Rail Accident Investigation Branch

Rail Accident Report

Investigation into the safety of automatic open level crossings on Network Rail's managed infrastructure

Department for Transport

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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.

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Contents

Appendices 47

Summary

Following the fatal accident at Halkirk automatic open level crossing, Caithness, on 29 September 2009, the RAIB decided to carry out two separate investigations. The first of these was into the Halkirk accident[1], while the second was to investigate the more general safety issues associated with automatic open level crossings installed on Network Rail's managed infrastructure. This report addresses the more general safety issues.

The RAIB's investigation confirmed that automatic open level crossings, which are protected only by road traffic light signals, and have no barriers, are the highest risk form of level crossing for vehicle drivers on public roads, and some of them have a significant history of *incidents* and accidents.

The investigation found that the lack of barriers at automatic open level crossings is the most significant factor contributing to vehicle drivers passing the road traffic light signals when they are operating, either deliberately or as a genuine error. The RAIB considers that the crossings with the highest risk of collision between trains and road vehicles should be upgraded, probably by fitting half barriers, but there may be other means which deliver an equivalent or better level of safety (eg closure).

The high cost of new level crossings is a reason why it can be difficult to justify upgrading existing crossings based on a cost benefit analysis. However, a system is being developed to retro-fit half barriers to existing automatic open crossings at a much lower cost than that of a new crossing. If this initiative is successful, it will be easier to justify the upgrade of existing crossings. The RAIB believes that this work should be prioritised accordingly.

The safety of level crossings can be improved by taking action against vehicle drivers who deliberately pass the flashing red lights. Where this behaviour is prevalent, red light enforcement equipment is a deterrent. The RAIB believes that the development of fixed digital cameras and their installation at selected level crossings, particularly in combination with greater penalties, would be beneficial in improving safety and should be prioritised.

The identification of factors at each crossing that lead to deliberate risk taking behaviour or genuine errors would enable appropriate risk reduction measures to be implemented. The RAIB believes that the existing risk assessments of automatic open level crossings should be reviewed to check whether all the relevant factors have been identified, and to determine whether additional mitigation measures are required.

Finally, the RAIB believes that Network Rail's process covering the risk assessment of level crossings should include guidance to its staff on how to identify the relevant *human factors*, and take account of the associated risk, at specific level crossings in order to determine the adequacy of existing mitigation measures and the need for additional measures. This builds upon a similar recommendation the RAIB made following its investigation of the Halkirk accident.

[1] The report on the RAIB's investigation of the accident at Halkirk automatic open level crossing on 29 September 2009 (report 16/2010) can be obtained from www.raib.gov.uk.

Preface

1 The sole purpose of a Rail Accident Investigation Branch (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.

Key Definitions

3 All dimensions and speeds in this report are given in metric units, except speed and locations on Network Rail, which are given in imperial dimensions, in accordance with normal railway practice. In this case the equivalent metric value is also given.

4 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B.

Introduction

Background

5 Following the fatal accident at Halkirk level crossing, Caithness, on 29 September 2009, the RAIB decided to carry out two separate investigations. The first of these was into the Halkirk accident (report 16/2010)[2], while the second was to investigate the more general safety issues (collisions between trains and road vehicles) at automatic open level crossings on Network Rail's managed infrastructure. This report addresses the more general safety issues.

6 The RAIB has also investigated the fatal accident at the automatic open crossing at Wraysholme, Cumbria on 3 November 2008 (report 26/2009).

7 The information in this report contains evidence obtained from relevant organisations which were making progress with various initiatives affecting the safety of automatic open crossings during the course of the RAIB's investigation.

8 At the time of publication, there were 115 automatic open crossings in operation on Network Rail's managed infrastructure, accounting for 8% of all level crossings on public roads. Some are also installed on industrial lines, heritage railways and light rail systems, but in these cases the risks are generally lower than on Network Rail's managed infrastructure because of low train speeds and, in the case of light rail systems, the ability of rail vehicles to stop on sight.

9 Almost all of the automatic open crossings installed on Network Rail's managed infrastructure are of the locally monitored type (AOCL). At this type of crossing, the train driver is responsible for checking that the crossing is clear of obstructions (at a specific distance from the crossing) and an intermittent white light is displayed indicating that the road traffic light signals are operating.

10 There is one automatic open crossing that is not an AOCL. This is the sole remaining automatic open level crossing of the remotely monitored type (AOCR) and is fitted to Network Rail's managed infrastructure, at Rosarie, in Scotland. To a road vehicle driver, the AOCR appears almost the same as an AOCL. The operation of AOCLs and AOCRs is explained in paragraphs 16 to 22 of this report.

Features of automatic open crossings

11 Automatic open crossings are protected by a pair of flashing red road traffic light signals (often known as 'wig-wags') of the normal configuration to be found at level crossings, swing or lifting bridges, tunnels, airfields or in the vicinity of premises used regularly by fire, police or ambulance vehicles. They do not have any form of barrier to close off the road when a train approaches and then passes over the crossing. A typical automatic open crossing is shown in figure 1.

[2] See www.raib.gov.uk.

Figure 1: Typical automatic open level crossing (Dolau, Powys)

12 The safe use of automatic open crossings requires approaching road vehicle drivers to observe and react to the lights correctly. The meaning of the lights (figure 2) is stated in the Highway Code[3] as follows:

- you MUST always obey the flashing red stop lights;
- you MUST stop behind the white line across the road;
- keep going if you have already passed the white line and the amber light comes on; and
- at crossings where there are no barriers, a train is approaching when the lights show.

There are no exceptions as to what may pass the road traffic light signals when the red lights are flashing; even emergency vehicles must stop.

Flashing red lights

Alternately flashing red lights mean YOU MUST STOP

At level crossings, lifting bridges, airfields, fire stations, etc.

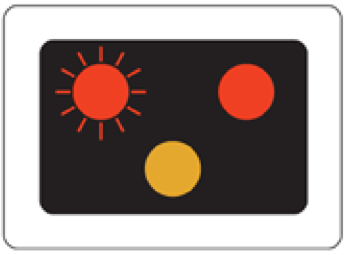

Figure 2: Road traffic light signals at level crossings (as shown in the Highway Code)

[3] Department for Transport Driving Standards Agency the Official Highway Code 2007 Edition, ISBN 9780115528149, see www.direct.gov.uk.

13 In each road direction a sign is provided to warn vehicle drivers that they are approaching a level crossing without gates or barriers. There is a second sign below it which depicts one of the road traffic light signals and the words 'STOP when lights show' (figure 3). Guidance on the location of these signs is provided in the *Office of Rail Regulation's* (ORR's) Railway Safety Principles and Guidance (RSPG), Part 2, Section E on level crossings[4] and in chapter 4 of the Traffic Signs Manual[5]. The form of the signage and signals is prescribed by the Traffic Signs Regulations and General Directions 2002[6].

Figure 3: Road signage on the approach to an automatic open level crossing

14 The conditions that permit the installation of AOCLs are contained in the RSPG on level crossings which is summarised as follows:

- the speed of trains over the crossing should not exceed 55 mph (88 km/h);
- there should be no more than two running lines;
- there are specific limits on maximum permitted crossing speed related to road and rail traffic levels;
- the carriageway on the approaches to the crossing should be sufficiently wide to enable vehicles to pass safely; and
- the road layout, profile and traffic conditions should be such that road vehicles are not likely to ground or regularly block back obstructing the railway.

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[4] Railway Safety Principles and Guidance, Part 2, Section E, Guidance on Level Crossings (currently being up-dated – see paragraph 85), see www.orr.gov.uk.

[5] Department for Transport, fourth edition, ISBN 9780115524110, see www.dft.gov.uk.

[6] Statutory Instrument 2002 No. 3113, ISBN 0 11 042942 7, see www.legislation.gov.uk.

15 New AOCRs are not permitted to be installed on Network Rail's managed infrastructure. The maximum permitted speed of trains over AOCRs was 75 mph (120 km/h) and there were specific limits on road and rail traffic.

The operation of automatic open level crossings

16 The specific operation of each automatic open crossing is prescribed in a Level Crossing Order made under the legislation that applied to level crossings at the time the Order was made. The current legislation is the Level Crossings Act 1983.

17 All AOCLs are designed to operate when a train is detected on approach, causing the activation of an automatic sequence to close the crossing to road traffic:

- the amber lights show for approximately three seconds and an audible warning (provided to warn pedestrians) begins; and
- after three seconds, the amber lights are extinguished and the intermittent red lights show.

18 In all cases, it is specified that not less than 27 seconds shall elapse between the amber lights first showing and the time when a train reaches the crossing.

19 Trains are required to approach the level crossing at a speed known as the *crossing speed*, which commences at a speed restriction board provided in each direction. These are positioned at the *braking distance* for trains at the crossing speed and from a point where train drivers can clearly see whether the crossing is clear or not.

20 Train drivers are required to monitor the operation of the crossing as they approach to check that it is not obstructed. They must also check that a signal facing approaching trains, known as a *driver's crossing indicator* and located just before the crossing, has changed from an intermittent red light to an intermittent white light. The intermittent white light shows if at least one of the red lights of each road traffic light signal is flashing and the main power supply has not failed.

21 If the intermittent white light does not show, the train driver must stop the train at the driver's crossing indicator. The train must not then proceed over the crossing unless the train driver has made sure it is safe to do so (at some crossings there is an emergency plunger which the train driver can use to operate the crossing if there has been a failure of the equipment).

22 The operation of the AOCR starts in the same way as an AOCL but there is no specific crossing speed (within the overall maximum speed of 75 mph (120 km/h)) and it is not fitted with a driver's crossing indicator. This is because the signaller can monitor the operation of the road traffic light signals from an indication provided in the signal box, which is always open when the line is open. The AOCR is also provided with telephones for the public to contact the signaller if required.

The history of automatic open level crossings

23 AOCLs were introduced in 1963 on little used railway lines with low train speeds and low road traffic levels. AOCRs were installed from 1983 onwards as a cheaper alternative to automatic half barrier (AHB) crossings. This followed a report[7] by a joint working party of officers from the British Railways Board and the Department of Transport (DoT). This was set up to 'consider ways in which methods of level crossing protection can be further developed in Great Britain, taking into account the cost and the need to maintain an adequate and publicly acceptable standard of safety'.

24 In the mid-1970s, efforts to reduce costs and improve level crossing safety were being frustrated by the high cost of AHB crossing installations. Costs had increased as a result of the recommendations made in the report on the accident at Hixon AHB crossing on 6 January 1968[8] in which a train collided with a heavy road transporter carrying a transformer over the crossing. As a result, three crew and eight passengers were killed.

25 The joint working party report also recommended that the maximum speed of trains at AOCLs should be increased from 35 mph (56 km/h) to 55 mph (88 km/h). The number of AOCLs and AOCRs on the national railway infrastructure after 1970 is shown in table 1.

Year	AOCRs	AOCLs	Year	AOCRs	AOCLs
1970		22	1993	2	164
1975		51	1994	1	157
1976		52	1995	1	148
1977		58	1996	1	149
1978		68	1997	1	143
1979		84	1998	1	138
1980		107	1999	1	137
1981		112	2000	1	137
1982		122	2001	1	134
1983	8	128	2002	1	132
1984	25	144	2003	1	128
1985	39	188	2004	1	126
1986	44	206	2005	1	120
1987	44	206	2006	1	120
1988	33	211	2007	1	116
1989	14	211	2008	1	116
1990	8	206	2009	1	115
1991	5	199	2010	1	114
1992	3	193			

Table 1: Number of automatic open crossings installed on Network Rail's managed infrastructure (courtesy of Network Rail)

[7] Level Crossing Protection, Report by officers of the Department of Transport and of the British Railways Board, Department of Transport, 1978, HMSO, ISBN 0-11-550482-6.

[8] Ministry of Transport, Report of the public inquiry into the accident at Hixon level crossing, January 6th 1968, HMSO, ISBN 10 1370160 1, see www.railwaysarchive.co.uk.

Government review of automatic open level crossings

26 Following the accident at the AOCR at Lockington on 26 July 1986, when eight passengers on the train and a passenger in the van involved were fatally injured[9], the Department of Transport[10] commissioned a review of automatic open level crossings. It appointed Professor P F Stott to carry out an independent review of their safety and also invited the Central Transport Consultative Committee (CTCC) (representing railway passengers) to contribute to the review. Professor Stott's report[11] of 1987 acknowledged that its statistical analysis of level crossing safety was based upon a small sample of accidents, but it concluded that the statistics were robust enough to show that collisions at AOCLs were about twenty times more likely than at an AHB for a given traffic load[12]. The rate at AOCRs was likely to be as great or worse.

27 Stott concluded that in collisions, road fatality rates appeared to be directly related to train speed and rail fatality rates were one-sixth of the road rate, based on the figures for the previous ten years. The report commented that fatality rates were likely to be reduced in the future by improved construction and crashworthiness of trains. Stott considered that pedestrian fatalities at automatic open crossings were not a major problem, with none killed in the previous ten years and he found that the visual and audible warnings provided at automatic open crossings were 'striking and effective' for people on foot. He considered that the Oppenheim report[13] had dealt adequately with the safety of pedestrians at level crossings.

28 The Stott report recommended that the conditions for automatic open crossings should be such that the predicted fatality rate for each crossing should be less than one in a hundred years, similar to the rate at AHB crossings. The approach to achieving this was to place limits on the permitted train speed dependent on the road and rail traffic levels (the *traffic moment*), modified to take account of the effect of the non-linear relationship between accident probability and road traffic levels (known as the *effective traffic moment*). The higher the effective traffic moment, the lower the permitted train speed.

29 As a consequence of the Stott report, 42 of the 206 existing AOCLs and 32 of the 44 existing AOCRs did not meet the new guidelines. For these crossings, an upgraded form of level crossing protection was required; the Stott report stated that this should be done within five years. This action was anticipated to reduce the number of automatic open crossings by 30%, and the expected number of fatalities at automatic open crossings by 90% (from an average of up to three fatalities per year to less than four in a ten year period). There is evidence that this was broadly achieved[14] but other improvement measures (such as improved road vehicle crashworthiness) are likely to have contributed.

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[9] The Department of Transport report is available at www.railwaysarchive.co.uk.

[10] The Department of Transport was later renamed the DfT.

[11] Automatic Open Level Crossings, a Review of Safety, Report by Professor P F Stott CBE FEng, HMSO, ISBN 0-11-550831-7.

[12] This refers to the 'standardised collision rate' (collisions per billion units effective traffic moment).

[13] Pedestrian Safety at Public Road Level Crossings, Report of a Committee Chaired by Rt Hon Sally Oppenheim MP, Department of Transport, 1983, HMSO, ISBN 0-11-550596-2.

[14] In the ten year period 2000 to 2009 (inclusive), seven occupants of road vehicles were fatally injured in four separate collisions.

30 The Stott report went on to examine the performance and design of automatic open crossings. It largely discounted lack of understanding of the significance of the red flashing lights as a cause of accident, but Stott had residual concerns about this issue and suggested changes to the wording of the advance warning signs to read 'STOP when lights flash' (this was not adopted because motorists are required to stop when the amber light is displayed (which is a steady indication), unless they have already crossed the stop line or are so close to it that to stop might cause an accident. The instruction is therefore 'STOP when lights show'– see figure 3).

31 The signing of automatic open crossings was described as 'a well intentioned clutter'. Stott considered that the *conspicuity* and visual impact of the crossing itself and the road traffic light signal head needed to be improved. He also suggested that red and white chequered borders be fitted to the road traffic light signal backboards, which has since been adopted. The operating systems of the crossings were considered to be well designed and 'technically safe'.

32 The CTCC recommended that a green traffic signal be added to automatic open crossings that would be lit at all times when it was safe for users to cross. It suggested changing the form of the road traffic light signals to be more like conventional highway traffic light signals using a steady red light. The CTCC also recommended the use of brightly painted 'sleeping policemen' (road humps) to slow road traffic down and that the addition of barriers might improve safety at some crossings. Apart from the addition of barriers at some crossings, these recommendations were not taken forward and the RAIB has been unable to find out why not. The form of road traffic light signal is currently being considered as a part of separate research projects led by the Rail Safety and Standards Board (RSSB) and the Department for Transport, into the form of signage and signals. This research was ongoing at the time of publication.

33 Following the Stott report, British Rail converted all but one of the AOCRs, mainly to AHBs, and many AOCLs have since been converted to either AHBs or automatic barrier crossings, locally monitored (ABCLs). In general, AOCLs are now in two main areas: rural locations where road traffic is low, and industrial/urban situations where trains are infrequent and train speed is very low. However, there are some examples which do not fit these criteria and are on busy roads with relatively frequent passenger trains, such as the AOCLs at Melton (Suffolk), and Ardrossan Princes Street (North Ayrshire).

34 Most of the AOCLs are located on single track railways with low crossing speeds, but there are exceptions, with 18 being located on double track railways and five with crossing speeds that are the maximum permitted for AOCLs (55 mph (88 km/h)). The distribution of maximum crossing speeds (at some AOCLs, the crossing speeds for each rail approach are different) at AOCLs on Network Rail's managed infrastructure is presented in figure 4. This includes the implementation of speed reductions at five crossings during the course of the investigation (paragraph 71).

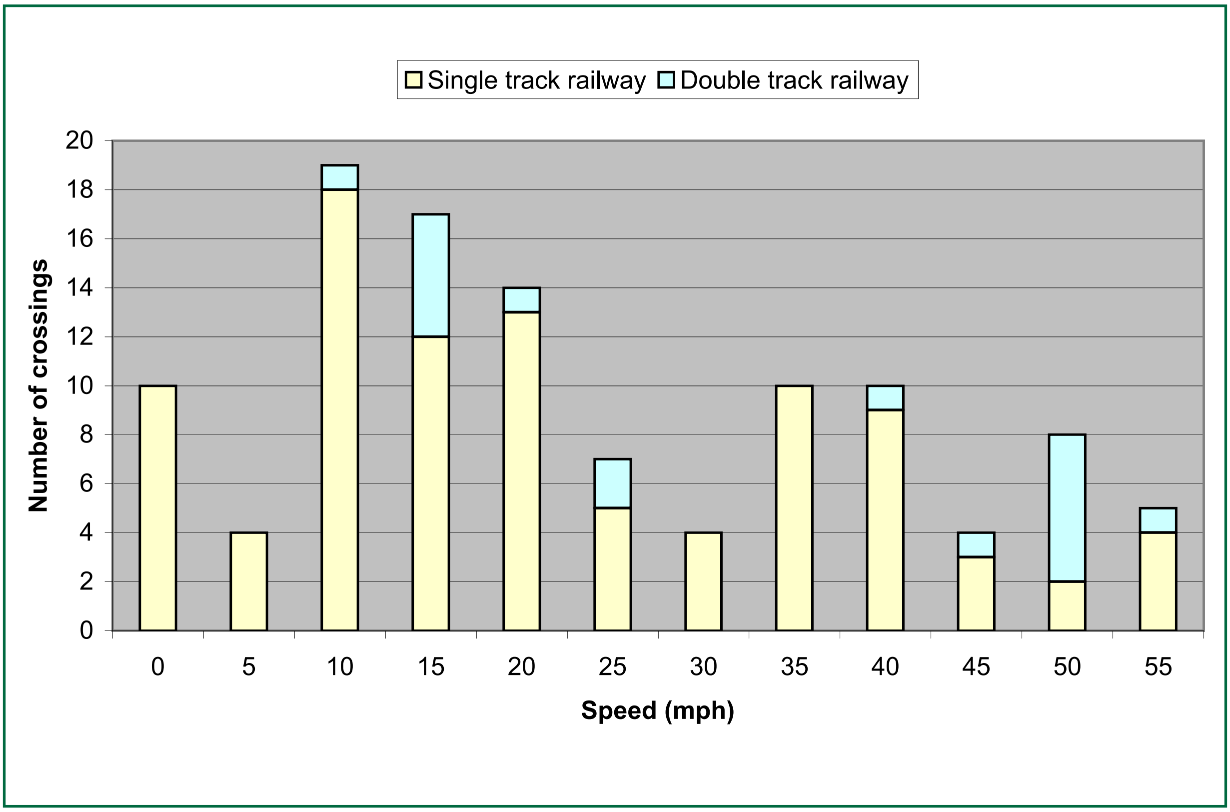

Figure 4: Crossing speed distribution at AOCLs on Network Rail in 2011 (a zero speed means all trains must stop before proceeding over the crossing)

The Investigation

Objectives

35 The objectives of the RAIB's investigation were to:

a. Review safety issues associated with the operation of AOCL type level crossings.

b. Understand the risks to rail and road users at AOCLs with reference to:

- error causing mechanisms that influence the likelihood of an accident or incident; and
- the factors that may influence the consequences to both rail and road users following the occurrence of an accident.

c. Review the applicable legislation and industry guidance for the use of AOCLs and the changes that are proposed, with particular reference to:

- the guidance for determining that an AOCL is a suitable solution for a crossing location; and
- the safety measures (signage, layout, etc) required for an AOCL.

d. Review the railway industry's management of risk at AOCLs, including the criteria for upgrading AOCLs to better forms of protection.

Sources of evidence

36 The following principal sources of evidence were used:

- information provided by the ORR, the RSSB, Network Rail and the DfT;
- reports on level crossing research; mainly carried out on behalf of the RSSB;
- reports from Network Rail on previous incidents and accidents at AOCLs;
- the results of a human factors study of AOCLs commissioned by the RAIB; and
- the results of a study of the survivability of vehicle occupants in collisions between trains and cars at different train speeds commissioned by the RAIB.

Key information

The safety of AOCLs

Overview of risk

37 Data supplied by member states of the European Union to the *European Rail Agency* shows that the UK has the safest level crossings of all the member states[15].

38 Within this overall context, over the ten year period to the end of 2009[16], the accident records show that the number of *fatalities and weighted injuries* (FWI) per year for the occupants of road vehicles, on a per crossing basis, is greater for AOCLs than any other form of level crossing on public roads in the UK. In the same period, they have also had the highest number of collisions between trains and road vehicles.

39 From figures provided by Network Rail, table 2 shows the number of level crossings on Network Rail's managed infrastructure at the end of 2009 (with end of 2010 figures shown in brackets).

UWC-T	*User-worked crossing* with telephone	1667 (1614)
UWC	User-worked crossing	883 (805)
OC	*Open crossing*	55 (53)
FP	Footpath crossing	2462 (2282)
MCG	Manually controlled gates	183 (189)
MCB	Manually controlled barriers	234 (230)
MCB-CCTV	MCB monitored by closed-circuit television	391 (390)
AHB	Automatic half barrier	453 (453)
ABCL	Automatic barrier crossing, locally monitored	52 (52)
AOCL	Automatic open crossing, locally monitored	115 (114)
AOCR	Automatic open crossing, remotely monitored	1 (1)
UWC-MSL	User-worked crossing – miniature stop lights	96 (96)

Table 2: Number of level crossings on Network Rail's managed infrastructure at the end of 2009 (figures in brackets are those for 2010)

40 The RSSB calculates the risk related to level crossings on behalf of the railway industry in the *safety risk model*, and publishes the data in its risk profile bulletin. The information is used in its annual safety performance reports (ASPR) and its special topic report on the road-rail interface[17]. The ASPR report for 2009/10 estimates the total risk from all level crossings to be 11.8 FWI per year. Most of this risk (61%) arises from pedestrians being struck by trains, where the results are usually fatal. The second largest area of risk (20%) relates to collisions between trains and road vehicles, most of which (around 75%) are cars and vans.

[15] Chart 34, Road-Rail Interface Special Topic Report, published April 2010, available from www.rssb.co.uk.

[16] The latest year for which statistics were available to the investigation.

[17] See www.rssb.co.uk.

41 The safety risk model shows that the predominant area of risk at AOCLs arises from collisions involving road vehicles (0.3 FWI/year), with most of that risk affecting the occupants of road vehicles rather than passengers and crew on trains. Collisions with larger vehicles such as lorries may give rise to injuries to persons on the train, but most collisions at AOCLs involve cars or vans. The risk of a pedestrian being hit by a train, which is outside the scope of this report, is predicted by the safety risk model to give rise to 0.11 FWI/year.

42 Figure 5 shows the number of collisions between trains and road vehicles that have occurred at level crossings by type over the ten years to the end of 2009. This shows that around a third of the collisions have occurred at AOCLs with more occurring at this type of crossing than at any other type of crossing. The red line on figure 5 shows the number of actual FWIs over the ten year period to the occupants of road vehicles arising from collisions with trains, for each crossing type (excluding suicides). Figures 6 and 7 show the information in figure 5 normalised by the number of crossings.

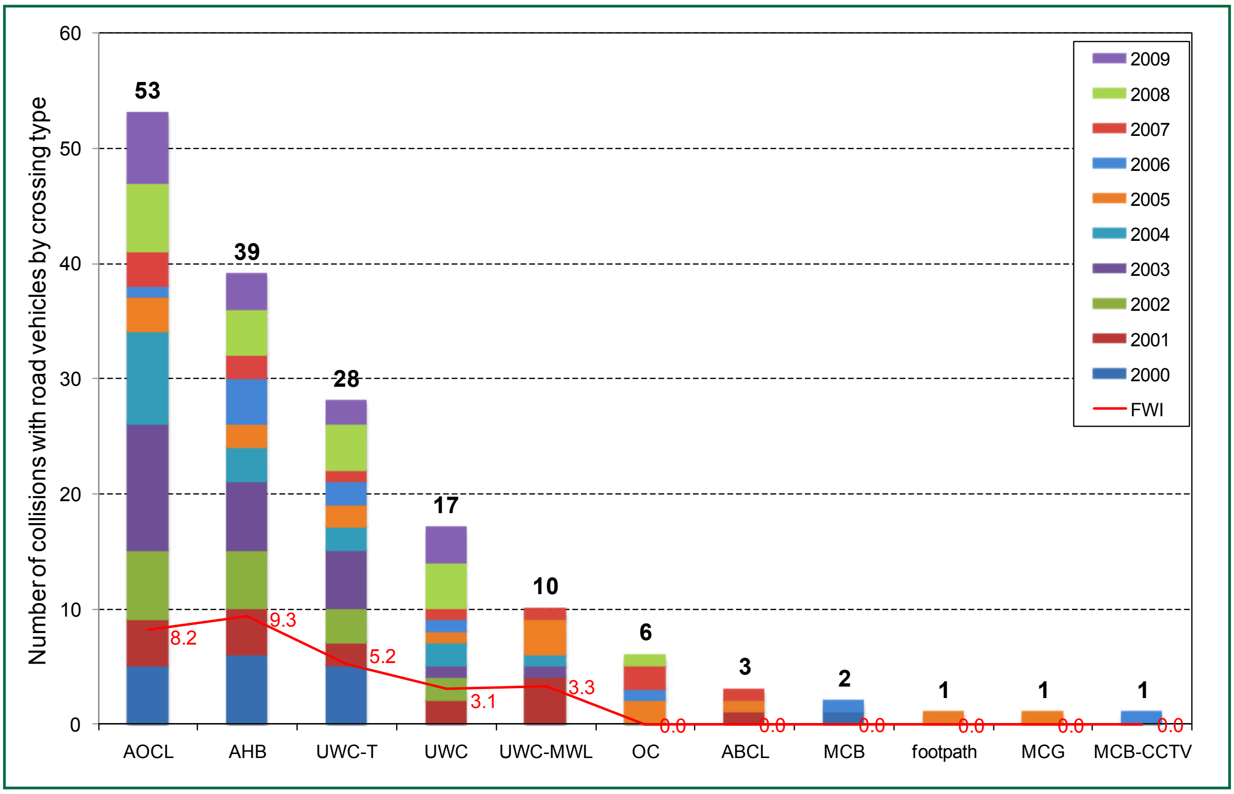

Figure 5: Train-road vehicle collisions and risk at level crossings over ten years (courtesy RSSB)

43 The normalised figures for the number of collisions between vehicles and trains for each type of crossing (figure 6) show that the record of AOCLs is substantially worse than for any other type of crossing. However, figure 6 does not take into account the consequences arising from the collisions such as whether a fatality occurred, or the severity of the injuries. Given that train speeds at AOCLs are restricted to 55 mph (88 km/h) maximum, and are much slower in many cases (figure 4), the severity of injuries would be expected to be less than at, eg an AHB, where train speeds are usually higher.

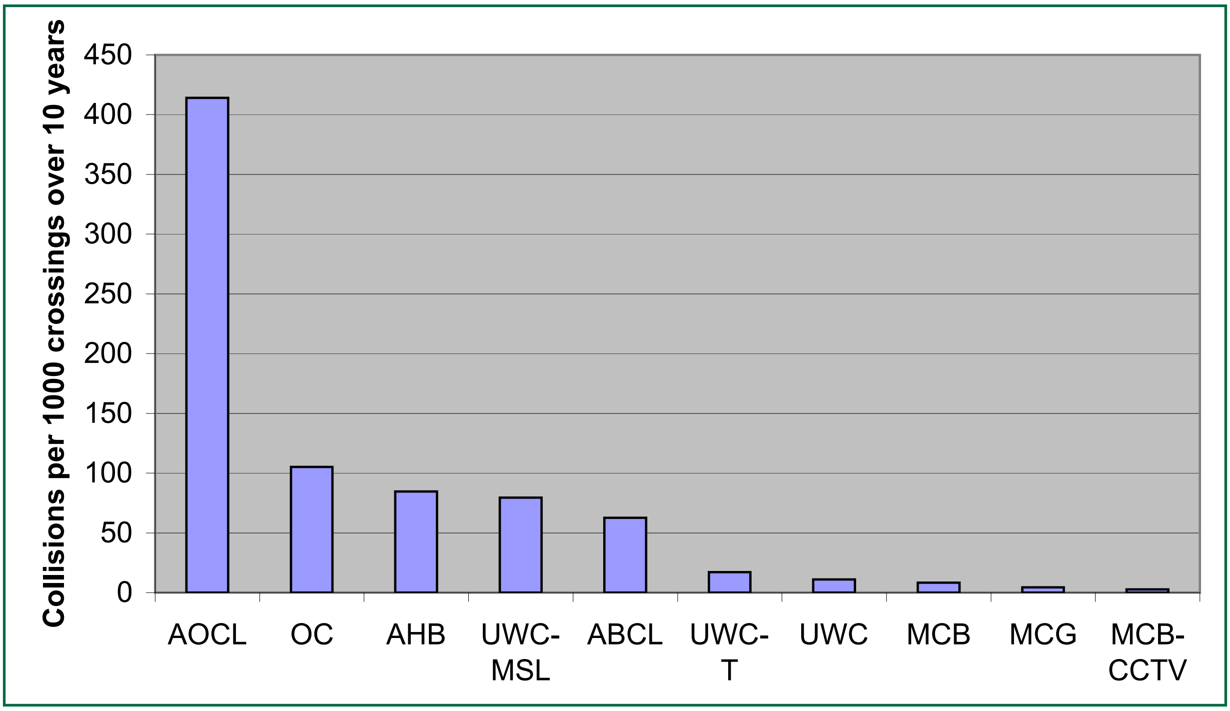

Figure 6: Train-road vehicle collisions per 1000 level crossings over ten years

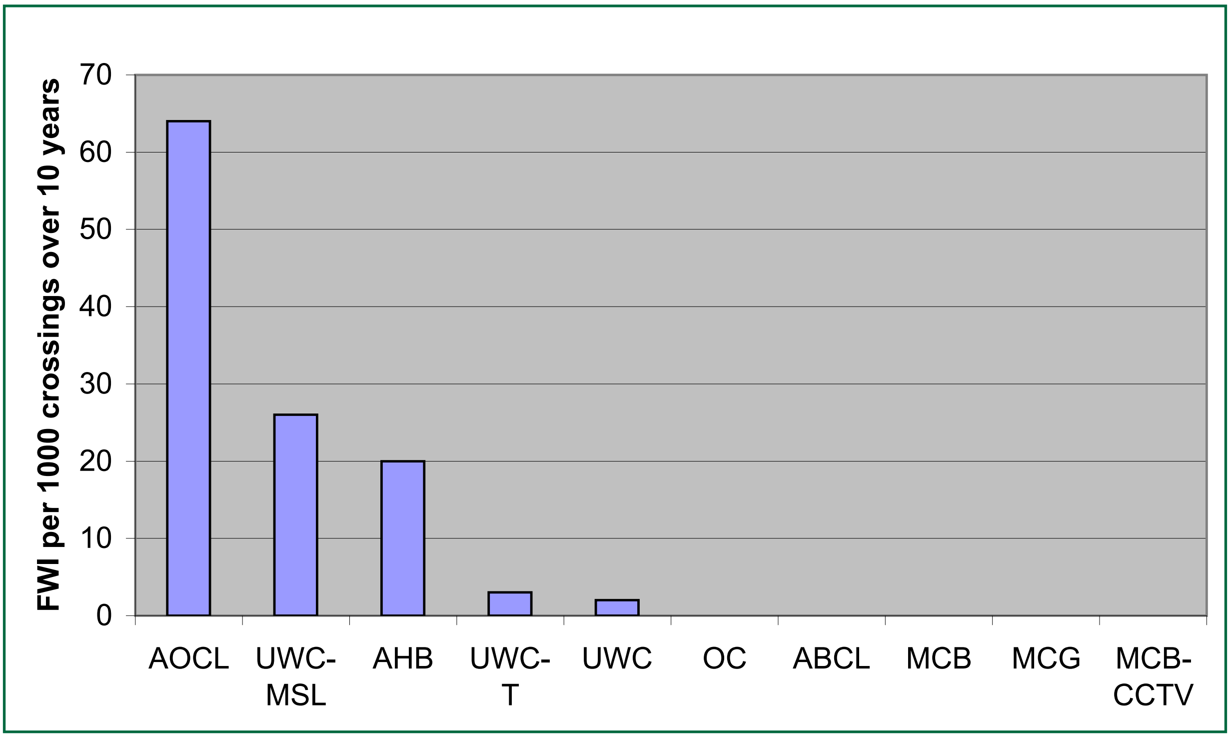

Figure 7: FWIs per 1000 level crossings over ten years

44 Figure 7 shows that for AOCLs, the number of actual FWIs to road vehicle occupants arising from road vehicle-train collisions has been significantly higher than for other types of crossing. Within the FWI figures relating to road vehicle-train collisions, there were seven fatalities in road vehicles in four collisions at AOCLs during the ten years to the end of 2009. By way of comparison, there were nine fatalities in road vehicles in nine separate collisions during the same period at AHBs, although there are about four times as many AHBs as AOCLs (table 2). These figures exclude suicides.

45 The number of road vehicle-train collisions has also been normalised by traffic moments. The results (figure 8) are an indication of the level of protection provided by the different types of crossing to be found on public roads.

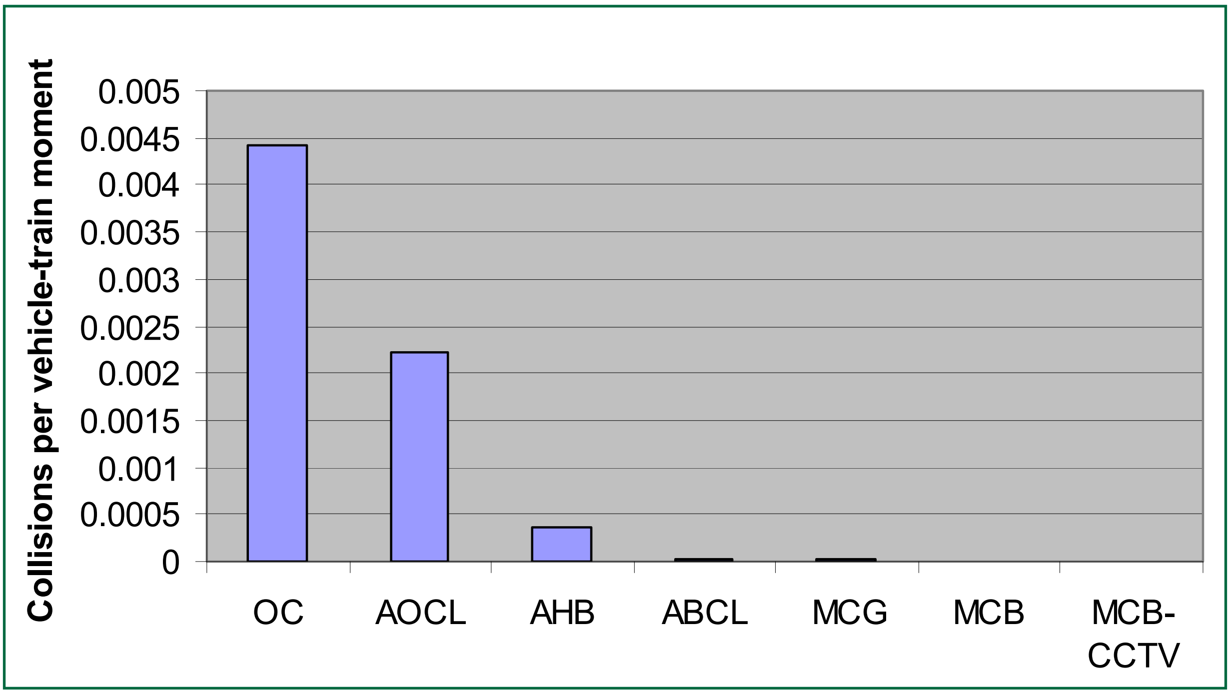

Figure 8: Road vehicle-train collisions normalised by traffic moment

46 Figure 8 shows that AOCLs have a significantly higher number of collisions per traffic moment than AHBs and ABCLs (although less than open crossings, which have neither lights nor barriers, and whose maximum speed is 10 mph (16 km/h), severely mitigating the consequences of any collision). The absence of any form of barrier appears to have a strong influence on the prevalence of collisions at AOCLs.

47 In summary, the figures show that for AOCLs:

- the FWI record related to road vehicle occupants for AOCLs arising from road vehicle-train collisions, when normalised by the number of crossings (figure 7), is higher than for any other type of crossing; and
- the number of road vehicle-train collisions per traffic moment is higher than for any other type of public crossing; except for the unprotected open crossing (figure 8).

Road vehicle users are therefore at significantly higher risk at an AOCL than at other types of protected public level crossing.

Current policies, processes and initiatives

Legislation and guidance

48 The particular arrangements at an AOCL such as the signs, signals, road markings and method of operation are specified in a Level Crossing Order. Level Crossing Orders are made under the Level Crossings Act 1983[18] and issued by the ORR, on behalf of the Secretary of State for Transport, when a level crossing on a public vehicular road is modernised or created.

49 The ORR's RSPG, Section 2, Part E (see paragraph 13) provides guidance to railway operators on the design of new and modernised crossings. Railway operators do not have to meet the guidance, but if they do not do so, they will need to satisfy the ORR that the risks will still be reduced so far as is *reasonably practicable*.

50 Before issuing a Level Crossing Order, the ORR must first be satisfied that the railway operator has chosen an appropriate type of level crossing protection for the location concerned, based on the guidance in the RSPG, and that the specific arrangements (as listed in the Order) are appropriate. The railway operator must comply with a Level Crossing Order once it comes into effect.

51 The Road Safety Act 2006 modified the Level Crossings Act 1983 to allow obligations to be placed on local authorities (and specified in Level Crossing Orders) regarding the provision and maintenance of protective equipment at level crossings.

Network Rail

Policy on level crossings (including AOCLs)

52 Network Rail's policy on managing level crossing safety is published on its website[19]. Its policy includes reducing the risk at level crossings by concentrating on those crossings that are determined as presenting the greatest collective risk (the risk to crossing users and those on board trains), or that exhibit a high risk to individual users.

53 At the time of this investigation, and outside the normal process of risk assessment, Network Rail had no specific strategy to upgrade AOCLs to a different form of protection. However, its staff advised that an action plan for each AOCL would be developed following an assessment three to five years before its planned renewal date (based on the condition of the equipment). In practice, an AOCL would be upgraded to an improved form of protection such as an ABCL when it was renewed. Given the age of the current AOCL installations, and their lifespan, this could lead to most AOCLs being replaced within a period of 10 to 15 years.

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[18] AOCLs created before the 1983 Act came into effect were made under earlier legislation such as the British Transport Commission Act 1957.

[19] See www.networkrail.co.uk.

54 The development of a low cost retro-fit barrier solution to fit to AOCLs could result in significant numbers of AOCLs being upgraded to a much earlier timescale (this initiative is described in more detail in paragraph 72).

Processes – risk assessment

55 Since January 2007, Network Rail's standard NR/L2/OPS/100 'Provision, risk assessment and review of level crossings' has required the use of the All Level Crossing Risk Model (ALCRM) to assess the risk[20] at level crossings. This should be supported as necessary by expert judgement, local knowledge or additional risk assessment processes (such as a human factors study; consideration of the impact of previous incidents and accidents; and any records of misuse) where appropriate. ALCRM is a computer model which predicts the risk level at level crossings. It is based upon the historic safety record of crossings as allocated to one of 14 types, and an input from the safety risk model, both being adjusted in response to various input variables, which are entered following the collection of data from site. It gives an output in two forms:

- the collective risk level computed as the average number of FWI that would be expected to occur on a scale of 1 (highest) to 13 (lowest); and
- the individual risk level measured as the computed probability of fatality per year that a regular crossing user (500 crossings per year) is exposed to from the operation of the railway on a scale of A (highest) to M (lowest).

56 Where the collective risk level is in the range 1 to 3, or the contribution of train accident risk to the total risk is above 50%, Network Rail requires that an operations risk control co-ordinator carries out a site visit to the crossing to assist in the identification of issues and possible risk reduction measures at that crossing.

57 Where the individual risk level is in the range A to C and the collective risk level is 4 or 5, the operations risk control co-ordinator must review the information and consider the need for a site visit to assist in the identification of issues and possible risk reduction measures.

58 Guidance on possible risk reduction measures is given by the level crossing risk management tool kit (www.lxrmtk.com) developed by Human Engineering Ltd on behalf of the RSSB[21]. Network Rail's procedures require that this is used to investigate possible options to reduce the risk. ALCRM can then be used to carry out a cost benefit analysis, which compares the safety benefit of a possible risk reduction measure with the cost of its implementation. The higher the predicted risk, and/or the more significant are the local issues, the greater is the range of options that should be considered in managing the risk.

59 Network Rail's procedures require that its staff consider other relevant information, such as the record of incidents and accidents at the crossing concerned, and do not rely solely on the results of the cost benefit analysis to decide whether or not to take forward risk reduction measures.

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[20] The risk of a road vehicle and train collision at a level crossing is the product of the likelihood of the collision and the consequences. A reduction of either of these two factors will reduce the risk.

[21] The LXRMTK was developed in 2005 (and updated in 2010) after a detailed and comprehensive review of human factors issues at level crossings of all types. A risk prioritisation exercise was carried out as part of the original research. For details, refer to RSSB research project T335, see www.RSSB.co.uk.

60 The process of risk assessment enables appropriate risk reduction measures at level crossings to be identified and implemented with the aim of reducing the risk so far as is reasonably practicable.

61 Network Rail requires that risk assessments are reviewed and periodically updated every 18 months, or when circumstances at a crossing have altered. This is to confirm that the design of the crossing is still appropriate for the location, which could be affected, eg by changes in the volume of road traffic, or a significant change in the environment on the approach to a level crossing. Crossing risk assessments must also be reviewed following accidents or incidents.

62 At the time of publication of this report, Network Rail had completed a study to identify improvements to its risk management system covering level crossings and was in the process of developing the work needed to implement them. This included the development of an e-learning course for those required to collect data at level crossings as part of the risk assessment process.

Network Rail's processes – inspections and maintenance

63 Network Rail's staff inspect level crossings in accordance with Network Rail company standard NR/L2/SIG/19608 'Level Crossing Infrastructure: Inspection and Maintenance'. This includes carrying out visual checks of the equipment and confirming that level crossings remain safe, reliable and compliant with legislation. The standard requires inspections of AOCLs to be carried out at seven weekly intervals or less.

64 Staff carrying out inspections use a checklist from standard NR/L2/SIG/19608 contained in a handheld computer. This also allows a limited amount of free text entry. When completed, the inspector docks the handheld computer and the information is uploaded to a computer database, which also schedules when the next inspection is due to be carried out.

65 Any identified defects that cannot be corrected at the time of the inspection are assigned priorities for rectification to timescales detailed in the standard, which relate to the severity of the hazard, and referred to the appropriate department for action.

66 Each level crossing is also required to undergo an annual test to confirm its correct functioning and to demonstrate that it is compliant with the Level Crossing Order.

67 Level crossings are maintained in accordance with Network Rail's standard NR/L3/SIG/10663 'Signal Maintenance Specifications'. Standard NR/L2/SIG/10661 'Signal Maintenance Task Intervals' specifies how often the maintenance should be undertaken.

68 Maintenance technicians record completed maintenance in hand held computers which are then docked to the computer database. This programmes the date of the next maintenance visit.

Network Rail's initiatives on level crossings, including AOCLs

69 Network Rail implemented a 'Don't Run the Risk' public awareness campaign in 2006 to educate the public on how to use level crossings safely and to warn them of the dangers of misuse. This included coverage on television and other media and the targeting of level crossings of all types on public roads suffering the highest levels of misuse.

70 Recent organisational changes in Network Rail, close to the time of publication, have resulted in the appointment of a national level crossing manager with responsibility for managing programmes to reduce level crossing risk.

71 When the accident at Halkirk AOCL occurred on 29 September 2009, Network Rail was already implementing, but had not completed, a programme of measures to improve the safety of AOCLs. Network Rail reported that these consisted of:

- The conversion of all road traffic light signals to use light emitting diodes (LEDs) in order to improve the conspicuity of the lights to approaching road vehicle drivers. At the time of publication, only three AOCLs remained to be completed.
- The conversion of the (train) Driver's Crossing Indicators to use LEDs. This is to be completed during the year 2011/2012.
- Reducing train speeds at five AOCLs to comply with the limits on road and rail traffic listed in the RSPG and Stott report (table 3). At the time of publication, these had been implemented by permanent speed restrictions at Halkirk, Watten, and Delny and by temporary speed restrictions (pending the implementation of permanent arrangements) at Althorne, and Sandscale.

Name of crossing	Network Rail Route	Previous fastest* crossing speed mph (km/h)		New fastest* crossing speed mph (km/h)	
		Up trains	Down trains	Up trains	Down trains
Althorne	Anglia	30 (48)	30 (48)	25 (40)	25 (40)
Sandscale	London North Western	10 (16)	40 (64)	10 (16) **	35 (56) **
Halkirk	Scotland	50 (80)	50 (80)	35 (56)	35 (56)
Watten	Scotland	55 (88)	55 (88)	45 (72)	30 (48)
Delny	Scotland	55 (88)	55 (88)	35 (56)	35 (56)

Table 3: crossing speed reductions at AOCLs (: slower speeds may apply to freight trains, **: still subject to final decision at time of publication)*

- The development of digital red light enforcement equipment (RLEE) to record motorists who pass operating road traffic light signals at level crossings so that they can be prosecuted. This equipment required approval by the Home Office so in advance of this, Network Rail was introducing mobile digital enforcement cameras operated by the British Transport Police (BTP). This use of mobile enforcement cameras was being supported by local advertising to maximise their deterrent effect.
- Awareness days, supporting the 'Don't Run the Risk' campaign, where Network Rail staff raise awareness of the correct use of level crossings by talking to motorists. Network Rail visited 150 level crossings within a recent twelve month period, 14 of which were AOCLs.

- The identification of AOCLs for closure, either by extinguishing the right to cross the railway or by diverting it (eg to use an existing nearby road that crosses the railway using a bridge). Network Rail was pursuing ten AOCLs for closure at the time of publication.
- The implementation of an application for vehicle satellite navigation systems which indicates a level crossing ahead on the screen and sounds an audible warning 100 metres before reaching a level crossing.

The development of retro-fit half barriers for AOCLs

72 At the time of publication of this report, Network Rail was close to finalising a design remit for the fitment of half barriers retrospectively to AOCLs and an initial list of AOCLs for fitment had been determined. It was expected that two trial fitments of the new barrier system would be made in autumn 2011.

73 The expectation is that modifying AOCLs in this way would be much cheaper than installing a new form of level crossing protection such as an ABCL or an AHB crossing.

Rail Safety and Standards Board

74 The RSSB manages the railway industry research programme funded by the DfT, much of which relates to level crossings and which is published on their website www.rssb.co.uk.

75 The RSSB also publishes reports on the railway industry's safety performance and special topic reports, including on the road-rail interface[22]. Much of the data used in these reports is taken from the *Safety Management Information System* (SMIS) which relies on the correct reporting of accidents and incidents.

76 The RSSB manages *Railway Group Standards* (RGSs). The number of RGSs has been reduced by the removal of those addressing risks which are the responsibility of a single party. These have been converted to company-specific standards. Through this process, one RGS now remains that is applicable to level crossings (RGS GK/RT0192 'Level Crossing Interface Requirements').

77 The former RGS GI/RT7011 'Provision, Risk Assessment and Review of Level Crossings', dated October 2002, contained a requirement to phase out AOCLs by 2 February 2013. At this time, some senior railway industry staff supported the abolition of all AOCLs over time, but when the standard was withdrawn in August 2006, Network Rail did not adopt this requirement. Their senior management thought that the cost could not be justified and other risks could be addressed more effectively with the money that would be required to eliminate all AOCLs, although the RAIB has been unable to find any formal analysis supporting this decision.

[22] See www.rssb.co.uk.

78 The RSSB is leading research, still ongoing at the time of publication of the RAIB's report, into the form of signage and road traffic light signals at level crossings. The research includes consideration of the configuration of the road traffic light signals and the level of understanding among motorists of the current steady amber/flashing red arrangement. Another issue that was considered was the desirability of providing a specific proceed indication for motorists at level crossings, but it was decided not to pursue this further following the completion of the first stage of the research.

79 The use of RLEE at level crossings was the subject of an RSSB sponsored research project that reported in 2007. At this time, RLEE was fitted at eight level crossings in Scotland, five of which were AOCLs (the RLEE being commissioned in early 2000), and seven in North East England, one of which was an AOCL (RLEE commissioned in 2003). The aim of the research was to investigate whether the use of RLEE was a cost effective way of deterring misuse.

80 The research found problems with the use of RLEE at level crossings as they used wet film, which had to be processed in time to enable a 'notice of intended prosecution' to be issued within 14 days of the offence (in accordance with the Road Traffic Offenders Act 1988[23]). Also, the BTP, who managed the use of the RLEE, had no powers to issue fixed notice penalties: fines and licence points had to be raised through the courts (this was still the case at the time of publication of this report).

81 The research found no statistically significant reduction in the rate of incidents following the installation of wet film RLEE with the rate of incidents actually increasing at one of the AOCLs fitted (Garve). A modest decrease was found in the rate of incidents at the AOCL at Dingwall Middle. The crossing at Cornton (an AHB) saw a significant reduction in misuse ('red light running'), which was probably due to the high number of widely publicised prosecutions.

82 The research concluded that RLEE could be cost effective at crossings with high levels of misuse, but it was based on a limited sample. The conclusions could be different if RLEE was fitted to a greater number of crossings as part of a well-advertised concerted campaign.

Office of Rail Regulation

83 Following the accident at Halkirk AOCL on 29 September 2009, the ORR published a position statement on AOCLs on its website[24], which describes a three phase action plan (appendix C). This included asking Network Rail to review train speeds at AOCLs by taking account of current road and rail traffic levels in order to assess compliance with the limits listed in the RSPG (which came from the report by Professor Stott, paragraph 28). This resulted in the train speeds at five AOCLs being reduced (table 3). ORR inspectors were also inspecting all AOCLs during their current 2010/11 work year to ensure that Network Rail was properly managing the risks and the crossings were compliant with safety legislation.

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[23] See www.legislation.gov.uk.

[24] See www.rail-reg.gov.uk.

84 The ORR is also supporting the Law Commission and the Scottish Law Commission in their review of level crossing law. At the time of this investigation, the Commissions' proposals had been issued for consultation and included simplifying the law to eliminate the current system of Level Crossing Orders. The more general provisions of health and safety legislation and related approved codes of practice and guidance would be applied to cover the implementation of level crossing upgrades. Another objective was to make it easier to close level crossings on public roads.

85 At the time of publication, the ORR was consulting on, finalising and updating RSPG, Part 2, Section E covering level crossings. The consultation draft of the RSPG section still allowed for the installation of new AOCLs but restricted to single track railways only. In practice, the ORR advised, it was likely that any new AOCLs would only be permitted in exceptional circumstances, such as on a new freight only railway operating at low speed.

86 The ORR had raised a concern to Network Rail about the effectiveness of its arrangements for risk assessments at level crossings. This concern had arisen from the ORR's own inspections and from the RAIB's investigation of level crossing accidents. The main area of concern related to the process to assess the risk at level crossings (paragraph 55), and a belief among some of Network Rail's staff that the use of ALCRM alone constituted a sufficient risk assessment. The ORR, like the RAIB, has pointed out that in addition to the results from ALCRM, site-specific risks also need to be taken into account, which depend on an accurate and realistic knowledge of the way the crossing is used. Furthermore, the ORR, like the RAIB, has been concerned about control measures arising from risk assessments not being completed to a reasonable timescale (a shortcoming in Network Rail's processes that the RAIB found in its investigations of the accidents at Halkirk and Wraysholme AOCLs).

Department for Transport

87 The DfT has responsibilities for level crossings relating to signage and signals, the safety of road vehicle drivers, and general rail policy.

88 At the time of publication, the form of road signage and signals at level crossings (prescribed by the Traffic Signs Regulations and General Directions 2002[25]) was planned to be the subject of a policy review by the DfT. This was to be informed by a research project on the understanding of signs and signals, including the level of comprehension of wig-wag signals.

89 A DfT representative was on the working group of the separate RSSB-led research into the form of signage and road traffic light signals at level crossings (paragraph 78). The policy review will take into account the findings of the RSSB-led research.

[25] See www.legislation.gov.uk.

90 In prioritising safety improvements, *highway authorities* make decisions on improvements at highway intersections based on the reduction in the rate of accidents to road users. Level crossings may therefore be a low priority for improvements compared with road junctions. Highway authorities do not take into account the potential risk at level crossings to railway staff and passengers, or other losses suffered by railway operators, when collisions occur, although the main risk is to road users (paragraph 41). Road-rail partnerships between Network Rail and highway authorities have been implemented so that the railway industry can engage with highway authorities and raise the profile of level crossing safety.

91 At the time of publication, Network Rail reported that, as a part of its response to the Law Commissions review of level crossing law, it had requested the Law Commissions to consider a formal duty of cooperation between rail and highway authorities at level crossings.

92 The DfT has expressed its support for increasing the likelihood of detection and prosecution of those crossing against the red lights at level crossings. It has also said that more prosecutions should be brought for the serious offence of dangerous driving at level crossings where vehicle drivers choose to undertake reckless and dangerous behaviour. RLEE has a strong role in supporting both of these.

European initiatives

93 In the Netherlands, the Government gave the national railway infrastructure provider 194 million Euros between 2005 and 2009 to replace all the automatic open crossings (about 600) with AHB crossings. Most of these had shortened barriers to avoid the expense of altering the carriageway to enable standard length barriers to be fitted where the carriageway was otherwise of insufficient width.

94 By converting automatic open crossings to AHB crossings, it was calculated that there would be a ten-fold reduction in accidents[26] at these crossings resulting from the fact that barriers are an additional and unmistakeable indication that the crossing is closed to road vehicles.

95 The Vienna Convention on road signs and signals[27], an international treaty to standardise road signs, traffic lights and road markings, mandates that road traffic light signals at level crossings should consist of double flashing red lights. However, in Germany and Austria, level crossing road traffic light signals have been progressively changed over a period of many years from the flashing red configuration to a steady amber and red indication in a vertical configuration. This is more like a conventional traffic light found at highway intersections, but without a proceed indication (figure 9). The effect on the accident rate as a result of this change is not known.

[26] Level Crossings in the Netherlands, paper presented to the Institution of Railway Signal Engineers by Jeroen Nederlof, Prorail, the Netherlands, 13 January 2010.

[27] The Vienna Convention was agreed by the United Nations Economic and Social Council in Vienna on 8 November 1968 and came into force on 6 June 1978. The UK is not bound by the Convention.

Figure 9: Configuration of road traffic light signals at an Austrian automatic open level crossing (courtesy Austrian Bundesministerium für Verkehr, Innovation und Technologie)

96 Level crossings in Norway are provided with road traffic light signals that comprise a flashing light signal. It consists of a single red flashing light to instruct road users to stop before the stop line when a train is approaching, and a white flashing light underneath it which shows when it is safe for road users to cross the railway. Road users are therefore provided with a specific indication that it is safe to cross the railway. The provision of such a proceed indication was considered as part of the first stage of the research into signage and signals being undertaken by the RSSB (paragraph 78).

Analysis

Human behaviour at AOCLs

The accident and incident record of AOCLs

97 The RAIB obtained the records from the RSSB of all reported incidents and accidents at AOCLs on Network Rail's managed infrastructure from the beginning of 1998 to January 2010 (as recorded by SMIS). The records of accidents from the beginning of 1990 to 1998, pre-dating SMIS, were also obtained from the RSSB. These showed that while some AOCLs had no incident or accident history, others had a more significant history. The full list of AOCLs in operation[28] on Network Rail's managed infrastructure at the time of publication of this report is presented in appendix D and the distribution of incidents across the population of AOCLs is in figure 10.

98 The records of incidents contained in SMIS include near misses and misuse. A near miss is an incident in which a train was close to colliding with a road vehicle. Misuse incidents are those where there was incorrect use of a level crossing, such as a road vehicle crossing against the red lights when they first start to flash, and the train is still some distance away. The RAIB has chosen to include misuse incidents in its analysis because under slightly different circumstances they could have been a near miss.

99 Many near misses are likely to go unreported, either because train drivers subjectively have different understandings of what constitutes a near miss, or because the near misses are unobserved. Many misuse incidents will also go unreported because they are unobserved.

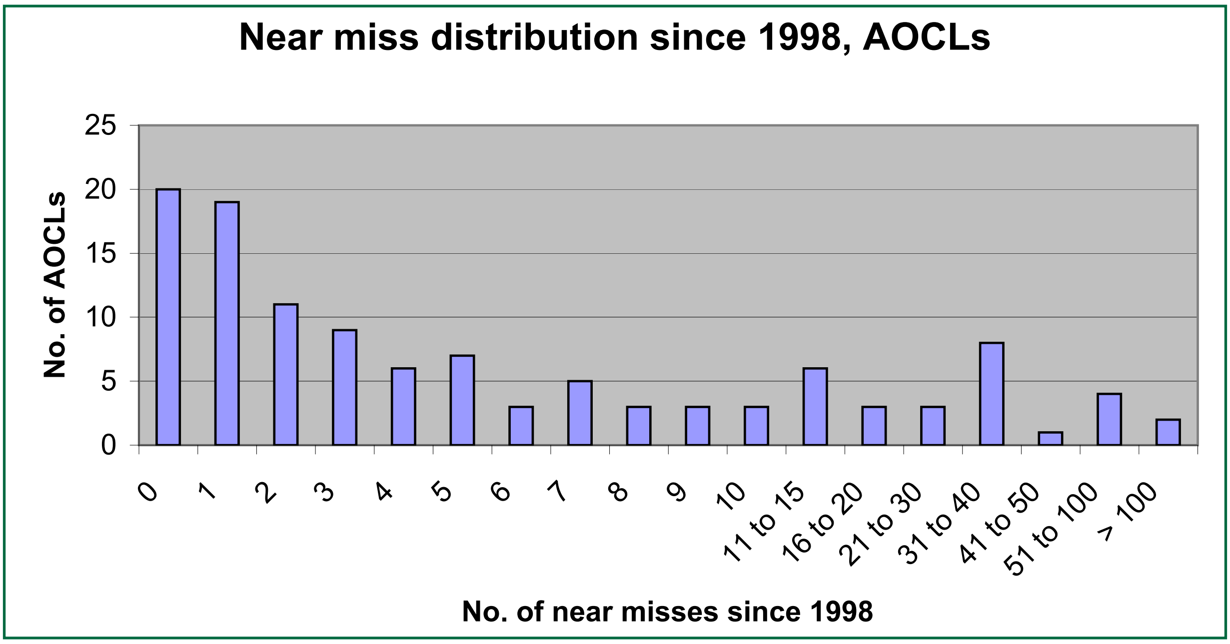

Figure 10: The distribution of incidents at AOCLs

28 A few other AOCLs are on lines that were not in operation when this report was published

100 The railway industry has reported[29], in relation to the most significant causes of train collisions with road vehicles at all types of level crossings between 2000 and 2009, that:

- 36% were caused by the road vehicle driver making an error, either by inadvertently not using the crossing correctly, by failing to observe the crossing, or by grounding.
- 24% were caused by road vehicle drivers deliberately misusing the crossing, such as ignoring the road traffic light signals when operating, or weaving around lowered half barriers.
- 15% were caused by road vehicle drivers failing to take account of adverse environmental factors such as fog or snow.
- In 11% of cases, the cause of the collision was unclear.

101 A study carried out in 1996 by the Transport Road Research Laboratory[30] on vehicle driver behaviour at level crossings analysed 419 witness statements taken by the BTP from vehicle drivers, most of who had driven past the road traffic light signals when operating. It found that 55% of them passed the lights deliberately because they were unwilling to stop (a violation). When questioned as part of the research, the same study found that only 54 out of 100 vehicle drivers, who had crossed when the lights were flashing, could correctly describe the meaning of the flashing red lights, and only 13 out of 100 vehicle drivers correctly understood what was meant by the amber light.

Human factors assessment of AOCLs

102 The RAIB commissioned a human factors study to understand why some AOCLs had a worse safety record than others. The objective of the work was to identify and understand the primary human factors issues which affect both the likelihood and consequence of incidents and accidents at AOCLs, and to identify reasonably practicable mitigation measures to reduce the risk to both rail users and vehicle drivers. The work was divided into four stages:

- a literature review;
- accident data analysis;
- site visits to designated AOCLs; and
- *human error analysis*.

103 The main risk at AOCLs arises from vehicle drivers who pass the road traffic light signals when they are operating (and when they would otherwise have time to stop before the lights). They usually do so for two main reasons: a deliberate and intentional action (a violation) or because they are unaware of the lights through being inattentive or distracted (an error). A third possible reason is that the vehicle driver does not understand the meaning of the road traffic light signals. This meaning is clearly stated in the Highway Code and therefore reflects a failure to understand the Highway Code (paragraph 12). Mitigation measures need to be targeted towards the range of features in and around AOCLs that contribute to violations and errors by crossing users.

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[29] Road-rail interface special topic report, published April 2010, section 3.4.3, see www.rssb.co.uk.

[30] Vehicle Driver Behaviour at Level Crossings, HSE Contract Research Report No. 98/1996, HSE Books, ISBN 0-7176-1093-4, see www.hse.gov.uk.

104 The study included a literature review of research relevant to AOCLs to identify the associated human factors issues and risks to road and rail users. The key findings of this are in appendix E.

105 The reports on the investigations of ten AOCL collisions were analysed. One of these investigations had been carried out by Railway Safety (the predecessor organisation to the RSSB), one by the RAIB and the remainder by Network Rail. The consultants' findings were limited by the size of the sample and by the fact that in those investigations carried out by the railway industry, the actions of the road vehicle driver involved were not investigated. The human factors issues identified were, however, consistent with those identified from the literature review.

106 Site visits were carried out to five AOCLs with varying features to examine the range of conditions in and around AOCLs that contribute to errors and deliberate disregard of the road lights by vehicle drivers. As an example, one of the crossings visited was at Bucknell, Shropshire, on the Central Wales line between Craven Arms and Llanelli (figure 11). The AOCL at Bucknell has a road junction in close proximity to the crossing and is next to the railway station.

Figure 11: The AOCL at Bucknell, Shropshire

107 The study made use of the existing human error analysis, developed from previous work that the consultants had undertaken for the RSSB[31]. The human error analysis lists:

- the tasks involved in using a level crossing;
- the potential errors and violations associated with each task;
- the factors that influence the making of errors, or the committing of violations; and
- the potential consequences.

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[31] RSSB report T335 'Improving road user and pedestrian behaviour at level crossings', see www.RSSB.co.uk.

This was used to identify the human factors issues which were considered to represent the most significant risk to the safety of road and rail users at AOCLs. They were determined from:

- the frequency with which each human factors issue contributed to incidents or accidents in historical data;
- the frequency with which each was highlighted as a risk in the research data; and
- the priority given to each human factors issue identified within the level crossing risk management toolkit (paragraph 58).

The results were combined to indicate, in order of importance, the human factors issues associated with AOCLs.

108 For each of the human factors issues, mitigation measures were identified which would address the underlying error causing mechanisms. The RAIB then determined the current status of the mitigation measures in the railway industry and considered what further action could be taken to reduce risk. This is tabulated in appendix F.

109 The study did not include correlating which human factors issues applied to specific AOCLs.

110 The top four human factors issues are discussed in more detail below in paragraphs 111 to 130).

Lack of physical barrier

111 The study identified the lack of a barrier as the top priority human factors issue.

112 The study identified the following factors which, in combination with the lack of a barrier, create a risk by potentially causing vehicle drivers to drive onto an AOCL when the lights are flashing and a train is approaching:

Violations

- a vehicle driver expects that there will be no trains in the area;
- a vehicle driver has succeeded in crossing the same way previously;
- a vehicle driver is familiar with the crossing and applies prior knowledge of train times/frequencies;
- a vehicle driver believes that they have enough time to beat the train;
- a vehicle driver becomes frustrated, believing they are being unreasonably prevented from proceeding;
- a vehicle driver misjudges the speed and distance of the train; and
- a vehicle driver wrongly believes that the road lights remain flashing for a period of time after a train passes.

Errors

- a vehicle driver does not see the road lights (factors contributing to this are discussed in more detail in paragraph 117); and
- a vehicle driver does not understand the meaning of the road lights.

113 The presence of a barrier would deter vehicle drivers from deliberately disregarding the road traffic light signals reducing the number of collisions.

114 A lowered barrier would be more visible in the vehicle driver's forward field of vision and therefore more likely to be seen by the inattentive or distracted vehicle driver.

115 Also, a lowered barrier would provide an unambiguous message to any vehicle drivers who did not understand the meaning of the flashing road traffic light signals.

116 The better safety record of ABCLs and AHBs (figures 5 to 8), compared with AOCLs, provides a good indicator of the effectiveness of barriers.

Insufficient conspicuity of the road traffic light signals

117 If the flashing lights fail to capture the attention of an approaching vehicle driver, they are likely to be passed in error. This could be caused by sunlight shining on to the road lights, limited light output or poor alignment. The study identified the following factors that increase the likelihood of a vehicle driver failing to notice the road lights:

- a vehicle driver is under time pressure;
- an expectation by a vehicle driver that there will be no trains in the area so they do not consciously perceive the road lights;
- a vehicle driver chooses to ignore the road lights because they can not correctly discern their meaning;
- light/glare obscures the road lights; and
- the road lights are partially obscured, eg by vegetation.

These factors are made more significant by poor conspicuity.

118 In its investigation of the accidents at Halkirk AOCL on 29 September 2009 and Wraysholme on 3 November 2008, the RAIB found the following further factors that relate to the ability of the flashing lights to capture the attention of approaching vehicle drivers:

- the vehicle driver's fitness to drive; and
- the poor condition of the backboards that support each pair of light units reducing the amount of *contrast* between each light and its background.

119 Network Rail has addressed the problem of insufficient conspicuity at AOCLs by implementing inspection and maintenance processes (paragraphs 63 to 68) so that the optimum alignment of the lights is maintained. It has also installed LED flashing lights which are more conspicuous than the filament bulbs previously fitted (paragraph 71).

120 Sunlight shining on the lights can wash-out their brightness to the extent that a vehicle driver is unable to tell whether or not they are flashing. The usual solution is to fit longer hoods over the lights in order to shield them from the sun. The effect of sunlight falling on the lights is also reduced when LED flashing lights are used, although they can still be adversely affected by sunlight.

121 A further possible mitigation measure (already in the level crossing risk management toolkit) is to reduce the speed of approaching road vehicles so that vehicle drivers have more time to observe the road traffic light signals, and a better chance of stopping at the stop line if the road lights come on (the CTCC also recommended measures to slow down road traffic in its contribution to the Stott report – paragraph 32). However, to be effective, it is likely that this measure would require the use of physical works to ensure the reduction in speed, which could have unintended consequences such as distracting the attention of vehicle drivers away from the road traffic light signals. This mitigation measure is only likely to be appropriate following assessment on a site-by-site basis.

Deliberate disregard of the road traffic light signals

122 Appendix F lists several examples of conditions which encourage vehicle drivers to take risks and deliberately choose to pass the road traffic light signals when they are operating. The study identified the following factors that increase the likelihood of vehicle drivers committing violations:

- a vehicle driver expects that there will be no trains in the area;
- a vehicle driver has succeeded in crossing the same way previously;
- a vehicle driver is familiar with the crossing and applies prior knowledge of train times/frequencies;
- a vehicle driver believes that they have enough time to beat the train;
- a vehicle driver is under time pressure;
- a vehicle driver becomes frustrated, believing they are being unreasonably prevented from proceeding;
- a vehicle driver misjudges the speed and distance of the train;
- a vehicle driver wrongly believes that the road lights remain flashing for a period of time after a train passes; and
- a vehicle driver has a low perception of risk.

None of the above factors provide a justification for violations at any type of level crossing.

123 The presence of a physical barrier would deter vehicle drivers from deliberately disregarding the road lights (as stated in paragraph 113), although, in the case of half barriers, instances could still occur of vehicle drivers violating the road lights by weaving around the lowered barriers.

124 The study concluded that the following circumstances could particularly lead to deliberate disregard of the road traffic light signals:

- At level crossings located next to railway stations, vehicle drivers estimate their waiting time to be much higher than at crossings located elsewhere. Vehicle drivers (especially regular/local users who are aware of increased waiting times) may be more inclined to disobey the road lights to prevent delays to their journeys.

- Vehicle drivers who are familiar with a crossing, because they live or work in close proximity to it, are more likely to perceive the risk at level crossings to be low and deliberately disregard the road lights, particularly if they are under time pressure and feel aggrieved at having to wait for trains to pass.
- Vehicle drivers are also increasingly likely to lose patience and deliberately ignore the road lights if they perceive that the lights show for what they consider to be an unreasonably long time. AOCLs are designed so that no train arrives in less than 27 seconds from the amber light showing (paragraph 18), but slower trains will take longer than this.
- Commercial vehicle drivers in particular may be tempted to 'beat the lights' as they usually work to strict timescales and are focused on reaching their destination.
- Where train speeds are low (20 mph (32 km/h) or less), vehicle drivers may perceive a lower risk, particularly if the railway is only a single track. This results in changes to their behaviour and a greater willingness to cross while the road lights are showing. At AOCLs with slow moving trains, vehicle drivers (and pedestrians) may be inclined to think they can beat the train. By being able to edge forward past a point of safety and look along the railway line, vehicle drivers may believe they have ample time to make a safe crossing in front of a slower train.
- A low frequency of trains reinforces the regular road vehicle driver's expectation that a train will not be seen and may lead them to behave less cautiously at the crossing.

125 The evidence[32] from the use of speed cameras and red light cameras at highway junctions suggests that violations at AOCLs could be reduced by installing RLEE at selected AOCLs, in conjunction with a robust policy of prosecuting offenders. The RLEE which has been installed at level crossings to date has been of limited effectiveness (paragraph 81), but the implementation of RLEE using digital cameras, either permanently installed at selected crossings or using mobile cameras, along with a high profile advertising campaign, could be much more effective. Changes to allow the police to issue fixed penalty notices would also make it easier to prosecute offenders (paragraph 80).

Failure to understand the road traffic light signals

126 The research published in 1996 (paragraph 101) suggests that some vehicle drivers do not understand the meaning of the indications given by the road traffic light signals. This is more likely to be the case with vehicle drivers who are unfamiliar with level crossings. These drivers may fail to respond to the road traffic light signals correctly. The study identified the following error causing mechanisms relating to this:

- the vehicle driver misinterprets the amber light to mean proceed with caution;
- the vehicle driver misinterprets the flashing red lights to mean proceed with caution; and
- the vehicle driver wrongly believes that the road lights continue to display for a period of time after a train has passed.

[32] The National Safety Camera Programme Four-year Evaluation Report, PA Consulting, December 2005, see www.dft.gov.uk.

127 The DfT reported the emerging findings from the more recent research into the awareness of the meaning of traffic signs (including the flashing lights at level crossings), which was still ongoing at the time of publication (paragraph 88). When the respondents who took part in the study were asked what they thought was meant by the wig-wag signals (figure 2), which had been set up at a tunnel portal, 80% of them knew that they mean stop and 12% of them thought they mean caution. The proportion of respondents correctly understanding the meaning of the flashing red lights rose to 91% when asked whether they could proceed past the flashing lights.

128 The fitment of barriers should also provide an unambiguous message that means stop for any driver uncertain of the meaning of the road lights (paragraph 115).

129 The consultant's study advised that appropriate mitigation where AOCLs are to remain is the continuing education of vehicle drivers through regular campaigns and the prosecution of offenders who have crossed against the flashing lights.

130 Germany and Austria have addressed this human factors issue by replacing flashing lights with lights of the configuration that are found at highway junctions and with which road vehicle drivers are already familiar (paragraph 95).

AOCLs with an enhanced likelihood of collision

131 The consultant's study identified AOCLs which have an enhanced likelihood of a collision occurring, between a train and a road vehicle, by taking into account the number of actual collisions and reported incidents. Such AOCLs were identified from the total population of AOCLs listed in appendix D by removing the following categories of data in sequential order:

- AOCLs with no incidents and collisions;
- AOCLs with only one incident or collision;
- AOCLs on roads that give access only to eg industrial premises and likely to be used regularly by a smaller population of familiar users who are a known risk regardless of crossing type;
- AOCLs with an average of less than one incident per year (less than 12 in total since 1998), and no collisions; and
- AOCLs on urban 'A' or 'B' class roads which will usually have a higher amount of traffic increasing the risk proportionately.

The consultants who carried out the study already had a record of the views of Network Rail's staff about specific AOCLs from previous work. As a result, six AOCLs removed by the above process were added back to the list and four further AOCLs were added making a total of 32 AOCLs (these are shown highlighted in appendix D).

132 The RAIB carried out a desktop study of the layout of all AOCLs to try and identify whether certain factors are more prevalent at the 32 AOCLs. In the case of the following factors, no such prevalence was found:

- urban environment;
- rural environment;
- *skew crossings*;
- proximity to a road junction; and
- bends in the road on approach.

However, the following factors were more likely to be present at the 32 AOCLs than the other AOCLs:

- A railway station adjacent to the level crossing (paragraph 124).
- The road at the level crossing is a rural 'A' class road. Such roads are likely to be used by faster moving, more frequent, traffic increasing the possibility of road vehicle drivers failing to observe and react to the road traffic light signals.

133 The AOCL at Garve in the Scottish Highlands (figure 12 and appendix D) had the highest number of reported incidents of any AOCL. It is an acute (skew) crossing located where the busy A835 road crosses the railway from Inverness to Kyle of Lochalsh. Garve railway station is located adjacent to the level crossing, which is characterised by low train speeds (10 mph (16 km/h)) and an infrequent train service. The railway parallels the road on both approaches making it easy for road vehicle drivers to judge whether or not they can cross the railway with a train approaching the crossing and the lights flashing. There are few distracting features in the environment.

Figure 12: The AOCL at Garve in the Scottish Highlands

134 By way of comparison, the AOCL at Forden, near Welshpool, had a very low reported incident record (figure 13 and appendix D). This may be because it has few of the features that are likely to cause vehicle drivers to be distracted or encourage risk taking behaviour. The speed of trains is the maximum permitted at an AOCL (55 mph (90 km/h)), so vehicle drivers who are familiar with the crossing are likely to perceive it as more dangerous than one with low train speeds and are therefore less likely to take risks.

Figure 13: The AOCL at Forden, near Welshpool

The management of risk

135 Network Rail's processes require the use of ALCRM to predict the risk at level crossings supported as necessary by expert judgement, local knowledge or additional risk assessments (paragraph 55). This includes consideration of the record of previous accidents and incidents at crossings.

136 The RAIB's investigation of the accident at Halkirk AOCL on 29 September 2009, which was most likely to have been caused primarily by the car driver's poor eyesight, also found that Network Rail did not fully understand the risk at that crossing; it did not take into account its previous incident and accident record in determining whether risk reduction measures were reasonably practicable. The previous incident and accident history may not be reflected in the ALCRM results and must therefore be considered separately.

137 The table in appendix D shows the ALCRM results for all AOCLs. Those identified as having an enhanced likelihood of collision (highlighted in appendix D) have collective risk levels in the range of ‘2’ to ‘6’, whereas the individual risk levels vary much more widely from ‘D’ to ‘M’ (paragraph 55). The AOCL at Garve (figure 12), for example, with the highest number of reported incidents, has a collective risk level of ‘4’ calculated by ALCRM. By contrast, the AOCL at Melton station, Anglia Route, has a higher collective risk level (‘2’), yet has a relatively good record of accidents and incidents.

138 In some respects, the crossings at Garve and Melton are similar, with both being located on single track rural railways which cross ‘A’ class roads near stations. However, the road and rail traffic levels are considerably higher at Melton (by an approximate factor of five and three respectively), and the speed of trains is higher. These factors have a strong influence on the risk levels calculated by ALCRM. The difference in collective risk levels between Garve and Melton may also be explained because there is more pedestrian traffic at Melton crossing. The contribution of pedestrian risk at Melton AOCL is therefore likely to be higher.

139 Network Rail’s staff consider risk reduction measures from the level crossing risk management toolkit (paragraph 58). This may include upgrading an AOCL to one with better protection, but there is very little likelihood that such an upgrade would pass a cost-benefit analysis, based on Network Rail’s current method of calculation and the costs of new level crossings. However, other risk factors must be considered as part of the process to decide whether work is reasonably practicable; an upgrade may be more easily justified if all the risks are taken into account.

140 An upgrade would be much more likely to be reasonably practicable if it consisted of the cheaper solution of retrofitting half barriers to existing AOCLs, rather than a complete renewal. Network Rail was working on the development of such a system at the time of publication (paragraph 72).

The consequences of accidents

141 The risk to level crossing vehicle users may be reduced by reducing the consequences of collisions between trains and road vehicles. Therefore, the risk at AOCLs which have low train speeds may be lower than at those with higher speeds. However, any benefit through this means must be balanced against a possible increase in violations (increasing the frequency of collisions) which may occur when train speeds are lower (paragraph 124).

142 In order to investigate the consequences of collisions for vehicle drivers, the RAIB commissioned a study on the train speeds for which a car’s occupant has a good chance of surviving being hit by a train. The work carried out by the consultants is described in appendix G.

143 The study found that there is a correlation between train speed and the probability of survival of the occupant(s) of a struck road vehicle. However, there is some uncertainty about the possible outcomes of a collision for a given train speed due to a number of factors such as the type of train involved, the exact location and type of the impact on the road vehicle and the age of the vehicle occupants.

144 Figure 14 in appendix G shows that a collision between a passenger train travelling at 20 mph (32 km/h) and a car would result in a nominal 95% probability of survival (within a range of 80% to 99%) for the car's occupants, whereas for a passenger train travelling at 55 mph (88 km/h) the nominal probability of survival is 65% (within a range of 34% to 88%). The consideration of more accident data, had it been available, could have reduced the degree of uncertainty in the results obtained.

145 In a 20 mph (32 km/h) collision a car occupant is likely to survive and passengers and crew on trains are unlikely to be injured. The train is unlikely to be derailed at this speed.

146 Collisions between trains and larger road vehicles, such as heavy goods vehicles (HGVs), have the potential to cause injuries to train passengers and train crew at lower speeds. The train may also be derailed.

Summary of key issues and conclusions

147 According to data supplied to the European Rail Agency, the UK has the best record on level crossing safety of any of the other member states of the European Union. However, within this overall context, the records show that on a per crossing basis, AOCLs are the highest risk form of level crossing to be found on public roads crossed by the main line railway network in Great Britain. They have also had the highest number of collisions between trains and road vehicles; most of them being cars or light vans.

148 Most of the consequences of collisions at AOCLs have been to vehicle drivers who have driven onto the crossings against the flashing road traffic light signals. Some will have done this deliberately as a violation, whereas others will have done so unwittingly because of lack of attention or distraction. Some other vehicle drivers may have misunderstood the correct meaning of the road traffic light signals (paragraphs 111 to 130).

149 The paragraphs below discuss the most significant issues identified by the RAIB as a result of its investigation.

Human factors issues and related mitigations

150 The human factors issues at AOCLs and related mitigations, identified by the human factors study undertaken for the RAIB, are listed in priority order in appendix F. All the mitigations in appendix F are already in the level crossing risk management toolkit for consideration by Network Rail's staff following risk assessment (paragraph 58), but the selection of appropriate mitigations depends on the correct identification of the human factors issues at each crossing.

Fitment of barriers

151 The most significant issue identified by the human factors study is the absence of a physical barrier to block the road when a train is approaching. Fitting barriers to AOCLs would reduce the number of collisions by reducing the occurrence of violations (by making violations more difficult to commit) and errors, because the presence of a physical barrier across the carriageway greatly reinforces the stop message given by the road traffic light signals.

152 The railway industry had planned to voluntarily phase out all AOCLs by February 2013 (paragraph 77), but Network Rail decided that the expenditure required could not be justified by the level of risk. Consequently, Network Rail had no specific strategy to upgrade AOCLs to an improved form of protection (paragraph 53), although one was starting to emerge, dependent on the successful completion of a development to retro-fit half barriers to AOCLs (paragraph 72).

153 Given the high cost of replacing AOCLs with crossings with barriers, it is unlikely that a case can be made to upgrade every such crossing. It is therefore evident that priority should be given to AOCLs with the highest risk. The RAIB believes that when identifying crossings for upgrade those listed in appendix D, which have an enhanced likelihood of collision, should be specially considered. However, the RAIB also recognises that Network Rail's more detailed assessment of the risks at AOCLs could identify different and/or additional crossings for upgrade (**Recommendation 1**).

154 The RSSB commissioned work, 'the cost of level crossings – an international benchmarking exercise', that reported in June 2006[33], to understand why upgrade costs in the UK were so high. The findings of the research included that there is a very wide variation in the costs of automatic half barriers in the countries studied and that cost elements related to design, installation, testing and project management dominate the overall cost.

155 Network Rail has determined that the upgrading of AOCLs by fitting barriers could be carried out much more cost effectively if a low cost solution was developed to retrofit half barriers to existing AOCL installations, rather than by renewing all the existing equipment. This initiative is likely to have a significant impact on the safety of AOCLs and would allow more to be upgraded. At the time of publication, the development of such a solution was one of Network Rail's initiatives.

Prosecuting those who deliberately disregard the lights

156 Enforcement is a key mitigation measure identified by the human factors study (appendix F).

157 The railway industry estimates that 24% of collisions at level crossings are caused by vehicle drivers who deliberately disregard the road traffic light signals; the figure is likely to be significantly higher in the case of AOCLs (paragraphs 100 and 101).

158 While the fitment of barriers would reduce the propensity of motorists to deliberately disregard the road lights, another effective deterrent is a robust enforcement policy to prosecute offenders. The means to detect offenders can either be by the installation of fixed cameras, or by mobile enforcement cameras (paragraph 71).

159 At the time of this investigation, Network Rail was developing fixed cameras that could capture digital images, but these required approval by the Home Office before they could be installed at crossings. In the meantime, Network Rail was bringing mobile cameras into use attended by suitable publicity.

160 A deterrent to disregarding the light signals is stronger if the penalties available are correspondingly severe and given publicity. In this respect, the greater use of the serious offence of dangerous driving at level crossings, as supported by the DfT (paragraph 92) would increase the deterrent effect of RLEE.

161 The RAIB has concluded that the initiative to develop fixed digital cameras for use at crossings will have a significant impact on level crossing safety and should be prioritised (**Recommendation 4**).

Failure to understand the road traffic light signals

162 The human factors study undertaken for the RAIB proposed that the failure to understand the road traffic light signals at level crossings may be a significant contributor to the risk at level crossings (paragraph 126 and appendix F).

[33] See www.rssb.co.uk.

163 The current form of flashing road traffic light signals at level crossings has been questioned at least since the fundamental review was undertaken into the accident at Lockington on 26 July 1986 (paragraph 26). Suggestions have been made that traffic lights of the same configuration as normal highway junction lights should be provided at level crossings instead of flashing red lights. In Germany and Austria, this change has been implemented, but without a proceed indication (paragraph 95).

164 Recent work carried out in the human factors department at Victoria's Monash University (Australia)[34] concluded that the use at level crossings of standard type traffic lights found at road junctions instead of flashing road lights did not appear to offer any additional safety benefits.

165 The emerging findings from the awareness of the meaning of traffic signs research carried out as part of the DfT's policy review of traffic signs found that 91% of the respondents who took part in the study gave the correct response to the question whether they could proceed past flashing red lights (paragraph 127).

166 Pending the completion of the research by the DfT and that being led by the RSSB (paragraph 78), the RAIB is not making any recommendation for change to address this human factors issue.

The management of risk

167 The RAIB notes that a poor understanding and under-estimate of the risk at a level crossing prevents the identification of appropriate mitigation measures. This makes it more difficult to justify risk reduction by upgrading the crossing. Proper consideration of factors, such as the previous incident and accident record, and other local factors such as the human factors issues present, is necessary to fully understand the risk. The RAIB made a recommendation (recommendation 4) relevant to this in the report on its investigation of the accident at Halkirk AOCL on 29 September 2009:

- Network Rail should issue improved guidance, and brief its staff, on assessing the risk from factors that are not currently included in the All Level Crossing Risk Model when carrying out risk assessments and making decisions on implementing risk reduction measures at crossings. This should include methods to be adopted when taking into account local factors such as the previous incident and accident history.

168 The RAIB concludes that a review of the existing risk assessments of AOCLs would identify whether all the relevant factors have been identified at each, and whether the appropriate mitigation measures have been implemented (appendix F). This is justified because both the RAIB and the ORR have identified that inadequate account is taken of local human factors issues and the history of incidents and accidents in risk assessments by Network Rail's staff (paragraph 86, **Recommendation 2**).

[34] Driver behaviour at rail level crossings: Responses to flashing lights, traffic signals and stop signs in simulated rural driving. Michael G. Lenné, Christina M. Rudin-Brown, Jordan Navarro, Jessica Edquist, Margaret Trotter and Nebojsa Tomasevic. Human Factors Group, Monash University Accident Research Centre, Monash University, Victoria 3800, Australia.

169 While linked to Halkirk recommendation 4, the RAIB also concludes that the process to risk assess AOCLs (and other level crossings) could be improved if Network Rail issued guidance to its staff on how the relevant human factors issues at any specific level crossing may be identified and the associated risks accounted for. This is fundamental to determining the adequacy of existing mitigation measures and understanding whether further mitigation measures are needed (**Recommendation 3**).

Mitigating the consequences

170 In the absence of suitable measures to reduce the likelihood component of risk, an alternative measure is to reduce the speed of trains passing over a crossing such that any collision is unlikely to result in fatal injuries to the occupants of the road vehicle, or any injury to train passengers and crew (paragraph 144).

171 However, the RAIB does not recommend this course of action because:

- Lower train speeds may encourage vehicle drivers to take risks and deliberately pass the road lights when operating (paragraph 124). Although collisions at low train speeds are likely to be of low consequence (paragraph 144), the costs of such collisions, including the trauma suffered by those involved, has to be taken into account.
- Network Rail has already implemented a reduction in the speed of trains at five AOCLs to bring them into compliance with the Stott criteria (paragraph 71).
- Lower train speeds at AOCLs would increase journey times for train passengers. This could make journeys less competitive with other modes and reduce further the economic viability of many of the lines on which AOCLs are installed.
- A reduction in speed does not address the consequences to trains in collisions with large vehicles, which can still be severe at low speed.

Recommendations

172 The following recommendations are made:[35]

1 *The intention of this recommendation is that Network Rail should upgrade the highest risk AOCLs by fitting barriers, or implementing other measures to deliver an equivalent or improved level of safety, such as by closing crossings.*

The RAIB envisages that when identifying those crossings to be upgraded, special consideration should be given to those 32 crossings with an enhanced likelihood of a road vehicle and train collision (listed at appendix D). However, it is anticipated that Network Rail's more detailed assessment of risk, taking into account factors such as the speed of trains, may identify different and/or additional crossings for upgrade.

The RAIB is aware that Network Rail's development of retrofit half barriers should allow a cost effective upgrade, but if this development is not completed and proved in the near future, the upgrading of the highest risk AOCLs should still be implemented based on existing forms of level crossing protection.

In addition, the RAIB is of the view that the implementation of a programme to upgrade AOCL crossings should not be delayed by the need to review and improve existing risk assessment management arrangements (as outlined in Recommendation 3).

Network Rail should immediately implement a programme to upgrade the highest risk AOCLs. The crossings for upgrade should be selected by appropriately skilled personnel, on the basis of factors that include:

- their past record of incidents and accidents;
- an assessment of risk and the safety benefit of the upgrade; and
- the human factors issues present at each.

Upgrades should consist of fitting barriers, or other measures delivering an equivalent or improved level of safety (paragraph 153).

continued

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[35] 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 it to carry out its 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 website www.raib.gov.uk.

2 *In parallel with, but not delaying Recommendation 1, the intention of this recommendation is that Network Rail reviews the existing risk assessments of all AOCLs to identify whether all the relevant human and local factors have been identified and appropriate mitigations implemented. Where this is not the case, a prioritised programme of improvements should be implemented:*

Network Rail should review its risk assessments at AOCLs to identify whether:

- all the relevant human and local factors have been identified (consideration should be given to the human factors issues in appendix F); and
- all appropriate mitigation measures have been implemented.

Where omissions are identified, these should be rectified by a prioritised programme of improvements (paragraph 168).

3 *In parallel with, but not delaying Recommendation 1, the intention of this recommendation is to improve the risk assessment of level crossings by the correct identification of specific human factors issues and other local factors, and the implementation of appropriate mitigation measures:*

Network Rail should review, and as necessary update, its processes, guidance, training and briefing of its staff, on how to identify and assess the specific human and local factors at level crossings, so that it can establish whether further mitigation measures should be implemented (paragraph 169).

4 *The intention of this recommendation is to make sure that the development of digital red light enforcement equipment is not delayed unnecessarily and that it is installed at selected AOCLs with a high incidence of violations:*

In collaboration with the police, Network Rail should, without unnecessary delay, complete the development of digital red light enforcement equipment and install it at selected AOCLs which have high levels of violations (paragraph 161).

Appendices

Appendix A - Glossary of abbreviations and acronyms

ABCL	Automatic barrier crossing, locally monitored
AHB	Automatic half barrier
ALCRM	All level crossing risk model
AOCL	Automatic open crossing, locally monitored
AOCR	Automatic open crossing, remotely monitored
BTP	British Transport Police
CTCC	Central Transport Consultative Committee
DfT	Department for Transport
FWI	Fatalities and weighted injuries
HGV	Heavy goods vehicle
HSE	Health and Safety Executive
ORR	Office of Rail Regulation
RGS	Railway Group Standard
RLEE	Red light enforcement equipment
RSPG	Railway Safety Principles and Guidance
RSSB	Rail Safety and Standards Board
SMIS	Safety Management Information System

Appendix B - Glossary of terms

Braking distance	The distance to stop taken by a train running at a particular speed following a normal (service) brake application.
Confidence limits	A statistical concept that sets the limits within which there would be (say) a 95% probability that something would be true.
Conspicuity	A subjective term which relates to the ability of an object to capture attention.
Contrast	The difference in colour and brightness that makes an object stand out from other objects or its background.
Crossing speed	The maximum permitted speed applicable to a train approaching and then passing over an AOCL/R or an ABCL. The point from which it applies is at the train's braking distance from the crossing at which it can be seen to be clear and the permitted speed may be further reduced by the level of road and rail traffic (the 'Stott criteria').
Driver's crossing indicator	A signal facing train drivers located just before a locally monitored crossing on both rail approaches that displays an intermittent white light when the red road lights are flashing and the mains power supply is available. Otherwise, an intermittent red light is displayed. When the white light is showing, the train may proceed over the crossing; when the red light is showing, the train must stop before the signal.
Effective traffic moment	The number of road vehicles using a crossing converted to the effective daily road user based on the fact that the accident probability is not directly proportional to actual road traffic. The effective traffic moment is the effective daily road user multiplied by the number of trains per day.
European Rail Agency	The organisation responsible for contributing to the implementation of European Community legislation aimed at supporting a competitive, open market for rail by enhancing the level of interoperability of railway systems; and by developing a common approach to safety on the European railway system.
Fatalities and weighted injuries	A concept used by the railway industry when recording safety performance: one fatality is equivalent to ten major injuries, and to 200 minor injuries.
Highway authorities	Organisations that are responsible for the maintenance of public roads. In the case of most AOCLs this will be the local authority eg county council.
Human error analysis	A structured process to determine the causes of human error when carrying out specific tasks.
Human factors	The science of human behaviour and its influence on the occurrence of human errors.

Incident	An event that includes: ● near misses in which a train was close to colliding with a road vehicle; and ● misuse incidents where incorrect use of a level crossing occurred but the train was still some distance away.
Mental model	Mental models are internal mental representations of an external reality. People develop a mental model of how to use a level crossing from their prior experience of using similar or comparable crossings (or road junctions), from instructions or by observing the behaviour of other users
Office of Rail Regulation	The safety regulator for the railways in Great Britain.
Open crossing	A level crossing that is unprotected either by barriers or road traffic light signals. Vehicle drivers must give way to trains.
Railway Group Standards	Documents that mandate technical and operational requirements to members of the railway group (Network Rail, train operators etc).
Reasonably practicable	Determining whether something is reasonably practicable involves weighing the risk on the one hand against the sacrifice (money, time or trouble) needed to avert the risk. This is more than comparing the safety benefit of a measure with its cost (a cost benefit analysis) because the risk reduction measure should be implemented unless it requires a sacrifice that is grossly disproportionate.
Rumble strips	A road safety feature to alert vehicle drivers to a hazard ahead by means of vibration and audible rumbling.
Safety Management Information System	A computer database used by the railway industry to record incidents and accidents.
Safety risk model	A computerised model managed by the RSSB which is a quantitative representation of the potential accidents resulting from the operation and maintenance of Britain's rail network.
Skew crossing	A crossing where the angle measured in an anti-clockwise direction from the road to the railway is more (an obtuse skew) or less (an acute skew) than a right angle.
Traffic moment	The number of road vehicles using a crossing multiplied by the number of trains passing in a given period.
User-worked crossing	A private level crossing, usually protected by outward opening farm type gates. Many are fitted with telephones which users crossing in a vehicle, or with animals, are required to use to obtain the permission of the signaller to cross. Some are fitted with red/green miniature stop lights.

Appendix C - ORR's position statement on AOCLs

The triple fatality at an automatic open level crossing locally monitored (AOCL) in Halkirk, Caithness in September has understandably increased concern over the safety of this type of level crossing.

AOCLs are protected by road traffic signals ("wig-wags") and audible warnings, but have no barriers. There are currently 128 AOCLs across Britain.

The Office of Rail Regulation (ORR) acknowledges that major incidents at level crossings are rare. Our overall policy on level crossings is described at www.rail-reg.gov.uk/server/show/nav.1564. In light of the incident at Halkirk, and some previous incidents, we have reviewed our approach to this type of crossing, and developed a three-phase action plan.

Phase one:

- We have asked Network Rail to review line speed at AOCLs, to ensure that train speeds do not exceed recognised industry guidelines.
- We have made it clear to Network Rail that we encourage innovative solutions to improving level crossing safety.
- We will complete our validation, as appropriate, of actions taken in respect of the Rail Accident Investigation Branch reports into a near-miss incident at Llanbadarn ABCL and a fatality at Wraysholme AOCL.

Phase two:

- We have asked Network Rail to develop a prioritised programme for upgrading AOCLs, involving local communities and highway authorities in the prioritisation process.
- We have also asked that Network Rail replace all remaining filament "wig-wag" lamps at AOCLs with LED light units.
- We have proposed that whenever possible or appropriate Network Rail upgrade AOCLs that are scheduled for like-for-like renewal to barrier crossings.
- We will complete the revision of our guidance on level crossings (RSPG2E) (consultation draft expected January 2010).

Phase three:

- We will ensure that Network Rail's upgrade programme is delivered.
- We will inspect AOCLs (including those on minor/heritage railways) in our next year's work plan, to assure ourselves of the robustness of risk management processes and compliance with the relevant Orders.
- We will put forward a submission to the Law Commissions' review of level crossings law that encourages the need to consider protective arrangements at AOCLs.

Appendix D - List of operational AOCLs on Network Rail's managed infrastructure

Name of crossing	Route	Mileage	Grid ref	Signal box/ control centre area	No. of lines	Crosses	Max Train Speeds** in each up/down direction	ALCRM score	No. of reported incidents from 1998 to January 2010	No. of collisions from 1998 to January 2010	No. of collisions from 1990 to January 2010
Althorne	A	40.31	TQ906979	Liverpool St	1	Estate access	20*	4D	32		
Blaxhall	A	86.31	TM348577	Saxmundham	1	Occupation	45	4D	1	1	1
Brampton	A	104.46	TM412834	Saxmundham	1	Minor road (rural)	40	3D	4	1	3
Dawdys	A	114.75	TM510918	Saxmundham	1	Minor road (rural)	55	4D	3		
Ferry Lane	A	79.04	TM276488	Saxmundham	2	Foreshore access	15	4D	11		
Haywards	A	79.07	TM276488	Saxmundham	2	Foreshore access	15	4D	10	1	1
Hydrocracker	A	29.04	TQ719816	Upminster	1	Wharf access	15	6F	1		
Laundry Lane	A	0.29	TL469587	Cambridge	1	Factory access	10	4I	29		
Lime Kiln	A	79.29	TM278494	Saxmundham	1	Foreshore access	15	4D	7		
Melton	A	80.31	TM287504	Saxmundham	1	A1152 (rural road)	20/stop	2J	9		
North Green	A	93.27	TM399664	Saxmundham	2	Minor road (rural)	45	4D	1		
Sun Wharf	A	79.31	TM278492	Saxmundham	1	Foreshore access	15	5E	5		
Wenhaston	A	99.52	TM393764	Saxmundham	1	Minor road (rural)	45/40	3D	3		
Weston	A	106.31	TM414863	Saxmundham	1	Minor road (rural)	55/40	3D	2		
Willow Marsh	A	96.09	TM405708	Saxmundham	2	Minor road (rural)	40/30	5D			
Brookland	KT	67.21	TQ998263	Ashford	1	A259 (rural road)	5	7M	1		
Winchelsea	KT	73.16	TQ900184	Rye	1	Minor road (rural)	25	4D	16	1	1
Wyborne	KT	32.06	TQ773751	Ashford	1	Occupation	15	8F	1		
Battersby Road	LNE	12.46	NZ594079	Nunthorpe	1	Minor road (rural)	15/20	6M	3		
Brewster Lane	LNE	3.06	TF482598	Thorpe Culvert	2	Minor road (rural)	50	4D	1		
Dawes Lane	LNE	0.32	SE901115	Scunthorpe	1	Factory access	10	4I	5		
Field Lane	LNE	66.66	SE623222	Hensall	1	Minor road (rural)	40	6H			
Gowdall Lane	LNE	66.51	SE619223	Hensall	1	Minor road (rural)	40	5D			
Graythorpe	LNE	0.25	NZ513280	Greatham	1	Factory access	stop	7M			
Guisborough Road	LNE	14.56	NZ618099	Nunthorpe	1	Farm access	30/35	5E			
Kiln Lane	LNE	0.51	TA213142	Immingham E Jc	1	Industrial road	20	5H	3		
Lymn Bank	LNE	1.46	TF467617	Thorpe Culvert	2	Minor road (rural)	45/50	4D	2		
Matt Pitts Lane	LNE	3.62	TF491592	Wainfleet	2	Minor road (rural)	30/50	4D	3		
Monsanto/BASF	LNE	1.46	NZ534241	Belasis Lane	1	Industrial road	stop	13M	1		
Morton Carr	LNE	4.68	NZ546147	Nunthorpe	1	Occupation	35/25	6E			
North Tees	LNE	4.19	NZ511226	Belasis Lane	1	Industrial road	15	6L			
Phillips No. 2	LNE	2.16	NZ539248	Belasis Lane	1	Industrial road	stop	6M	1		
Phillips No. 3	LNE	2.22	NZ539250	Belasis Lane	1	Industrial road	stop	6K	3		
Rohm Haas	LNE	1.42	NZ533241	Belasis Lane	1	Industrial road	stop	5M	9		
Seacroft	LNE	8.02	TF547620	Skegness	2	Occupation	50	5D	1		
Seal Sands	LNE	4.71	NZ511236	Belasis Lane	1	Industrial road	stop	4L	4		
Seal Sands Chemicals	LNE	2.11	NZ539247	Belasis Lane	1	Industrial road	stop	8M	2		
Seal Sands Road	LNE	2.18	NZ539249	Belasis Lane	1	Industrial road	stop	6K			
Snaith	LNE	68.08	SE642223	Goole	1	A1041 (rural road)	stop/20	4H	2	1	2
Thorpe	LNE	68.43	SE580105	Doncaster	2	Minor road (rural)	25	5E	8		
Burneside Lower	LNW	4.11	SD501959	Carlisle	1	Minor road (rural)	5	5M	13		
Bush-on-Esk No. 2	LNW	1.07	NY361682	Carlisle	1	MoD depot access	5/stop	8L	1		
Green Road	LNW	42.34	SD189838	Foxfield	2	Minor road (rural)	20/50	4D	2		
Launton	LNW	17.12	SP618237	Claydon L&NE Jct	1	Minor road (rural)	30	5G			
Regent Road	LNW	5.53	SJ334949	Edge Hill	1	Industrial road	10	4M	4	1	1
Sandscale	LNW	31.44	SD197737	Park South	1	Factory access	10/35*	4D	7	2	2
Turton	LNW	15.19	SD730156	Manchester Picc	1	Factory access	25/10	6D	5		
Whitbeck	LNW	49.55	SD116838	Silecroft	2	Occupation	55	5D	2		
Wraysholme	LNW	12.42	SD382754	Grange-o-Sands	2	Minor road (rural)	50	4D	7	2	2
Toton No. 4	M&C	122.24	SK484358	Trent	2	Depot access	15	4F	3		
Achterneed	Sc	4.55	NH489597	Inverness	1	Minor road (rural)	20/40	4D			
Ardrossan Harbour	Sc	31.25	NS227419	Paisley	1	B780 (urban road)	stop/15	4H	47	1	1
Ardrossan Princes St	Sc	31.06	NS231421	Paisley	1	B714 (urban road)	15/stop	2G	32	2	3
Balnacra	Sc	22.12	NG984464	Inverness	1	A890 (rural road)	40/20	4D	20	1	1
Brora	Sc	90.31	NC906038	Inverness	1	Minor road (urban)	15	4H	36	1	1
Bunchrew	Sc	3.58	NH631457	Inverness	1	Minor road (rural)	35	4D	10	1	1
Corpach	Sc	1.33	NN096768	Banavie	1	Wharf access	10	4F	12	1	1
Dalchalm	Sc	91.31	NC905053	Inverness	1	Minor road (rural)	50	5E	7	1	1
Delny	Sc	34.79	NH745725	Inverness	1	Minor road (rural)	35*	4D	5	1	2
Dingwall Middle	Sc	0.67	NH546592	Inverness	1	A862 (urban road)	20	3G	74	3	6
Dingwall No. 1	Sc	0.57	NH549593	Inverness	1	Minor road (urban)	20	4F	19		2
Dingwall No. 2	Sc	1.05	NH544592	Inverness	1	A832 (urban road)	20	3G	31		
Forsinard	Sc	125.67	NC890424	Inverness	1	A897 (rural road)	10	6M	1		
Garve	Sc	11.71	NH394614	Inverness	1	A835 (rural road)	10/stop	4K	135		
Halkirk	Sc	145.59	ND132583	Inverness	1	Minor road (rural)	35*	4E	6	2	4
Hoy	Sc	0.72	ND148603	Inverness	1	B874 (rural road)	40	3E	8	1	1
Kinbrace	Sc	118.25	NC862316	Inverness	1	B871 (rural road)	40/20	4E	5	1	1
Kirkton	Sc	82.44	NH798985	Inverness	1	Occupation	55	6E	1		
Lairg	Sc	67.11	NC584041	Inverness	1	A836 (rural road)	15/stop	4M	36	1	1
Morar	Sc	36.56	NM678929	Banavie	1	B8008 (rural road)	10	5G	2		
Rosarie (AOCR)	Sc	27.2	NJ383502	Keith	1	Minor road (rural)	60	5D			

Name of crossing	Route	Mileage	Grid ref	Signal box/ control centre area	No. of lines	Crosses	Max Train Speeds** in each up/down direction	ALCRM score	No. of reported incidents from 1998 to January 2010	No. of collisions from 1998 to January 2010	No. of collisions from 1990 to January 2010
Rovie	Sc	76.35	NC718024	Inverness	1	Minor road (rural)	25	5E			
Strathcarron	Sc	45.77	NG942420	Inverness	2	A890 (rural road)	15/stop	4J	23		
Watten	Sc	153.68	ND250557	Inverness	1	B870 (rural road)	45*	4D	8		
Allens	W	94.42	SH582087	Machynlleth	1	Car'van site access	25/40	9E			
Bennar Fawr	W	105.04	SH583224	Machynlleth	1	Minor road (rural)	40	4D	2		
Borth Capel Soar	W	87.59	SN609894	Machynlleth	1	Minor road (rural)	50/35	4D	10		
Brynmarlais	W	12.28	SN621143	Pantyffynnon	1	Minor road (rural)	25	4E	1		
Bucknell	W	8.01	SO355736	Pantyffynnon	1	B4367 (rural road)	stop/10	4I	93	1	1
Chapel	W	300.56	SW842606	Goonbarrow Jn	1	Minor road (rural)	25/35	6E	1	1	1
Coswarth	W	298.48	SW873595	Goonbarrow Jn	1	Minor road (rural)	30/10	6F	1	1	2
Dolau	W	25.24	SO139671	Pantyffynnon	1	Minor road (rural)	10/stop	6M	2		
Fairbourne	W	97.71	SH615128	Machynlleth	1	Minor road (urban)	stop/20	3D	21	3	3
Ffairfach	W	17.16	SN628212	Pantyffynnon	1	A483 (rural road)	10/stop	4L	40		
Filton Tip	W	0.34	ST609796	Bristol	1	Depot access	10	6M	4		
Fishguard Harbour	W	288.11	SM951389	Clarbeston Road	2	Station access	stop/15	5I	38		
Forden	W	38.21	SJ218006	Machynlleth	1	Minor road (rural)	45/55	6D	2		
Fountain	W	1.05	SS882834	Tondu	1	Minor road (rural)	20	6H	4		
Gwaen-cae-Gurwen	W	16.15	SN702121	Pantyffynnon	1	A474 (rural road)	stop	4J			
Halloon	W	296.22	SW907595	Goonbarrow Jn	1	Minor road (rural)	15/10	4M	12	2	2
Iron Acton	W	1.66	ST676833	Bristol	1	Minor road (rural)	15	7H			
Langford Lane	W	20.52	SP576203	Oxford	1	MoD depot access	35/30	6E	1		
Llandybie	W	13.08	SN620155	Pantyffynnon	1	Minor road (rural)	stop/15	4M	13	1	1
Llangadog	W	23.62	SN700286	Pantyffynnon	1	A4069 (rural road)	stop/10	4M	72		
Manorbier	W	279.06	SS069993	Whitland	1	Minor road (rural)	stop/10	5K	9		
Molinnis	W	287.76	SX018593	Goonbarrow Jn	1	Minor road (urban)	5/30	6F	1		
Oddington	W	24.11	SP542159	Oxford	1	Occupation	35	8E	1		
Plassers	W	6.71	TO162807	Slough New	2	Factory access	20	3D	54	1	2
Raven	W	14.71	SN687132	Pantyffynnon	1	Minor road (rural)	10	5J		1	1
Rhiwderin	W	1.35	ST260874	Park Jn	1	Minor road (urban)	10	4H	5		
Salmon Pool	W	180.09	SX827990	Crediton	2	Minor road (rural)	25	5E	4		
Shiplake	W	33.66	SU776797	Reading	1	Minor road (urban)	stop/20	3D	120	1	1
Speedway (Gds bch)	W	244.27	SX504556	Plymouth	1	Depot access	10	8J	3		
Talwrn Bach	W	107.67	SH579268	Machynlleth	1	Minor road (rural)	30	3D	37		
Tregoss Moor	W	292.32	SW961609	Goonbarrow Jn	1	Minor road (rural)	20	6E	6		
Trencreek	W	301.35	SW829608	Goonbarrow Jn	1	Minor road (rural)	20/10	3G	7		
Ty-Uchaf	W	14.11	SN676136	Pantyffynnon	1	Minor road (urban)	10	5K			
Umberleigh	W	204.32	SS609234	Crediton	1	Minor road (rural)	25	4D	2		
Waterton	W	1.13	SS924779	Cowbridge Road	1	A48 (dual carriageway)	5	6M	3		
Weig Lane	W	54.26	SO018929	Machynlleth	1	Minor road (rural)	30/35	5D	5		
Canute Road	WX	79.02	SU426110	Eastleigh	1	B3038 (urban rd)	stop	3I	11		
Chapel Road	WX	78.52	SU428116	Eastleigh	1	Minor road (urban)	10	3H	6	1	1
Hamworthy Park	WX	117.21	SY997903	Hamworthy	1	Minor road (urban)	10	5J	1		

Notes to above table

Key to Network Rail routes:

- A – Anglia
- KT – Kent
- LNW – London North Western
- LNE – London North Eastern
- M&C – Midlands and Continental
- Sc – Scotland
- W – Western
- WX – Wessex

The up direction is generally towards London and the down direction is generally away from London.

* AOCLs which have had their crossing speeds reduced following the recent assessment of all AOCLs against the Stott criteria on road and rail traffic levels (paragraph 71).

** At some AOCLs, lower speeds apply to freight trains.

The ALCRM score is made up of two components: the collective risk on a scale of 1 (highest) to 13 (lowest), and the individual risk on a scale of A (highest) to M (lowest) (paragraph 55).

AOCLs highlighted in grey in the table above are those that have been identified as having an enhanced likelihood of a collision occurring between a train and a road vehicle (paragraph 122).

The ALCRM data in the table is by courtesy of Network Rail and the data on reported incidents and collisions is from SMIS and by courtesy of the RSSB.

Appendix E - Key findings from the literature review undertaken as part of the human factors study of AOCLs

Documents included in the review

Title	Author	Publication	Year	Primary Country of Origin
Vehicle Driver behaviour at Level Crossings	TRL (Pickett, M.W. & Grayson, G.B.)	HSE Contract research report no. 98/1996	1996	GB
A Review of Risks at a Selection of Automatic Open Level Crossing (AOCL) Sites and Identification of Safety Improvements for Various Site Conditions	TRL	Railtrack	2002	GB
RAIB - Halkirk AOCL Accident Investigation	Atkins Rail	RAIB	2010	GB
Driver Behaviour at Flashing Light, Rail-Highway Grade Crossings	Aberg, L.	Accident Analysis & Prevention, 20(1), 59-65.	1987	Sweden
Car Driver Behaviour at Flashing Light Railroad Grade Crossings	Tenkink, E. & Van der Horst, R.	Accident Analysis and Prevention, 22, 229-239.	1990	Netherlands
An Observational Study of Driver Behaviour at a Protected Railroad Grade Crossing as Trains Approach	Meeker, F.L. & Barr, R.A.	Accident Analysis and Prevention, 21(3), 255-262.	1988	USA
An Analysis of Video-Recorded Driver Behaviour at Level Railway Crossings	Wilde, G.J.S., Hay, M.C. & Brites, J.N.	Proceedings of the 22nd Annual Conference of the Human Factors Association of Canada, November 26-29, 1989.	1989	Canada
Visual Factors in Rail-Highway Grade Crossing Accidents.	Mortimer, R.G.	Automotive Engineering & Litigation. Volume 2, Edited by G.A. Peters and B.J. Peters. Garland Law Publishing, New York.	1991	USA
Conspicuity of Flashing Warning Lights at Dutch Open Level Crossings	Tenkink, E. & Walraven, J.	Vision in Vehicles – II, Edited by A.G. Gale, M.H. Freeman, C.M. Haslegrave, P. Smith and S.P. Taylor. North-Holland, Amsterdam.	1988	Netherlands
Human Factors Assessment of the Risks Associated With MWL Crossings (T269)	Human Engineering Ltd	RSSB	2004	GB
T333 - Report No. 1. Assessment of the Effectiveness of Existing Red Light Enforcement Equipment at Level Crossings	Atkins Rail	RSSB	2007	GB
Updating the Level Crossing Risk Management Toolkit	Human Engineering Ltd	RSSB	2010	GB
The Cost of Level Crossings - An International Benchmarking Exercise (T364)	Arthur D. Little	RSSB	2006	GB
Another Train Coming Warnings at Automatic Level Crossings	Arthur D. Little	Research Paper	2009	GB
Analysis of Fatalities at Level Crossings April 1994 - March 2004	Mouchel Parkman	HSE	2005	GB
SELCAT D3: Report on Risk Modelling Techniques for Level Crossing Risk and System Safety Evaluation	Safer European Level Crossing Appraisal and technology (SELCAT)	SELCAT	2008	GB (RSSB Led)

Main findings

Behavioural factors

- Outside of working hours (08:00 hrs – 16:00 hrs), there are lower levels of accidents. This may be because drivers feel less time pressure and are less inclined to take risks.
- From witness statements taken during a study for the Health and Safety Executive[36], the majority of road vehicle drivers who had been observed crossing at automatic crossings when the road traffic light signals were activated, it was found that over half of the vehicle drivers concerned were unwilling to stop and therefore crossed deliberately when the lights were flashing.
- In instances where there are queues of traffic leading to level crossings, group mentality is often observed. This is where motorists travelling in a 'platoon' of traffic appear to follow the car in front of them without fully assessing the risk for themselves.
- Vehicle drivers familiar with crossings (especially those in the local area) are more likely to take risks at level crossings as they have become habituated to the crossing procedure, time required to cross, etc. Furthermore, if risk taking behaviour at level crossings is undertaken frequently (ie crossing while the warning lights are active), and results in a successful crossing in front of a train, this will constitute reinforcement, making the same behaviour more likely in the future.
- Accidents that have occurred due to deliberate crossing violations have been caused by vehicle drivers underestimating the time taken to cross combined with overestimating the time between the activation of the road traffic light signals and the arrival of a train.
- There is currently a limited focus on level crossings in the Highway Code and driving tests. Therefore vehicle drivers may not understand certain aspects of the crossing procedure. For instance, some vehicle drivers thought it was legal to cross during the amber light phase and that the lights at level crossings do not indicate that vehicle drivers must stop but rather they act to inform vehicle drivers that they need to make a decision about whether or not to cross.

Environmental/Physical

- Environmental factors make the safety margin more difficult to judge for motorists approaching AOCLs. Poor weather, night time driving, poor lighting conditions and obstructed views of the road traffic light signals (eg by foliage) all reduce the amount of information available to the driver to determine subjectively the risk associated with crossing.
- The position of the crossing geographically in the local area can have an effect on risk taking behaviour, for example crossings located at or near stations may be subject to longer closure times while trains are stopped at platforms and this may encourage road users to take risks and continue their journey. Users may also misinterpret the road traffic light signals to mean that the crossing is closed for a train they can see at a platform rather than another approaching train. Orientation of the crossing or curvature of track may influence a user's decision to cross against the warnings based on what the user can see.

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[36] Vehicle Driver Behaviour at Level Crossings, HSE Contract Research Report No. 98/1996, HSE Books, ISBN 0-7176-1093-4, see www.hse.gov.uk.

- The AOCL's layout/markings may influence the user's decision to stop and wait in a position of safety. For instance, AOCLs with a yellow box with hatchings across the unsafe parts of the road to be stopped at may influence drivers not to edge further across the track.

Appendix F - List of human factors issues relating to AOCLs in order of importance (as assessed by the RAIB's human factors consultants)

	Human factor issue	Mitigation	Current status within the railway industry	Further action that could be taken
1	The lack of a physical barrier can result in increased risk taking behaviour later in the crossing cycle when vehicle drivers are at greatest risk of being hit by a train	• Fit barriers • Prosecute those who deliberately disregard the flashing lights • Carry out targeted education campaigns	• There is no specific strategy to fit barriers • Regular enforcement initiatives are carried out by BTP • Red light enforcement cameras are being developed • Regular campaigns are run in the media and more locally by Network Rail	• Upgrade crossings with barriers (including the use of barriers that can be retrofitted to AOCLs) • Install red light enforcement cameras at selected crossings • Implement a more robust policy (including penalties) against offenders
2	Reduced conspicuity of the road traffic light signals may result in approaching vehicle drivers failing to see them operating	• Fit long hoods where falling sunlight is a problem • Fit LED road signals • Optimise the alignment of the road signals • Reduce the approach speed of road traffic	• Long hoods are fitted at crossings where falling sunlight has been identified as a problem • LED road signals have been fitted to all AOCLs • The maintenance of the correct alignment of the road signals is covered by existing inspection and maintenance procedures • There is no specific initiative to look at reducing road approach speeds	• Implement recommendations 5 (maintenance of alignment) and 6 (fitment of long hoods) made in the RAIB's report on its investigation of the accident at Halkirk level crossing, Caithness, on 29 September 2009 (report 16/2010) • Reduce the road approach speeds at AOCLs in conjunction with local authorities
3	Vehicle drivers deliberately disregard the road traffic light signals when they are operating. Such risk taking behaviour is encouraged by: • AOCLs located near stations • Vehicle drivers' familiarity with a crossing • Vehicle drivers' perception that road closure times are too long; particularly if some are long due to slower trains such as freight trains • High volumes of commercial road traffic • Single track railways • Low train speeds • Low train frequencies • Crossings located on vehicle shortcuts • Crossings on roads that provide sole access to premises • Road junctions close to AOCLs • AOCLs located close to farms generating farm traffic	• Red light enforcement cameras • Robust policy on the prosecution of offenders • Education campaigns	• Regular enforcement initiatives are carried out by BTP • Red light enforcement cameras are being developed • Regular campaigns are run in the media by Network Rail	• Install red light enforcement cameras at selected crossings • Implement a more robust policy (including penalties) against offenders
4	Crossing users fail to understand the meaning of the flashing road traffic light signals	• Education campaigns	• Regular campaigns are run in the media and more locally by Network Rail	• Continue the regular education campaigns

	Human factor issue	Mitigation	Current status within the railway industry	Further action that could be taken
5	Vehicle drivers fail to stop in response to the amber light	• Reduce the road approach speed • Education campaigns	• There is no specific initiative to look at reducing road approach speeds • Regular campaigns in the media and more locally are run by Network Rail	• Reduce the road approach speeds at AOCLs in conjunction with local authorities
6	Crossing users have an incorrect '*mental model*' of how a crossing works resulting in crossing when the lights are flashing	• Reduce the road approach speed • Education campaigns	• There is no specific initiative to look at reducing road approach • Regular campaigns in the media and more locally are run by Network Rail	• Reduce the road approach speeds at AOCLs in conjunction with local authorities
7	Foliage obscures information on the approach to and at the level crossing and/or reduces the overall conspicuity of the level crossing ahead	• Vegetation management to ensure visibility is maintained	• Vegetation management is already covered by Network Rail's inspection and maintenance processes	• Continuation of existing processes
8	Vehicle drivers are distracted on approach to crossings impairing their performance	• Reduce the road approach speed • Installation of *rumble strips* • Vegetation management • Optimisation of the position of the flashing lights • Identify potential distractions	• There is no specific initiative to look at reducing road approach speeds • There are no AOCLs where rumble strips are fitted • Vegetation management is already covered by Network Rail's inspection and maintenance processes • The position of the flashing lights is already covered by Network Rail's inspection and maintenance processes • The correct alignment of the flashing lights is already covered by inspection and maintenance procedures	• Reduce the road approach speeds at AOCLs in conjunction with local authorities • Identify crossings to fit with rumble strips and progress with local authorities • Continuation of existing processes
9	Visual clutter on the approach to AOCLs impairs vehicle drivers' ability to detect level crossing ahead	• Installation of rumble strips • Vegetation management • Optimisation of the position of the flashing lights • Reduce road approach speed • Fit LED road signals	• There are no AOCLs where rumble strips are fitted • Vegetation management is already covered by Network Rail's inspection and maintenance processes • The correct alignment of the flashing lights is already covered by inspection and maintenance procedures • There is no specific initiative to look at reducing road approach speeds • LED road signals have been fitted to AOCLs	• Identify crossings to fit with rumble strips and progress with local authorities • Reduce the road approach speeds at AOCLs in conjunction with local authorities
10	Sign pictogram warning vehicle drivers of AOCL ahead does not provide useful information concerning the crossing	• Ensure signage is appropriate • Education campaigns	• The form of signage and signals at level crossings is the subject of an RSSB led research project • Regular campaigns in the media and more locally are run by Network Rail	• Consider the results of the research • Continue regular education campaigns which should be targeted

	Human factor issue	Mitigation	Current status within the railway industry	Further action that could be taken
11	A higher proportion of elderly drivers in the local population may give rise to a greater likelihood of errors being made and the lights passed when operating	• Installation of rumble strips • Reduce the road approach speed • Fit red strip LEDs or red cat's eyes along crossing stop lines	• There are no AOCLs where rumble strips are fitted • There is no specific initiative to look at reducing road approach speeds • There is no current initiative to use red strip LEDs or red cat's eyes along stop lines	• Reduce the road approach speeds at AOCLs in conjunction with local authorities • Identify crossings to fit with rumble strips and progress with local authorities • Consider the use of red strip LEDs or red cat's eyes
12	Location of AOCLs near major roads increases risk taking behaviour and may lead to 'blocking back' onto the crossing	• Enforcement • Ensure signage is appropriate • Reduce signage clutter	• Regular enforcement initiatives are carried out by BTP • There is no specific initiative to review signage	• Continuation of existing processes • Review signage
13	Environmental features such as bends, hills etc increase the risk of error by vehicle drivers	• LED road signals • Installation of rumble strips • Reduce the road approach speed • Review signage • Maintain vegetation clearance	• LED road signals have been fitted • There are no AOCLs where rumble strips are fitted • There is no specific initiative to look at reducing road approach speeds • The clearance of vegetation is covered by existing processes	• Identify crossings to fit with rumble strips and progress with local authorities • reduce the road approach speeds at AOCLs in conjunction with local authorities
14	Level crossings on rural roads lead to a reduced awareness of the level crossing ahead	• Reduce the road approach speed • Cut back vegetation • Fit LED road signals • Installation of rumble strips	• There is no specific initiative to look at reducing road approach speeds • The clearance of vegetation is covered by existing processes • LED road signals have been fitted • There are no AOCLs where rumble strips are fitted	• Reduce the road approach speeds at AOCLs in conjunction with local authorities • identify crossings to fit with rumble strips and progress with local authorities
15	See-through effect results in vehicle drivers failing to see the crossing	• Reduce the road approach speed • Install red strip LEDs or cat's eyes along stop lines • Cut back vegetation • Installation of rumble strips	• There is no specific initiative to look at reducing road approach speeds • Installing red strip LEDs or cat's eyes • The clearance of vegetation is covered by existing processes • There are no AOCLs where rumble strips are fitted	• Reduce the road approach speeds at AOCLs in conjunction with local authorities • Consider the use of red strip LEDs or red cat's eyes • Identify crossings to fit with rumble strips and progress with local authorities
16	Road descents to a level crossing increases risk taking behaviour	• Reduce the road approach speed • Enforcement • Fit vehicle activated signs to warn of overspeed • Review and provide enhanced signage	• There is no specific initiative to look at reducing road approach speeds • Regular enforcement initiatives by BTP • The use of vehicle activated signs is a new initiative • There is no specific review currently undertaken of the signage in the vicinity of level crossings	• Reduce the road approach speeds at AOCLs in conjunction with local authorities • Implement a more robust policy (including penalties) against offenders • Assess possible fitment of vehicle activated signs • Review the signage at and in the vicinity of level crossings

Appendix G - The consequences of collisions on level crossings

1 The RAIB asked consultants to advise on the approximate train speeds where a collision with a car has a good chance of being survivable for the car's occupants. The consultants carried out three tasks to help provide this information:

- Task 1: train accident and data analysis using information from SMIS on previous collisions between trains and cars on level crossings. A statistical process was then used to produce curves of fatality risk against train impact speed.
- Task 2: basic calculations to estimate the train to car impact speeds that are equivalent to regulatory and consumer tests for cars in which the occupants have a good chance of surviving a collision.
- Task 3: analysis of data on side-on collisions between heavy goods vehicles (HGVs) and cars and its relevance to collisions between trains and cars.

Task 1, train accident and data analysis

2 The consultants used data from 165 level crossing collisions that occurred from the beginning of 2000 to March 2010. The number of collisions subject to analysis was reduced to 69 collisions (all trains) and 60 collisions (passenger trains) by removing collisions that involved vehicles other then cars or light vans, or collisions that were not side-on (eg a car hit the side of a train or the collision was a glancing one). Fatality risk curves against train impact speed were produced for all train types and passenger trains. The fatality risk curve for passenger trains (most trains on lines that have AOCLs are passenger trains) is presented in figure 14.

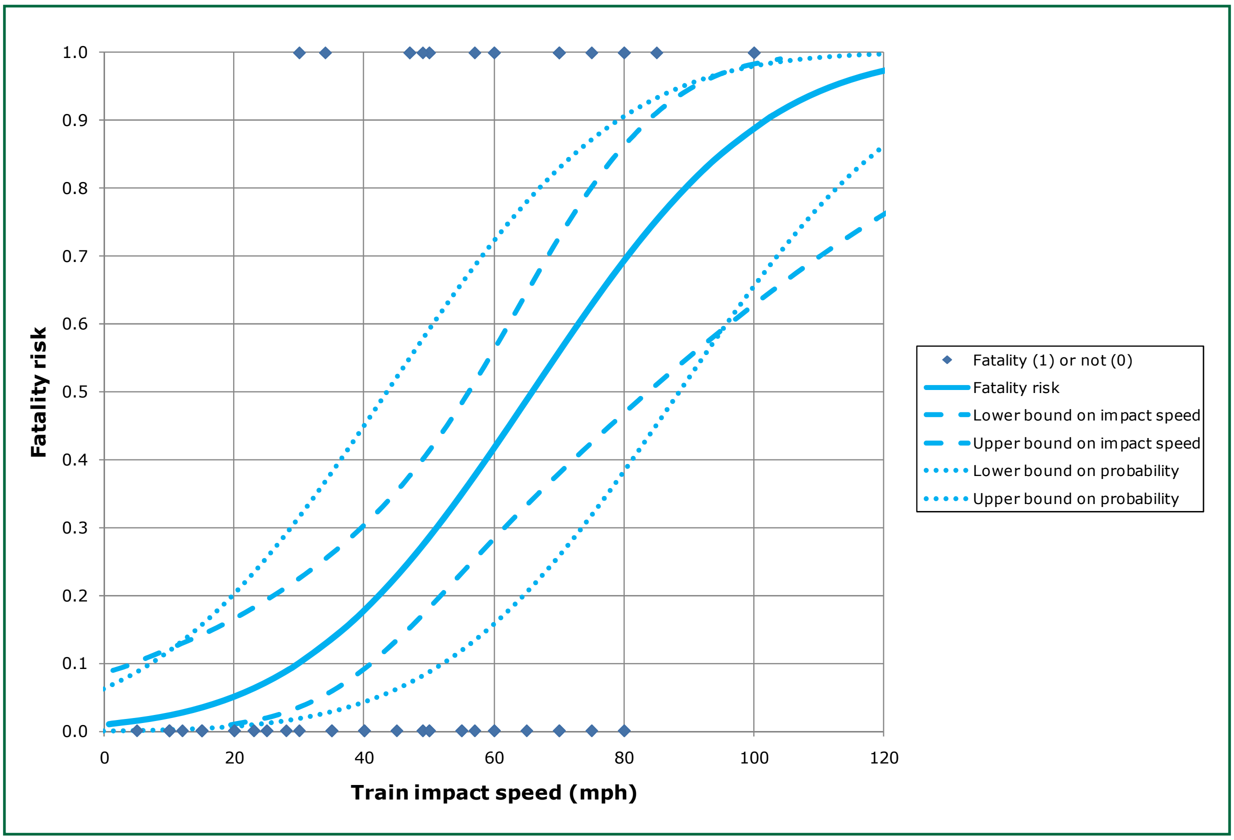

Figure 14: Fatality risk to occupants of car/van occupants by passenger train impact speed

3 The fatality risk curves produced are nominal 'best fits' for the data, but there is a high degree of uncertainty relating to them. Figure 14 contains two sets of 95% *confidence limits*. If, for instance, the impact speed is required that gives a 20% fatality risk, the 95% confidence limits on this value are obtained by reading horizontally on the 0.2 fatality risk line between the upper and lower confidence limit bounds on impact speed. These are represented by the dashed lines in figure 14. However, if the fatality risk is required for an impact speed of say 40 mph (64 km/h), the 95% confidence limits on this value are obtained by reading vertically on the 40 mph line between the upper and lower confidence limit bounds on probability. These are represented by the dotted lines in figure 14.

4 Estimates of the fatality risk and confidence limits for train impact speeds between 20 mph (32 km/h) and 55 mph (88 km/h) are given in table 4.

Train type	**Train impact speed mph (km/h)**	**Nominal fatality risk (%)**	**Range of fatality risk within 95% confidence limits (%)**
All train types	20 (32)	6	1 – 24
	30 (48)	12	2 – 35
	40 (64)	19	5 – 47
	50 (80)	29	9 – 60
	55 (88)	35	12 – 66
Passenger trains only	20 (32)	5	1 – 20
	30 (48)	10	2 – 31
	40 (64)	18	4 – 45
	50 (80)	29	9 – 59
	55 (88)	35	12 – 66

Table 4: Fatality risks and confidence limits on the probability for train impact speeds for all train types and for passenger trains only

5 Table 4 shows that a collision at 55 mph (88 km/h) has a fatality risk estimated to be 35% for all train types and for passenger trains. At 30 mph (48 km/h), the fatality risk is estimated to be 12% for all train types and 10% for passenger trains. For 20 mph (32 km/h), the fatality risk is estimated to be 6% for all train types and 5% for passenger trains.

6 The confidence limits in figure 14 and table 4 are wide because there are many factors that can affect the consequences of a collision. Some of these are listed below:

- The data available for the analysis did not differentiate between whether the occupant of the road vehicle (in most collisions, there was only one person in the car/van) was on the struck side of the vehicle or the non-struck side. Occupants on the struck side are at greater risk than those on the non-struck side.
- The position of the impact along the length of the car/van is likely to have a large influence: impacts to the passenger compartment, with the occupant on the struck side, are likely to have the most severe consequences. This is particularly likely to be true where the corner of a train lines up with the passenger compartment of the road vehicle causing higher penetration into the passenger compartment as the vehicle rotates away from the train.

- Side impacts where the road vehicle is not initially perpendicular to the train may similarly lead to higher penetration into the passenger compartment, and hence higher risk of fatality.
- The age of the occupant of the road vehicle will affect the consequences, with the elderly being more vulnerable to being killed.
- Vehicle age will affect consequences as modern cars have much higher safety standards than older cars. Fatality risk will decrease to some extent over time due to this, as the number of cars to current safety standards increases.
- Crushing impacts, such as where a vehicle gets wedged under the train, are more likely to result in a fatality than where the road vehicle is pushed away.

7 The information represented in figure 14 and table 4 should therefore be treated with caution due to the variability in the circumstances of a collision. In the data that was used in the analysis, the lowest speed at which a fatality occurred involving a passenger train was 27 mph (43 km/h). On the other hand, many car/van occupants have survived collisions at higher impact speeds (eg 80 mph (129 km/h) in one case).

Task 2, basic calculations against automotive regulatory and consumer rating tests

8 The requirements for the performance of cars in regulatory and consumer rating tests are set such that an occupant in a side-on accident between two vehicles should have a good chance of surviving (eg a 95% chance of survival). The aim of task 2 was to estimate the train to car impact speeds equating to the conditions of the regulatory and consumer rating side impact tests.

9 The consultants calculated that impact speeds in the range of 11 mph (17 km/h) to 22 mph (35 km/h) should be survivable for the occupants of cars when hit side-on by a train.

Task 3, heavy goods vehicle accident data analysis

10 In this task, the consultants analysed the results of collisions between HGVs and the sides of cars on the basis that these were similar to impacts between trains and cars. However, the front end of an HGV is less aggressive than the front of a train, because trains have protruding features such as couplers and anti-override devices. A side-on collision between an HGV and a car is therefore likely to cause less damage and reduce the risk of injury to the occupant of the car.

11 The final data sample contained 15 car-HGV collisions involving 24 car occupants. Five of the car occupants were fatally injured. The results showed that car occupants could be killed at speeds as low as 10 mph (16 km/h) and receive only minor injuries at speeds as high as 30 mph (48 km/h). This demonstrates again that there are many factors which affect the consequences of a collision (paragraph 6, above). In the case of HGV-car accidents, the factors include the car occupant’s age; whether they were seated on the struck side or non-struck side of the car; and whether the impact was to the part of the passenger compartment where the occupant was sitting.

12 Because of the less aggressive front end design of an HGV compared with a train, it is feasible that an occupant of a car in a train to car impact could receive fatal injuries at speeds less than those observed in accidents with an HGV.

The risk to passengers and crew on board trains involved in collisions at automatic open crossings

13 Since the accident at Lockington AOCR in 1986 (paragraph 26, main body of this report), almost all the accidents at automatic open crossings have resulted in injuries to vehicle drivers but have not caused physical injuries to those on board the trains involved. However, where the road vehicle involved is larger than a car, there is a progressively greater likelihood, as shown by the following two paragraphs, that a derailment will occur and passengers will be injured.

14 In the accident at Blaxhall AOCL, Suffolk, on 15 April 2002, a single car class 153 diesel multiple unit struck the rear of a high sided articulated trailer and tractor unit which had driven over the level crossing when the road traffic light signals were showing. The train, which was travelling at the authorised crossing speed of 45 mph (72 km/h), was derailed and several of the passengers and the train crew were injured.

15 In the accident at Sewage Works Lane user-worked level crossing, Suffolk, on 17 August 2010, a two-car class 156 diesel multiple unit struck the trailer of a loaded articulated tanker lorry on the crossing, causing the leading carriage of the train to derail. There were about 19 passengers on the train and two train crew, all of whom were injured. The accident was being investigated by the RAIB at the time of this report.

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