Rail Accident Investigation Branch

Rail Accident Report

Investigation into runaways of road-rail vehicles and their trailers on Network Rail

Department for Transport

Report 27/2009
October 2009

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

Any enquiries about this publication should be sent to:

RAIB	Email: enquiries@raib.gov.uk
The Wharf	Telephone: 01332 253300
Stores Road	Fax: 01332 253301
Derby UK	Website: www.raib.gov.uk
DE21 4BA	

This report is published by the Rail Accident Investigation Branch, Department for Transport.

Investigation into runaways of road-rail vehicles and their trailers on Network Rail

Contents

This page is left intentionally blank

Preface

1 The sole purpose of an RAIB investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

Definitions and appendices

3 Appendices at the rear of this report contain the following:

- abbreviations, in Appendix A;
- technical terms (shown in *italics* the first time they appear in the report), in Appendix B;
- relevant standards, including publication date and issue number, in Appendix C;
- pictures of typical road-rail vehicles, in Appendix D;
- previous road-rail vehicle/trailer events involving runaways, in Appendix E;
- analysis of underlying factors arising from previous events of road-rail vehicle/trailer runaways, in Appendix F;
- the system life cycle as described in standard BS ISO/IEC 15288:2002, in Appendix G; and
- the relationship between the recommendations made in this report and those made in other RAIB reports involving road-rail vehicles and their status, in Appendix H.

Executive summary

4 This report describes an investigation carried out by the Rail Accident Investigation Branch (RAIB) into runaways and collisions involving road-rail vehicles (RRVs) and trailers that couple to them. The RAIB was concerned by the number of these events occurring on the main line railway operated by Network Rail and therefore decided to carry out this class investigation.

5 The focus of the investigation was to determine whether there are sufficient systems and controls in place to prevent runaways and collisions and to determine whether these are properly implemented. The report makes recommendations that the RAIB believes, if implemented, will reduce the likelihood of further runaway events occurring.

Conclusions

6 Suppliers have developed RRVs in response to market opportunities, and Network Rail (and Railtrack before it) has not managed the different stages of an RRV's life cycle starting from defining the requirements. This has resulted in a proliferation of different types of plant, many of which were designed and procured before Network Rail came into existence, and which may not be optimised for the tasks that they are to carry out, or specified to a level that will ensure an acceptable degree of safety.

7 There have been no runaway accidents or incidents involving trailers since the fatal accident at Tebay on 15 February 2004, although there have been runaway incidents since where trailers have been operating coupled to RRVs.

8 The biggest proportion of previous runaways has arisen during the *on- or off-tracking* process where the operator placed the RRV, with no brakes fitted to the rail wheels, into a freewheel, unbraked, condition. An engineering means to prevent this occurring is progressively being fitted. In the meantime, the prevention of a freewheel condition occurring depends on the operator correctly following the on/off-tracking procedure.

9 Other runaways have occurred during braking where the rails were wet and in some cases contaminated. A significant gradient was also a factor in some incidents. Friction between the rubber tyres and steel wheels or rails was overcome causing wheel slide to occur, extending the stopping distance. Although RRVs have to meet standard stopping distances on dry rails, there are currently no standard requirements relating to other rail head conditions.

10 A factor in some runaways and collisions has been the length of *work sites* in which RRVs had to travel a significant distance to where they were required to work. In accordance with the railway's Rule Book, such movements are generally required to be made at 'extreme caution'. This is probably unrealistic where a work site extends over several miles.

11 An important control measure for safety is a robust planning process that takes account of gradients, the possible effect the work taking place may have on the rail head condition, and the possible influence of work being carried out by others. RRVs that are dependent on a rubber/steel interface have significantly extended stopping distances if the rail head is wet and unpredictable stopping distances if the rail head is contaminated. These stopping distances are extended still further by a significant downward gradient, or if the RRV is hauling a loaded trailer. Staff operating RRVs should be briefed on these hazards and how they may affect the operation of the machine.

Recommendations

12 Recommendations can be found in paragraph 240. They relate to the following areas:

- Network Rail managing the planning and operation of RRVs on its network throughout their system lifecycle;
- Network Rail assessing the operation of existing RRVs and trailers with the aim of reducing the risk of runaways and collisions arising from the operation of these vehicles; and
- Network Rail improving the reporting of accidents and incidents involving RRVs in order to reduce the level of under-reporting.

The Investigation

13 RRVs are vehicles that can travel under their own power on the road and also, by means of a rail wheel guidance system, on railway track. Such vehicles are not allowed to operate on railways outside *possessions*. In some cases RRVs are converted from existing road vehicles, whereas in other cases RRVs are constructed from new with both a road-going and rail-going capability. Companies that purpose-build RRVs are known within the industry as original equipment manufacturers (OEMs). Companies that adapt existing road vehicles to run on road and rail are known as converter companies.

14 There have been at least 18 accidents and incidents since the start of 2001, listed in Appendix E and collectively referred to in this report as events, where RRVs and trailers have run away in an uncontrolled manner, resulting in collisions or near misses. The aim of the investigation was to identify common immediate and underlying causes of these events, and to make recommendations to reduce the number of occurrences.

15 The use of the term 'runaway' covers two particular circumstances in this report:

- an uncontrolled movement occurring from rest; and
- an uncontrolled situation occurring during braking when the RRV/trailer is already moving and attempting to stop.

16 There are many different types of RRVs that are permitted by Network Rail to operate on its infrastructure. Most of these are contractors' plant with the most common type being wheeled excavators. Other types include crawler excavators; *mobile elevating work platforms* (MEWPs); dumper trucks; bulldozers; *Unimogs*; lorries and vans. The term MEWP is a generic one that includes *self-propelled booms,* and access platforms fitted to proprietary goods vehicle chassis. Pictures of typical types of RRVs are in Appendix D, as well as in Figures 1 to 4.

17 During the course of this investigation, Network Rail set up and populated a database of RRVs and their trailers. The figures in the database change often as new plant is brought into use and life expired equipment is scrapped. Table 1 shows the number of RRVs able to operate on Network Rail as of 7 July 2009.

Type of RRV	Number of vehicles
Wheeled excavators	720
Crawler excavators	263
Lorries	37
Laser controlled bulldozers	92
Self-propelled booms	158
Buggies	102
Dumpers – load carrying	78
Off-road vehicles	52
Other	167
Total	**1669**

Table 1: Types and number of RRVs (courtesy of Network Rail)

18 This investigation used data from the following events, which were investigated by the RAIB:

- the derailment of an RRV and two trailers at Terryhoogan, near Scarva (Northern Ireland) on 9 March 2008;
- the collision between two RRVs at Glen Garry on 5 December 2007;
- the runaway of RRVs between Brentwood and Romford on 4 November 2007, and at Snow Hill, Birmingham on 31 October 2007.

19 The investigation also used data from the following three events which the RAIB attended, but did not report on separately, as it was concluded that the issues raised could be dealt with in this report:

- the collision between two RRVs at Drumfrochar, near Greenock, on 23 May 2008;
- the runaway of an RRV on the Graham Road Curve, Hackney, on 12 October 2008; and
- the runaway of an RRV and trailer in the Severn Tunnel on 26 April 2009.

20 The findings of investigations into other runaway events back to the year 2001 have also been used. These were not investigated by the RAIB and the reports on the investigations were obtained from the railway industry.

21 The RAIB analysed the reports on previous runaways and identified the measures already adopted by various organisations to eliminate the factors that led to the accident or incident. The RAIB then considered what further measures could be taken to reduce the risk of runaway of RRVs and their trailers. These further measures form the basis of the recommendations in this report.

22 At the same time, the RAIB considered RRVs from the perspective of the system life cycle, covering the specification of what is required through to ultimate disposal, described in BS ISO/IEC 15288:2002, 'Systems engineering – System life cycle processes' and assessed the current RRV system against it. Where gaps were identified, the RAIB has made appropriate recommendations to eliminate them.

23 The report covers the use of RRVs on Network Rail's managed infrastructure in the following sections:

- standards and guidance in paragraphs 47 to 66;
- training and competence in paragraphs 69 to 84;
- overview of risk in paragraphs 120 to 127;
- under-reporting of accidents and incidents in paragraphs 138 to 143; and
- the work planning process (including possession planning) in paragraphs 144 to 176.

24 The investigation also reviewed the processes in place to control the risk of RRV runaways on the London Underground system, and obtained limited information concerning the use of RRVs elsewhere in the European Community.

25 The use of RRVs on the London Underground system is covered in paragraphs 105 to 114.

26 The use of RRVs elsewhere in the European Community is covered in paragraphs 115 to 119.

27 *On-track machines* (OTMs) are excluded from this report, except for the consideration of the accident at Badminton on 31 October 2006[1] (RAIB report 30/2007). This accident is included in the context of the length of work sites in possessions.

28 The fatal accident involving an RRV at Ancaster on 5 March 2004, while not arising from a runaway, is also included in the context of the length of work sites in possessions.

29 Hand trolleys are also excluded from this report except for the reference to the RAIB's investigation of the runaway of a trolley at Larkhall (RAIB report 20/2006) in the context of the effect of gradients and contamination on braking performance.

30 Network Rail, the *Rail Safety and Standards Board* (RSSB), London Underground Limited, and those plant hire and manufacturing companies approached freely co-operated with this investigation.

[1] The RAIB's report on this is available at www.raib.gov.uk.

Key Information

Road-rail vehicles

31 RRVs have been used in the UK for many years, but until before the early 1990s their use was limited to Unimog RRVs for shunting in yards, and specialist vehicles used for recovering derailed railway vehicles. From the early 1990s, and leading up to the privatisation of British Rail, the use of RRVs in carrying out infrastructure engineering works increased substantially, because they were more economic and flexible than the locomotives and engineering trains used previously.

32 Converter companies saw an opportunity to develop vehicles by taking existing road-going plant and fitting *rail gear* to them. The newly privatised rail infrastructure maintenance and renewals companies then adopted RRVs for carrying out work on the railway infrastructure. Converter companies developing types of RRV to meet a market need has continued from that time.

33 OEMs were also supplying the market with RRVs that had been purpose-built rather than converted from existing road plant. RRVs manufactured by OEMs had already been in use elsewhere in Europe for several years, with the low ride type (described in paragraph 37) predominating. Although more expensive than conversions, they have several advantages, including:

- ongoing support from the manufacturer for the complete vehicle;
- more sophisticated vehicle systems such as a load monitoring system on high ride RRVs to ensure constant force between the road wheels and the rail wheels that compensates for tyre wear (conversions require this to be manually adjusted) and on/off-tracking systems that only permit the rail gear to be lowered at one end of the machine at a time; and
- the design and construction of the whole machine is optimised for use as an RRV, whereas a base vehicle that has been converted was not initially designed with use as an RRV in mind.

34 An example of where the design of conversions is not optimised is where the weight is increased by fitting new counterweights and other ballast to increase the lifting duties that would otherwise be limited by the reduced wheelbase of the vehicle. The base machine would not have been designed in the first instance to take account of this extra weight.

35 RRVs and their trailers are classed as *On-Track Plant* (OTP) and are only permitted to work in work sites within possessions. RRVs are permitted to travel along the railway outside work sites but otherwise within the confines of a possession. OTP also includes rail-mounted maintenance machines (RMMMs) and attachments with rail guidance wheels. These are not part of this report but are covered in some of the standards applicable to RRVs and trailers.

36 OTMs, such as *tampers* and *ballast regulators*, are permitted to travel under their own power outside possessions, and are covered by different standards.

37 RRVs in the UK have three basic configurations of rail gear classified as 'Type 9' under the proposed European Standard EN 15746, 'Railway Applications – Track – Road-rail machines and associated equipment' (in two parts). They are:

- Type 9A: braking and traction forces transmitted directly to the rail wheels (i.e. the rail wheels are self-powered). See Figure 1.
- Type 9B: traction forces indirectly transmitted from the road wheels to the rail wheels and the braking force either indirectly from the road wheels to the rail wheels or direct on the rail wheels, with the load entirely on the rail wheels. These are often known as 'high ride' RRVs (Figure 2 and Appendix D).
- Type 9C: braking and traction forces transmitted to the road wheels with the load shared between the road and the rail wheels. These are often known as 'low ride' RRVs (Figure 3).

Figure 1: Example Type 9A RRV with self-powered rail wheels

38 The area of contact between a road wheel tyre and the rail head, as used in low ride RRVs, is greater than that between the road wheel tyre and rail wheel on high ride RRVs. Low ride RRVs also have only one interface – between the road wheel tyre and the rail head; high ride RRVs have two interfaces – between the road wheel tyre and the rail wheel, and between the rail wheel and the rail head. The result of this is that low ride RRVs have very good adhesion during traction and braking on rails that are clean and dry. The contact pressure between the road tyres and the rail head of low ride RRVs can thus be less than that between the road tyres and the rail wheels of high ride RRVs extending tyre life.

Figure 2: Example Type 9B high ride RRV with traction and braking through the road wheels to the rail wheels

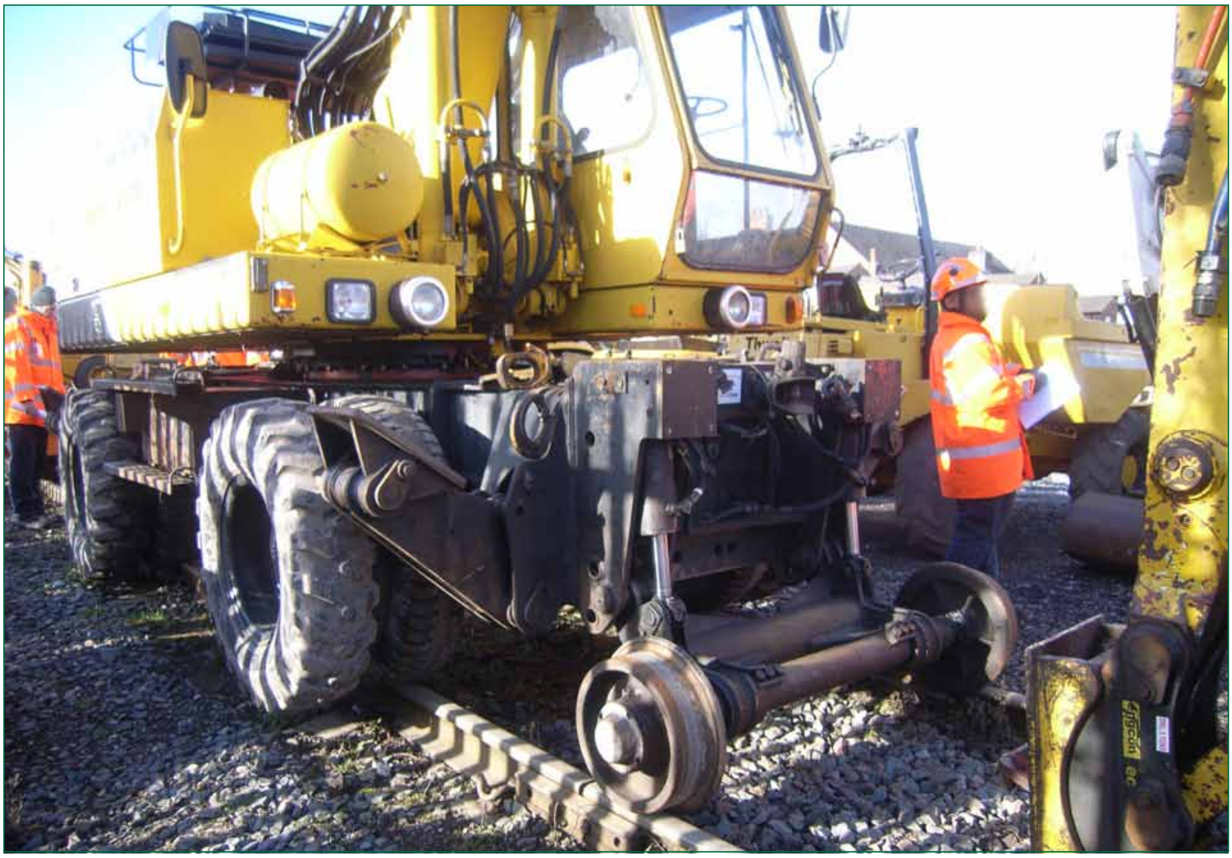

Figure 3: Example Type 9C low ride RRV with traction and braking through the road wheels

39 There is a variation within Type 9B high ride RRVs where the drive from the road wheels is onto spigots fitted to the axle ends, instead of direct to the rail wheels. This is required where the road wheel spacing is greater than the rail wheel spacing. Some spigots have a smooth surface; others have a knurled or splined surface with the aim of providing a more effective interface with the rubber road wheels (Figure 4).

Figure 4: Type 9B high ride RRV with extensions fitted to the rail wheels (spigots)

40 The use of spigots is likely to result in an overall increase of the area of contact between the road and rail wheels because, so far as the *structure gauge* allows, they are longer than the thickness of a rail wheel tread (Figure 5). However, this is likely to be offset to a degree because of the spigot's significantly smaller radius which acts to reduce the area of contact. There are two issues arising from their use which have to be considered by designers and operators:

- The road wheels and spigots act as a gear ratio; this leads to a significant increase in travel speed compared with the road mode of operation, unless controlled by, for example, restriction to the use of first gear only when in rail mode. For other high ride RRVs where the road wheels bear onto the rail wheels, there is no step up gear ratio in this way.
- A greater force is needed at the spigot to road wheel contact point to generate the traction or braking force required, giving rise to a greater tendency for the rubber tyre to steel spigot interface to slide. However, this effect is offset by the greater rubber to steel contact area.

Figure 5: Road wheel/spigot contact area

41 From the figures provided by Network Rail, about 53% of the RRVs shown in Table 1 are Type 9B high ride, about 28% are Type 9A self-powered and 19% are Type 9C low ride.

42 All tracked vehicles must of necessity be self-powered (crawler excavators and laser controlled bulldozers in Table 1), whereas Unimogs, buggies and many lorries are low ride. About 10% of the wheeled excavators are low ride and a few are self-powered. Some lorries are also self-powered. Most RRVs in the UK have been converted from the base road-going machines, although some have been produced as complete machines by OEMs.

43 The advantages and disadvantages of the different types of RRV are summarised in Table 2.

Trailers

44 Many RRVs tow or propel a variety of trailers, either one at a time, or several connected together.

45 Trailers commonly in use are Type 0A fitted with parking brakes and *service brakes*, and Type 0B which are fitted with a parking brake only. For Type 0A trailers the number (and therefore load) that can be hauled by an RRV is limited only by the traction capability of the RRV, as the service braking capacity of each trailer is sufficient to allow it to stop itself . For Type 0B trailers the load that the RRV can haul is limited in railway industry standards to no more than the RRV's weight, and the RRV/trailer combination is required to meet the specified stopping distances applicable to the RRV alone in the governing standard.

RRV Type	Advantages	Disadvantages
9A Self-powered	• No interface problem between rubber and steel and therefore more consistent with normal rail vehicles. • The only system that can be fitted to tracked vehicles.	• Potentially higher cost than Types 9B and 9C.
9B High ride	• Simple conversion (in its basic form with the rail wheels unbraked) from the basic road vehicle and therefore relatively low additional cost.	• Traction (and braking where the rail wheels are not separately braked) relies on two interfaces: between the road wheels and the rail wheels and between the rail wheels and the track. • Friction between rubber and steel is very variable depending on the conditions (poor when wet/contaminated. It is also dependent on the maintenance of the correct force between the rubber wheels and the rail wheels). • Wheel slide can occur even on a clean dry rail if the rail wheels lock against the rubber road wheels. • An unbraked condition can occur during on- or off-tracking if the process is not carried out correctly (covered in paragraphs 177 to 181). • When in rail mode driving forward, the drive train must run in reverse compared with normal on-road use.
9C Low ride	• Road wheels provide traction and braking directly onto the rail with only one interface between the (braked) road wheels and the track (as opposed to two interfaces in Type 9B machines). This gives very good adhesion on a rail head that is clean and dry. • A simple conversion and therefore relatively low cost.	• Important to have correct load sharing between the rail and road wheels to ensure that the rail wheels provide sufficient guidance and the road wheels provide sufficient traction and braking, even when adhesion is poor from wet and/or contaminated rails . • Can be susceptible to operator abuse by lifting the rail wheels to improve adhesion from the road wheels where adhesion conditions are poor. • Cannot be used in areas where conductor rails are fitted and care is needed where there are level crossings, high ballast shoulders, lineside magnets etc.

Table 2: Summary of advantages and disadvantages of different types of RRVs

46 For Type 0B trailers, the parking brake is spring applied and requires either hydraulic or pneumatic pressure to release it. Applying the parking brake on an RRV applies the parking brake on any attached trailers and any failure of the coupling between an RRV and an attached trailer or between trailers causes loss of pressure and the parking brake to apply automatically to all trailers. Figure 6 shows a typical trailer.

Figure 6: Typical trailer for use with an RRV

Standards and guidance

Operational rules and processes for RRVs used on Network Rail

47 Rules covering the operation of OTP are contained in Module OTP, On-Track Plant, of *Railway Group Standard* GE/RT8000 (the Rule Book). This contains the following matters which are directly relevant to this report:

- A *machine controller* is the person with overall responsibility for the safe operation of OTP and must hold a current machine controller certificate of competence. A machine controller must be appointed whenever OTP will be on- or off-tracked or used in rail mode. Subject to confirmation by means of a risk assessment, there does not need to be a machine controller appointed for each item of OTP; a machine controller can be in charge of several items of OTP. The machine controller must be with the OTP when it is being on- or off-tracked, being set up, and when it is working. The machine controller must also be with the OTP when it is travelling (a movement in rail mode where the OTP is not working), except where a risk assessment has been carried out demonstrating that this is not necessary, and the other specific conditions listed in the Rule Book can be met. In this case, a machine controller must meet the OTP at the end of its travel distance.

- The operator is responsible for operating OTP safely and must hold a current certificate of competence issued by their employer to operate the OTP in rail mode.
- The machine controller must make sure that the operator tests the lights, brakes, horn and any movement limiting devices before the OTP is placed on the track.
- The OTP must display two white lights at the leading end and at least one red light at the rear. If the OTP's speed can exceed 20 mph (32 km/h), it must also have a headlight at the leading end.
- OTP working on Network Rail's infrastructure must carry a *certificate of engineering acceptance* containing information relevant to the particular OTP. The machine controller must check this certificate to ensure he is aware of any limitations that may be stated on it and that the OTP is suitable for its intended use.
- On- or off-tracking must only take place within a work site.
- The operator must always make movements in a work site at extreme caution and at no greater than walking pace, unless given specific instructions by the machine controller on what is the maximum speed. A speed greater than walking pace is only permitted in a work site if there are no staff on or about the railway in the area of the movement and it is the *engineering supervisor's* responsibility to tell the machine controller what this speed should be.
- When moving between work sites, in a possession, the speed of OTP must not exceed 40 mph (64 km/h) subject to any lower permissible speed limit that may apply to a section of line. Speeds over points and within sidings must not exceed 5 mph (8 km/h). The operator must always be able to stop the OTP within the distance that he can see to be clear of any obstruction.
- The machine controller must get permission from the engineering supervisor to make a movement within a work site. Outside a work site but within the possession, the machine controller must get permission for a movement from the *person in charge of possession* (PICOP). The machine controller must then authorise each movement with the operator by using radio or handsignals.
- The machine controller must brief the operator about any particular hazards such as poor rail-head conditions and gradients.
- Where closed circuit television is being used to get a clear view ahead (because a full view ahead cannot otherwise be obtained in the direction the OTP is to move), the speed must not exceed 10 mph (16 km/h).
- Multiple movements of OTP may take place in a possession outside a work site if this has been agreed at an engineering planning meeting. Operators must keep OTP at least 100 metres apart and not exceed 20 mph (32 km/h), or any lower speed limit that may apply.

48 Rule Book Module T3, 'Possession of the line for engineering work', contains requirements relating to possessions and work sites. These include that the length of the possession must be kept as short as possible and that work site *marker boards*, when required, should be placed at least 100 metres from each end of the work site.

49 There used to be no limits on the length of work sites, but following the RAIB's report on its investigation of a collision at Badminton on 31 October 2006 (RAIB report 30/2007), a rule was introduced that work sites should be as short as possible. This was not yet in Rule Book Module T3 at the time of this report. The rule change was implemented firstly through a *Periodical Operating Notice* and then Rule Book Amendments Module AM, which came into force, on 6 December 2008.

50 As well as the Rule Book, the *M&EE Networking Group* has developed a range of codes of practice covering the operation of OTPs and other equipment such as trolleys. These make recommendations for best practice in the industry. The M&EE Networking Group is made up of industry representatives, including the Rail Plant Organisation (a trade organisation representing suppliers of plant to the railway industry) and the RSSB, under the chairmanship of Network Rail.

51 Network Rail has subsequently mandated some of the codes of practice on the industry as being compulsory. The codes of practice that are relevant to this investigation are described in the following paragraphs; all of these have been mandated except for COP0001 and COP0019.

52 COP0001 'Code of Practice for Operator Competency Standards for Possession Only Rail Vehicles' details the minimum competences required by operators (described more fully in paragraph 71).

53 COP0002 'Code of Practice for Minimum Requirements for the Planning and Management of Possession-only Rail Vehicles' defines the planning process for work involving the use of RRVs and RMMMs. This includes identifying the safety risks at the site; developing a method of work; identifying what plant is required; establishing the personnel requirements including competencies; determining the possession arrangements; and identifying contingency arrangements, for example machine failures. COP0002 does not identify gradients as a hazard.

54 NR/L2/RVE/0007 (formerly COP0007) 'Code of Practice for On and Off Tracking of Road-rail Vehicles' gives guidance for the safe on- and off-tracking of RRVs in order to mitigate the possibility of derailment or overturning (but not running away). It requires that RRVs are only on- and off- tracked at an approved on- and off-tracking point (except for those that have a Network Rail approved system for on- and off-tracking at other locations). These are known as road-rail access points (RRAP) and consist of, for example, a level crossing, a proprietary track access system, or secured timbers level with the rail head. During the planning of the work, those carrying out the work are required to assess RRAPs to identify any hazards that have the potential to cause derailment or overturning.

55 COP0014 'Code of Practice for Trailers and Attachments with RRVs and RMMMs' states that if a breakaway occurs, a trailer must be braked to a stop. It also requires that whenever a trailer is placed on the track, or a trailer is to be left unattended on the track, the machine controller must ensure a functional brake test is carried out by conducting a pull test on the vehicle by checking that the brakes resist the movement when pulled by a coupled RRV. COP0014 also includes requirements relating to the maintenance of trailer brakes and states that this must be carried out to the periodicity stated in the maintenance plan certified under rail industry standard RIS-1530-PLT (described in the next section).

56 COP0016 'Code of Practice for RRV & RMMM Machine/*Crane Controller* Checklists' specifies a common format of checklist to be completed by machine and crane controllers when carrying out pre-use checks of RRVs and RMMMs. The checklist includes whether the machine controller has briefed the operator on the work and factors that may influence the work within the method statement, and whether the machine controller has witnessed a successful functional brake test being carried out. There is no specific reference to the existence of any gradient hazard and measures that may be required to mitigate it.

57 COP0019 'Code of Practice for Action to be Taken in the Event of Accident or Incident with a Possession-Only Rail Vehicle' includes the action to be taken by the machine controller following a collision involving an RRV. The machine controller is required to assess the force of the collision and report as necessary to the engineering supervisor or PICOP.

58 Network Rail company standard NR/L3/RVE/0167 'On site management of on track plant' defines the roles and responsibilities of those involved in the operation of OTP. It includes that before on-tracking, the machine controller must undertake checks that include:

- relevant documentation, such as the certificate of engineering acceptance, is available;
- that the machine controller has the required competency documentation for the activity being undertaken;
- checking that operators are fit for duty and have the required competency documentation;
- briefing operators on matters that include gradients and railhead conditions;
- access to the railway, on- and off- tracking, travel arrangements; and
- the action to be taken in the event of defective equipment.

Engineering processes in Network Rail – standards

59 Prior to April 2006, the acceptance requirements that authorise the use of OTP on Network Rail were covered by Railway Group Standard GM/RT1300 'Engineering Acceptance of Road-Rail Plant and Associated Equipment '. The industry decided that OTP was no longer a matter suitable to be covered by a Railway Group Standard as there was no interface between different railway operators; the use of OTP is wholly controlled by Network Rail. However, the RSSB's Plant Standards Committee thought that there should still be a standard that covered OTP so the outcome was the replacement of GM/RT1300 by *Railway Industry Standard* RIS-1530-PLT, 'Engineering Acceptance of Possession-only Rail Vehicles and Associated Equipment', Issue 1, dated April 2006. This was produced by a cross-industry drafting group under the RSSB's leadership.

60 RRVs and trailers must meet the requirements of Rail Industry Standard RIS-1530-PLT before they can operate on Network Rail's infrastructure. RIS-1530-PLT is a voluntary standard issued by the RSSB, which Network Rail has mandated on its suppliers through its internal processes.

61 Under RIS-1530-PLT, RRVs and trailers must be approved by Network Rail before they can operate on the main line railway network. They must also undergo an engineering acceptance process which confirms conformity of the design, construction and maintenance plan with all applicable Railway Group Standards and RIS-1530-PLT. The acceptance process must be carried out every seven years to the standards in force at the time.

62 *Vehicle acceptance bodies* assess conformity with RIS-1530-PLT and issue a certificate of engineering acceptance if conformity is confirmed.

63 RIS-1530-PLT contains a number of key requirements that are relevant to this report as follows:

- A certificate of engineering acceptance is valid for a maximum of seven years. An item of OTP must be re-assessed before the expiry of the current certificate in order to remain in service. This re-assessment must be carried out to the latest applicable standards.
- Braking performance is specified for a fully laden vehicle plus any permitted trailing load on dry, level track at speeds up to 35 mph (56 km/h). There are no requirements relating to braking performance in wet conditions or on gradients.
- RRVs built after 31 December 2006 which are designed to tow or propel trailers must be fitted with a service brake that controls the service brake fitted to trailers (trailers built after 31 December 2006 must have service brakes). Those RRVs built before 31 December 2006 without a means to apply the service brake on trailers must be limited to a maximum speed of 10 mph (16 km/h) while towing or propelling.
- A parking brake must be able to hold an RRV and any permitted fully loaded trailer combination on a 1 in 29 gradient.
- Where an emergency stop button is fitted (these are fitted to MEWPs and to RRVs that are approved to operate on the London Underground system), it must apply the brakes and stop all movements when operated.
- Vehicles over 75 kg gross weight must be fitted with two white marker lights at the front and two red lights at the rear. A headlight must also be fitted when such vehicles are required to travel (as opposed to being in working mode) along the railway.
- A documented procedure describing the on- and off- tracking system must be assessed and should conform with the Network Rail company standard NR/L2/RVE/0007 ‘Code of Practice for On- and Off-Tracking of Road-Rail Vehicles’.
- During on- or off-tracking, there should be no inadvertent movement of the vehicle by ensuring that at least one braked axle with the brakes applied sufficient to hold the vehicle on the steepest gradient (1 in 29) is in contact with either the rail or the ground.
- Unless a service brake is provided, the towed or propelled weight of a laden trailer (or trailers) must not exceed 100% of the fully laden weight of the towing vehicle, and a speed restriction of not more than 10 mph (16 km/h) shall apply.
- OTP must have an approved and certified maintenance plan which must include the requirements for maintaining the road wheel tyres and to include checking tyre pressures and condition, and compatibility between tyre types.

64 Issue 1 of RIS-1530-PLT is being replaced by Issue 2 although this had not been formally issued at the time of this report. Significant changes proposed that are relevant to this report are as follows:

- Network Rail must maintain an asset register of all vehicles and each one must have a unique identity number.
- High ride RRVs must have at least two rail wheels directly braked, applied by the vehicle parking brake, and capable of holding the vehicle on a maximum 1 in 25 gradient specified by the standard.
- RRVs built after 3 October 2009 which are designed to tow or propel braked trailers must be fitted with an air service brake capable of controlling the air service brake on the trailers.
- A parking brake must be able to hold an RRV and any permitted fully loaded trailer combination on a 1 in 25 gradient.
- Where an emergency stop button is fitted, its operation must stop movement along the track and meet the specified stopping distances, stop the movement of other vehicle components and prevent further movement, including along the track.
- RRVs intended to carry out lifting operations (e.g. MEWPs, cranes and excavators) must be provided with a data logging system which must include the recording of any exceedance of maximum permitted speed on rail in both travel and work modes.
- During on- or off-tracking at least one braked axle must be in contact with either the rail or the ground sufficient to hold the vehicle on the most adverse gradient (1 in 25) on which it can be on- and off-tracked. This state must be achieved by engineering means rather then by operational procedures.
- The maintenance plan must detail the permitted tyre types and tyre type combinations, and the requirements/adjustments needed following tyre change.

65 The proposed European Standard prEN 15746, Parts 1 and 2 ‘Railway Applications – Track – Road-rail machines and associated equipment’ covers RRVs (but not trailers). Part 1 covers the technical requirements for running and working, and Part 2 covers the safety requirements. The Euro Norm had been through consultation and the comments were being considered at the time of this report. Publication is expected in around 2010. For trailers, there was a draft Euro Norm in existence which was still to go through consultation. Estimated publication date is 2010/2011.

66 RIS-1700-PLT ‘Rail Industry Standard for Safe Use of Plant for Infrastructure Work’ states that items of OTP to be used on Network Rail’s infrastructure must be approved. It covers the planning of work, including the identification of hazards and the measures to mitigate risks in a documented safe system of work. This includes the assessment of gradient with appropriate measures to be included in the safe system of work to eliminate the likelihood of runaway.

Prevention of freewheel condition

67 Following the runaway of a MEWP at Copenhagen Tunnel, London King's Cross, on 15 October 2006, the *Office of Rail Regulation* (ORR) issued an enforcement notice requiring that engineering measures be taken to prevent MEWPs being able to achieve a freewheel condition during the on- or off-tracking process. This was implemented by the fitment of interlocks so that one set of rail wheels has to be completely deployed and in contact with the road wheels before the other set of rail wheels can be deployed. The compliance date of the notice was 31 December 2007 and it was complied with by that date.

68 Subsequently, the ORR has agreed with Network Rail that an engineering means to prevent RRVs achieving a freewheel condition be extended firstly to other high ride RRVs fitted with an emergency stop button (a London Underground requirement and described further in paragraph 109) by 31 December 2009, and for all other high ride RRVs by 31 December 2013. This requirement is also carried forward into the proposed Issue 2 of the draft RIS-1530-PLT (see paragraph 64).

Training and competence – operators (on Network Rail's managed infrastructure)

69 RIS-1700-PLT states that personnel required to plan, operate, control or maintain OTP should be competent for such work. The specific competence requirements those operating and controlling OTP are required to have, in order to meet module OTP of the Rule Book, are listed in the standard and include:

- the relevant parts of the Rule Book, GE/RT8000;
- maintenance and pre-use checks;
- functions of all controls available to the operator;
- the on- and off- tracking process; and
- movements within possessions.

70 Those operating and controlling OTP should have their competence re-assessed at least every two years.

71 COP0001 details the minimum competencies that operators of OTP should have to be able to operate such plant on Network Rail's infrastructure. It states that they should possess:

- a generic competency, applicable to all OTP, which includes the procedure for on/off-tracking, pre-work checks, safe use of trailers and relevant Rule Book requirements;
- for RRV excavator and excavator crane operators, a current CPCS (Construction Plant Competence Scheme) certificate for an excavator in road mode and to be competent in the correct operation of the specific machine; and
- for operators of RRVs other than excavators and excavator cranes, competency in the correct operation of the machine, and if it is a bulldozer to hold a CPCS certificate.

72 The Construction Plant Competence Scheme is a construction industry scheme which provides certification for plant operators when they have been assessed as competent. It covers proficiency in using the plant in road mode only and aims to provide assessment to common standards across the industry. Persons assessed as competent are issued with a CPCS card which lists the card holder's competencies and their expiry dates. For use in rail mode, the *Rail Plant Association* developed additional competence standards grouped into modules and which formed the basis of training. These are not mandatory.

73 In order to provide a single mandatory industry-wide system for the management of competence of operators, Network Rail introduced company standard NR/L2/CTM/025 'Competence & Training in On Track Plant Operation' detailing the competence standards that are required to be met to operate RRVs in rail mode. The standard has a compliance date of 31 December 2010.

74 Operators of RRVs must hold a current certificate to operate them in road mode (eg one issued by CPCS) before being assessed against the competence standards in NR/L2/CTM/025.

75 Network Rail has adopted the competence standards developed by the Rail Plant Association, and grouped them into modules in NR/L2/CTM/025. The modules consist of a core module (covering Rule Book module OTP), which is compulsory for all operators, and specific modules relating to generic machine type e.g. 'operate road rail excavator - tracked'.

76 The core module includes an element that deals with restrictions and precautions including the speed of OTP movements and stopping distances. Another element is the rules and procedures for travelling in a work site, and in a possession. This includes a knowledge and understanding of making multiple movements and the conditions that must be satisfied, and the procedures to be followed when working on a gradient. The specific modules include an element on on- and off-tracking and the module covering MEWPs includes how to prevent a freewheel situation and what to do if the vehicle has started to run away.

77 Training providers deliver courses that include assessments which qualify trainees as meeting Network Rail's competence standards for the plant that they are to operate. If a trainee successfully passes the assessment, he is issued with a provisional competence card. Following this, trainees are required to be mentored by a more experienced operator who must be present on the same work site where the provisional operator is working. The operator is also issued with a log book which must be used to record experience both while being mentored and subsequently when experienced. At the end of the mentoring period (normally four months), the operator is assessed again and, if he passes, is issued with a full competence card valid for two years. At the end of two years, the operator must be re-assessed. The assessor must consider the evidence recorded in the log book when re-assessment takes place.

78 Network Rail has also brought OTP operators into the *Sentinel scheme*. Trainers and assessors have to be registered with the scheme and operators are registered on the *National Competency Control Agency* (NCCA) database, and carry a valid Sentinel competence card. The Sentinel card contains details of competence in a generic type of plant e.g. RRV, whereas the competence relating to specific types of plant is contained on a separate counterpart document issued by Sentinel.

Training and competence – machine controllers (on Network Rail's managed infrastructure)

79 RIS-1700-PLT applies to machine controllers as described in paragraphs 69 and 70.

80 The Network Rail competence management system applicable to machine controllers follows the same principles as the system applying to operators under the Sentinel scheme. Network Rail company standard NR/CS/OPS/046 'The Train Operations Manual' details the competence requirements applying to Network Rail's own staff who operate OTP and carry out the machine controller role. Supporting standard NR/L3/OPS/048/TMMIND 'Train Operations Manual Industry Mandatory Section' applies to contractors involved in the operation and supervision of OTP.

81 Procedure TMM001 'Machine/Crane Controller Competency', within NR/L3/OPS/048/TMMIND, requires machine controllers to be registered on the NCCA competency database, and to carry a valid Sentinel OTP/OTM competence card, separate counterpart document and a logbook. The Sentinel card only records the core machine type (e.g. RRV), with the specific machine types, trailers and attachments being recorded on the separate counterpart document.

82 Training must be carried out by organisations licensed by Sentinel using national training modules. Machine controllers are required to undertake a core module assessment and they are issued with a provisional Sentinel card if they pass this. They are then required to be mentored as they gain workplace experience for a period up to four months, following which a further assessment is carried out. If the machine controller passes this, he will be issued with a full Sentinel card.

83 The core competence standard applicable to RRVs consists of four elements. The second element covers controlling the movement of RRVs including travel to the access point, on- and off-tracking, and travel movements along the railway. Included in this element is the requirement that trainees understand how to avoid the machine being placed in an unbraked condition.

84 Competence in machine variations within the machine type is not covered by the Sentinel scheme and must be dealt with separately by the machine controller's employer.

Design issues

The interface between the road wheels and the rail wheels of high ride RRVs and between the road wheels and the rails of low ride RRVs

85 Type B high ride RRVs (Figure 2 and Appendix D) depend on friction between the rubber road wheels and either the steel rail wheels or the spigots fitted to the axle ends (paragraph 38), and on the friction between the steel rail wheels and the steel rails to achieve traction and braking. Low ride RRVs (Figure 3) depend on the friction between the rubber road wheels and the steel rails.

86 The level of friction available varies dependent upon whether the environmental conditions are dry, wet and/or contaminated. Where the required braking force overcomes the level of friction available, braking distances can be extended considerably. This occurred in the runaway of an RRV at Glen Garry, between Blair Atholl and Dalwhinnie, on 5 December 2007, where the RRV and coupled trailer had insufficient adhesion at its braked wheels to stop on the gradient, most likely due to rail contamination from vegetation clearance work combined with rain water (RAIB report 05/2009).

87 In order to increase friction and overcome slippage at the rail head, there have been cases of operators of low ride RRVs transferring more of the load onto the road wheels, and of operators of high ride RRVs transferring to road traction while in rail mode. This increases the risk of derailment, however, because the load on the rail wheels is reduced.

88 *Coefficient of friction* (μ) values for 'steel on steel' vary in the available literature with one source[2] quoting values of 0.1 to 0.3 for dry conditions and 0.02 to 0.08 with oil lubrication. The RAIB's report on its Autumn Adhesion Investigation, Part 3: Review of adhesion-related incidents, Autumn 2005 (RAIB report 25/2007 (Part 3)) refers to typical μ values for between steel wheel and steel rail of at least 0.2 in dry conditions, falling to 0.10 in wet conditions. Severe contamination of the rail head can cause the value of μ to drop to below 0.03.

89 Comparable μ values for 'rubber on steel' also vary with one source[3] quoting 0.6 to 0.9 in dry conditions. The RAIB was unable to find up-to-date μ values in the available literature for wet conditions; an Institution of Automobile Engineers paper from 1925 quoted μ values obtained from the Dunlop Motor Company of 0.12 for 'rubber on steel' in wet conditions (the same paper quoted 0.52 for rubber on steel in dry conditions).

90 The μ values from paragraphs 88 and 89 are in Table 3 and can be taken as being reasonably indicative of the differences.

Condition	'Steel-on-steel' μ values	'Rubber on steel' μ values
Dry	0.1 to 0.3	0.6 to 0.9
Wet	0.1	0.12

Table 3: indicative coefficient of friction values

91 Table 3 shows that the coefficient of friction between 'rubber and steel' is significantly higher than for 'steel on steel' in dry conditions. This can result in the locking up of the rubber/steel interface on high ride RRVs because the coefficient of friction between the rail wheels and the road wheels is greater than the coefficient of friction between the rail wheels and rail head. Wheel slide then occurs along the rail head, causing the vehicle to be out of control.

92 Table 3 also shows that in wet conditions, with water lubrication of the surfaces, the levels of friction between both 'steel on steel' and 'rubber on steel' are reduced to similar levels, with a greater proportionate reduction in the case of 'rubber on steel'. Contamination of the rail head reduces friction levels still further.

---

[2] A Collection of Technical Formulae by K and R Gieck, 9th Edition, ISBN 9783920379227

[3] An Engineering Data Book by A J Munday and R A Farrar, ISBN 0333258290 (now out of print)

93 In the derailment of a low ride RRV at Terryhoogan, near Scarva, Northern Ireland on 9 March 2008 (RAIB report 03/2009), the RRV did not have enough traction through its road wheels to drive itself and two wagons coupled to it that were overloaded by a factor of 1.87 (one in front and one behind). It was raining heavily, reducing the friction available, and to overcome this, the operator transferred more of the RRV's weight from its rail to its road wheels.

94 RIS-1530-PLT only specifies braking requirements (braking to a stop) in dry conditions on level track for speeds up to and including 35 mph (56 km/h). The standard has no requirements relating to braking performance in wet and/or contaminated conditions. Designers of high ride RRVs specify the amount of tyre compression that will deliver sufficient load to achieve adequate traction and meet the braking requirements of RIS-1530-PLT in dry conditions. For low ride RRVs the determining factor for braking is the load on the road wheels and the need to ensure sufficient load remains on the rail wheels to prevent derailment occurring. This load sharing between road and rail wheels is specified in RIS-1530-PLT.

95 Following the accident at Glen Garry (paragraph 86), the RAIB conducted braking tests at different speeds on the RRV on a similar gradient to the accident site and while coupled to a trailer that wasn't fitted with service brakes carrying a similar load. The tests were carried out on a range of different rail head conditions, including wet and contaminated conditions in which it was found that the adhesion available was insufficient to brake the RRV and trailer.

96 The RAIB attended the collision between a moving RRV and a stationary RRV at Drumfrochar, near Greenock, on 23 May 2008. Both RRVs were of the low ride type and given the wet conditions and gradient, it is likely that adhesion between the road wheels and the rails was a factor that extended the braking distance.

97 The RAIB also attended the near miss in the Severn Tunnel on 26 April 2009. It is believed that wet/contaminated rails caused low adhesion conditions that affected the RRV's ability to stop. This incident is described more fully in paragraphs 148 to 152.

98 The braking ability of low ride and high ride RRVs is affected by tyre pressure and tyre type, and in the case of high ride RRVs by the amount of compression between road and rail wheels (or spigots). The RAIB was unable to find evidence of any work carried out to quantify the tyre pressures, compression and rubber composition to give the optimum traction and braking forces.

99 The overriding design criterion relating to the rubber/steel interface is that contained in standard RIS-1530-PLT covering the braking performance in dry conditions on level track; there are no equivalent requirements relating to wet track. When wet track is also contaminated, the braking performance cannot be predicted with certainty due to the variable friction levels which pertain.

100 Self-powered RRVs (Type 9A, Table 1) eliminate the problems associated with the rubber/steel interface on high ride and low ride RRVs and give a performance that is more in line with conventional railway vehicles, but they can still have extended braking distances in poor rail head conditions.

Emergency stop buttons

101 European Standard EN 280 'Mobile elevating work platforms – design calculations – stability criteria – construction-safety – examinations and tests' requires that emergency stop controls are fitted to MEWPs at each control position. Their function when operated is to disable the hydraulic system and prevent further movement of vehicle systems such as the work platform and to brake a moving machine to a stand through its normal braking system.

102 The requirements of EN 280 are met in the UK by the fitment of emergency stop buttons, which are normally red mushroom-headed switches that may be labelled 'emergency stop'. RIS-1530-PLT also includes the fitment of emergency stop buttons to 'MEWPs and on the outside of certain other vehicles' (paragraph 63, 5th bullet point).

103 Emergency stop buttons will not stop a runaway Type 9B high ride RRV when operated if the road wheels are not in contact with the rail wheels. Operating the emergency stop button stops the engine causing loss of hydraulic power and prevents the operator bringing the rail wheels into contact with the road wheels to re-establish braking. This was a factor in the runaway of a MEWP at Brentwood on 4 November 2007 (RAIB report 11/2009), although in that incident, the operator would have been unable to engage the rail wheels because *locking pins* were incorrectly located, preventing full movement of the rail gear. The RAIB recommended enhancement of the training given to machine controllers in respect of the actions to be taken in the event of a runaway (Appendix H).

104 The movement of those MEWPs that have been modified to prevent a freewheel condition occurring during the on- or off-tracking process (paragraph 67) should now be stopped if an emergency stop button is operated because there should always be road wheels either in contact with the ground or the rail.

London Underground processes

105 RRVs have been used on the London Underground (LUL) network, where it is not in tunnel, since the 1990s for the same sort of track renewal work as on the main line network. Low ride machines cannot be used because of the conductor rail; the main type used are therefore either high ride, or where tracked RRVs are required, self-powered.

106 LUL takes plant that has been used elsewhere and lays down additional requirements relevant to LUL. Records of certified plant are kept on a database with both the LUL infrastructure organisations having their own databases. At the time of this report, 77 RRVs were certified to operate on the LUL network.

107 The approval of RRVs for use on LUL is independent of Network Rail's approval arrangements (although the existence of a Network Rail approval will be taken into account) and is carried out 'in house', rather than by use of a vehicle acceptance body. There are two aspects to it, a plant approval and a route approval.

108 A technical engineering requirements document specifies the approval requirements and an operational safety plan and instructions document specifies how the plant should be used. The process requires dialogue with the supplier concerning LUL's requirements on gauge, brakes, the fitment of emergency stop buttons etc. The maximum speed for operation on LUL is 5 mph (8 km/h) and RRVs also have to meet standards for electro-magnetic compatibility and braking capability. The latter is verified through brake tests, although there are no standard stopping distance requirements applicable to RRVs. When all of LUL's requirements are satisfied, a 'Certificate of Technical Conformance for Rolling Stock' is issued.

109 LUL has a special requirement going beyond EN280 for the fitment of emergency stop buttons to wheeled excavators because they work in close proximity to personnel in more confined areas than is often the case on the main line network. Operation of an emergency stop button applies the brakes to the road wheels and will therefore stop the machine on rail providing, in the case of high ride RRVs, there is contact between the road and the rail wheels.

110 LUL requires a *train master* to precede any RRV travel move on foot and this ensures that an RRV can proceed at no more than walking pace. Travel lengths can be of up to two kilometres in length. Train masters are not required to have specific training about RRVs although Balfour Beatty Projects (BBP), working on track renewals, has trained the train masters that they use to make them competent to deal with RRVs and to fulfil more of the competent machine controller role used on Network Rail. BBP also makes use of qualified Network Rail machine controllers to supervise the on- and off-tracking operation.

111 On LUL, RRV operators are deemed to be competent if they have met the normal industry requirements of holding a CPCS card and a separate card to demonstrate competence in the on-track elements. Operators are also required to have LUL track accustomed competence.

112 There is no requirement to brief out the gradient details to those at a site before work using RRVs starts. All trailers used have service brakes and parking brakes and must be able to hold on a 1 in 29 gradient with a 10% overload and a 50% braking efficiency.

113 LUL reported it has had only one collision on record that occurred about two years ago: it led to very minor consequences. The incident was not reported to or investigated by the RAIB.

114 LUL is a member of the M&EE Networking Group and aims to keep up to date with changes affecting Network Rail through this means. The process that LUL has in place to review new and altered standards should also identify changes to standards applicable to Network Rail and which may be relevant to LUL.

Practice elsewhere in the European Community.

115 The RAIB sent questionnaires to a range of contacts in other European Community countries to find out how and to what extent RRVs are used in those countries. The results showed that RRVs are used extensively in other European Community countries.

116 In Sweden, about 400 to 500 RRVs converted from road machines are in use, which are mostly high ride and low ride excavators. About 100 of the RRVs are access platforms for overhead line work and these are self-powered. Under Swedish regulations, 'fail-safe' brakes must be fitted to all the rail wheels and they must be able to stop a machine on a 1 in 25 gradient.

117 Holland uses mainly high ride RRVs built by OEMs as low ride, but converted to high ride for use in Holland because low ride machines are not permitted. There are about 100 of these RRVs and they have the traction and braking through the road wheels and are not required to have brakes fitted to the rail wheels. There have been several incidents of runaway trailers that were not fitted with brakes, which occurred during coupling or uncoupling. Trailer brakes are not currently required, but will be under a new national standard.

118 Around 1600 RRVs are in use in Germany. Most of them are low ride machines that have been manufactured from base road vehicles by OEMs. There are a few high ride RRVs which have brakes fitted to the rail wheels. Trailers are not required to be fitted with brakes.

119 The Czech Republic also uses mainly low ride RRVs with about 135 in use. A small number of self-powered RRVs are also in use. Operation of low ride RRVs on wet rails was an acknowledged problem.

Overview of risk

120 The RSSB developed its Safety Risk Model[4] to represent the causes and consequences of potential accidents arising from the operation of the network operated by Network Rail. It aims to provide risk information and risk profiles relating to the main line railway and an understanding of the contribution of a particular item of equipment or failure mode to the overall risk.

121 The current Safety Risk Model is based on 120 hazardous events that could lead to injury or death during the operation and maintenance of the main line network. The model uses historical accident data, or where little accident data exists, in the case of low frequency potentially high consequence accidents, predictive techniques such as *Fault Tree Analysis* and *Event Tree Analysis* are used. The outputs of the model are based on number of *fatalities and weighted injuries per year* (FWI/yr).

122 At the time of this report the latest version of the Safety Risk Model was version 6.0, dated June 2009. The previous version 5.5, dated May 2008, specifically included OTP operations but this category was widened in version 6.0 to cover the total risk inside possessions and therefore includes engineers trains and OTMs. The figures from version 5.5 have therefore been used to illustrate the contribution of OTP (RRVs, RMMMs, trailers and attachments with rail guidance wheels) to the overall risk on the main line railway as used by the model.

123 Version 5.5 identified a total risk of 146.3 FWI/yr across the network from all types of accident of which 0.565 FWI/yr was attributable to OTP inside possessions (excluding trespass). This figure was based on an estimated 76.21 events per year related to hazardous events involving OTP and included *non-movement accidents* (the total estimated for *train accidents* and *movement accidents* alone was 68.09 events per year).

[4] Available at http://www.rssb.co.uk/safety/spr/srmodel.asp

124 Accidents involving OTP were therefore estimated to have contributed 0.4% of the overall risk.

125 The top ten OTP-related hazardous events accounted for about 77% of the total OTP-related risk. About 52% of the total OTP-related risk arose from the top five hazardous events, three of which were train accidents and the other two movement accidents. These were as follows:

- 0.081 FWI/yr - OTP derailment on passenger lines inside possessions (train accident);
- 0.077 FWI/yr - adult trespasser struck/crushed by OTP inside possession (movement accident);
- 0.046 FWI/yr - OTP collision with non-passenger train inside possession (train accident);
- 0.046 FWI/yr - OTP collision with passenger train resulting from OTP incorrectly outside possession (train accident); and
- 0.042 FWI/yr - OTP track worker fall from OTP running inside possession (movement accident).

126 While the train accidents listed in paragraph 125 have the potential to lead to catastrophic consequences, the probability of this occurring is low because most OTP accidents occur at low speed, do not obstruct adjacent lines and result in only minor consequences.

127 The assessment of OTP-risk in the Safety Risk Model depended on the accurate reporting of OTP-related accidents in the *Safety Management Information System* (SMIS). The correct assessment of OTP-risk relied on the use of sound data relating to the occurrence of accidents and incidents. Any significant under-reporting of such accidents or incidents (covered in paragraphs 138 to 143) will have resulted in an under-estimate of OTP-related risk on the network in the Safety Risk Model.

Previous events

128 Details of previous occurrences of runaways and collisions occurring on the main line network were obtained from SMIS, from which records were available as far back as 2001. In some cases, internal railway investigation reports for these events were also obtained, along with information from the RAIB's own investigations and deployments (paragraph 19). These events are listed in Appendix E.

129 The causes of the events in Appendix E are analysed in the analysis section of this report (paragraphs 182 to 199). The sections that follow before then, in paragraphs 130 to 181, provide background information to the occurrence of some of their underlying factors.

Inappropriate practices – all operators

130 The investigation found evidence of inappropriate operator practices involving RRVs.

131 The RAIB obtained evidence from an RRV operator involved in an accident at Rugby on 12 July 2008. The operator was driving a high ride RRV and stated that while using the machine to drag a length of rail he was obtaining insufficient traction between the rubber tyred wheels and the steel rail wheels in the prevailing wet conditions. To overcome this, he lowered the rubber road wheels onto the rail head effectively changing the machine to low ride mode in an attempt to improve traction. Given that this action would have reduced the loads on the rail wheels, the risk of a derailment occurring would have been increased. There would also have been a risk of putting the machine into an unbraked condition leading to a runaway.

132 The operator concerned carried out the above practice without any instruction and gave evidence that he used his own experience as an operator. This suggests that the practice was probably not a 'one off' and was likely to be undertaken by other operators.

133 A variation of the practice in paragraph 131 applies to low ride RRVs which incorporate a system to ensure correct load sharing between the road wheels and the rail wheels to minimise the risk of a derailment occurring. The RAIB investigation of the accident at Terryhoogan found that the operator used the cab controls to overcome the load sharing system and transferred more of the RRVs weight from its rail wheels to its road wheels to increase traction. This was one of the causal factors of the RRV derailing.

134 There have been instances of trailers being overloaded. This was a contributory factor to the accident at Terryhoogan and led to the operator shifting more of the RRVs weight onto its road wheels. Elsewhere, evidence was obtained of an RRV runaway at Kenilworth caused by overloaded trailers which was only stopped by the operator putting the boom onto the ground. This followed a rain shower which reduced the friction between the road and rail wheels. Excess loads of ballast had been loaded onto the trailers to complete the work more quickly. The incident was not reported further within the industry.

135 Evidence was also obtained that in some cases, the machine controller's checklist in COP0016 (paragraph 56) is not completed correctly, or at all. The checks required by the checklist may also not always be done – there was evidence that this was the case for the RRV involved in the incident in the Severn Tunnel on 26 April 2009 (described in paragraphs 148 to 152).

136 On- and off-tracking takes place at locations other than RRAPs, or without a proprietary on/off-tracking system being available (and therefore not in accordance with NR/L2/RVE/0007 (paragraph 54)). This can lead to damage to the infrastructure and/or the RRV, and the risk of overturning the RRV if its centre of gravity moves outside the machine's base. The issue of NR/L2/RVE/0007 and subsequent briefings aimed to reduce this problem.

137 The improved competence management system being introduced for operators on Network Rail (paragraphs 73 to 78) is aimed at reducing the number of inappropriate practices carried out. Effective site control is also important to eliminate inappropriate practices involving RRVs.

Under-reporting of accidents/incidents – Network Rail

138 Where an incident occurs, which does not give rise to actual damage or injury, it is not always reported further. This is particularly likely to be the case if the engineering supervisor, or site manager, has not witnessed or been made aware of the occurrence (paragraph 134). Derailments of RRVs are an example where this could arise, given that, if they have not been damaged, they can re-rail themselves again afterwards.

139 Following a request from the industry's Track Safety Strategy Group, the RSSB carried out a workforce survey on the safety of operation of RRVs and published a report on the results in September 2005[5]. One of the aims of the survey was to find out the rate at which accidents and incidents occur and what accidents/ incidents are reported and what goes unreported. Questionnaires were sent to frontline staff (both operational and management) through the Rail Plant Association and the National Union of Rail, Maritime and Transport Workers.

140 There were 85 respondents to the questionnaires and 40% of them agreed with the statement that incidents are always reported and followed up. A similar percentage also believed that accidents/incidents would only be reported if they caused actual injury.

141 Respondents were also asked to estimate how many occurrences of specific types of incidents they were aware of in the past year. This included runaways, for which respondents were aware of 28 instances in the previous year.

142 Personnel working on the railway can report safety concerns to the Confidential Incident Reporting and Analysis Service (CIRAS) if they wish their report to be treated confidentially. For the period 1 January 2005 to 24 July 2009, CIRAS had received six reports concerning RRVs, but only one of these related to matters covered by this report. This concerned occasions where machine controllers had been instructed to drive at a speed deemed to be unsuitable for the weather and lighting conditions, because of time pressures.

143 The RAIB has not been able to find any evidence of work carried out in the industry to follow up the findings of the RSSB workforce survey with the aim of improving accident/incident reporting.

Work planning processes – Network Rail

144 Network Rail company standard NR/L3/INI/CP0044 'Work Package Planning process' covers the planning and management of construction work to be carried out on site sponsored by the infrastructure investment function of Network Rail. This standard details a three stage process for the control of risks at site during the execution of construction work, including the movement of OTP. The process described has the aim of ensuring compliance with the applicable health and safety legislation that applies to construction work. The three stages are:

- the construction phase plan, which includes a description of the project, the names of key personnel, the applicable standards, the work methodology, the schedule for the production of work packages, information for contractors, communications and co-operation, accident and incident reporting, emergency procedures, welfare, and monitoring and audit arrangements;

[5] Workforce survey on the safety of the operation of RRVs and RMMMs, RSSB, September 2005

- the work package plan, which includes risks and mitigation measures, site access, the movements of OTP, emergency procedures, welfare, and briefing arrangements; and
- the task briefing sheet, which includes a description of the work, the control of risks, permits required, site details relevant to the task such as access and OTP movement, communications and contact details, emergency arrangements, and welfare.

145 Network Rail company standard NR/L3/MTC/PL0006 'Planning for the use of on-track plant' applies to planning the use of RRVs, RMMMs, trailers and attachments. The specified process includes the following steps:

- identify the work to be carried out;
- undertake a site visit (to include an examination of the on-/off- tracking point);
- select the appropriate OTP;
- define the scope of work (to include on-/off- tracking points, the method for on-/off- tracking and gradients);
- prepare lifting plan and method statement;
- authorise lifting plan and method statement; and
- requisition OTP and secure resources.

146 COP0002 (paragraph 53) also covers the planning of work involving the use of RRVs. This lists the following minimum stages of planning to be carried out when RRVs are to be involved in the work:

- identify the work required (the nature and scope of the work);
- identify risks through a site survey as appropriate (such as on- and off-tracking; track layout, line speeds, direction of travel, track access constraints etc);
- develop the method of work, the appropriate plant to be used; and verification of lift plans, where appropriate;
- establish personnel requirements and competencies (machine operators, machine controllers etc);
- determine possession requirements (paragraphs 153 to 159);
- identify required contingencies; and
- document the plan for inclusion in the site specific method statement (i.e. the work package plan).

147 The risks arising from the use of RRVs and their trailers should therefore be identified in advance of the work and appropriate measures put in place to mitigate them.

Example of where lack of planning was a factor – incident in the Severn Tunnel, 26 April 2009

148 The RAIB attended the site of an incident that occurred inside the Severn Tunnel on 26 April 2009 (paragraph 19). A wheeled excavator RRV propelling a trailer with a people transporter cage on it, and towing a trailer, was unable to stop when the brakes were applied. The machine controller and other workers were in the transporter cage and staff working on the line had to jump clear of the RRV as it approached.

149 The RRV was moving down a gradient of 1 in 100 in a work site 2.5 miles (4 km) long. Shortly before the RRV's movement, the rails had been examined by a team of inspectors who had applied water to the rails in the course of their work. It is believed that the water left on the rail head, plus the addition of contaminants from the tunnel environment caused conditions of low adhesion. The operator of the RRV was unaware of these conditions and the effect they would have on the braking capability of the RRV.

150 The planning process for the operation of the RRV had not taken into account that the rail head conditions would be degraded by the activities of the rail inspectors. Furthermore, the influence of the gradient had also not been assessed and those directly involved with the RRV's operation had not been briefed on its presence.

151 The length of the work site was also likely to have been a factor in the incident. There was evidence that the RRV had been travelling at greater than the walking pace required while travelling through the work site.

152 There was evidence that the pre-use checks required by COP0016 had also not been completed (paragraph 56).

Possession planning processes

153 Network Rail's National Delivery Service (NDS) plans possessions, with blockages of the line for engineering work having to be agreed with the train operators and in accordance with the '*rules of the route'.* The planning process may take two to three years for major items of work, but the normal duration is nine months for routine maintenance and renewals work.

154 Work requiring a possession is submitted to NDS through the computer based Possession Planning System. The application will include details of the location of the work, the lines affected, the type of work, the duration of the work and the desired possession limits.

155 NDS's possession planners must then decide how to package the various work items in order to obtain as much benefit as possible from the possession. The human resource requirements for the possession must be considered and the length of the possession must be minimised (paragraph 48).

156 A major factor in the length of possessions is the availability of access points by which *handsignallers* can access the lineside to place/remove the *possession limit boards* and *detonators*. The availability of access points also influences the length of work sites, because in many cases, an access point is required within a work site in order to enable plant and equipment to reach site. This is a particular issue for RRAPs. The access point may be some distance from where the work is taking place.

157 There are a number of stages during the Network Rail possession planning process, which were specified in Network Rail standard NR/L2/MTC/PL0056 'Work and possession planning for the railway infrastructure (meetings management pack)'. These are shown in Table 4.

Milestone stage	Actions required
T-26 weeks	Confirmation of the extent of the possession with train operators
T-14 weeks	Review arrangements and change as necessary
T-6 weeks	Review arrangements and change as necessary
T-3 weeks	Review arrangements and change as necessary
T-10 days	Arrangements at this stage are published in the *Weekly Operating Notice*
T-48 hours	The PICOP will run through the possession arrangements with the relevant engineering supervisors and confirm the final details

Table 4: Milestones in the possession planning process (the descriptor 'T-' refers to the time to possession)

158 Work can be planned for the possession until six weeks out, by which time the plan should nearly be in its final form. After this, any work needing to be done to a shorter timescale (up to 10 days out) requires a business case if it involves trains, RRVs, or will affect other work. Work required to be done to shorter timescales than 10 days can be accommodated in the plan if it is of an urgent nature such as the rectification of rail defects arising from a recent inspection. Such work must be published in a supplement to the Weekly Operating Notice.

159 Possessions should be planned to minimise the distance that engineering trains and OTMs are required to run without the normal signalling system, which is suspended within the possession limits. This is not always achieved, because all the work planned to be undertaken 26 weeks earlier, when the possession length is fixed, may not be realised in practice. Possession lengths are not generally reduced subsequently to reflect this, because this is thought to introduce risk if all involved are not properly advised. There may also be requests for work to be carried out at a late stage in the area of the possession that would otherwise be reduced and therefore there is a reluctance by Network Rail to reduce possession lengths once set.

The introduction of work site marker boards

160 The current possession arrangements can be traced back to a supplement to the 1950 Rule Book that was issued in 1970. This introduced the concept of a person to be in charge of the possession (PICOP) and where more than one job was to be carried out within the possession, the need to appoint an engineering supervisor in charge of each job. The PICOP could take on the engineering supervisor's role if appropriate. At this stage, there was no mention of the term 'work site' in the rules.

161 By 1980, concerns had arisen about the propelling of trains in and out of possessions, leading to a consideration of the use of marker boards to denote work locations. This was initially dismissed, but re-examined in April 1982 with a decision to develop marker boards. Around this time, there was a fatal collision of two engineering trains at Roade Junction on the West Coast Main Line. This strengthened the view within the industry that it was necessary to amplify the Rule Book in the areas of ensuring adequate communications; minimising possession lengths as far as practicable, and reconsidering the safe movement of trains in possessions.

162 In 1983, a working party sponsored by British Rail's Director of Civil Engineering proposed that marker boards would be a step forward and that the use of radios in the bigger possessions would be advantageous. Where two work sites were no more than 0.25 mile apart, it was proposed that there would only be one set of marker boards around both.

163 By 1984, the proposals were becoming firm with marker boards being seen as the demarcation between the PICOP's and the engineering supervisor's areas of control. No marker boards would be required where there were no trains involved or only one work site with the only movements by on-track machines. The distance between work sites for each to have separate marker boards was reduced to a minimum 100 yards apart. Implementation was by a Rule Book change in February 1985.

Proposed changes to the current possession arrangements

164 At the time of this report, Network Rail was reviewing the current system of possession arrangements and was proposing to make changes to them. As a first stage, Network Rail was proposing to abolish the use of possession limit boards and detonators, but to retain the use of work site marker boards to delineate work sites. The arrangements were also to be enhanced to provide greater protection against train movements and make it easier for possession planners to plan shorter possession lengths as the requirement to provide access to the track to place the possession limit boards and detonators will be removed (paragraph 156). A staged roll out of the new rules is proposed with full implementation planned for 31 March 2010.

165 The proposed second stage was a more fundamental change to the possession arrangements by introducing a 'Track Occupancy Permit' system as used in North America. This system is based on the issue of a permit-to-work following a conversation between the signaller and the person-in-charge and is designed to permit much shorter blockages to be taken than is the case under the current arrangements. Network Rail anticipated an implementation timescale of some time after June 2010 (when it was expected the new rules would have been agreed).

Previous accidents where the length of possessions and work sites was a factor

166 The length of possessions and work sites was a factor in the following events (going wider than those solely affecting OTP, or involving runaways):

- the collision between OTP at Ancaster on 5 March 2004;
- the collision between OTMs at Badminton on 31 October 2006 (RAIB report 30/2007);
- the runaway of an RRV and trailer at Glen Garry on 5 December 2007 (RAIB report 05/2009);
- the collision between two trains at Leigh-on-Sea on 26 April 2008 (RAIB report 24/2009);
- the collision between RRVs at Drumfrochar on 23 May 2008; and
- the runaway of an RRV and trailer combination in the Severn Tunnel on 26 April 2009.

167 The collision at Ancaster occurred between an RRV excavator and an RMMM on a 1 in 100 rising gradient and led to fatal injuries to one of the trackworkers. The accident was investigated by the RSSB.

168 The Rule Book instructions at the time included (in module T11) that all movements within the work site be authorised by the engineering supervisor, but did not set any maximum speed; only that movements must be made at caution; nor did it set the separation distance between vehicles. The term ‘at caution’ was not defined further.

169 One of the recommendations made was that the RSSB should review the rules applicable to the operation of more than one item of OTP within a work site, in a possession. The review should include consideration of the speed of movements, and a robust system for maintaining a separation distance between individual machines within the work site. Since then, the Rule Book has been enhanced to emphasise that movements in a work site must be made at extreme caution, and at no greater than walking pace (unless authorised by the engineering supervisor).

170 The collision at Badminton occurred when a tamper collided with a stationary ballast regulator in a work site. Both these OTMs had travelled from a siding at Chipping Sodbury, west of Badminton, and along the up main line. The immediate cause was the driver of the tamper did not control his speed or react to the presence of the stationary regulator on the line ahead, so as to be able to stop short of it. A contributory factor was driving at more than the permitted (at the time) maximum 20 mph (32 km/h) limit applicable in a work site where there were people working under the protection of a lookout (the limit otherwise was extreme caution, i.e. not greater than walking pace).

171 The extreme length of the work site (17.56 miles (28.25 km)) resulted in an arrangement which permitted the two machines to travel long distances on the same section of line simultaneously. The RAIB’s report recommended that the RSSB propose a rule change to require work sites to be kept as short as possible. This has since been implemented.

172 The Rule Book was also amended following the Badminton collision to bring the speed limits applying to engineering trains and OTMs when in work sites in possessions into line with those applying to OTP (i.e. movements to be at extreme caution under all circumstances, unless the engineering supervisor gives specific instructions for a higher speed to be applied).

173 The runaway of an RRV at Glen Garry occurred in a possession between Blair Atholl and Dalwhinnie where several areas of work were taking place. However, the whole possession was a single work site in which RRV movements should have been at no more than walking pace unless the engineering supervisor authorised otherwise. The engineering supervisor gave no such authority, and the RRV speed was estimated to be between 9 and 11 mph (14 and 18 km/h) while travelling from the RRAP to the working area, a distance of 2.7 miles (4.35 km). The speed of the RRV, arising from the length of the work site, was one of the contributory factors of the accident. The RAIB's report recommended that operator training should be enhanced to improve operators' understanding of the speed limit within work sites.

174 While not involving RRVs, the collision between a moving train and a stationary train at Leigh-on-Sea occurred in a work site 4.11 miles (6.6 km) from the marker boards at the start of the work site. Despite the fact that the Rule Book required the movement to be made at no more than walking pace, the speed of the moving train was as high as 25 mph (40 km/h) and the driver had not recognised that he was within a work site. The immediate cause of the accident was that the driver of the train did not control his speed or react to the presence of the stationary train on the line ahead, so as to be able to stop short of it. The RAIB has made recommendations that include:

- there should be a challenge stage within the possession planning process to ensure that possession and work site lengths are minimised; and
- possession and work site lengths are considered within the risk assessment process and contained in the hazard list within the pack provided to PICOPs.

175 The collision between two RRVs at Drumfrochar occurred in a possession of the line from Wemyss Bay Junction to Wemyss Bay and the whole possession was designated as a work site. The travel distance for the RRVs was about 6.2 miles (10 km) to where work was taking place from the RRAP and both travelled back separated by a distance of 100 to 200 metres. As at Glen Garry, the movements should have been at walking pace (unless the engineering supervisor authorised otherwise, which was not the case) but speeds reached 15 mph (24 km/h) in practice.

176 The significance of the work site length to the incident in the Severn Tunnel on 26 April 2009 was described in paragraph 151.

The on- and off-tracking process – Type 9B high ride RRVs

177 Carrying out the on- and off-tracking of high ride RRVs correctly is fundamental to avoiding a freewheel condition occurring in which none of the braked road wheels are in contact with rail wheels that are themselves unbraked. Network Rail's standards do not prescribe how this should be done, but there is an 'industry' method for carrying out on- and off-tracking safely.

178 The industry method for on-tracking is as follows:

- drive the fixed end (as opposed to the steering end) onto the railway, line up the rail wheels with the rails and lower them until the road wheels are clear of the ground (but not fully engaged with the rail wheels at this time) (Figure 7a);
- position the RRV so that the rail wheels at the steering end of the machine are lined up with the railway (but not deployed) (Figure 7b);
- fully lower the fixed end rail wheels so that they are completely engaged with (and therefore braked by) the road wheels (Figure 7c);
- lower steering end rail wheels, straighten up the steering end road wheels, then finish lowering the steering end rail wheels to bring them into full engagement with the road wheels (Figure 7d); and
- apply the steering locks to prevent steering movement of the road wheels and carry out a brake test in both directions on the railway.

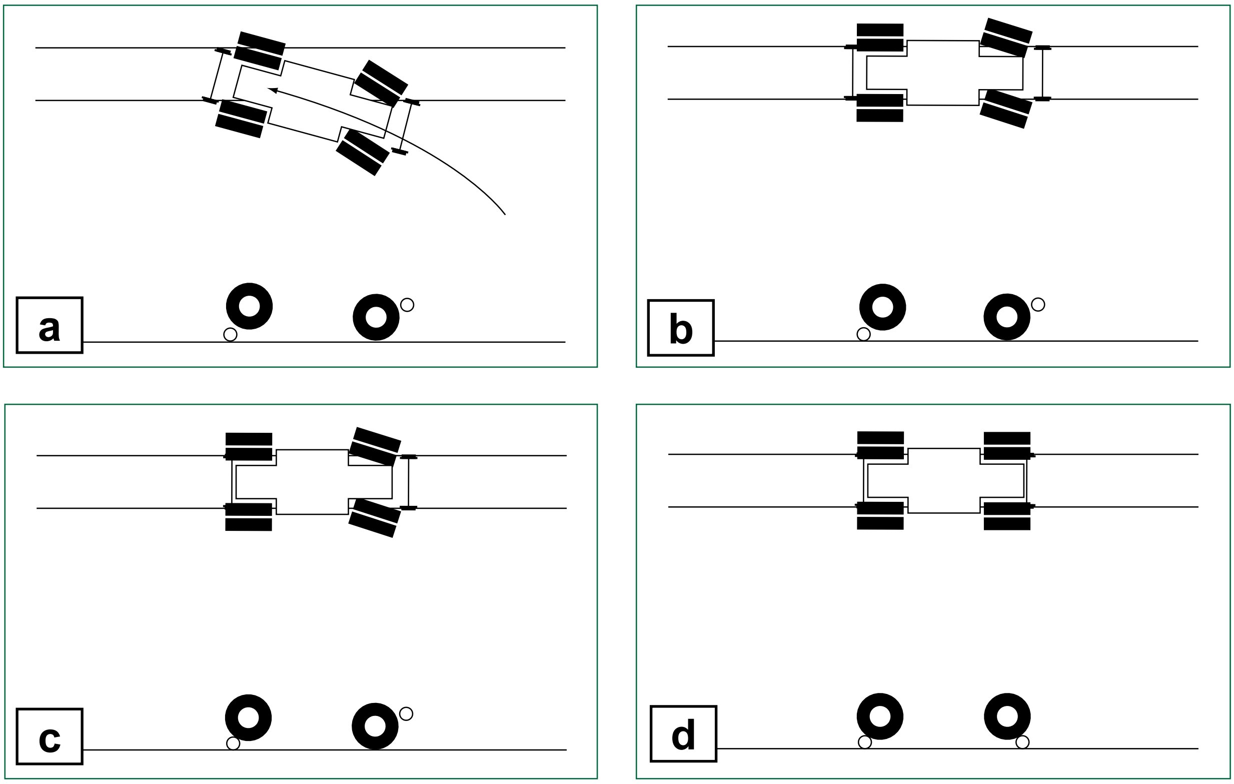

Figure 7: the four stages of on-tracking

179 If the sequence described in paragraph 178 is not followed exactly, the outcome may be a situation where none of the road wheels are in contact with the rail wheels, or with the ground, generating a condition where the machine is unbraked. If this condition occurs on a gradient, a runaway may occur. Examples of this happening are listed in Appendix E.

180 The procedure for off-tracking is the reverse of that described above.

181 The unbraked risk condition that can lead to an RRV running away from rest does not arise when on- or off-tracking type 9A self-powered RRVs fitted with rail wheels which have brakes, or type 9C low ride RRVs where the road wheels are always in contact with the rail or the ground. Type 9B high ride RRVs that have been modified with an engineering means to prevent an unbraked condition (paragraph 67) should also not be at risk of runaway during on- or off-tracking.

Analysis

The system life cycle (on Network Rail's managed infrastructure)

182 In addition to the analysis of previous specific events described above, the RAIB considered to what extent the use of RRVs and trailers on Network Rail conformed to BS ISO/IEC 15288:2002, 'Systems Engineering – System life cycle processes'. This standard describes a common framework for system life cycles from conception through to disposal, and the different stages and their purpose are in Appendix G. The RAIB has taken the RRV system to include the machines/trailers themselves, the people who will operate and maintain them, and the procedures that govern the system.

183 The system covering the use of RRVs and trailers, as currently operated on Network Rail's infrastructure, does not conform to the principles in BS ISO/EC 15288, although Network Rail does have standards that embody a systems engineering approach covering other types of railway vehicle. There was no high level requirements specification relating to the use of RRVs in Network Rail. RRVs have been developed by suppliers in response to market opportunities (paragraphs 31 to 33). Standard RIS-1700-PLT includes safety requirements covering approval, maintenance and operation of plant but there is no requirement issued by Network Rail to carry out formal safety analysis (hazard analysis, risk assessment and human factors study), or for OEMs/converter companies to have a configuration management system[6] in place.

184 The absence of any requirements specification has led to a situation where the use of RRVs has developed in an unplanned and uncoordinated way. Design is left to the suppliers who must only demonstrate conformity with standard RIS-1530-PLT in order to gain acceptance to use a particular type of RRV on Network Rail's infrastructure. RIS-1530-PLT contains a list of detailed technical requirements that OTP must meet if they are to operate on Network Rail's infrastructure, but it does not contain requirements relating to how the design should be carried out. This allows suppliers of RRVs the freedom to develop new types of machines without recourse to the client organisation (Network Rail), to choose between RRVs from OEMs or converter companies, the type of rail gear and braking system to be fitted (within the limitations of Table 2), and the type of tyres. This is currently based on economic cost and the ease of conversion with tyre type and rail gear configuration being varied to achieve conformity with standard RIS-1530-PLT.

185 Railway Group Standards, Network Rail's standards and codes of practice do not require suppliers to carry out any formal safety analysis to ensure that implemented designs are safe to an acceptable integrity level. Such formal safety analysis, which is well established in other areas of the railway industry, such as in the design of railway rolling stock, and in industries outside railways, such as defence, includes *Hazard & Operability studies* (Hazops), *Failure Modes and Effects Analysis* (FMEA) and Fault Tree Analysis (FTA). The RAIB did not find any evidence that such techniques were employed as part of the design process of RRVs.

[6] A configuration management system should keep track of specifications, designs, drawings and manuals, ensure that any changes are properly controlled, and therefore avoid unplanned variations between machines within a build.

186 The railway industry's own guidance on how it should approach engineering safety management is published by the RSSB and entitled 'Engineering Safety Management' (the Yellow Book)[7]. It gives guidance on the application of safety management principles for people who are changing or maintaining the railway and adopts a similar life cycle model to that contained in BS15288:2002. The Yellow Book advocates that during the requirements definition phase, the hazards are identified and risk assessed. The safety requirements should be identified by determining the required mitigations to reduce the risks to an acceptable level.

187 Other system engineering elements relating to RRVs that are not currently provided are:

- a verification plan covering all elements of the system to verify that the design requirements are being fulfilled and that the equipment is fit for purpose;
- validation of equipment operating processes to confirm that when in use, an RRV will meet the requirements and is fit for purpose;
- site inspections and audits configured to the overall system; and
- a change control process relating to operating procedures and modification of equipment.

The causes of previous events of runaways and collisions

188 The 18 reported events since January 2001 in Appendix E involved the types of plant listed in Table 5. The incidents at Glen Garry on 5 December 2007 and Severn Tunnel on 26 April 2009 involved RRV and trailer combinations. These are included in Table 5 in both the 'trailer' and the 'wheeled excavator' rows.

Type of plant	**No. of events**	**RRV type** (paragraph 37)
Self-propelled booms	6	High ride
Trailer	6*	N/A
Wheeled excavator	3*	High ride
Unimog with access platform	2	Low ride
Dump truck with access platform	2	High ride
Tractor	1	High ride

* *two of these events were of wheeled excavator and trailer combinations: at Glen Garry on 5 December 2007 and in the Severn Tunnel on 26 April 2009.*

Table 5: type of plant involved in previous events

[7] Engineering Safety Management (the Yellow Book), RSSB, 2007, available at www.yellowbook-rail.org.uk

189 Six of the eighteen events in Appendix E were plant becoming out-of-control while braking where wet rails (in some cases combined with contamination and gradients) was a factor. The remainder ran away from rest. Those where plant became out-of-control when braking were:

- runaway of a wheeled excavator at Pontsmill on 6 December 2006 (wet rails and gradient);
- runaway and collision of a wheeled excavator and trailer at Glen Garry on 5 December 2007 (wet and contaminated rails and gradient);
- runaway and collision of a Unimog RRV at Ingatestone on 12 February 2008 (icy rails);
- runaway and collision of a Unimog RRV at Drumfrochar on 23 May 2008 (wet rails and gradient);
- runaway and collision of a MEWP RRV at Milton Keynes on 29 November 2008 (wet/icy rails); and
- runaway of a wheeled excavator propelling one trailer and towing another in the Severn Tunnel on 26 April 2009 (wet rails and gradient).

190 The three runaways and minor collisions at Ingatestone, Drumfrochar and Milton Keynes all occurred during inclement weather conditions where rail head condition in combination with the separation distance of the RRVs was a factor in each case. In none of these cases was there evidence of pre-planning or pre-assessment of the possible consequences of wet weather.

191 The two instances of trailer runaways at Patchway and at Howe & Cos Sidings gave rise to modifications to the trailer parking brake system to ensure its application when the hydraulic hose connection to an RRV is uncoupled. Since the accident at Tebay (caused by a criminal act) there have been no further reported instances of trailers running away on their own; the runaway incidents at Glen Garry and in the Severn Tunnel occurred where trailers were operating coupled to RRVs. The fitment of service brakes to new trailers (paragraph 63, 3rd bullet point) should reduce the level of incidents involving RRVs coupled to trailers. Eventually, as trailers without service brakes are scrapped, all trailers permitted to operate will have both parking brakes and service brakes.

192 The biggest proportion of runaways has arisen from the on- or off-tracking process. Of the seven such events, six involved self-propelled booms and the remaining incident involved a dump truck with access platform. Few events have been reported involving wheeled excavator RRVs – the only two on record being those that occurred at Pontsmill and Glen Garry. If a runaway involving a wheeled excavator RRV does occur, the operator has an option of lowering the boom so that the bucket (or other attachment) digs into the ground. This was the means by which the runaway at Pontsmill was stopped (and also the runaway, that is not on official record, which occurred at Kenilworth – paragraph 134) .

193 The main causes of RRV runaways thus appear to arise from:

- the on- or off-tracking process being carried out in such a manner as to lead to a completely unbraked condition occurring; and
- an uncontrolled situation occurring during braking where, for high ride RRVs the friction between the rubber tyres and steel wheels and/or steel wheels and steel rails is insufficient, and for low ride RRVs, the friction between the rubber tyres and the steel rails is insufficient, in both cases leading to a loss of adhesion.

194 Following the MEWP collision at Holbeck Junction on 9 November 2003 in which the operator raised the rail wheels at both ends at the same time, putting the machine into an unbraked condition, modifications were made to high ride RRVs to ensure only one set of rail gear at a time could be operated. This still did not eliminate the possibility of an unbraked condition arising during the on- or off-tracking process of high ride RRVs; this is now being achieved by the fitment of an engineering means (paragraph 67) to ensure that at least one set of road wheels is always in contact with either the ground or the rail head. Until this work is completed (planned for the end of 2013 – paragraph 68), the prevention of runaways during on- or off-tracking depends on the operator rigorously carrying out the correct procedure (paragraphs 171 to 181).

195 Work is not being carried out to eliminate the causes of low adhesion leading to runaways. RIS-1530-PLT only specifies braking requirements in dry conditions and on level track (paragraph 63, 2nd bullet point); there are no requirements relating to braking performance on wet rails, where braking distances will be increased. Where the rail head is also contaminated, as well as being wet, the braking performance of RRVs is unpredictable, particularly in combination with significant gradients. This was the case in the incidents at Glen Garry on 5 December 2007 and in the Severn Tunnel on 26 April 2009.

196 RIS-1530-PLT states that RRVs can haul 100% of their own weight without limitation, other than meeting the stopping distance requirements on dry rails (paragraph 63, 9th bullet point). This standard does not warn that towing such loads on gradients may lead to runaways when water (and possible contamination) lubricates the rubber tyre/rail interface reducing the level of friction.

197 The planning process should adequately assess the risk arising from wet rails, contaminated rails and gradients and ensure that appropriate mitigations are implemented (paragraphs 144 to 147).

198 Work site length has been a factor in several events (paragraphs 166 to 176). In the case of OTP, the Rule Book says that movements in a work site must be made at extreme caution and at no greater than walking pace unless given specific instructions by the machine controller (paragraph 47, 7th bullet point). The evidence from previous events suggests that the requirement to move at no more than walking pace, unless authorised by the engineering supervisor, is not always observed and is probably unrealistic where work sites are long. No evidence was found of cases where the machine controller (following authority given by the engineering supervisor) gave the operator specific instructions to travel faster than walking pace, although there was a report to CIRAS (paragraph 142) of occasions where machine controllers had been instructed to drive at speeds that were considered to be unsuitable for the conditions.

199 Analysis of the reports on the events listed in Appendix E identified the underlying factors for each event. The RAIB then considered the measures that are currently in place in the industry and further measures that might reduce the risk. The next section of this report discusses this further. The information in Appendix F summarises this information.

Possible improvements

200 The following paragraphs describe possible improvements to RRVs based on paragraphs 182 to 187 and Appendix F.

201 RRVs have developed in response to perceived market needs. If the client organisation had issued a requirements specification for the work needing to be carried out, the equipment from the supply industry might have evolved differently (paragraph 184). Applying a systems engineering approach to the design, build, operation and maintenance of RRVs and their trailers is good practice and should be adopted by the industry. Network Rail has also identified this in their OTP project carried out during the duration of the RAIB's investigation (paragraphs 225 to 231 refer) (Recommendation 1).

202 Recommendation 1 only applies to new RRVs. Recommendation 2 deals with existing RRVs, which should be reviewed using structured safety analysis techniques to identify hazards, assess the risks, and to consider the mitigations which may be applied to reduce the risks. The factors described below in paragraphs 203 to 221 should be taken into account.

203 The fitment of service brakes to trailers has already been dealt with following the recommendations made in the RAIB's report on the accident at Glen Garry on 5 December 2007 (Appendix H), but consideration should be given to the safety of operation of trailers in the interim before all are fitted with service brakes. Tests carried out with the RRV and trailer involved at Glen Garry showed that with the prevailing gradient and rail head conditions present, the RRV was not able to stop itself and the loaded trailer. A general derating of the load carrying capacity of trailers without service brakes should be considered to reduce the possibility of runaways of coupled RRVs and trailers occurring on gradients where the rail head is wet and contaminated (Recommendation 2(a)).

204 The ORR has dealt with the fitment of engineering controls to all high ride RRVs to prevent them being able to be placed in a completely unbraked situation (paragraph 67). The RAIB does not therefore need to make a further recommendation on this matter.

205 In the period, up to the end of 2013, before all RRVs are fitted with engineering controls to prevent the occurrence of an unbraked situation arising, there remains the possibility of a runaway caused by operator error. The RAIB's report on its investigation of the runaways at Brentwood and Birmingham Snow Hill on 4 November 2007 and 31 October 2007 has already made recommendations about improving machine controller and operator training (Appendix H). A further improvement would be made if a standard step-by-step procedure for on- and off-tracking each type of RRV was written and displayed in the cabs of all RRVs. This would help control the risk of an operator omitting a step or carrying them out in the wrong order (Recommendation 2(b)).

206 Fitting service brakes to the rail wheels of RRVs would remove the impact of the rubber/steel interface on braking and give improved braking performance in wet/contaminated rail head conditions in line with normal railway vehicles. This is particularly significant in cases where travel distances are long and RRVs may be travelling in convoy. The practicalities of fitting service brakes to new RRVs and a retrospective fitment to existing ones should be investigated to see whether this would be reasonably practicable (Recommendation 2(c)).

207 Compliance with standard RIS-1530-PLT does not guarantee that RRVs (and RRVs and trailer combinations) are able to stop safely under all conditions of gradient and environment encountered during their operation. The braking performance of RRVs is currently not specified in wet conditions and performance is further degraded if the condition of the rail head is contaminated.

208 It is known that while the friction between rubber and steel is very good in the dry, it is significantly worse in the wet. Long stopping distances are the result in any but dry conditions; an effect that is increased if the rail head is contaminated or on gradients. Researching the variability of friction in different conditions and with different types of tyres would enable the operating characteristics of RRVs to be specified more accurately in all conditions so that loads and speeds in particular conditions can be specified in advance, rather than being left to the judgement of the operator. This would remove undesirable variability that is currently left for the operator to cope with (Recommendation 2(d)).

209 Training courses for operators could include raising awareness of hazards that can affect machine operation (e.g. rail lubrication equipment), and driving machines on wet and contaminated rails so that (under controlled conditions) they experience the effect on braking. Such training (often referred to as 'skid pan' training) is already in place for train drivers as a means to mitigate the effects of leaf fall onto the railway during autumn (Recommendation 2(e)).

210 In the runaway MEWP RRV incidents at Brentwood (4 November 2007), Copenhagen Tunnel (15 October 2006) and Stockport (5 August 2004 and 17 August 2004), the emergency stop button was depressed in the hope that this would brake the machine. However, this had no effect because the braked road wheels were not in contact with the unbraked rail wheels. The training of operators and machine controllers could be enhanced to cover the operation of the emergency stop button (where fitted) and its effect (Recommendation 2(e)).

211 Once high ride RRVs are modified to prevent a freewheel condition being able to occur during on- or off-tracking, the operation of the emergency stop button, where fitted, should stop the machine. The RAIB does not therefore need to make a further recommendation on this matter.

212 The RAIB's report on the runaway at Brentwood on 4 November 2007 has already made recommendations about the role of machine controllers, particularly their involvement in the on- or off-tracking process and the limits of their competence (Appendix H). The RAIB does not therefore need to make further recommendations on these specific matters

213 It is important that the specified tyre pressures are maintained in order to achieve the correct force between the road wheels and the rail wheels on high ride RRVs. This needs to be in conjunction with the correct adjustment of the rail gear to cater for tyre wear and the use of tyres in good condition. These matters could be explicitly prescribed in the maintenance plan that is approved by the vehicle acceptance body (Recommendation 2(f)).

214 The RAIB's report on the incident at Glen Garry on 5 December 2007 has already made a recommendation to enhance the training of operators to improve their competence when working RRVs on gradients (Appendix H). This could be enhanced further to include machine controllers (included in Recommendation 2(e)).

215 RRVs travelling too fast and/or too closely together resulted in collisions while travelling at Ancaster (5 March 2004), Glen Garry (5 December 2007), Ingatestone (12 February 2008), Drumfrochar (23 May 2008), Milton Keynes (29 November 2008) and in the Severn Tunnel (26 April 2009). Machine controller and operator training could be enhanced concerning the safe maximum speeds in different situations of gradient, rail head condition, travel length and separation distance (included in Recommendation 2(e)).

216 Given that RRVs driving in convoy in a possession or work site are driving on sight in the same way that they would be driven on the road, a useful enhancement could be to fit brake lights (Recommendation 2(g)).

217 The length of possessions and work sites is a factor in how far RRVs have to travel to reach where they are required to work. This is influenced by the location of RRAPs which must be in a work site. Network Rail is already reviewing the arrangements for possessions and the location of RRAPs and their effect on RRV travel distances should be taken into account (Recommendation 2(h)).

218 Although there is a procedure in place for machine controllers to complete a checklist before using an RRV (paragraph 56), the checks are not always carried out, as was the case for the RRV involved in the incident in the Severn Tunnel on 26 April 2009 (paragraphs 135 and 152). The content of the checklist should be investigated further to verify that it is appropriate to the risks required to be mitigated and with the aim of improving the degree of compliance with carrying out the checks (Recommendation 2(i)).

219 The RAIB's report on the accident at Glen Garry on 5 December 2007 has already made a recommendation concerning the need to risk assess rail contamination and gradients (Appendix H). This has been accepted by Network Rail and the ORR is considering its response. Although not the RAIB's normal practice, the recommendation is repeated in this report to ensure that the totality of RRV recommendations is located in one place. The Glen Garry report also referred to the RAIB's investigation of the runaway of a trolley at Larkhall (RAIB report 20/2006) which recommended that Network Rail should brief relevant contractors and staff of the risk associated with braking performance on gradients, in wet/icy conditions, and with contaminated brakes. The RAIB therefore specifically recommends that during its planning process, Network Rail, or its contractors, as appropriate, should assess the risk of wet and/or contaminated rails, as well as gradients, the possible effect on machine operation and the specific mitigation measures that may be required (Recommendation 2(j)).

220 Possible further risk control measures relating to wet and/or contaminated rails and gradients are to inform machine controllers of the gradient and brief them on any mitigation measures required so that this information concerning the effect on machine operation can be briefed to operators (Recommendation 2(k)).

221 Awareness of gradients would be increased if information was posted at RRAPs and included in the *sectional appendix*. These last two measures have already been the subject of an RAIB recommendation arising from the Glen Garry accident. This has been accepted by Network Rail and the ORR is considering its response. Although not the RAIB's normal practice, they are included again to ensure that the totality of RRV recommendations is located in one place (Recommendation 2(l)).

222 There is strong evidence to suggest that there is under-reporting of incidents involving RRVs and trailers and that the number recorded in SMIS does not reflect the true total (paragraph 138 to 143) to the extent that the true nature of their risk contribution to the overall safety of the railway network is unclear. Opportunities to learn the lessons from these incidents are also missed. Work should be carried out to improve the level of reporting (Recommendation 3).

223 A Network Rail briefing issued following the runaway incident at Copenhagen Tunnel (paragraph 67) stated that timber baulks placed on the track could be used if it was considered there was a risk of an uncontrolled runaway. The briefing was withdrawn almost immediately. The use of a timber baulk or other similar means was discussed in the RAIB's report into the runaway and collision at Armathwaite on 28 January 2007 (RAIB report 05/2009) where it was stated that the use of such protection could result in an overall increase in the risk to system safety.

Actions reported as already taken or in progress relevant to this report

OTP database

224 During the period of the RAIB's investigation, Network Rail set up and populated a database of currently certificated OTP permitted to be used on its infrastructure (paragraph 17).

Network Rail's OTP project

225 Also, during the period of the RAIB's investigation, Network Rail undertook a project on the control and safety of OTP. This focused on three areas:

- roles and responsibilities (including processes and procedures);
- training and competence, rules and regulations and compliance; and
- machine design.

226 The project included comparison with highways, the military and continental railways; the holding of confidential workshops, the carrying out of observation visits to operator and machine controller training schools, and visits to sites where RRVs were in use.

227 The project was also to evaluate the continued need for machine controllers and whether their role could be fulfilled by other means.

228 The main findings of the project were:

- The quantity of rules, standards and guidelines covering OTP can lead to confusion, and the highly technical nature of some of them can be difficult for some staff who work with OTP. Also, that the time available when carrying out OTP work can make it difficult to apply all the health and safety practices required.
- Last minute changes to operational plans can result in health and safety arrangements that have not been properly considered and may result in sub-optimal equipment being used.
- The method of introduction of OTP leads to a proliferation of significant, operating differences and disparities in capacity of apparently similar plant. This gives rise to the risk of misuse, and the requirement for staff to have additional training. Network Rail has no documented or accepted process for new plant design and should take the lead on future machine design, matched to the needs of clearly defined activities where possible. Little emphasis has been placed on recording the user needs specification.
- Good communication links between the machine or crane controller and the operator are of vital importance if safety risks are to be minimised.
- Removing the machine controller role would increase risks to other site staff to an unacceptably high level unless other changes were made to mitigate the risk.
- There is often a long distance between RRAPs, necessitating travel within a possession, often through other work sites.
- A staff survey found that 40% of those questioned blamed time pressure, and a further 20% blamed peer pressure for a tendency towards unsafe working practices.

229 Recommendations made that are relevant to the RAIB's investigation are:

- that a design procedure for future OTP be created and mandated;
- that the certificate of engineering acceptance should specify the safest method for on/off-tracking;
- that OTP accident and incident reporting into SMIS be reviewed;
- that the rules for OTP be simplified and consolidated, given the large number of separate documents that apply;
- that an OTP training course for planners be developed;
- that the content and qualification of machine controller/crane controller training courses be reviewed; and
- that the skill base of site supervision relating to the effective control of OTP operation in possessions should be evaluated.

230 Each recommendation is being taken forward by the issue of a remit to be carried out to a timebound project plan.

231 Following the OTP project, Network Rail issued a draft requirements specification applicable to an RRV wheeled excavator to carry out lifting duties for consultation on 16 July 2009. The intended vehicle is to be of Type 9A (i.e. self-powered), removing problems associated with the rubber/steel interface (paragraphs 85 to 100) and the consultation is intended to be finalised by the end of September 2009. The specification will then form part of the invitation to tender documentation for the provision of new vehicles to replace existing RRVs.

232 During the course of the RAIB's investigation, Network Rail advised that standard RIS-1700-PLT (paragraph 66) is to be replaced by a more stringent standard NR/L2/RMVP/0206, due for implementation by June 2010 (no other information about the new standard was provided). In addition, standard NR/L2/MTC/0056 (paragraph 157) was superseded by a new suite of planning standards in September 2009 and some changes have been made to the timescales shown in Table 4. The new stages are shown in Table 6

Milestone stage	Actions required
To T-26 weeks	Produce the possession plan (known as the Confirmed Period Possession Plan) describing the detail of the engineering work proposed within the rules of the route
To T-12 weeks	Amend the weekly timetable
To T-4 weeks	Finalise the work required to be carried out while minimising the extent of disruption to the network. Produce draft Weekly Operating Notice
T-8 days	Publish the Weekly Operating Notice
T-3 days	PICOP pack of documents produced

Table 6: New key milestones in the possession planning process

Review of possession arrangements

233 Paragraphs 164 and 165 describe the work being carried out by Network Rail to review the current arrangements for possessions of the line.

Reducing the consequences of a runaway

234 Also, during the period of the RAIB's investigation, Network Rail investigated the use of a device that would warn staff working on or about the railway of any unintended railway vehicle movement.

235 The device under test consisted of a treadle able to be attached to the side of the rail magnetically and capable of being operated by a railway wheel. The treadle was connected to an alarm unit by 200 metres of cable laid out along the railway. Operation of the treadle sounded the alarm. The device was designed to be 'fail safe' such that if the treadle fell from the rail, connections became disconnected or the device was set up incorrectly, the alarm would sound.

236 This device would not derail or damage any railway vehicle if it were inadvertently left in position, and Network Rail was continuing to evaluate the use of such a device in specific circumstances at the time of this report. It was unlikely to find general application because a quantified risk assessment had concluded that in some situations, the level of risk could be increased because staff would need to access the track and walk along it in order to install the device.

237 The RAIB's report into the runaway and collision at Armathwaite on 28 January 2007 (RAIB report 05/2009) concluded that a warning system to warn staff of any approaching runaway vehicles was not considered to be a practical measure, therefore, no recommendation has been made for its use.

Publication of gradients

238 Network Rail published locations where the gradient is steeper than 1 in 50 in the *Hazard Directory* from December 2008 and required that this information be obtained when planning any type of work.

239 Network Rail does not currently publish gradients in its sectional appendix documents (although this was recommended by the RAIB's report on the Glen Garry accident – Appendix H), or specifically provide this information to its contractors when working on such gradients.

Recommendations

240 The following safety recommendations are made[8]:

1. *The intention of this recommendation is that Network Rail should manage the specification, design, operation and maintenance of RRVs acquired after the issue of this report using a systems engineering process, incorporating formal safety analysis methods.*

   Network Rail should implement a process that manages the specification, design, operation and maintenance of RRVs on its network throughout their system lifecycle (paragraph 201). The process should include the following elements:

   a) a high level requirements specification of the task;

   b) a safety requirement specification, including the application of safety analysis techniques such as Hazops, FMEA and FTA;

   c) specifications relating to the plant, the relevant personnel and the applicable procedures;

   d) RRV configuration management systems;

   e) verification and validation requirements;

   f) site inspections and audits of the arrangements; and

   g) a change control process.

2. *The intention of this recommendation is that Network Rail should carry out a structured assessment of the safety of operation of existing RRVs and trailers with the objective of reducing the risk of runaways and collisions arising from their operation. The assessment should take account of identified factors arising from the RAIB's analysis of previous runaway events.*

   Network Rail should assess the operation of existing RRVs and trailers to satisfy itself, on the basis of a process of structured safety analysis, that there are adequate technical and operational controls to prevent RRVs running away.

continued

---

[8] Those identified in the recommendations, have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail Regulation to enable them to carry out their duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 167 to 171) can be found on RAIB's web site at www.raib.gov.uk.

The assessment should take account of the factors listed below and consider the reliability of the primary controls identified. It should identify any realistically possible failures of the primary controls, and where these are identified, what emergency control measures (which may be implemented through operator training) should be put in place.

Network Rail should amend their processes as appropriate to implement any improved controls identified.

The factors for consideration should include:

a) the use of trailers that are not fitted with service brakes (paragraph 203);

b) for each type of RRV, a specific procedure covering the method of on- and off-tracking (paragraph 205);

c) the operation of RRVs without braked rail wheels (paragraph 206);

d) the operation of RRVs which rely on an interface between rubber and steel for traction and braking giving rise to extended and unknown braking distances in wet/contaminated conditions and on gradients (paragraph 208);

e) the content of operator and machine controller training courses as they relate to:

- driving on wet and/or contaminated railway lines;
- the use of the emergency stop button;
- the awareness of any gradient hazard and its effect on machine operation;
- the recovery from runaway events; and
- the measures required to ensure that travel movements are carried out safely (paragraphs 209, 210, 214 and 215).

f) the adequacy of maintenance documentation in relation to the maintenance of the rubber and steel interface, including tyre condition, tyre pressure and the correct adjustment of the rail gear (paragraph 213);

g) whether brake lights would reduce the likelihood of collision when RRVs undertake multiple transits in a work site (paragraph 216);

h) the location of RRAPs, the arrangements for possessions and work sites and their effect on RRV travel distances (paragraph 217);

i) the adequacy and the practicality of the system of pre-use checks of RRVs and trailers (paragraph 218);

j) the adequacy of planning processes which should assess the risk of RRV operation on wet and/or contaminated rails, as well as gradients, and include specifically notifying its contractors and suppliers of the possible effect on machine operation and the specific mitigation measures that may be required (paragraph 219);

continued

k) the briefing of machine controllers so that they can brief operators about the gradients that RRVs will be working on, the likely effect on machine operation and any required mitigation measures (paragraph 220); and

l) the absence of signage at RRAPs and inclusion of information in the sectional appendix stating the gradient of the railway (paragraph 221).

3. *The intention of this recommendation is that Network Rail should reduce the amount of under-reporting of accidents and incidents involving RRVs and their trailers.*

Network Rail should review the system of reporting accidents and incidents involving RRVs and trailers, and make any changes that would reduce the amount of under-reporting.

Relationship between the recommendations in this report and those made in other completed RAIB investigations

241 The RAIB investigations of the runaway incidents at Brentwood on 4 November 2007 and Birmingham Snow Hill on 31 October 2007, and at Glen Garry on 5 December 2007 have made specific recommendations. The relationship of these recommendations, and their current status (which is in the form of an initial response to the ORR), to the recommendations in paragraph 240 is shown in Appendix H.

Appendices

Appendix A - Glossary of abbreviations and acronyms

BBP	Balfour Beatty Projects
CIRAS	Confidential incident reporting and analysis service
CPCS	Construction plant competence scheme
LUL	London Underground Limited
MEWP	Mobile elevating work platform
NCCA	National competency control agency
NDS	National Delivery Service
OEM	Original equipment manufacturer
ORR	Office of Rail Regulation
OTM	On-track machine
OTP	On-track plant
PICOP	Person in charge of possession
RMMM	Rail-mounted maintenance machine
RRAP	Road-rail access point
RRV	Road-rail vehicle
RSSB	Rail Safety and Standards Board
SMIS	Safety management information system

Appendix B - Glossary of terms

All definitions marked with an asterisk, thus (*), have been taken from Ellis' British Railway Engineering Encyclopaedia © Iain Ellis. www.iainellis.com

Ballast regulator	An on-track machine used for ballast regulation using an arrangement of ballast ploughs and brushes to distribute the ballast evenly along the track and to the correct profile across it.*
Certificate of engineering acceptance	A certificate, issued by a vehicle acceptance body, recording that a vehicle meets the required standards and gives any necessary operating restrictions.
Coefficient of friction (μ)	The ratio of the force (F) causing a body to slide along a plane (in the direction of sliding) to the normal force (N) pressing the two surfaces together. $\mu = F/N$.
Crane controller	A machine controller with additional competences who has overall responsibility for the safe operations when on-track plant is carrying out mechanical lifting operations.
Detonator	The correct term is railway fog signal. They are a small disc shaped explosive warning device designed to be placed on the railhead for protection and emergency purposes. It explodes when a train passes over thus alerting the driver. Despite not fulfilling the definition of an explosive detonator in any way, detonator is the industry standard term.*
Engineering Acceptance Certificate	A certificate issued following an assessment that a vehicle conforms to the requirements of the applicable standards.
Engineering supervisor	The person nominated to manage the safe execution of works within a work site that has been set up on the railway.
Event Tree Analysis	A structured method of analysis that considers the events that can occur following the occurrence of an unsafe event such as a failure or accident.
Failure Modes and Effects Analysis (FMEA)	An analytical safety analysis technique for establishing the effect of the failure of individual components in a system.
Fatalities and weighted injuries	An overall measure of harm, taking account of injury and fatalities: one FWI = one fatality = 10 major injuries = 200 statutorily reportable minor injuries = 1000 non-statutorily reportable injuries.
Fault Tree Analysis (FTA)	A structured method of analysis that considers the probability and contribution of factors to the occurrence of an unsafe event.

Handsignaller	a) a competent person authorised to control the passage of trains by means of coloured flags and detonators in the absence of normal signalling. b) a competent person authorised to undertake protection of the line in emergencies and for planned work.*
Hazard & operability studies (Hazops)	A structured technique to identify the hazards resulting from malfunctions in a system.
Hazard directory	A database maintained by Network Rail which contains details of the health, safety and environmental hazards known to exist on Network Rail's infrastructure.
Locking pins	Steel pins on a Basket 14 MEWP type RRV that are used to secure the rail gear in its fully lowered position.
Machine controller	A person trained and authorised to control and supervise an item of on-track plant or on-track machine other than a rail crane.*
M&EE Networking Group	Industry working group concerned with the operation of on-track plant on the UK's railways.
Marker boards	A device used to delimit the ends of an engineering work site. They are made of yellow plastic and are fitted with two highway-style flashing road lamps. These show yellow on the work site side and red on the possession side. One is placed on each track at each end of the work site and the area between them is under the jurisdiction of the engineering supervisor. Outside this area is controlled by the Person in Charge of Possession.*
Mobile elevating work platform	The generic name given for any wheeled machine designed to provide a safe working platform for one or more operatives and capable of adjusting this height under the control of the operator*. The term includes self-propelled booms and access platforms fitted to dumper truck conversions.
Movement accident	Accidents to people involving trains, but excluding injuries sustained in train accidents.
National competency control agency	The organisation responsible for managing the control of qualifications on the railway for staff working in certain safety critical roles.
Non-movement accidents	Accidents that are unconnected with the movement of trains which occur to people on railway premises.
Office of Rail Regulation	The independent health and safety regulator for the UK railway industry.
On- or off-tracking	The process whereby an RRV transfers from road to rail or vice versa.

On-track machine	Any piece of specialist railway plant which moves only on the rails and is normally self-propelled.*
On-track plant	These can only be used in possessions and include road-rail vehicles, rail-mounted maintenance machines (these are brought to site and placed on the rails), trailers and attachments with rail guidance wheels.
Periodical Operating Notice	Bi-monthly publications containing amendments to the Rule Book and other publications concerning operations on the railway. These amendments have previously appeared in the Weekly Operating Notice.*
Person in charge of possession	The person who manages safe access to the track for work to take place during a possession.
Possession	A period of time during which one or more tracks are blocked to trains to permit work to be safely carried out on or near the line.*
Possession limit board	A miniature version of the stop sign used on the roads, denoting the end of a possession.*
Rail gear	Sub-assemblies on both ends of an RRV comprising the rail wheels and the structure used to lower and raise them.
Rail Plant Association	Industry association for organisations involved with the operation of rail plant.
Rail Safety and Standards Board	An independent rail industry body which manages the creation and revision of certain mandatory and technical standards (including Railway Group Standards) as well as leading a programme of research and development on behalf of government and the railway industry.
Railway Group Standard	A document issued by the RSSB mandating technical or operating standards.
Railway Industry Standard	A voluntary standard, issued by the RSSB, defining functional and technical requirements that industry parties have agreed to work to. It can be mandated by a railway organisation (e.g. Network Rail) as part of a company standard or contract condition.
Rules of the route	The document agreed between the infrastructure operator, freight operating companies and train operating companies that records when possessions may be taken and how severe temporary speed restrictions may be.*
Safety management information system	A national database used by railway undertakings and infrastructure managers to record any safety-related events that occur on the railway.
Sectional appendix	An operating publication produced by Network Rail that includes details of running lines, permissible speeds, and local instructions.

Self-propelled boom	A type of MEWP that consists of an access platform that is not based on a vehicle chassis.
Sentinel scheme	The system used by Network Rail for managing the competence of staff working in certain safety critical roles.
Service Brake	The brake that is normally used to stop the motion of a rail vehicle.
Structure gauge	The set of minimum dimensions relative to the track to which any structure must conform.*
Tamper	An on-track machine that can (generally) lift and slew the track and simultaneously compact the ballast under the sleepers.*
Train accident	An accident involving a train that occurs on, or affecting, a running line.
Train master	A person, certificated by LUL, to supervise and control an engineer's train or mechanised vehicle at the site of work.
Unimog	A rugged four wheel drive utility vehicle manufactured by Mercedes-Benz.
Vehicle Acceptance Body	Body authorised by the RSSB to assess the compliance of vehicles with railway standards and issue certificates of engineering acceptance.
Weekly Operating Notice	A document published by Network Rail that provides information about engineering work, speed restrictions, alterations to the network and other relevant information to train drivers.*
Work site	The area within a possession that is managed by an engineering supervisor. A work site is delimited by marker boards when engineering trains are present. It may contain many work groups each controlled by a controller of site safety.*

Appendix C - Relevant standards

European standards

EN 280, September 2001	Mobile elevating work platforms - design calculations - stability criteria - construction-safety - examinations and tests
prEN 15746 Parts 1 (July 2008) and 2 (June 2008)	Railway applications – track – road-rail machines and associated equipment

Railway Group standards[9]

GE/RT8000	The Rule Book
GM/RT1300 (now superseded)	Engineering acceptance of road-rail plant and associated equipment

Rail industry standards[9]

RIS-1530-PLT, Issue 1, April 2006 (Issue 2 was being consulted this investigation)	Engineering acceptance of possession-only rail vehicles and associated upon during equipment
RIS-1700-PLT, Issue 1, April 2007	Safe use of plant for infrastructure work

Network Rail standards

NR/L2/CTM/025, Issue 01, 1 September 2008	Competence and training in on-track plant operation
NR/L2/RVE/0007 (formerly COP0007) Issue E1, April 2007	Specification for on and off-tracking road-rail, vehicles
NR/L2/MTC/PL0056, Issue 2, 1 June 2008	'Work and possession planning for the railway infrastructure (meetings management pack)'
NR/L3/INI/CP0044, Issue 3, 1 June 2008	Work package planning process
NR/L3/MTC/PL0006, Issue 2, 1 June 2008 (Issue 3, dated 6 June 2009 was also issued during this investigation)	Planning for the use of on-track plant
NR/CS/OPS/046, Issue E6, October 2006	The train operations manual

[9] Publically available from www.rgsonline.co.uk

NR/CS/OPS/048/TMMIND, Issue 7, 1 December 2008	Train operations manual industry mandatory section

M&EE codes of practice[10]

COP0001, Issue 5, July 2007	Operator competency standards for possession-only rail vehicles
COP0002, Issue 4, December 2006	Minimum requirements for the planning and management of possession-only rail vehicles
COP0014, Issue 4, July 2008	Trailers and attachments with RRVs and RMMMs
COP0016, Issue 2(a), March 2007	RRV & RMMM machine/crane controller checklists
COP0019, Issue 2, November 2006	Action to be taken in the event of accident or incident with a possession-only rail vehicle

[10] Publically available from www.rgsonline.co.uk

Appendix D - Typical types of RRV

Self-powered crawler excavator RRV

High ride dumper with access platform RRV

Low ride lorry RRV

High ride self-propelled boom RRV

Low ride Unimog with access platform RRV

High ride wheeled excavator RRV

Appendix E - RRV/trailer events involving runaways and collisions

Date and source	Location	Circumstances	Immediate cause	Underlying factors
03/01/2001 from Railtrack's investigation report	Auchterarder	An RRV trailer became detached from its RRV and ran for 10 miles (16 km) passing over two public road level crossings that were open to road.	Inadequate maintenance.	Failure of a sub-contactor to carry out maintenance to the required standards.
10/12/2002 from Network Rail's investigation report	Patchway	An RRV trailer ran away for approximately one mile (1.6 km) before colliding with an RRV.	Following the uncoupling of the trailer from an RRV, the trailer was left on a gradient without the parking brake applied. The uncoupling was carried out by a person who was not trained or competent to perform the task.	(a) The design of the parking brake made it possible to uncouple the hydraulic brake hose and trap oil in the system with the result that the parking brake was not applied. (b) The method statement for the site activities failed to consider and control the risk arising from the use of rail trailers on a gradient of 1 in 100 or steeper. (c) The machine operator assumed that the person performing the uncoupling of the rail trailer from the RRV was competent to undertake the task without ascertaining this person's competence.
19/01/2003 from Network Rail's investigation report	Howe & Cos Sidings	An RRV trailer ran away for 1.5 miles (2.4 km) while being uncoupled from the RRV.	The trailer braking system did not 'fail safe' in that the brakes failed to apply when the hydraulic brake pipe was disconnected.	The RRV operator failed to comply with the instructions and procedures when uncoupling the trailer from the RRV, causing it to runaway out of the possession. The RRV operator had not been assessed specifically on the task of uncoupling trailers from an RRV.
09/11/2003 from Network Rail's investigation report	Holbeck Junction, Leeds	RRV MEWP ran away during the off-tracking process and collided with a stationary MEWP.	The operator adopted an inappropriate technique for off-tracking the machine, resulting in a period when the machine was unbraked on a significant falling gradient, resulting in the machine running away.	(a) The operator possibly failed to correct this runaway, owing to a lack of knowledge and experience of operating the machine and a possible degree of 'panic'. (b) There was an alternative possibility that prior to the runaway, a relay had become dislodged, which would have resulted in the rail wheels becoming stuck in an unsafe position. (c) The design of the machine allowed the operator to raise both sets of wheels together resulting in a period when the machine was unbraked. (d) The operator had not received an adequate level of training for operating the machine and was uncertified for its use. (e) The training package for use of the machine was insufficient to ensure that staff received adequate training and certification. (f) The demonstration of the road/rail capabilities of the machine by the hiring company's engineer had failed to provide sufficient clarity to persons involved, that the independent axle facility should be used at all times for on- and off- tracking.

Date and source	Location	Circumstances	Immediate cause	Underlying factors
15/02/2004 from the RSSB's investigation report	Tebay	A loaded RRV trailer ran away from its RRV at Scout Green and ran for 3.25 miles (5.2 km) down the gradient killing four railway staff.	Absence of functional brakes following criminal act by trailer hirer when left unattached on a 1 in 76 falling gradient.	(a) The disturbance of the trailer whilst being unloaded which permitted the means of chocking it to fall off the railhead. (b) The disablement of the brakes resulting from an earlier application of an excessive hydraulic pressure at a time, and by persons unknown. (c) The absence of clear, explicit and practical instructions for checking the effectiveness of trailer parking brakes, and the failure to verify that the parking brakes on the trailer were fully functional both before leaving the depot and before commencing operation at Scout Green. (d) A lack of awareness on the part of the machine controller or operator, of the magnitude and length of the gradient at Scout Green. (e) The pressures arising from the use of very short lead times during the final stages of the planning process leading to an unwillingness to refuse to supply when approved and serviceable plant was not available.
05/05/2004 from Network Rail's investigation report	Shieldmuir	RRV tractor ran away for about 0.5 mile (0.8 km). Operator alleged parking brake had been interfered with.	The operator left the RRV unattended without applying the parking brake.	(a) The lack of any rules or control measures to address the hazard of an operator leaving an RRV unattended with the parking brake off. (b) The design of the RRV and Railway Group standard GM/RT1300 does not address the hazard of an RRV being left unattended with the parking brake off. (c) The method statement for the work had not been changed to show that the particular RRV tractor concerned was being used instead of an RRV trailer. (d) The requirement for RRVs to be operated by a member of the Railway Group is not adequately addressed in contractor's assurance case. (e) There may be scope to improve the effectiveness of the West Coast overhead line equipment project inspection regime. (f) Although version 2 of Rule Book module OTP requires the provision of gradient information, the reason for this is unclear as risk controls to prevent runaways do not require gradient information. Moreover, Network Rail has no process to provide gradient information to comply with this requirement. (g) Although there had been no previously reported incidents of RRVs running away due to the parking brake not being applied, it is likely that such incidents have occurred previously.
05/08/2004 from Network Rail's investigation report	Stockport	RRV MEWP ran away during off-tracking.	The operator raised both sets of rail gear at the same time thus putting the machine into an unbraked condition.	(a) Insufficient controls to prevent an unbraked situation and an over-reliance on human performance. (b) The machine operator had not received practical training or assessment to identify the onset and recovery from a runaway situation. (c) The operator did not follow the defined on/off- tracking. (d) The lack of knowledge of the emergency stop button. By depressing this button the machine operator was unable to recover from the onset of the runaway.

Date and source	Location	Circumstances	Immediate cause	Underlying factors
17/08/2004 from Network Rail's investigation report	Stockport	RRV MEWP ran away during off-tracking.	The operator raised both sets of rail gear at the same time thus putting the machine into an unbraked condition.	(a) Insufficient controls to prevent an unbraked situation and an over-reliance on human performance. (b) The machine operator was not trained and not been assessed on the machine and had not received practical training or assessment to identify the onset and recovery from a runaway situation. (c) The operator did not follow the defined on/off- tracking. (d) The lack of knowledge of the emergency stop button. By depressing this button the machine operator was unable to recover from the onset of the runaway.
15/10/2006 from the RAIB's preliminary examination of the site and Network Rail's investigation report	Copenhagen Tunnel, King's Cross	RRV MEWP ran away during on-tracking on a 1 in 55 gradient for about 500 m derailing and stopping about 30 m inside Copenhagen Tunnel.	The operator raised both sets of rail gear at the same time thus putting the machine into an unbraked condition.	(a) The contractor did not follow their own company procedures when hiring in safety critical agency staff. (b) The site manager failed in his responsibilities to assess the certification of the staff on site and to provide adequate on site briefings. (c) The machine controller at the time of the incident did not have the relevant Sentinel competency and had not been assessed to work with the particular type of MEWP. (d) The machine operator's use of English was poor. (e) There were communication issues between the machine controller and the machine operator. (f) On-tracking was carried out in an inappropriate manner contrary to the laid down procedure. (g) The activation of the emergency stop button prevented the operator and controller from taking action to bring the MEWP under control.
06/12/2006 from basic details obtained from SMIS but no investigation report available	Pontsmill	RRV wheeled excavator was unable to stop on a 1:40 gradient during wet conditions and ran for about 3 metres. The operator put the bucket down to stop the movement.	Not known.	No record of any investigation.
31/10/2007 from the RAIB's investigation report	Birmingham Snow Hill	A dumper RRV with access platform ran away for about 3 metres while off-tracking and collided with a stationary RRV MEWP.	The RRV was put into a condition where its rail wheels carried the full weight of the machine but were unbraked either by a direct or an indirect means.	(a) During off-tracking, there was no check that there was contact between the rear rail and road wheels before deciding to raise the front rail gear. (b) Network Rail had decided that an interlock was not needed in the rail gear deployment system of the TD-18 type RRV involved in response to an Improvement Notice issued by the Office of Rail Regulation (ORR) covering MEWPS following the runaway at Copenhagen Tunnel. (c) The operator of the TD-18 did not have sufficient time to decide the correct course of action to re-establish braking. (d) There was a general lack of awareness of the severity of the gradient at the road-rail access point used.

Date and source	Location	Circumstances	Immediate cause	Underlying factors
04/11/2007 from the RAIB's investigation report	Brentwood	An RRV MEWP ran away during on-tracking with the operator exiting the basket after leaving the possession and while the MEWP was still in motion. The machine controller pressed the emergency stop button which shut down the engine and disabled the hydraulic control. The RRV ran for 6.75 miles (11 km).	The RRV was put into a condition where its rail wheels carried the full weight of the machine but were unbraked either by a direct or an indirect means.	(a) During on-tracking, it was not observed that because the locking pins on the MEWP were incorrectly located, there was no contact between the rail and road wheels at the one end of the machine before the rail gear was lowered at the other. (b) On site, and before starting to on-track, the operator did not reach an understanding with the machine controller regarding the specific actions they were each going to take. No procedure or training specifically required this. (c) The general lack of awareness of the scope of the Sentinel competences held by the machine controller, and that although they showed he was competent to control the MEWP they didn't show he could assist the operator with on-tracking it. (d) No previous appreciation that incorrectly located locking pins on the MEWP can prevent braking being re-established - because the rail gear arms cannot fully lower - and therefore, that no mitigation measures were implemented to address this risk. (e) The machine controller's decision to press the emergency stop button, which prevented braking being re-established because hydraulic power was cut. (f) There was a general lack of awareness of the severity of the gradient at the road-rail access point used.
05/12/2007 from the RAIB's investigation report	Glen Garry	An RRV wheeled excavator and trailer ran away and collided with a stationary RRV.	The RRV and trailer had insufficient adhesion at its braked wheels to stop on the gradient, most likely due to rail contamination from vegetation clearance operations combined with water from the rain.	(a) The use of a trailer not fitted with service brakes on the gradient without measures being taken to address likely adhesion conditions. Network Rail standards allow such use. (b) Network Rail did not provide information on the gradient at the site to their contractor; the machine controller did not warn the RRV operator of the gradient or the potential for rail contamination. (c) The road tyres of the RRV were not inflated to the correct pressure. (d) The RRV was travelling at a higher speed than allowed by the Rule Book as the driver was not aware of the speed limit for movements within a work site. (e) The RRV operator had received no training on what to do in a braking emergency. (f) The use of one large work site covering all work within the possession led to RRVs theoretically having to travel long distances at walking pace and may have encouraged the RRV operators to exceed the speed limit.
12/02/2008 from Network Rail's preliminary investigation report	Ingatestone	A Unimog RRV collided with a stationary Unimog RRV.	The moving Unimog RRV failed to brake sufficiently to avoid a collision with a stationary Unimog RRV.	(a) The rail head conditions were icy, and with a downward gradient of 1 in 257, the Unimog RRV careered at low speed into the stationary Unimog RRV. (b) The operator of the moving Unimog RRV was unable to appreciate the effect that the rail head conditions would have on its braking system.

Date and source	Location	Circumstances	Immediate cause	Underlying factors
23/05/2008 from the RAIB's preliminary examination of the site	Drumfrochar	A Unimog RRV collided with another stationary Unimog RRV.	The machine operator of the moving RRV did not maintain enough separation from the vehicle in front and, when he braked, the RRV slid.	(a) The stationary Unimog was not fitted with brake lights (no requirement). (b) Neither operator was aware of the 1 in 66 gradient and the hazard was not taken into account during the planning of the work. (c) An extra person was in the cab sitting on the dashboard with back to windscreen. (d) The machine controller did not instruct how far apart the two Unimogs should be driven. (e) The RRVs were travelling at faster than walking pace, but the work site was over six miles long so the RRVs were carrying out a long transit. (f) Braking distance was extended by the downward gradient and wet rail head. (g) The tyre pressures were less than recommended and operators had no means available to check them. (h) The road wheels might have been offloaded because the mode switch was in 'work mode'. (i) The load sharing between the road wheels and the rail wheels might have been sub optimal. (j) The operator might not have met the combination of circumstances present when the collision occurred as he was deemed competent only three months earlier.
12/10/2008 from the RAIB's preliminary examination of the site	Graham Road curve, Hackney	A dumper RRV with access platform ran away while being on-tracked and ran for about 300 metres.	The operator deployed the rear rail wheels but did not engage them with the road wheels before raising the front wheels. The forward/reverse lever was not in the neutral position (which would have applied the parking brake to the rail wheels).	(a) The machine operator could not see the rear wheels from the driving position and believed that the machine controller should advise him when the rear wheels are deployed correctly. (b) The machine controller had no experience of the type of machine, was one month into the job and first time with this MEWP. (c) The machine controller did not consider that he had any machine related duties. (d) The machine operator had no training on how to correct a runaway (he jumped clear after a few seconds) - the runaway could have been prevented by moving the forward/reverse switch to neutral or stopping the engine). (e) The machine operator was given no information about the 1 in 32 gradient.
29/11/2008 from the contractor's investigation report	Milton Keynes	An RRV MEWP was travelling at walking pace behind two other MEWPs and when they stopped, the remaining MEWP collided with the second in line.	The operator was too close to the machine in front.	The MEWP operator only had general MEWP competence and not for the specific MEWP in use or for use on rail.
26/04/2009 from the RAIB's preliminary examination of the site	Severn Tunnel	An RRV wheeled excavator propelling a trailer and towing a trailer ran out of control as it approached a work site inside the Severn Tunnel resulting in a near miss with staff at that work site.	The RRV and trailer had insufficient adhesion at their braked wheels to stop on the gradient, most likely due to rail contamination.	(a) The long work site might have encouraged the RRV to travel at excessive speed. (b) The gradient risk had not been assessed and not briefed to those on site. (c) Those responsible for the RRV were unaware of ultrasonic testing work requiring the application of water to the rail head. (d) There was therefore no on site awareness of operational/environmental changes that affected the use of the RRV.

Appendix F - Analysis of underlying factors arising from previous events of RRV/trailer runaways

Underlying factor	No. of occurrences in 18 events	Possible measures to address underlying factor	Current status of measures in the industry	Further measures which could be taken
Insufficient assessment and briefing of a gradient hazard	12	• Include gradient information and required mitigations in method statements and brief to staff on site.	• Gradients of 1 in 50 or steeper are published in the Hazard Directory (paragraph 238).	• Those planning and carrying out the work should assess the risk arising from gradients at a work site and determine appropriate mitigation measures (already recommended by the RAIB's report on the incident at Glen Garry on 5 December 2007 (Appendix H)). • Network Rail to formally advise its contractors of the gradient at a work site (already recommended by the RAIB's report on the incident at Glen Garry on 5 December 2007 (Appendix H)). • Brief machine controllers and operators of the gradient hazard. • Provide gradient information at RRAPs in the same way that track layout information is already provided at some access points.
Insufficient engineering controls to control the risk	11	• Fit trailers with service brakes. • RRVs should always have at least one braked wheelset in contact with the rail or the ground during on- or off-tracking. • Fit service brakes to the rail wheels of high ride RRVs to make them more like a normal rail vehicle. • Emergency stop buttons where fitted should operate the RRV's brakes when operated.	• Trailers built after 31 December 2006 must have service brakes. • Issue 2 of RIS-1530-PLT proposes that when being on- or off-tracked, RRVs must have at least one wheelset in contact with the rail or the ground. • None proposed. • Issue 2 of RIS-1530-PLT proposes more explicitly that the operation of an emergency stop button should result in the brakes being applied to stop an RRV in all cases.	• A timebound plan to eliminate trailers without service brakes (already recommended by the RAIB's report on the incident at Glen Garry on 5 December 2007 (Appendix H)). • A timebound plan for the fitment of engineering controls that will prevent an RRV being placed into an unbraked condition during on- or off-tracking (already actioned by the ORR – paragraphs 67 and 68). • Review the practicality of fitting service brakes to the rail wheels of high ride RRVs. • None further required (modification of RRVs to prevent an unbraked condition occurring – paragraph 68 - will allow the operation of an emergency stop button to stop a machine).

Underlying factor	No. of occurrences in 18 events	Possible measures to address underlying factor	Current status of measures in the industry	Further measures which could be taken
Error made during on- or off-tracking of high ride RRVs	7	• Improved operator training and assistance from the machine controller where necessary. • Fit engineering controls to prevent an unbraked situation occurring.	• In response to recommendations from Network Rail's OTP project (paragraphs 225 to 231), Network Rail has commissioned work to look at all aspects of training covering the operation of OTP. • See above under 'insufficient engineering controls to control the risk'.	• Improve operator and machine controller training (already recommended following the RAIB's report on the incidents at Brentwood and Birmingham Snow Hill on 4 November 2007 and 31 October 2007 (appendix H)). • Enhance training so that machine controllers are aware of the limits of their competence concerning the on- and off-tracking process (already recommended by the RAIB's report following the incidents at Brentwood and Birmingham Snow Hill on 4 November 2007 and 31 October 2007 (Appendix H)). • Devise a standard procedure for on- and off-tracking (paragraphs 177 - 180) and display in the cabs of RRVs. • See above under 'insufficient engineering controls to control the risk'.
Environmental conditions reducing the adhesion between the rubber tyred road wheels and the steel rail wheels (high ride) or steel rail (low ride)	6	• Understand the variability of friction between rubber and steel under different environmental conditions. • Improve operator training in braking in poor conditions. • Require braking tests in wet conditions as part of the acceptance process. • Ensure that maintenance documentation stresses the importance of correct tyre pressure, good tyre condition and correct adjustment of the road-rail gear. • Machine controllers and operators to understand the environmental conditions that can impact on braking.	• No current measures. • In response to recommendations from Network Rail's OTP project (paragraphs 225 to 231), Network Rail has commissioned work to look at all aspects of training covering the operation of OTP. • No current measures. • No current measures. • Work planning processes to assess the risk of poor adhesion. Appropriate mitigation measures to be in method statements and briefed to machine controllers and operators.	• Research the variability of friction between rubber and steel under different environmental conditions. • Operator training to include experience of braking in poor conditions of adhesion. • Network Rail should prescribe the required braking capability (including when hauling trailers) in wet conditions and on gradients. The application (ie use, speeds, risk of adjacent open line/working gangs etc) would need to be assessed against capability. • Network Rail should prescribe that the maintenance plan emphasises the importance of correct tyre pressures, good tyre condition and correct adjustment of the road-rail gear. • Means to be available so that operators can check tyre pressures. • Work planning processes should take account of the possible variability in stopping distances arising from wet/contaminated rails; including the possible effect that work being carried out by others might have on available adhesion levels.

Underlying factor	No. of occurrences in 18 events	Possible measures to address underlying factor	Current status of measures in the industry	Further measures which could be taken
Deficiency in machine controllers' competence and responsibilities not properly defined	6	• Clarify the machine controller's role concerning to what extent he should assist the operator during the on- and off-tracking process. • Enhance training to include the effects of gradient.	• Network Rail has reviewed the machine controllers' role and responsibilities as part of its OTP project. • In response to recommendations from Network Rail's OTP project (paragraphs 225 to 231). Network Rail has commissioned work to look at all aspects of training covering the operation of OTP.	• Review training having established role and responsibilities to ensure delivery of adequate competence. • Enhance training to increase awareness of the gradient hazard, the effect of wet/contaminated rails and the possible effect on braking distances. • See above under 'error made during on- or off-tracking of high ride RRVs'.
Failure of trailer braking	5	• Adequate maintenance of brakes. • Fit trailers with service brakes that are operated when the service brake is applied to the towing RRV.	• Covered in maintenance documentation. • See above under 'insufficient engineering controls to control the risk'.	• Design for reliability. • See above under 'insufficient engineering controls to control the risk'.
Operators are not practically trained to recover from a runaway situation	5	• Improve operator training, which could include 'skid pan' training, and to improve awareness of the gradient hazard.	• In response to recommendations from Network Rail's OTP project (paragraphs 225 to 231), Network Rail has commissioned work to look at all aspects of training covering the operation of OTP.	• Enhance the training of operators to raise awareness of the gradient hazard, the effect of wet/contaminated rails and the possible effect on braking distances. • Enhance the training of operators to give them practical experience of a runaway under controlled conditions and how to stop it (RAIB's report on the accident at Glen Garry on 5 December 2007 (appendix H) has a recommendation to improve operator training in respect of dealing with a runaway situation).
Inappropriate use of the emergency stop button – paragraph 103 - (as fitted to MEWPs and RRVs approved for use on LUL)	5	• Train operators and machine controllers about how to recover from an emergency, runaway situation, and the effect of the operation of the emergency stop button.	• See above under 'insufficient engineering controls to control the risk'.	• Enhance the training of operators and machine controllers about the operation of the emergency stop button and its effect.

Underlying factor	No. of occurrences in 18 events	Possible measures to address underlying factor	Current status of measures in the industry	Further measures which could be taken
RRV going too fast/following too closely resulting in a collision	5	• Improved operator competence. • Improved supervision by machine controllers.	• In response to recommendations from Network Rail's OTP project (paragraph 225 to 231), Network Rail has commissioned work to look at all aspects of training covering the operation of OTP.	• Enhance machine controller and operator training concerning the safe maximum speeds in different situations of gradient, rail head condition, travel length and separation distance.
		• Restrict the length of work sites to discourage excessive speeds, restrict the length of RRV transits to discourage excessive speeds, increase the separation distance stipulated in the Rule Book (paragraph 47, 12th bullet) between machines travelling together.	• Network Rail is reviewing the current arrangements governing possessions and intends to firstly abolish possession limit boards and detonators followed later by the introduction of a new system based on track occupancy permits. This should result in shorter works sites.	• Deliver shorter work sites so that RRVs do not have to travel so far.
		• Fit brake lights.	• None proposed.	• Consider fitting brake lights to RRVs.

Appendix G - System lifecycle: technical processes as per BS ISO/IEC 15288:2002

	Purpose
Stakeholder Requirements Definition Process	To define the requirements for a system that can provide the services needed by users. The high level document specifying what needs doing and the performance expected
Requirements Analysis Process	To transform the stakeholder requirements into technical requirements, including the use of safety analysis such as Hazops, FMEA and FTA, relating to a product that could deliver the services needed
Architectural Design Process	To develop a design solution that meets the system requirements defined at the beginning. This includes breaking the design down into elements such as the hardware to be built, the operating and maintenance manuals and the competence management system
Implementation Process	To translate the design into hardware within a configuration management system, train personnel in accordance with designed procedures, draft operating and maintenance procedures
Integration Process	To assemble a system that is consistent with the design originated from the architectural design process
Verification Process	To confirm that the specified design requirements are fulfilled by the system. This is done by testing to designed test specifications and competence assessments
Transition Process	To establish a capability to provide the services specified in the stakeholder requirements
Validation Process	To provide objective evidence that the services provided by a system when in use comply with the stakeholders' requirements originated right at the start
Operation Process	To use the system in order to deliver its services. This includes work planning, risk management, the use of trained and qualified operators, in site checks and audits, accident/incident reporting procedures and analysis, and a feedback and continuous improvement process
Maintenance Process	To sustain the capability of the system to provide a service in accordance with the maintenance plan. Includes controlled processes for changes to operating and maintenance procedures and for carrying out modifications
Disposal Process	To end the existence of the system entity

Appendix H - Relationship between the recommendations[11] in this report and those made in other completed RAIB investigations covering RRVs

Road-rail vehicle runaway incidents at Brentwood, Essex and Birmingham Snow Hill, 4 November 2007 and 31 October 2007

Brentwood/Snow Hill recommendation	Relevant class investigation recommendation
1. Network Rail should require all organisations that are permitted to use high ride RRVs on its infrastructure to identify those machines that require the operator to be assisted by another person(s) during on/off-tracking and to enhance their procedures so that: • for each machine, the operator is made aware that he needs assistance before he starts working with the machine; and • operators are aware of the need to come to a clear understanding with the person(s) assisting them before starting to on/off-track; this understanding should include, but not necessarily be limited to, the steps to be gone through, who is responsible for each step, and the clear and unambiguous communication that is to be used so that the RRV can be safely on/off-tracked.	None made
2. Network Rail should require all organisations that are permitted to use high ride RRVs on its infrastructure to review their procedures for on/off-tracking and also the supporting training given to their operators. If necessary, organisations should enhance their procedures and training so that: • the defined steps their operators need to go through during on/off-tracking result in a brake force sufficient to prevent the RRV running away on the maximum gradient permitted for on/off-tracking, and that this force is consistently applied at the holding end of the RRV (the end of the RRV that is opposite to the end at which the rail gear is being lowered (or raised)); • the operator understands his responsibilities for following these defined steps and how the steps assure the braking condition described above; and • that if assistance is required: o the respective roles of the operator and the person(s) assisting (machine controller or otherwise) are identified for each step; and o any special training and competency requirements for the person(s) assisting are identified and implemented, and that the operator understands his responsibilities for checking such competencies.	2. Network Rail should assess the operation of existing RRVs and trailers to satisfy itself, on the basis of a process of structured safety analysis, that there are adequate technical and operational controls to prevent RRVs running away. The assessment should take account of the factors listed below and consider the reliability of the primary controls identified. It should identify any realistically possible failures of the primary controls, and where these are identified, what emergency control measures (which may be implemented through operator training) should be put in place. Network Rail should amend their processes as appropriate to implement any improved controls identified. e) the content of operator and machine controller training courses as they relate to: • driving on wet and/or contaminated railway lines; • the use of the emergency stop button; • the awareness of any gradient hazard and its effect on machine operation; • the recovery from runaway events; and • the measures required to ensure that travel movements are carried out safely.
3. Network Rail should enhance the relevant modules of the Sentinel training so that machine controllers: • are aware that operators need to come to an understanding with any person assisting them with on/off-tracking; and • understand the control measures that prevent an unbraked condition occurring during on/off-tracking.	2 (e) As above.

[11] At the time of this report, Network Rail had accepted all the recommendations with the exception of recommendation 6 of the Glen Garry investigation. Network Rail did not believe this recommendation was reasonably practicable. The ORR was considering its response to the RAIB

4. Network Rail should enhance the relevant modules of training given as part of the Sentinel machine controller competency scheme so that those persons holding this Sentinel competency are aware of the specific duties they should be competent to perform and any specific tasks, for example assisting the operator with on/off-tracking, that this competency does not cover.	2 (e) As above.
5. Network Rail should enhance the relevant modules of Sentinel training for machine controllers to give guidance and practical training on the actions needed to re-establish braking in the event of a runaway.	2 (e) As above.
6. Network Rail should review the MEWPs that were not modified as a result of the ORR Improvement Notice issued following the incident at Copenhagen Tunnel on 15 October 2006. If necessary, Network Rail should require that enhancements are made to these MEWPs so that they are not at risk of being in an unbraked condition during on/off-tracking.	None made

Runaway of a road-rail vehicle at Glen Garry, 5 December 2007

Glen Garry recommendation	Relevant class investigation recommendation
1. Network Rail should publish the gradient of lines in an easily accessible way, for example in the sectional appendix and at track access points.	2. Network Rail should assess the operation of existing RRVs and trailers to satisfy itself, on the basis of a process of structured safety analysis, that there are adequate technical and operational controls to prevent RRVs running away. The assessment should take account of the factors listed below and consider the reliability of the primary controls identified. It should identify any realistically possible failures of the primary controls, and where these are identified, what emergency control measures (which may be implemented through operator training) should be put in place. Network Rail should amend their processes as appropriate to implement any improved controls identified. k) the briefing of machine controllers so that they can brief operators about the gradients that RRVs will be working on, the likely effect on machine operation and any required mitigation measures; l) the absence of signage at RRAPs and inclusion of information in the sectional appendix stating the gradient of the railway.
2. Network Rail should brief their contractors using on-track plant on the hazards of rail contamination and gradient to RRV operation.	2. Network Rail should assess the operation of existing RRVs and trailers to satisfy itself, on the basis of a process of structured safety analysis, that there are adequate technical and operational controls to prevent RRVs running away. The assessment should take account of the factors listed below and consider the reliability of the primary controls identified. It should identify any realistically possible failures of the primary controls, and where these are identified, what emergency control measures (which may be implemented through operator training) should be put in place. Network Rail should amend their processes as appropriate to implement any improved controls identified. d) the operation of RRVs which rely on an interface between rubber and steel for traction and braking giving rise to extended and unpredictable braking distances in wet/contaminated conditions and on gradients; k) the briefing of machine controllers so that they can brief operators about the gradients that RRVs will be working on, the likely effect on machine operation and any required mitigation measures; j) the adequacy of planning processes which should assess the risk of RRV operation on wet and/or contaminated rails, as well as gradients, and include specifically notifying its contractors and suppliers of the possible effect on machine operation and the specific mitigation measures that may be required.
3. Network Rail should require that contractors include the risks from rail contamination and gradient in their risk assessments along with proposed mitigation measures.	2. Network Rail should assess the operation of existing RRVs and trailers to satisfy itself, on the basis of a process of structured safety analysis, that there are adequate technical and operational controls to prevent RRVs running away. The assessment should take account of the factors listed below and consider the reliability of the primary controls identified. It should identify any realistically possible failures of the primary controls, and where these are identified, what emergency control measures (which may be implemented through operator training) should be put in place. Network Rail should amend their processes as appropriate to implement any improved controls identified. d) the operation of RRVs which rely on an interface between rubber and steel for traction and braking giving rise to extended and unpredictable braking distances in wet/contaminated conditions and on gradients; k) the briefing of machine controllers so that they can brief operators about the gradients that RRVs will be working on, the likely effect on machine operation and any required mitigation measures.

4. Network Rail should enhance the Sentinel On-Track Plant documentation for RRV operator training so that positive confirmation of the operator's understanding of the speed limit within a work site, and of the meaning of the term 'work site' is understood, is obtained.	2. Network Rail should assess the operation of existing RRVs and trailers to satisfy itself, on the basis of a process of structured safety analysis, that there are adequate technical and operational controls to prevent RRVs running away. The assessment should take account of the factors listed below and consider the reliability of the primary controls identified. It should identify any realistically possible failures of the primary controls, and where these are identified, what emergency control measures (which may be implemented through operator training) should be put in place. Network Rail should amend their processes as appropriate to implement any improved controls identified. e) the content of operator and machine controller training courses as they relate to: • driving on wet and contaminated railway lines; • the use of the emergency stop button; • the awareness of any gradient hazard and its effect on machine operation; • the recovery from runaway events; and • the measures required to ensure that travel movements are carried out safely.
5. Network Rail should enhance the Sentinel On-Track Plant documentation for RRV operator training to include advice to trainee operators on: • operating on gradients; • operating in low adhesion conditions; and • what to do in a braking emergency.	2 (e) As above.
6. Companies who own or operate RRV/trailer combinations not fitted with service brakes should provide clear guidance to machine operators on the maximum speed and hauled load that the RRV can operate to, given the gradient and track conditions expected or existing at site. This guidance should take the form of a duty chart, covering all duties, displayed in the cab.	2. Network Rail should assess the operation of existing RRVs and trailers to satisfy itself, on the basis of a process of structured safety analysis, that there are adequate technical and operational controls to prevent RRVs running away. The assessment should take account of the factors listed below and consider the reliability of the primary controls identified. It should identify any realistically possible failures of the primary controls, and where these are identified, what emergency control measures (which may be implemented through operator training) should be put in place. Network Rail should amend their processes as appropriate to implement any improved controls identified. a) the use of trailers not fitted with service brakes.
7. Network Rail should provide a time-bound plan for the elimination of the use of RRV trailers not fitted with service brakes from its network.	2 (a) As above.

This report is published by the Rail Accident Investigation Branch,
Department for Transport.

Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Telephone: 01332 253300
Fax: 01332 253301
Email: enquiries@raib.gov.uk
Website: www.raib.gov.uk