available evidence; specifically the vehicle type, vehicle loading and condition of the infrastructure, the investigation team were able to preclude vehicle type and condition of the infrastructure as an immediate cause of the derailment. The only conclusion available therefore, is that the load within the vehicle caused the vehicle stability to be affected. F1.2. The investigation team identified that the load had shifted substantially and although considered that this was caused by the derailment itself, felt that in consideration of the available evidence and by precluding other potential causes, considered that the load was not secured and did affect vehicle stability prior to the derailment, and is therefore considered as an immediate cause.

Local Investigation report Underlying Cause	F2. Underlying causes F2.1. The investigation team discussed the processes and systems employed by the carrier (Freight Liner Intermodal) and its customers in relations to loading and security of loads within containers. F2.2. The investigation team noted that the carrier has limited jurisdiction with regards loading of goods prior to the goods being moved by rail. The carrier is given limited access to contents of goods being carried, which includes knowledge of hazardous materials and has no interface per-say with loading or security at point of origin. F2.3. It was noted therefore that the status of the load; its security, loading and transit characteristics could not be ascertained, checked or assessed to confirm readiness for transit in traffic and the investigation team felt that this was a fundamental flaw in the process. F2.4. It is therefore considered that the failure in the process and system of the carrier not being able to ensure load security was an underlying cause.

Event Date	02/05/2012
Location	Felixstowe South FLT
Investigation Report	Local Investigation Report
SMIS Narrative text	At 1251 hours it was reported that 4L02 (GBRf 0355 (Wed) Hams Hall – Felixstowe) had been involved in a derailment at Felixstowe South. The train was formed of 24 loaded FEA wagons, hauled by locomotive 66727. Wagon 640682 became derailed by all wheels on one bogie, near RT4 points. The incident was confirmed as being on Network Rail infrastructure, and the RAIB were advised, as it was initially unclear as to whether the location of the incident was deemed a running line. Attendance by the same was considered until it was established that the location, at the convergence of Creek Reception No. 1 and No. 2 lines, was deemed a siding. Rerailing commenced at 1500 hours, and was completed at 1710 hours. Remedial work was undertaken with it confirmed that all work had been completed and the terminal reopened at 2315 hours.
Local Investigation report Immediate Cause	F1. Immediate Cause F1.1 As Loco No 66727 hauled 24 loaded FEA flat container wagons into the South Terminal and came to a halt; a wheel unloading effect occurred during the braking movement, leading to the trailing bogie of wagon No 640682 climbing the rail gauge face and crossing to the left hand side of the railhead.
Local Investigation report Underlying Cause	F2. Underlying causes F2.1. Relief of vertical wheel load; arisen due to the uneven distribution of the vehicle load. The 20ft container mounted to the leading end of the derailed wagon was heavily laden at 32.5 Ton (2.5 ton overweight - see vehicle weight plan section J2), whilst the 40ft container mounted over the trailing bogie was at a much reduced weight of 5.2Ton – with a payload spread of 1.3 Ton at each corner. The uneven distribution of the load effectively causes the vehicle to experience a significant loss of load to the end or corner of the vehicle.

Potential risks to road and rail transport associated with asymmetric loading of containers

This report considers the risks associated with transporting ISO Containers by road and rail. Each year millions of these containers are moved around the world by road, rail and sea, 4.8 million being handled at UK ports in 2012. Containers offer an efficient, secure and safe means of transporting goods over long distances and between different modes of transport.

On the railway, asymmetric loading / a high centre of gravity increases the potential for wheel unloading leading to a derailment. There are similar risks for road transportation, with an increased risk of instability and overturning. In practice, emphasis is placed on the speedy and accurate transfer of containers between transport modes rather than the assessment of load distribution which could impact on efficiency and productivity of the interchange.

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