RESEARCH AND DEVELOPMENT

RSSB A Better, Safer Railway

Guidance on the Limits of Freight Train Trailing Length as Governed by Coupler Strength

T1256

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Published:

July 2022

RSSB A Better, Safer Railway

Executive Summary

This report redefines the relationship between coupler strength and the historic coupler 'traction rating' designation used within the rail freight industry. This includes:

- Reclassification of historic British Rail and current European traction rating designations.
- Development of a calculation tool which enables improved definition of maximum train trailing load.
- Definition of the benefits that the use of reclassified ratings and improved trailing load calculation can bring.
- Definition of a plan to implement the recommendations of this report.

Reclassification

Our analysis shows that different 'reserve factors' (factors of safety) have historically been applied to couplers. New traction rating designations have been derived using the lower reserve factor of the current 56 t couplers. This enabled:

- An increase in the traction rating of a (TR) 34.5 t coupler to TR 40 t (highlighted in the table below).
- New traction ratings for the European couplers:
  - TR 48 t for the 1.2 MN coupler
  - TR 63 t for the EN 1.5MN coupler (also highlighted in the table below).

The results of these reclassifications are shown below, based on the GB rolling stock database 'R2.' (All comments in this report refer to the GB only rolling stock fleet, vehicles in Northern Ireland are not included in this analysis.)

Existing		New			
TR (t)	Quantity	TR (t)	Quantity	TR change (%)	Quantity change (%)
Unclassified	1,934	Unclassified	1,934	0%	0%
23.0	144	23.0	144	0%	0%
34.5	10,925	40.0	10,925	16%	42%
-	-	48.0	0	39%	0%
50.0	1	50.0	1	0%	0%
56.0	13,261	56.0	10,929	0%	0%
56.0	2,332	63.0	2,332	13%	9%
Total	**26,265**		**26,265**	**Total**	**50.5%**

This table shows that there are 10,925 TR 34.5 t couplers which can receive a 16% strength uplift to TR 40 t. It was concluded that 2,332 TR 56 t couplers were actually EN 1.5 MN couplers which could receive a 13% uplift to TR 63 t. Overall, over half the registered vehicles could receive a strength increase. Note: It is not mandatory to record coupling type in R2; therefore, these figures are indicative.

Improved trailing load calculation tool

The trailing loads within Network Rail's 'Loads Book' are largely based on horizontal and vertical curve parameters defined in the British Rail MT19 document published before rail privatisation. This applies the most severe gradient and curvature on the route across the entire train consist to define the maximum trailing load within the track section being analysed.

The project has produced an Excel based calculation tool which recalculates the maximum trailing weight, governed by drawgear traction rating, by applying a greater level of granularity to the track section.

Benefits of changes

The benefits from improving traction rating and greater granularity of calculation are shown below for three real life case studies.

		Wagons in consist		Journey (e/way,	Cost saving (£)			Environmental saving		
	Case study	Initially	Revised	miles)	Daily	Annually	%	CO2 (t)	NOx (kg)	PM2.5 (g)
1	Jet, WLL	24	27	50	350	291K	7.3	0.25	2	25
2	Intermodal, Harringey	14	16	235	945	245K	10.9	1.4	8	171
3	Intermodal, Beattock	19	23	235	1400	364K	14.3	2.1	13	263

Significant financial benefits accrue due to the train length increase, with savings of around 10% achieved with linked environmental benefits. On a typical Anglo-Scottish intermodal flow, 2 tonnes of carbon dioxide emissions can be saved, as well as considerable amounts of Nitrogen Oxides and Particulate emissions.

Implementation

There is a lack of existing standards control around the definition of traction rating, so it is suggested that RSSB modify the appropriate standards which then enables Network Rail to make changes to their Loads Book. Recognising that this will take time, a two-stage implementation plan is recommended.

In the short term RSSB should issue some guidance which will enable Network Rail to facilitate change by making the new trailing loads calculation tool available, recalculation of acceptable trailing loads, then use the existing 'Service Plan Review' process to enable longer trains.

In the longer term, when changes to Standards are made by RSSB, Network Rail can include the algorithm of the calculation tool within any new editions of the Loads Book.

Table of Contents

1 Introduction

Railfreight Consulting Ltd (RfC) has been commissioned by RSSB to deliver research project T1256 'Guidance on Limits of Freight Train Trailing Length as Governed by Coupler Strength'. This document is the final report on that project and examines the relationship between coupler strength and the historic 'traction rating' designation used within the rail freight industry.

The objectives from RSSB's T1256 'Schedule of Requirements' Appendix A are repeated here:

> *By redefining the relationship between coupler strength and permitted trailing load, the project aims to enable the rail freight industry to unlock additional trailing load capability offered by couplers already in use but capped by the current rating system. It will create the opportunity to:*
>
> *a) increase the efficiency through a better deployment of resources for given hauling capacity,*
>
> *b) increase the transport capacity - that is the amount of goods that can be transported on the track in a given time, and*
>
> *c) reduce emissions per given load carried.*
>
> *The outcomes will include case studies to provide an estimate of the economic effects of applying new higher load limits on three representative routes. This will be complemented by a framework to expand this to more routes to inform the case for updating the trailing load limits. Furthermore, it will give freight operators better evidence to inform decisions on when to upgrade couplers to suit their operations.*
>
> *This project also aims to provide further support on related initiatives on the introduction of digital automatic coupling.*

2 Scope

The deliverables from the assignment were:

- Proposed redefinition of the coupler strength / traction load rating relationship (Section 3).
- Trailing load calculation tool (Section 4).
- Review of common coupler types (Section 5).
- Determination of economic and environmental benefits (Section 6).
- Proposed implementation plan (Section 7).

Conclusions and recommendations are presented in Sections 8 and 9.

3 Coupler strength versus traction load

This section gathers data regarding coupler strength and the historic British Rail traction load rating (TR), including reviewing legacy standards and various BR drawgear drawings. This data is then used to examine the historical relationship between the proof and breaking strengths of drawgear and the assigned traction load rating.

The relationship between coupler strength and TR designation is then reviewed using engineering judgment, relevant railway standards and standards for other equipment that have safe working load ratings. The existing BR traction load ratings are compared to the EN 15566 [7] drawgear ratings.

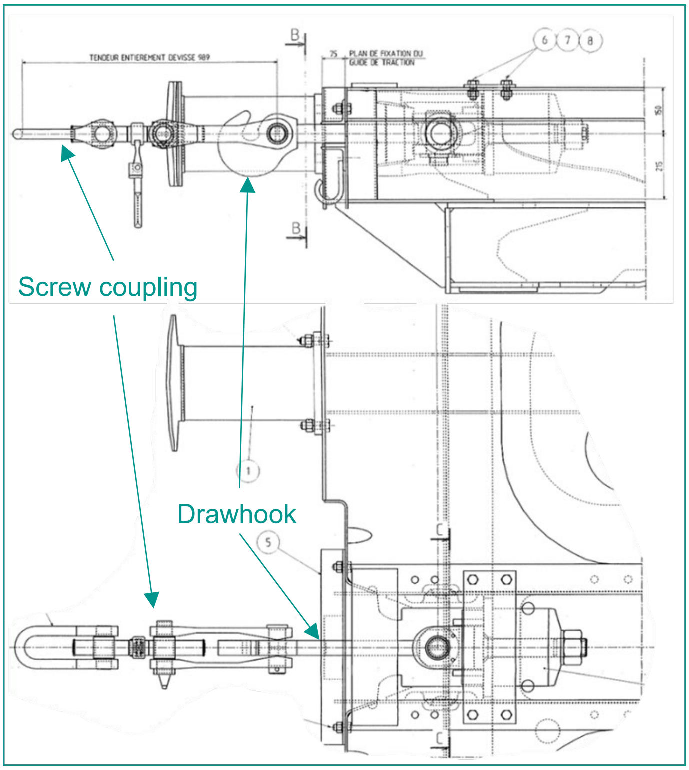
New traction load ratings are suggested based on the findings.

3.1 Historic GB drawgear strengths

The drawgear (or coupler) consists of two principal parts as listed below (see also Figure 1).

- The **screw coupling**, which consists of two chain links connected by a screw tensioning device, which is tightened to provide a close fit between wagons and thereby mitigate vehicle 'snatch' when accelerating.
- The **drawhook**, which is connected via the 'screw coupling' to the adjacent vehicle and transfers traction tensile load into the wagon structure.

Figure 1 Example of screw coupling and drawhook (section above, partial plan below)



3.2 GB traction load rating

From a review of legacy documents available to RfC, the earliest categorisation of coupling strengths by 'traction load' was found in British Rail document MT19 [1] as shown in Figure 2.

Figure 2 Extract from MT19

LOAD LIMITATIONS - STRENGTH OF COUPLINGS

Selected types of vehicle couplings used on B.R. have been tested and allocated a value of Traction Load. The Traction Load is the maximum sustained load which can be applied safely, without permanent extension to the coupling.

Table 5 shows the maximum loads permitted for vehicles in general use and Table 6 gives the maximum loads to be used for trains composed of Bogie Vehicles fitted with roller bearings for the coupling types detailed below:

	TRACTION LOAD	COUPLING
: 1	22.1/2 T	Three Link (RCH 1403) B.R. Screw (RCH 212) Freightliner Short Screw (59061 : Yellow)
: 2	34 T	Standard International Screw (RCH 2827),(8467) B.R. Screw (7316) Freightliner Short Screw (3546 : Green) Locomotive Screw (1130)
: 3	55 T	Strengthened Instanter (1165) Freight Screw (Experimental) (7381) 100T Tippler Screw (2576) Locomotive Screw (Experimental) (1475)

In MT19 [1] these traction load ratings are in 'long tons' (imperial tons, T) where 1 T = 1.016047 t (tonne, metric ton). These imperial traction load ratings are converted to metric values in Table 1.

Traction load is the maximum load that can be sustained by the screw coupling; it can be likened to the safe working load (SWL) of cranes or lifting equipment.

Note: 'traction load rating' is also referred to as 'traction rating', 'load rating, 'traction load' or 'TR' throughout this document.

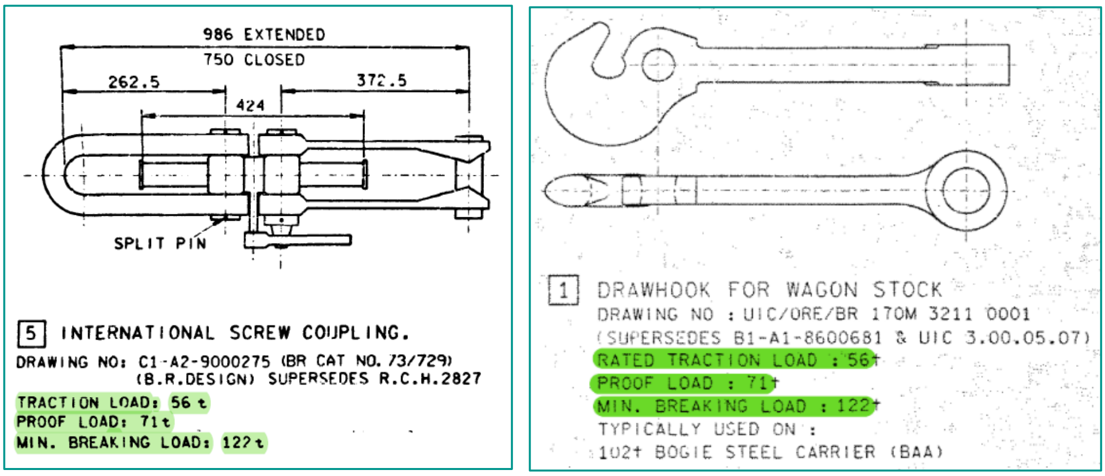
Table 1 Traction ratings

Imperial traction load rating from MT19 Imperial (T)	Modern traction load rating, converted (t)
22 ½	23.0
28	28.5
34	34.5
50	51.0
55	56.0
80	81.3

3.3 GB strength vs traction load rating

From the review of legacy documents it was found that the relationships between drawgear strength and traction load rating are given on drawings 9029821 [2] and 9029843 [3]; example extracts are shown in Figure 3.

Figure 3 Examples of the GB strength system, extracts from 9029821 and 9029843



Proof strength definition -	*Upon removal of the load there is no significant permanent deformation, and the equipment remains useable.*
Breaking strength definition -	*Ultimate strength. The minimum load which the equipment can sustain without fracture, after removal of the load the equipment may no longer be useable.*

Drawgear is designed to be weaker than the wagon structure and therefore acts as a 'fuse' to protect the wagon from damage as the drawgear is cheaper and easier to replace than the wagon structure.

The data from these drawings is summarised in Table 2 (and more detail is provided in Section 11).

We found:

- Strength vs rating information is only available for TR 34 t and TR 56 t rated equipment. No other source of strength vs traction load rating could be found.
- In Great Britain, the screw couplings have the same strengths as drawhooks. This is not the case in Europe, see Section 3.4, where the screw coupling is designed to have a lower strength than the drawhook to ensure the 'fuse' is the cheapest most replaceable item—the screw coupling.

It was noted that the TR vs strength relationship in Table 2 was not consistent—when the reserve factor (RF) between 'proof strength and TR' and 'ultimate strength and TR' is calculated as shown in Table 3, the RFs were not consistent between the TR 34.5 t and TR 56 t.

Note: *Reserve factor (RF) is used by structural engineers to express how much stronger a system is than it needs to be. It can be used interchangeably with factor of safety (FoS) and safety factor (SF). It is defined as 'strength / working load'. 'Factor of safety' is not preferred nomenclature in rail standards.*

This inconsistency contrasts with common practice for other mechanical applications where mechanical load bearing items (e.g. lifting equipment) have a consistent RF between their working load and their strength, some examples are given in Table 4.

Table 2 GB strength vs TR summary

Traction load rating (t)	Proof strength (t)	Ultimate strength (t)
34.5	51.0	102.0
56.0	71.0	122.0

Table 3 Strength and traction load ratings summary

Traction load rating (t)	Proof strength (t)	Proof RF	Ultimate strength (t)	Ultimate RF
34.5	51.0	1.48	102.0	2.96
56.0	71.0	1.27	122.0	2.18

Table 4 Reserve factor principles in other applications

Source	Proof reserve factor (RF)	Ultimate reserve factor (RF)
Lifting equipment, EN 13155 clause 5.1.1.1	2	3
Rail vehicle bodies, EN 12663 5.4.2 and 5.4.3	1.15	1.5

3.4 European strength system for drawgear

The European system defines 3 strength ratings in EN 15566 [7]: 1.0 MN, 1.2 MN and 1.5 MN. Throughout EN 15566, forces are expressed in Newtons; however, for consistency when comparing with GB strengths, these will be converted and discussed as tonnes (9,810 N = 1 t).

EN 15566 specifies lower maximum strengths for screw couplings than for drawhooks; therefore, only these are considered.

EN 15566 does not specify proof strength; however, unlike the GB system, it does specify fatigue loads which are split into high cycles and low cycles. The low cycle force magnitude is very similar to the proof strength for similar GB equipment. Therefore, for the purposes of this report, these values will be assumed to be the proof strengths.

Ultimate and proof strengths are taken from EN 15566 table 1 and table A.3 respectively and shown in Table 5.

Table 5 European screw coupling strengths from EN 15566 [7]

Rating	Proof strength (t)	Ultimate strength (t)	
		Minimum	Maximum
1.0 MN	58.6	86.6	101.9
1.2 MN	70.3	104.0	122.3
1.5 MN	92.8	137.6	153.9

3.5 Proposed TR system

To propose a simple system for future traction ratings it was decided to apply a consistent approach based on the reserve factors (RF) for the TR 56 t equipment, which is the predominant freight traction equipment in Great Britain. While doing this, we decided to consider how it would apply to the European screw couplings defined in EN 15566 [7]; refer to Section 3.4.

In Table 6, the designations are prefixed 'TR' for the GB traction rating system and 'EN SC' for the EN 15566 system for screw coupler strength. The proof strengths are divided by the TR 56 t proof RF of 1.27 and the ultimate strengths are divided by the TR 56 t ultimate RF of 2.18 (from Table 3). The minimum of the resulting values, rounded to zero decimal places, is then assigned as the traction rating.

Table 6 Proposed drawgear TRs

Existing designation	Proof strength (t)	Ultimate strength (t)	Proposed TR by proof strength factor	Proposed TR by ultimate strength factor	Proposed TR (rounded) (t)
EN SC 1.0 MN	58.6	86.6	46.5	39.9	**40**
TR 34.5 t	50.8	101.6	40.2	46.8	**40**
EN SC 1.2 MN	70.3	104.0	55.2	47.7	**48**
TR 56 t	71.1	121.9	56.0	56.0	**56**
EN SC 1.5 MN	92.8	137.6	73.4	63.3	**63**

As the TR 56 t equipment is the base point for this designation; its TR is unaffected. Applying this common reserve factor-based system to the TR 34.5 t equipment lifts its TR to 40 t, a 16% increase. It also enables new TR 48 t and TR 63 t traction ratings to be defined for the EN screw couplings which are already fitted to some wagons operating in GB. The EN SC 1.2 MN and EN SC 1.5 MN equipment are presently assigned low ratings of TR 34.5 t and TR 56 t respectively (i.e. the nearest available GB designation that would not overload the coupling). The new ratings would represent increases of 39 % and 12.5% respectively.

However, the vehicle structural strength must also be considered for traction ratings above 56 t to ensure the wagon body can manage the higher applied loading; see Section 3.6.

3.6 Wagon underframe strength

3.6.1 Design standards

Since at least January 1965 (the past 57 years at the time of this report), the structure of a GB wagon must withstand a proof tensile load of 150 t (e.g. see Figure 4).

Figure 4 Extract from MT235 [4]

21. Automatic Couplers

All wagons built after 1.1.65 must have the underframe designed to take, without major alterations, a full automatic buff and draw coupler. Details of the space required, and positioning of the drawgear are shown on drawing No. DE/58831.

The underframe must be designed to take the following forces through the automatic coupling :-

Draw : 150 tonnes maximum

Buff : 200 tonnes maximum

This remained in place until 5 March 2011 when GM/RT2100:3 [8] was superseded by GM/RT2100:4 [9] which mandated the use of EN 12663 [5], which specified 1,500 kN (153 t) at location 'a' or 1,000 kN (102 t) at location 'b', depending on the traction stop designs, see Figure 5 and Figure 6.

Figure 5 Extract from EN 12663-1

Table 5 — Tensile force at coupler attachment

Force in kilonewtons

Locomotives	Passenger rolling stock					Freight wagons	
Category L	Category P-I	Category P-II	Category P-III	Category P-IV	Category P-V	Category F-I	Category F-II
1 000 [a]	1 000 [a]	1 000	600 [b]	300 [b]	150 [b]	1 500 [c] 1 000 [d]	1 500 [c] 1 000 [d]

a A higher force (e.g. 1 500 kN) may be necessary for certain types of coupling.

b These values can be adjusted but shall cover the maximum force which can be developed in normal operation or emergency recovery.

c Tensile force of 1 500 kN applied to the draw gear stops "a", if this draw gear stop is used (see EN 12663-2).

d Tensile force of 1 000 kN applied to the draw gear stops "b", if this draw gear stop is used and for other types for coupler attachment (see EN 12663-2).

Figure 6 Extract from EN 12663-2, plan view of dragbox

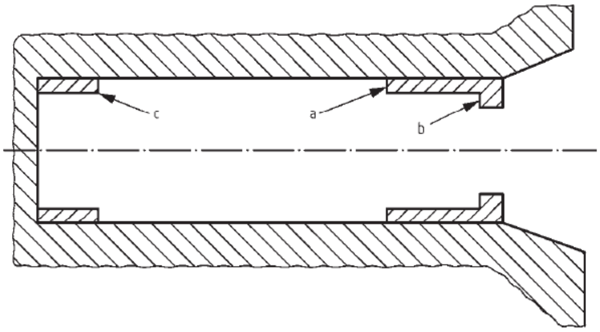
Table 5 — Tensile force in coupler area

Force in kilonewtons

Freight vehicles	
Category F-I	Category F-II
1 500 [a]	
1 000 [b]	

[a] Tensile force of 1 500 kN applied to the draw gear stops "a" if this draw gear stop is used, see Figure 4.

[b] Tensile force of 1 000 kN applied to the draw gear stops "b" if this draw gear stop is used and for other types of coupler attachments, see Figure 4.

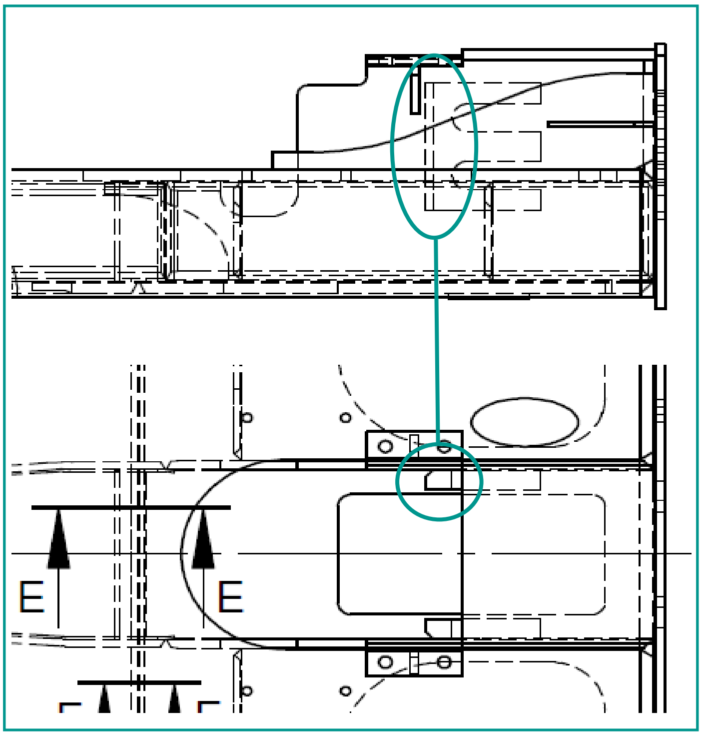


If a wagon were to be designed for only the location ‘b’ load case, then the existing TR 56 t and EN SC 1.2 MN rated equipment would be stronger than the wagon structure (refer to Table 6), an un-acceptable situation. Therefore, it must be assumed that the application of this reduced load at location ‘b’ is because this ‘flanged’ design of traction stop is weaker, and this limits the load into the wagon structure (i.e. this becomes the ‘fuse’ to protect the wagon structure). Furthermore, the traction stop design ‘b’ is sometimes used by UIC wagon designers but is not traditionally used by GB wagon designers who prefer design ‘a’, see Figure 7.

Therefore, it can be concluded that the structures of GB wagons are designed to withstand a tensile drawgear load of 153 t (1,500 kN).

The proposed approach for higher traction ratings is given in Sections 3.6.2 to 3.6.4.

Figure 7 Example of typical GB traction stops



3.6.2 Up to TR 56 t equipment

This is the status quo therefore wagon structures are already strong enough for this rating.

3.6.3 Up to TR 63 t equipment

For this new rating (see Table 6) the wagon proof strength load of 1,500 kN is similar to the maximum ultimate strength of EN 15566 [7] 1.5 MN drawgear (see Table 5). Setting the wagon's proof (no significant permanent deformation) strength at the same value as the drawgear ultimate strength (no fracture/failure) seems a reasonable condition, especially when EN 12663 [5] includes a proof factor of 1.15. Therefore even 1.5 MN rated drawgear would be expected to break before causing any damage to the wagon structure.

Furthermore, it is assumed that EN 12663 and EN 15566 are in synergy with each other as they are both European railway standards.

Therefore, the strength of wagon structures would be suitable for up to TR 63 t without further work.

3.6.4 Above TR 63 t

For stronger drawgear to take advantage of the proposed new rating system (above TR 63 t rating), the wagon structural strength must be confirmed to be suitable. For example, the wagon EN 12663 [5] proof strength requirement should be 1,500 kN or 10% higher than the drawgear ultimate strength, whichever is the greater.

3.7 Recommendations

We make these recommendations:

1. Drawgear be assigned the traction ratings given in Table 6 on page 11.

   Note: This lifts the rating of TR 34.5 t and EN SC 1.0 MN equipment by 16%, EN SC 1.2 MN equipment by 39 % and EN SC 1.5 MN equipment by 12.5%.

2. A similar rating system could be applied to stronger drawgear (e.g. above EN SC 1.5 MN, TR 63 t) provided the wagon strength is confirmed to be suitable for the higher drawgear ultimate strength (see Section 3.6.4).
3. The use of a reduced load at traction stop position ‘b’ should be reviewed (see Section 3.6).
4. To guarantee that the cheapest replaceable component is the ‘fuse’ in the tensile load system, the EN method of a specifying a maximum screw coupling strength should be adopted (the screw coupling is guaranteed to be weaker than the drawhook).
5. Coupler strength designations above 63 t should not be used without confirming that the wagon’s structural strength is sufficient for this increased loading.

4 Trailing load calculation tool

4.1 How the tool works

4.1.1 Introduction

The method applied by the tool is based on British Rail document MT19 [1]. MT19 contains the source calculations from which the existing Network Rail Load Book values are derived. The calculations within MT19 provide a method for the calculation of trailing resistance for any given combination of vehicle masses, track curvature and gradient.

The tool is built using the conventions defined in the FAST standard available at https://www.fast-standard.org . FAST was originally developed for time-based financial models but is a very useful standard methodology for creating complex and scalable Excel tools of this type. By adopting the FAST principles, the tool can more easily be adapted in the future and calculations within the file are more transparent and interrogable.

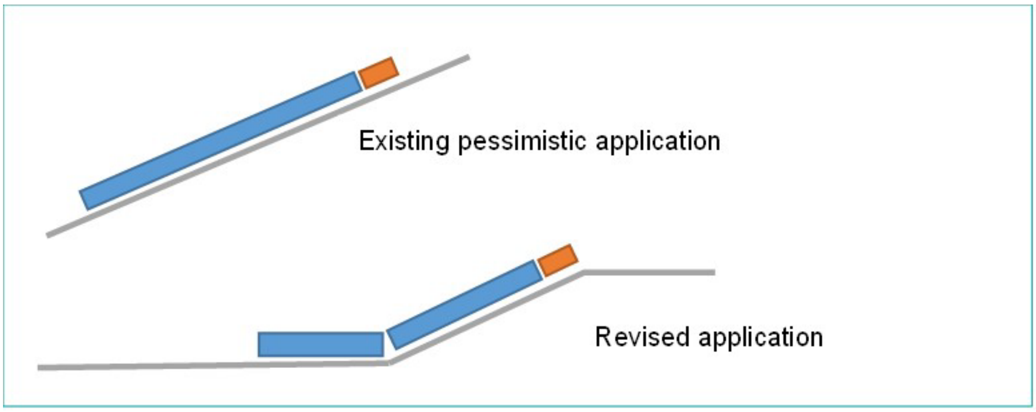
Note Since the calculation methodology applied is based on a public domain document and was developed for the RSSB - a publicly funded organisation - the code and methodology applied in this tool is provided under the UK Open Government Licence Version 2 (OGLv2). Users are free to copy, publish, adapt, improve, and use this code for commercial and non-commercial purposes as defined in the OGLv2 on condition that the original source of the information is clearly acknowledged.

4.1.2 Improved geographical granularity

The current application of these calculations to GB rolling stock assumes a worst-case gradient and curvature along the entire train length. This is a conservative approach and, as trains become longer, there is significant scope for improvement by applying the calculations to each segment of the train for the portion of the route occupied. This will, for example, take account of the portion of a vehicle on a downhill gradient or level segment as shown in Figure 8.

The tool works by splitting the route into discrete segments and applying the MT19 methodology to each portion of the train to give a more accurate calculation of the total trailing load.

Figure 8 Improved geographical granularity



4.1.3 Improved calculation of curvature resistance

The tables produced within MT19 are simplified by grouping curvature into three distinct categories:

- very sharp
- sharp
- relatively straight.

The tool uses the exact curvature values for each route segment to calculate the trailing resistance due to curvature more accurately, further improving the accuracy of the resulting calculations.

4.1.4 Optimisation technique within the tool

So that the number of wagons on a particular route can be optimised, a macro within the tool steps the train along the route and reports the maximum coupler force seen. The tool iterates, increasing the number of wagons in the train, until the coupler limit is reached.

4.2 Using the tool

Basic information about the route is entered by the user on the calculation sheet (e.g. as shown in Figure 9).

Figure 9 Example inputs

Data Input

Vehicle data

Mass per wagon	101.60	t
Wagon length	18.50	m
Coupler traction load rating	EN 1.5 MN (Proposed Rating)	
Coupler traction rating	63.00	t

Route data

Segment	Start ID (Optional)	End ID (Optional)	Gradient (1 in "x")	Horizontal curve radius (m)	Segment length (m)
Route Description					
1			57	10,000	26
2			57	500	150
3			49	100,000	60
4			49	500	46
5			57	10,000	44
6			57	10,000	600
7					
8					
9					
10					

Initial model parameters

Minimum quantity wagons to try	20
Maximum quantity wagons to try	50

Restore defaults

To enable users to make use of existing route knowledge and experience, provision is also made for setting a start (minimum quantity of wagons) and end (maximum quantity of wagons) between which the tool will iterate.

Once all data are entered into the tool, activating a button icon initiates the macro which will then iterate through the various combinations of vehicle position and train length before displaying a results table.

In line with FAST modelling best practice, the macro will only alter inputs within the spreadsheet and does not directly perform calculations. All calculations are contained within the Excel sheets and every iteration of the macro, along with the input conditions applied, is recorded on the ‘Macro Output’ sheet for interrogation if necessary.

The calculation then produces an output table as shown in Figure 10. This reports the maximum trailing load, number of wagons and the critical location.

Figure 10 Example outputs

Results		
Maximum trailing load with this configuration	2,563	t
Number of wagons in train	41	(see note below)
Max force is when front of train is at	747	m from start of segment 1
Note: coupler limit was set to	56.00	t

Note:
The number of wagons given is a theoretical maximum value; for example, it will be impossible to achieve an odd number of wagons using permanently coupled pairs. The maximum trailing weight may increase or decrease if a different wagon length is chosen.

4.3 Coupler types

There is a pre-loaded list of coupler types and their strengths provided within a separate worksheet in the calculation tool, e.g. see Figure 11, which can then be selected by the user to represent the weakest coupler strength within the train's consist. In anticipation of future changes, the list can be altered by the user.

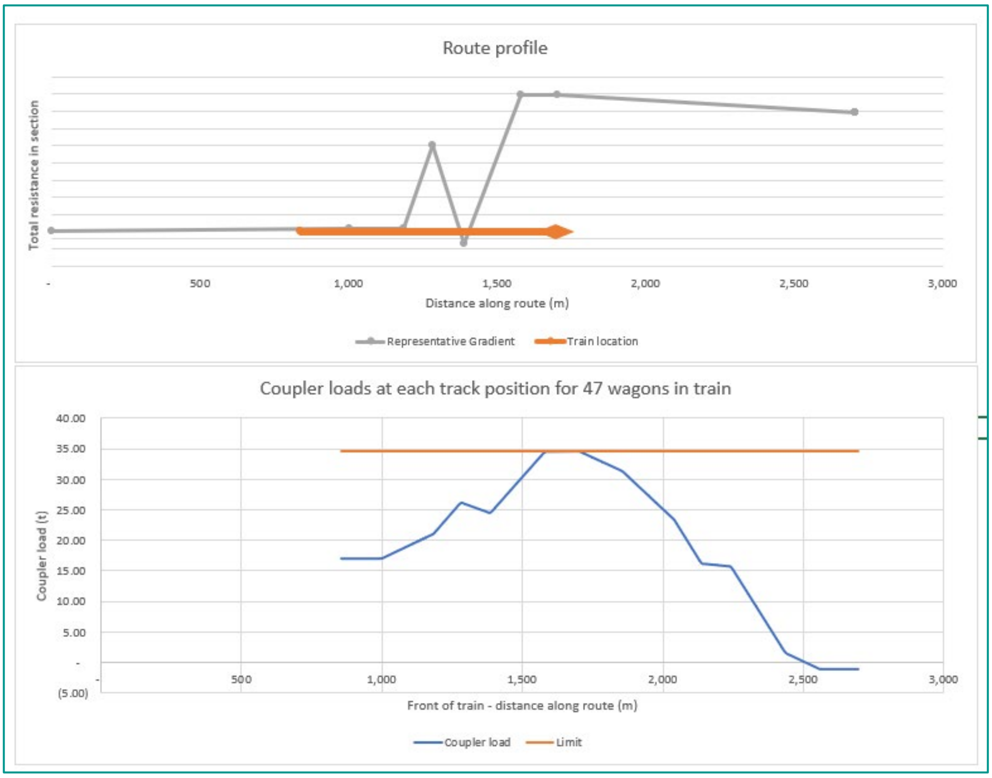
Figure 11 List of coupler types

Coupler Type	Rating (t)	Notes
EN 1.0 MN (Original Rating)	34.55	Equivalent BR rating currently applied for a 1.0 MN EU coupler.
EN 1.0 MN (Proposed)	40	Rating is taken from table 6 in report T1256/R01-A, Table 6.
BR TR 34.5 t (Original Rating)	34.55	Original BR value for the traction rating.
BR TR 34.5 t (Proposed Rating)	40	Rating is taken from table 6 in report T1256/R01-A, Table 6.
EN 1.2 MN (Original Rating)	34.55	Equivalent BR rating currently applied for a 1.2 MN EU coupler.
EN 1.2 MN (Proposed Rating)	48	Rating is taken from table 6 in report T1256/R01-A, Table 6.
BR TR 56 t	56	Rating is taken from table 6 in report T1256/R01-A, Table 6.
EN 1.5 MN (Original Rating)	56	Equivalent BR rating currently applied for a 1.5 MN EU coupler.
EN 1.5 MN (Proposed Rating)	63	Rating is taken from table 6 in report T1256/R01-A, Table 6.
AAR-E	135	Based on a knuckle ultimate strength of 650,000 lbs / 2.18 (from report T1256/R01-A, Section 6).

4.4 Additional features

To aid understanding of the output, the tool contains a 'visualisation' worksheet which diagrammatically shows the train in the worst-case position, e.g. see Figure 12. This is supported by a graphical output showing coupler loads as the train moves along the route.

Figure 12 Detailed reporting visualisations



4.5 Tool validation

To validate the tool a comparison was made between the tool outputs and the 33 existing MT19 [1] table results.

Since the output of the tool is given in wagons, rather than a trailing load, a wagon mass of 1 tonne was applied to the tool for verification. The tool was then run and the resulting number of wagons was compared to the MT19 trailing load values.

The maximum variance seen between tool outputs and the existing MT19 tables was 0.23% (typically 2 tonnes of trailing load). Further interrogation found that the MT19 tables contain maximum loads given to the nearest 5 tonnes and so the variance is probably zero.

Details of the results of tool validation can be found within the tool verification record worksheet.

4.6 Worked example

The following worked example illustrates the improvements that can be gained by the more granular analysis of the new tool.

In this example, the wagon parameters used are for a TEA wagon, having a GLW of 101.60 tonnes, a length of 18.80 m and fitted with TR 56 t rated drawgear. The route applied is shown in Table 7.

Table 7 Worked example route information

ID	Gradient (1 in 'x')	Horizontal curve radius (m)	Segment length (m)
1	57	-	26
2	57	500	150
3	49	-	60
4	49	500	46
5	57	-	44
6	57	-	600

By entering the vehicle and route parameters into the tool and reviewing the 'Route Calculations' tab it is possible to determine the route segment with the worst-case resistance. The largest value for 'Total Resistance in Segment' is within segment 2 (see Figure 13).

Figure 13 Worked example outputs

Calculations										
Section ID					1	2	3	4	5	6
Gradient		1 in X	+ indicates an incline, - indicates a decline	-	57	57	49	49	57	57
Prevailing Curve Radius		m	The prevailing curve radius for each segment.	-	-	500	-	500	-	-
Segment Length		m	"Value" Cell is the total length of the route.	-	26	150	60	46	44	600
Description	**Value**	**Units**	**Notes**							
Curve Starting Resistance Force										
Trailing Load in Section	2438.4	t	"Value" Col. = Total Rake Mass		141	811	324	249	238	677
Curve Starting Resistance Force (Metric)		kg/t			3.3064	5.3598	3.3064	5.3598	3.3064	3.3064
Starting Resistance Force Due to Curve	**10**	**t**	"Value" Col. = Total Resistance Due to Curvature		**0.4646**	**4.3449**	**1.0721**	**1.3324**	**0.7862**	**2.2371**
Total Force if all Sections are Full										
Starting Resistance Force Due to Curve	10.24	t	"Value" Col. = Total Resistance Due to Curvature		0.4646	4.3449	1.0721	1.3324	0.7862	2.2371
Resistance Due to Gradient	44.42	t	"Value" Col. = Total Resistance Due to Gradient		2.4651	14.2217	6.6175	5.0734	4.1717	11.8704
Total Resistance in Segment	**54.66**	**t**	**"Value" Col. = Total Resistance of Rake**		**2.9297**	**18.5666**	**7.6896**	**6.4058**	**4.9579**	**14.1075**

Using this segment in MT19 [1] Table 6:3 (see Figure 14), the curvature classification is 'sharply curved' (curves between 301.8 m and 502.9 m) gives an allowable trailing load of 2,275 tonnes (the lower value would be applied). Dividing this by the wagon GLW of 101.6 tonnes gives an allowable number of wagons of 22.

Figure 14 MT19 Table 6:3

MAXIMUM GROSS TRAILING LOADS ON RISING GRADIENTS - TONNES MXLG0084 CATE 26/10/77 TABLE 6: 3
TYPE OF COUPLING INSTANTER(1165),F'GHT SCREW(EXP 7381),100T TIPL SCREW(2576),LCCC SCREW(EXP 1475) COUP0003
TRAILING LOAD BOGIE VEHICLES WITH ROLLER BEARINGS. TRFR08
LIMITATION DUE TO COUPLING STRENGTH - TRAINS NOT ASSISTED IN REAR
TRACTION LOAD 55.88 TONNES CATE 26/10/77

RISING GRADIENT 1 IN	MAXIMUM LOAD FOR TYPE OF TRACK: VERY SHARPLY CURVED	SHARPLY CURVED	RELATIVELY STRAIGHT
RES LB/TON	25.00	15.00	12.00
36	1435	1620	1685
38	1490	1690	1765
40	1545	1760	1840
42	1595	1830	1915
44	1650	1900	1950
46	1695	1965	2060
48	1745	2030	2135
50	1795	2095	2205
52	1840	2155	2270
54	1880	2215	2340
56	1925	2275	2405
58	1965	2335	2470
60	2005	2390	2535

In comparison, applying these parameters within the tool gives a result of 24 wagons (see Figure 15), allowing an additional 153.3 tonnes of product to be carried within the same train (TEA wagon tare weight is 24.95 tonnes).

Figure 15 Calculation tool results

Results	
Maximum trailing load with this configuration	2,438 t
Number of wagons in train	24 (see note below)
Max force is when front of train is at	451 m from start of segment 1
Note: coupler limit was set to	56.00 t

Note:
The number of wagons given is a theoretical maximum value; for example, it will be impossible to achieve an odd number of wagons using permanently coupled pairs. The maximum trailing weight may increase or decrease if a different wagon length is chosen.

5 Common coupler types

Data from RSSB's R2 library (formerly 'the rolling stock library') was supplied and analysed. It was found that the data for traction rating was a little inconsistent:

- some ratings were entered correctly as 'traction load rating', but others were entered as breaking strength
- some ratings were entered in imperial Tons
- many vehicles had no ratings data entries.

Therefore, where it was rational to do so, the data provided was corrected, including strength entries of 102 t were converted to TR 34.5 t, and imperial ratings were converted to metric.

The findings, based on the corrections applied, are shown in Table 8 where it can be seen that:

- 42% of wagons could have their traction rating up-rated by 16%
- 9% of wagons could have their traction rating up-rated by 13%.

Table 8 R2 coupler strength analysis

Existing		New			
TR (t)	Quantity	TR (t)	Quantity	TR change (%)	Quantity change (%)
Unclassified	1,934	Unclassified	1,934	0%	0%
23.0	144	23.0	144	0%	0%
34.5	10,925	40.0	10,925	16%	42%
-	-	48.0	0	39%	0%
50.0	1	50.0	1	0%	0%
56.0	13,261	56.0	10,929	0%	0%
56.0	2,332	63.0	2,332	13%	9%
Total	**26,265**		**26,265**	**Total**	**50.5%**

It is possible to further uplift some of the current 34.5t TR wagons a to 48t TR if they have EN 1.2 MN couplers fitted in lieu of standard 34.5 t couplers, but the extent of this fitment is not known.

It was also noted that there was a wide variety of data entered and its value/purpose is not immediately apparent, e.g see Table 8 and Table 10.

The data would benefit from a rationalisation of the existing entries and a review of the entry criteria, including data entry integrity checking.

Table 9 R2 data entry fields for couplers

R2 data entry field title
Compressive Coupling Strength Number One End
Compressive Coupling Strength Number Two End
Tensile Coupling Strength Number One End
Tensile Coupling Strength Number Two End
UIC Vehicle Coupling Type Code
UIC Vehicle Coupling Type Name
Vehicle Coupling Type Number One End Code
Vehicle Coupling Type Number One End Name
Vehicle Coupling Type Number Two End Code
Vehicle Coupling Type Number Two End Name

Table 10 Coupler types and quantities

Coupler type	Count of qty. of vehicles
Auto Solid Shank (Tightloc)	1
Auto Solid Shank (Tightloc) and BR Screw	1
Screw and Drawhook and Permanent Screw	1
Auto Drop Head (Buckeye) and Auto Solid Shank (Tightloc)	2
BR Screw and LUL Coupler	2
Dellner/Scharfenberg Automatic Latched Coupler All Variants (Outer) + Bar Coupler (Inner)	4
Auto Drop Head (Buckeye) and Auto Solid Shank (Buckeye)	9
Instanter and Bar Coupler (Inc London Underground)	9
BR Screw and Aar E/F Coupler	19
International Screw and Automatic Tightlock	27
Auto Drop Head (Buckeye)	67
Rotary and Non-Rotary Centre	79
BR Screw and Bar Coupler (Rigid)	141
International Screw and Aar E/F Coupler	207
Unspecified - can be self-contained within vehicle and changeable operationally	306
Bar Coupler (Rigid) Both Ends	539
International Screw & Bar Coupler	1,035
Instanter or 3 Link	1,887
Aar E/F Coupler	1,954
BR Screw	2,380
International Screw	17,595
Total	**26,265**

6 Economic and environmental benefits

6.1 Introduction

Increasing coupler strength enables economic and environmental benefits by enabling longer trains. Consideration of the fixed and variable costs of freight train operation demonstrates the value of running longer trains.

The fixed costs are:

- provision and maintenance of the locomotive
- locomotive track access costs
- provision of labour (driver and ground staff)
- payment of any third-party access fees (charged on 'per train' basis)
- corporate overhead.

The variable costs are:

- Provision and maintenance of wagons (longer trains, more wagons).
- Track access cost for wagons.
- Fuel, although this is not a linear increase. Fuel requirements for overcoming aerodynamic resistance are unchanged however there is a (non-linear) increase in fuel for starting and climbing power requirements.

This commentary demonstrates that a, say, 20% increase in train length will not lead to a 20% increase in train cost, thereby generating a saving. The reduced fuel loading also leads to environmental benefits.

The benefits are assessed via case studies of three geographical locations. The increases in trailing load was calculated and 'before and after' calculations of cost and environmental impact were conducted, using a model held by the Network Rail freight team.

The three case studies are movement of:

- jet fuel across the West London Line: TR 56 t increased to TR 63 t - increase in wagons from 24 to 27
- containers through Haringey: TR 34.5 t increased to TR 40 t - increase in wagons from 14 to 16
- containers up Beattock summit: TR 34.5 t increased to TR 40 t - increase in wagons from 19 to 23.

6.2 Financial

The output from the West London Line (WLL) case study shows an increase in train price from £4,260 to £4,442, whilst the payload increases from 1,800 t to 2,025 t. This results in a 7.3% reduction in the cost per tonne hauled, leading to a saving of £350 on a 2,025 t train. If the train runs every day the saving is £291,000 per year.

The WLL case study is a relative short haul and larger savings of £945 (10.9%) and £1,400 per day (14.3%) are realised on the longer distance container flows.

6.3 Environmental

The environmental calculations are based on work completed within RSSB's T1187 project, which derived emission factors for freight movements on a per tonne-km basis for NO_x, $PM_{2.5}$, and PM_{10}. Regression analysis of real-world OTMR data show that energy usage and emissions are a function of the train mass, with increasing trailing weight leading to lower emissions on a per tonne-km basis (within the envelope of real journeys examined as part of that project). CO_2 emissions are based on estimates of the amount of fuel consumed for each journey. The output in Figure 16 shows the calculation for the Harringey case study, illustrating the environmental benefits of increasing trailing weight.

Figure 16 Cost benefit

OUTPUT: Environmental comparison (real terms)					
	BASE	SCENARIO	Variance	VALUE	Saving (tonnes (g) /train)
CO2 (tonnes / tonne)	0.01987	0.01738	- 0.00249	-£ 109.60	- 1.394
NOx (g / tonne)	189.184	174.821	- 14.363	-£ 70.44	- 8,043.280
PM2.5 (g / tonne)	3.878	3.571	- 0.307	-£ 0.02	- 171.92
PM10 (g / tonne)	2.857	2.679	- 0.178	N/A	
			Total	-£ 180.06	

It can be seen over the journey 1.4 tonnes of carbon dioxide is saved, 8 kg of NO_x and 171 g of $PM_{2.5}$. Financial values have been calculated using figures in DfT's TAG guidance, widely used for quantifying the benefits of reducing air pollution and greenhouse gas emissions in the transport sector. It should be noted that the future 'value' of CO_2 saving will substantially increase within the guidance, the 2022 central figure is £78.62/tonne, this becomes £104.83 in 2032 and £186.73 in 2042 and are not subject to discounting. This means that the overall environmental benefit of increased trailing weight is set to increase in value. For NO_x and $PM_{2.5}$, the benefit values are calculated using the health damage cost rates for the rail sector (which are subject reduced rate discounting for multi-year analysis) and these benefits values will be much more stable over time than for CO_2.

6.4 Summary

The summary of the three case studies is given in Figure 17.

Figure 17 Benefit Summary

Case study		Wagons in consist Initially	Revised	Journey (e/way, miles)	Cost saving (£) Daily	Annually	%	Environmental saving CO2 (t)	NOx (kg)	PM2.5 (g)
1	Jet, WLL	24	27	50	350	291K	7.3	0.25	2	25
2	Intermodal, Harringey	14	16	235	945	245K	10.9	1.4	8	171
3	Intermodal, Beattock	19	23	235	1400	364K	14.3	2.1	13	263

The proposed changes to traction ratings will enable significant savings to both haulage costs and emissions.

7 Implementation plan

7.1 Introduction

This research has developed:

- a tool which enables train length extension based on existing coupler strengths
- the definition of new traction ratings which will enable existing couplers to increase their loading.

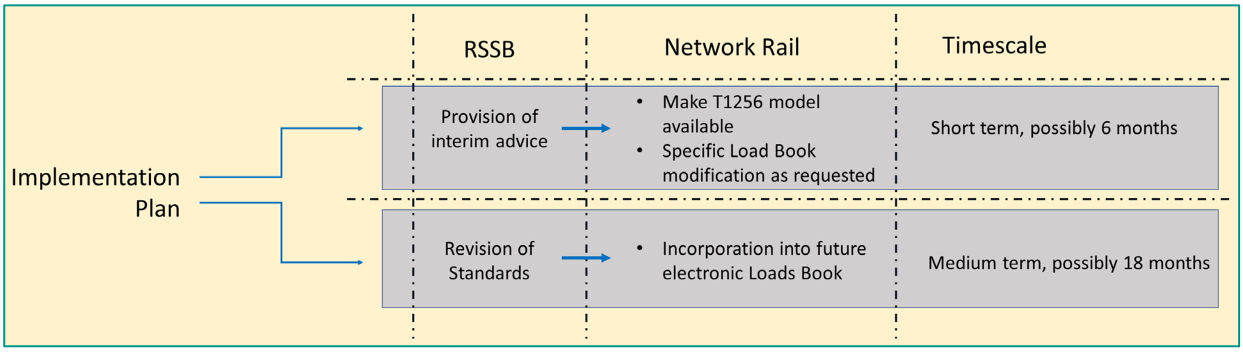
The adoption of these beneficial changes needs two things:

- Formal recognition though a change to standards, or the guidance around standards, to enable the changes to be adopted. It is suggested that this is the responsibility of RSSB.
- Formal adoption of the tool and the modified traction ratings by Network Rail, and incorporation into a revision of the Loads Book.

7.2 Implementation plan workflow

Figure 18 shows how the changes can be implemented.

Figure 18 Implementation plan



7.2.1 Standards

In the medium to long term revision to the Standards will be required. The following Standards should be considered:

- RIS-2790-RST - Rail Industry Standard for Compatibility of Rail Vehicle Couplings and Interconnectors (December 2014)
- GMGN2688 - Guidance on Designing Rail Freight Wagons for use on the GB Mainline Railway
- RIS-2780-RST - Design of rail vehicle structures

It is envisaged that this formal change could take some time, possibly 18 months. To enable receipt of the benefit more immediately RSSB may be able to issue some interim advice based on this report to enable changes to be made.

7.2.2 Loads Book

Network Rail are in the process of upgrading their existing Loads Book with the aim to eventually make it available electronically. It is envisaged that this update will not only consider changes to trailing length based on the coupler strength, as discussed in this report, but also based on improvements in locomotive tractive effort, which is the more usual constraining factor.

In the short-term Network Rail could make the calculation tool and the modified traction ratings available to the freight community and enable beneficial change through NR's established flow Specific Service Plan review process.

7.2.3 Communication

Benefit will only accrue if stakeholders are aware of the potential benefit and seek to use it. Therefore, stakeholder communication is of great importance. Once RSSB and Network Rail have agreed an interim process for the benefits to be realised it is suggested that this opportunity is briefed out through the existing stakeholder forums RSSB and Network Rail have with the freight community.

8 Conclusions

1. Drawgear can be assigned the traction ratings given in Table 6 on page 11.

   Note: This lifts the rating of TR 34.5 t and EN SC 1.0 MN equipment by 16%, EN SC 1.2 MN equipment by 39 % and EN SC 1.5 MN equipment by 12.5%.

2. Coupler strength designations above 63 t could be assigned provided the wagon's structural strength is confirmed to be sufficient for the increased loading.

3. The calculation tool developed as part of this assignment can be used to recalculate permitted trailing load (taking advantage of greater granularity applied to the geography and new traction rated couplers).

4. The use of the traction ratings and greater granularity within the new trailing loads calculation tool will enable train length extension, bringing both financial and environmental benefits. The three case studies analysed show a typical 10% improvement in cost and savings of up to 2 tonnes in emitted CO_2, plus associated savings in NO_X and particulates.

9 Recommendations

1. There is a lack of process around the definition of traction rating and how trailing loads are calculated from it. RSSB should provide some additional guidance on this.

2. Whilst this RSSB guidance is being provided, Network Rail, with RSSB's support, could enable changes to be made using their existing Service Plan Review process.

3. The use of a reduced load at traction stop position 'b' should be reviewed (see Section 3.6).

4. To guarantee that the cheapest replaceable component is the 'fuse' in the tensile load system, the EN method of a specifying a maximum screw coupling strength should be adopted (i.e. the screw coupling is guaranteed to be weaker than the drawhook).

10 References

[1] BRB Chief Engineer (Traction and Rolling Stock) Department 'Manual of Maximum Freight Train Loads on Gradients for Various Types of Locomotives'. RfC's copy is hand annotated with the reference 'MT19', see Figure 3. MT19 appears to be a compilation of information with no version control, proper sequential sections or page numbers. Estimated production date from the 1950s to the 1980s.

[2] BRB M&EE drawing B1-C0-9029821-G, Couplings.

[3] BRB M&EE drawing B1-C0-9029843-A, Drawhooks.

[4] BRB, Chief Mechanical Engineer MT235:May 1964, Requirements and recommendations for the design of wagons running on BR lines.

[5] BS EN 12663-1:2014 and BS EN 12663-2:2010, Structural requirements of railway vehicle bodies

[6] BS EN 13155:2009, Non-fixed load lifting attachments.

[7] BS EN 15566:2016, Drawgear and screw coupling.

[8] Railway group standard GM/RT2100:3, Structural requirements for railway vehicles.

[9] Railway group standard GM/RT2100:4, Requirements for rail vehicle structures.

[10] Railway Group Standard GM/RT2102:1, Structural requirements for drawgear and buffers on railway vehicles. Withdrawn.

11 GB drawgear strength vs traction rating

Table 11 provides the background behind the information provided in Section 3.

Table 11 GB strength vs TR

Item	Drawing	Item Nº	Traction load rating (t)	Proof strength (t)	Ultimate strength (t)
*Screw coupling for fitted wagons**	*9029821[2]*	*11*	*22.0*	*-*	*-*
*Loco screw coupling**	*9029821[2]*	*3*	*34.0*	*40.5*	*96.5*
*International screw coupling**	*9029821[2]*	*6*	*34.5*	*-*	*86.6*
Coach emergency screw coupling	9029821[2]	1	34.5	51.0	102.0
Standard coach screw coupling	9029821[2]	2			
Screw coupling for fitted wagons	9029821[2]	7			
Heavy duty screw coupling for Freightliners	9029821[2]	8			
Drawhook for Freightliners	9029843[3]	4			
Drawhook for Freightliners with imperial bushing	9029843[3]	5			
Drawhook for Freightliners with imperial bushing	9029843[3]	6			
Drawhook for wagon stock	9029843[3]	8			
Tailpin	9029843[3]	9			
Instanter coupling	9029821[2]	4			
International screw coupling	9029821[2]	5	56.0	71.0	122.0
Screw coupling for fitted wagons	9029821[2]	9			
Loco screw coupling	9029821[2]	10			
Drawhook for wagon stock	9029843[3]	1			
Drawhook for wagon stock	9029843[3]	2			
Drawhook for wagon stock	9029843[3]	3			
Tailpin	9029843[3]	7			
Drawhook for wagon stock	9029843[3]	10			

Note: Couplings 9029821-3, 9029821-6 and 9029821-11 (highlighted grey italics) were 'dismissed' as they do not follow the trend of the other drawgear items or lacked information.