

FATAL TRAIN ACCIDENTS ON BRITAIN'S MAIN LINE RAILWAYS: END OF 2011 ANALYSIS

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Summary

This paper updates the author's previous statistical analyses of fatal train accidents on running lines of the national railway system of Great Britain to the end of 2011, based on fatal accident data over the 45-year period 1967 to 2011. As in 2010, there were no fatal train collisions, derailments and overruns in 2011, and one fatal collision between a train and a road motor vehicle. That good performance contributes to further reductions in the estimated mean frequencies of both classes of accident. The estimated mean frequency per year of fatal train collisions, derailments and overruns fell from 0.41 in 2010 to 0.38 in 2011, and the mean number of fatalities per year in such accidents fell from 1.6 to 1.5. The estimated mean frequency per year of fatal collisions between trains and road vehicles fell from 2.4 in 2010 to 2.3 in 2011, and the mean number of fatalities per year in such accidents fell from 3.4 to 3.2. The long-term rate of reduction in the accident rate per train-kilometre is estimated to be 6.7% per year for train collisions, derailments and overruns, and 3.4% per year for collisions between trains and road motor vehicles. The paper examines the evolution of the estimates since 2001, and makes comparisons with results of the Safety Risk Model (SRM) of the Rail Safety and Standards Board. Both sources estimate long term reductions in mean fatalities per year in train collisions, derailments and overruns, but the SRM has consistently estimated somewhat more fatalities per year than this paper.

Keywords

Railways, safety, accidents, fatalities, train protection, road vehicles.

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1 INTRODUCTION

This paper updates the author's previous statistical analyses of fatal train accidents on running lines of the national railway system of Great Britain. The paper presents estimates of frequencies of fatal train accidents and fatalities based on accident data over the 45-year period from 1967 to 2011. Two kinds of fatal accidents are analysed:

- (1) train collisions, derailments and overruns on running lines; and
- (2) collisions between trains and road motor vehicles, both at level crossings and elsewhere.

The basic methodology was presented in the *Journal of the Royal Statistical Society* (Evans 2000). The previous version of this paper included data to the end of 2010, and was circulated in March 2011 (Evans, 2011).

This paper incorporates:

- (1) data on fatal train collisions, derailments and overruns for 1967-2011;
- (2) data on fatal collisions between trains and road motor vehicles for 1967-2011;
- (3) data on train-kilometres to the end of 2011.

The main statistical results presented are:

- (1) estimates of the mean frequencies of fatal train collisions, derailments and overruns in 2011, and of the trends in fatal accidents per train-kilometre;
- (2) estimates of the mean frequencies of fatal collisions between trains and road motor vehicles in 2011 and of their trends; and
- (3) estimates of mean fatalities per year in 2011.

The paper for end-of-2008 saw a change in the methodology for estimating the frequency of fatal train collisions, derailments and overruns. Prior to 2008, separate estimates of the trends in accident rates were made for four different types of accident, and these were then combined to give the overall trend and frequencies of accidents. Since the end-of-2008 analysis a single trend is estimated for all train collisions, derailments and overruns taken together.

The paper continues as follows. Section 2 summarises the basic approach to risk estimation adopted in this paper. Section 3 presents the data and analysis of train collisions, derailments and overruns. Section 4 presents the data and analysis of collisions between trains and road motor vehicles. Section 5 presents a brief summary of the main results. Section 6 summarises the evolution of the results of these papers since 2001, and compares them with those of the Railway Safety and Standards Board's (RSSB) Safety Risk Model. Appendix 1 contains the detailed accident data; Appendix 2 gives statistical information about the fit of the accident frequency models to the data.

2 BASIC APPROACH

The basic model of accident occurrence is that accidents, either all together or of a specified type, are presumed to occur randomly at a rate of λ per billion train-kilometres. Once an accident has occurred, the number of fatalities is also random, and has a probability distribution with mean μ . The mean number of fatalities per billion train-kilometres is then the product $\lambda\mu$. This quantity is

the primary measure of the risk of accidental death. Either or both of λ and μ may change over time, and there may be sets of different λ 's and μ 's for different types of accident.

The parameters λ and μ are not directly observable, but they can be estimated. In this paper, the approach is to estimate them directly from data on past accidents. Estimating fatality risks $\lambda\mu$ requires three steps:

- (1) Estimating mean accident rates λ , and trends in λ , from data on accident frequencies;
- (2) Estimating mean accident consequence μ , from data on accident consequences; and
- (3) Multiplying the estimates of λ and μ to give fatality risk $\lambda\mu$.

These steps are followed separately for train collisions, derailments and overruns, and for collisions between trains and road motor vehicles.

3 FATAL TRAIN COLLISIONS, DERAILMENTS AND OVERRUNS

3.1 Data

This section describes the data on the data on fatal train collisions, derailments and overruns. Not all the available data are used in the current method for estimating mean frequencies in accidents and fatalities, but the data are retained for the record and for possible future use.

Table A1 (in Appendix 1) presents the list of all fatal main line collisions, derailments or overruns in 1967-2011. There were no such accidents in 2011, so Table A1 is unchanged from the previous paper, and indeed since 2007. There are 81 accidents in the dataset, with 321 fatalities. It may be noted that one of the accidents (at Milford in 1978) resulted in a collision between a train and a car; it is included in this dataset rather than the dataset of collisions between trains and road motor vehicles because it was due to a signal passed at danger (SPAD). However, the collision at Great Heck in 2001 between a train and an errant car from the M62 motorway, which then led to a collision between two trains, is counted with the collisions between trains and road vehicles. The derailment of a passenger train at Ufton Nervet level crossing in 2004 due to a collision with a car is likewise counted with the collisions between trains and road vehicles.

Each accident in Table A1 is classified by whether it was preventable by Automatic Train Protection (ATP) or not. The ATP-preventable accidents are subdivided into those due to signals passed at danger (SPADs), excess speed, or buffer overruns. The SPAD accidents are subdivided into those involving a train passing a signal protecting a conflicting movement, and those involving trains proceeding in the same direction on the same track, a 'plain line' SPAD. Of the 81 accidents, 15 were due to conflicting movement SPADs, 8 were due to plain line SPADs, 9 were due to ATP-preventable excess speeds or buffer overruns, and 49 were non-ATP-preventable.

Each accident is also classified by whether a loaded or empty passenger train was involved or only non-passenger trains. The passenger trains are then further classified by the type of train and rolling stock: 'Mark 1' or post-Mark 1, and multiple unit or locomotive hauled. Collisions involving both a multiple unit and locomotive hauled passenger stock are classified as 'multiple unit'. The penultimate column of Table A1 gives data on the speed of the trains involved in accidents: in the case of collisions, this is the 'closing speed'; in the case of buffer overruns, it is the speed at which the train hit the buffers; in the case of derailments, it is the speed at which the

train derailed. The speed data were originally assembled as part of an investigation for HMRI in 2001.

The consequences of fatal accidents are measured by the number of fatalities. It should be noted that, except where otherwise indicated, the data and discussion in this paper refer to fatalities rather than fatalities and weighted injuries (FWIs), which is used by the Railway Group to measure a combination of fatalities and injuries. The Railway Group's current weights are 1 for a fatality, 0.1 for a major injury, and 0.005 for a minor injury. During 2000 the author estimated the ratio of FWI to fatalities in collisions and derailments, using HMRI cumulative figures of the numbers of fatalities, major injuries and minor injuries to passengers and staff in train accidents over the 18¼ years 1978 to 1995/96, which were 159, 550 and 5,774 respectively. When these figures are combined with the weights above, the ratio of FWI to fatalities is found to be 1.527. In 2008, the Railway Group formally altered the weights for certain types of minor injury relative to a fatality (RSSB, 2008, page 5). However, the weights for minor injuries in train accidents were not affected.

Table 1 gives the numbers of fatal accidents in each of four categories mentioned above in nine five-year periods covering 1967 to 2011. The table also gives train-kilometres, and the calculated numbers of accidents per billion train kilometres for each category of accident.

Table 2 gives the distributions and averages of the numbers of fatalities in accidents by type of train, and, for accidents involving passenger stock, for multiple units, locomotive-hauled stock, Mark 1 stock, and post-Mark 1 stock. The distribution of the number of fatalities in accidents is skew: most accidents have a small number of fatalities, but a few have large numbers. The overall number of fatalities per fatal accident is currently 3.96, shown in the bottom right-hand corner of Table 2.

3.2 Accident rates and trends

As noted in section 1, the present method for estimating the overall trend and mean accident rates is to fit a single exponential trend to the total number of accidents per billion train-kilometres given in the right-hand column of Table 1. Appendix 2 gives the details of the fitting process and its results. The fitted trend is shown in Figure 1, together with the nine data points. The estimated rate of reduction in accidents per train-kilometre over the whole period is 6.7% per year, with a standard error of 1.0% per year. The right-hand end of the curve gives the estimated mean number of accidents per billion train-kilometres in 2011, which is 0.668. There were 0.572 billion train-kilometres in 2011 (figure provided by RSSB), which implies that the estimated mean number of accidents per year in 2011 was 0.668×0.572 , or 0.38.

Table 3 shows these results. The table also shows the result of combining the estimated mean of 0.38 accidents per year in 2011 with the estimate of 3.96 fatalities per fatal accident discussed in the Section 3.3, to give an estimated mean of 1.5 fatalities per year in 2011 in collisions, derailments and overruns.

Table 1: train-kilometres; fatal train collisions, derailments and overruns; and accident rates: national railway system: 1967-2011

Period	Years	Train-kilometres (billion)	Number of accidents					Accidents per billion train-km				
			ATP-preventable			Non-ATP-prev.	All	ATP-preventable			Non-ATP-prev.	All
			Conf. SPAD	Plain SPAD	Other			Conf. SPAD	Plain SPAD	Other		
1967-1971	5	2.25	2	2	5	16	25	0.9	0.9	2.2	7.1	11.1
1972-1976	5	2.18	2	3	2	7	14	0.9	1.4	0.9	3.2	6.4
1977-1981	5	2.13	2	2	1	5	10	0.9	0.9	0.5	2.4	4.7
1982-1986	5	1.99	2	1	0	8	11	1.0	0.5	0	4.0	5.5
1987-1991	5	2.15	3	0	1	6	10	1.4	0	0.5	2.8	4.7
1992-1996	5	2.13	2	0	0	4	6	0.9	0	0	1.9	2.8
1997-2001	5	2.47	2	0	0	1	3	0.8	0	0	0.4	1.2
2002-2006	5	2.61	0	0	0	1	1	0	0	0	0.4	0.4
2007-2011	5	2.75	0	0	0	1	1	0	0	0	0.4	0.4
1967-2011	45	20.66	15	8	9	49	81	0.7	0.4	0.4	2.4	4.0

**Table 2
Fatalities in main line collisions, derailments and overruns: 1967-2011**

Type of accident	Number of accidents with given number of fatalities														Total fatalities	Fatalities/acc.	
	1	2	3	4	5	6	7	9	10	13	31	35	49	All			
Passenger stock																	
Multiple unit	16	7	2	4	3		2	1		1	1	1	1	39	218	5.59	
Loco hauled	10	2	1	1	2	3	2		1					22	73	3.32	
Pre- & Mark 1	15	8	1	4	5	3	2	1	1			1	1	42	210	5.00	
Post-Mark 1	11	1	2	1			2			1	1			19	81	4.26	
All passenger	26	9	3	5	5	3	4	1	1	1	1	1	1	61	291	4.77	
Non-passenger	11	8	1											20	30	1.50	
All	37	17	4	5	5	3	4	1	1	1	1	1	1	81	321	3.96	

Figure 1: Fatal train accidents per billion train-kilometres: 1967-2011

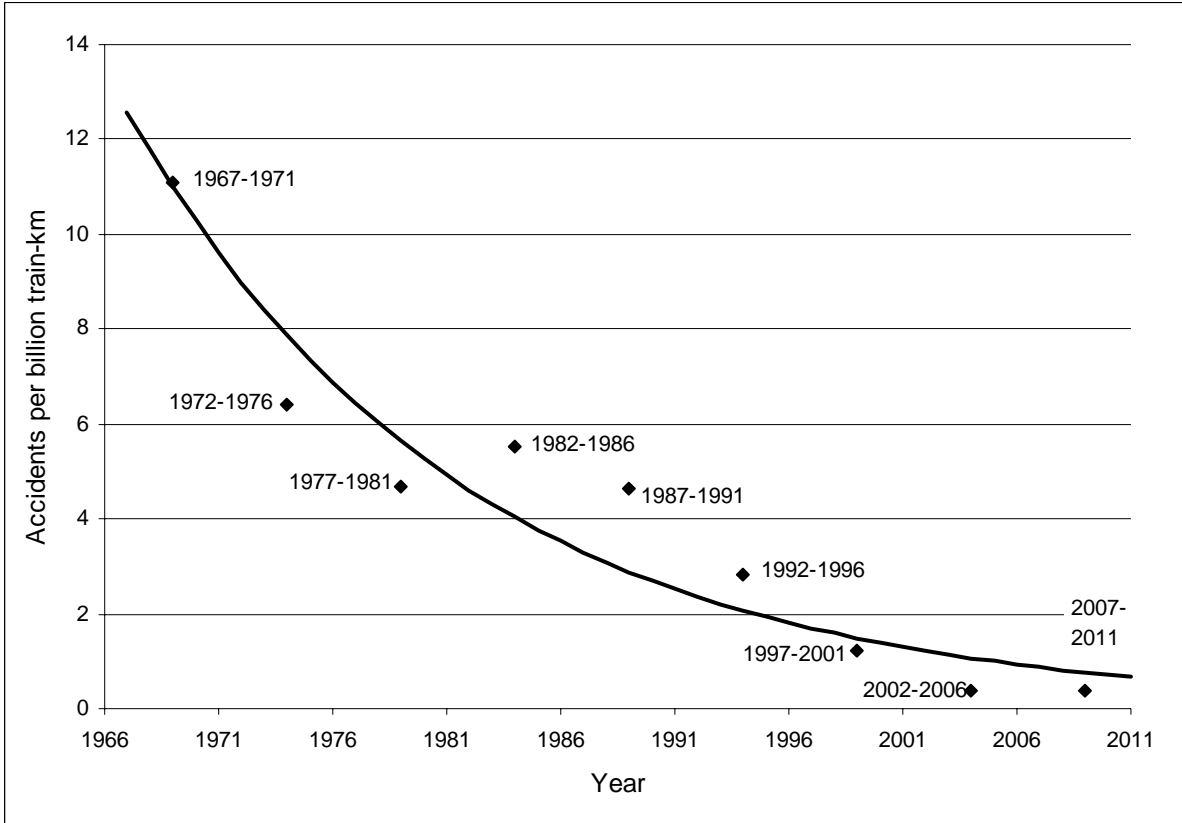


Figure 2: Fatalities in train collisions, derailments and overruns: 1967-2011

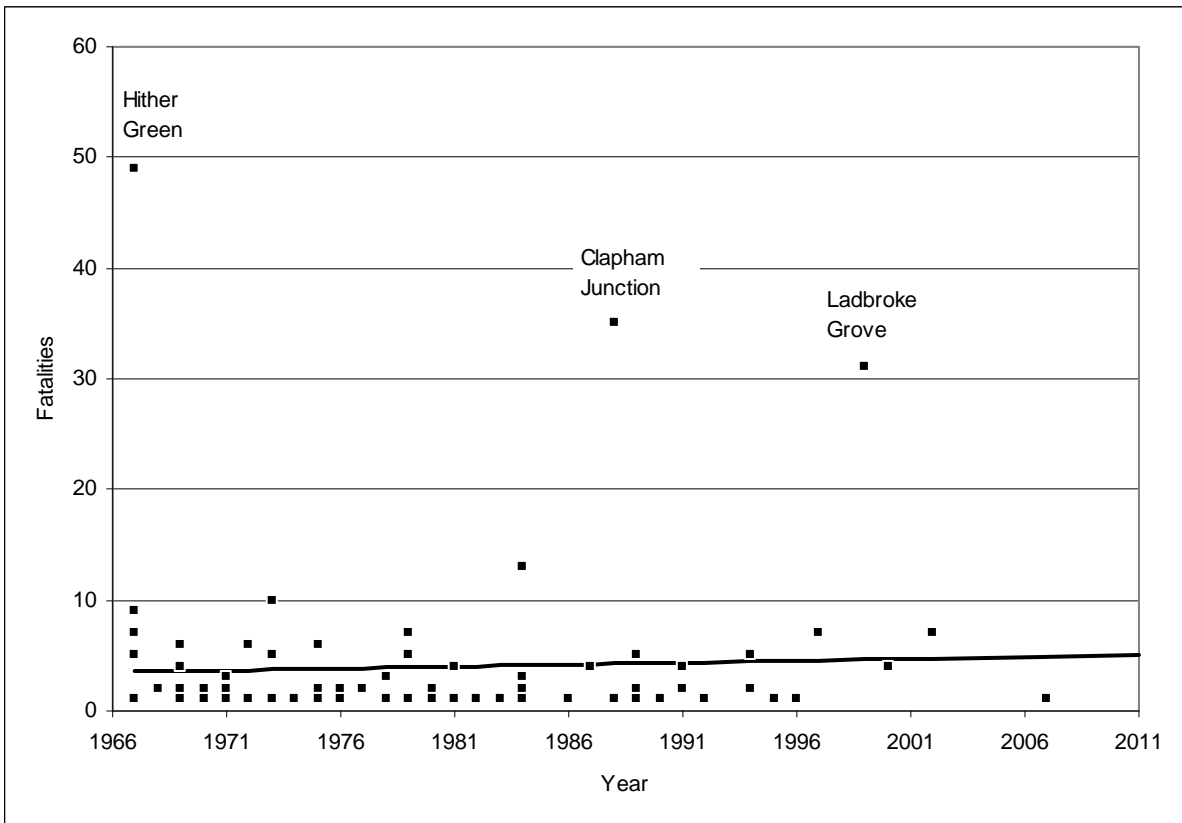


Table 3
Fatal train collisions, derailments and overruns: 1967-2011

Form of model	Estimated rate of change in accidents per train-km (with standard error)	Estimated mean accidents per year in 2011	Fatalities per accident	Estimated mean fatalities per year in 2011
Single trend	-6.7% (se 1.0%) p.a.	0.379	3.96	1.50

3.3 Accident consequences

As noted in section 3.1, the consequences of accidents are measured by the number of fatalities. Although the type of train, rolling stock and impact speed may be expected to affect the numbers of fatalities in accidents, and the writer has undertaken various analyses in the past using the data on these factors in Table 2, his present estimate of the mean fatalities in train collisions, derailments and overruns is simply the observed overall average number of fatalities per accident in the bottom right-hand corner of Table 2, which is currently 3.96.

There are two reasons for using this simple estimate. First, the observed mean numbers of fatalities per accident in the various sub-categories of passenger train accident in Table 2 are not statistically significantly different from each other. Secondly, there is no significant trend over time in the mean number of fatalities per accident. Figure 2 plots the fatalities in the individual accidents over time, and shows the trend line fitted by 'least squares'. It can be seen that the slope is positive, but it is not statistically significantly different from zero, so we treat the mean as constant.

3.4 Estimates of mean numbers of fatalities per year in 2011

Table 3 (above) gives the estimated mean number of fatalities per year in 2011. This is simply the estimated mean frequency of fatal accidents in the left of the table multiplied by 3.96, which is the mean number of fatalities per accident. The estimated mean number of fatalities in 2011 is 1.50, compared with 1.64 in 2010 and 1.87 in 2009.

4 FATAL COLLISIONS BETWEEN TRAINS AND ROAD MOTOR VEHICLES

4.1 Data

There was one accidental fatal collision between a train and a road motor vehicle in 2011, at Balderton level crossing near Chester on 26 July, where a road user was killed.

Including the accident above, there were 185 fatal main line accidental collisions between trains and road motor vehicles between 1967 and 2011. Of these, 171 occurred at level crossings and 14 elsewhere. Seven of the collisions at level crossings and 2 elsewhere resulted in fatalities to train occupants; in all others the fatalities were not train occupants. Table A2 in Appendix 1 lists the accidents in which there were train occupant fatalities and those not at level crossings, but only summarises the 164 level crossing accidents in which only road vehicle occupants were killed, because these are too numerous to list individually, and for many few details are recorded. Table A3 in Appendix 1 gives the number of fatal accidents in each year, and the distribution of fatalities in these.

The 185 accidents caused a total of 260 fatalities, of which 42 were train occupants and 218 were road vehicle occupants. The four most serious accidents all involved train occupant fatalities: they were at Hixon level crossing in 1968 with 11 fatalities, Lockington level crossing in 1986 with 9 fatalities, Great Heck in 2001 with 10 fatalities, and Ufton Nervet level crossing in 2004 with 6 fatalities.

Table A2 shows that no collisions between trains and road vehicles not at level crossings were recorded between 1967 and 1975. Since such accidents have subsequently occurred fairly regularly, albeit infrequently, there must be doubt about whether the pre-1976 record is complete. It is possible, for example, that such accidents were recorded at that time as trespassers. For that reason, the number of such accidents in the period 1967-1971 is treated in the statistical analysis as unknown.

The consequences of fatal train/road vehicles collisions are again measured by the number of fatalities. However, the ratio of fatalities and weighted injuries (FWIs) to actual fatalities for occupants of road vehicles is lower than in train collisions and derailments, because the proportion of injuries that are fatal is higher. The most relevant RI data are casualties to third parties in train accidents, because these are mostly road vehicle occupants. The numbers of fatalities, major injuries and minor injuries over the 18¼ years 1978 to 1995/96 were 101, 88 and 301 respectively. When these figures are weighted with the Railway Group's usual weights, the ratio of FWIs to fatalities for road vehicle occupants is found to be 1.102. Given that 83% of fatalities in train/road vehicle collisions are road vehicle occupants and 17% are train occupants, the overall ratio of equivalent fatalities to actual fatalities is 1.171.

4.2 Accident rates and trends

Table 4 presents the numbers of fatal collisions between trains and road vehicles at level crossings and not at level crossings, and the collision rates per billion train-kilometres for the nine periods. As noted in Section 4.1, the number of non-level crossing accidents in 1967-1971 is treated as unknown in the analysis.

Figure 3 plots the data and also shows the fitted trend, which falls at a common rate of 3.4% per year for accidents both at level crossings and not at level crossings. It should be noted that the vertical scale in Figure 3 is different from that in Figure 1. The estimated mean numbers of fatal collisions between trains and road vehicles in 2011 are 2.07 per year at level crossings and 0.21 per year at other locations.

Appendix 2 and Table A5 present the key statistical results and discussion of the goodness of fit of the modelled trend to the data. The fit is somewhat less good than that for the train collisions, but it is adequate. Table 4 and Figure 3 show that there was an increase in the accident rate between the late 1970s and the early 1980s; this may have been associated with the replacement of manned level crossings by certain types of automatic ones.

Table 4: Train-kilometres, fatal train/road vehicle collisions and accident rates: national rail system 1967-2011

Period	Years	Train-kilo- metres (billion)	Number of accidents			Accidents per billion train-km		
			At LCs*	Not at LCs	All	At LCs	Not at LCs	All
1967-1971	5	2.25	38	†0	38	16.9	†0	16.9
1972-1976	5	2.18	22	1	23	10.1	0.5	10.6
1977-1981	5	2.13	16	3	19	7.5	1.4	8.9
1982-1986	5	1.99	30	1	31	15.0	0.5	15.5
1987-1991	5	2.15	20	2	22	9.3	0.9	10.2
1992-1996	5	2.13	14	2	16	6.6	0.9	7.5
1997-2001	5	2.47	11	3	14	4.5	1.2	5.7
2002-2006	5	2.61	11	2	13	4.2	0.8	5.0
2007-2011	5	2.75	9	0	9	3.3	0.0	3.3
1967-2011	45	20.66	171	14	185	8.3	0.7	9.0

*LC = level crossing
†No fatal non-level crossing accidents are referred to in the RI reports for 1967-1971. However, there must be some doubt about whether there really were none, or whether this type of accident was not recorded at the time. Therefore this figure is treated as 'unknown' in the statistical analysis.

Figure 3: Fatal collisions between trains and road motor vehicles per billion train-km: 1967-2011

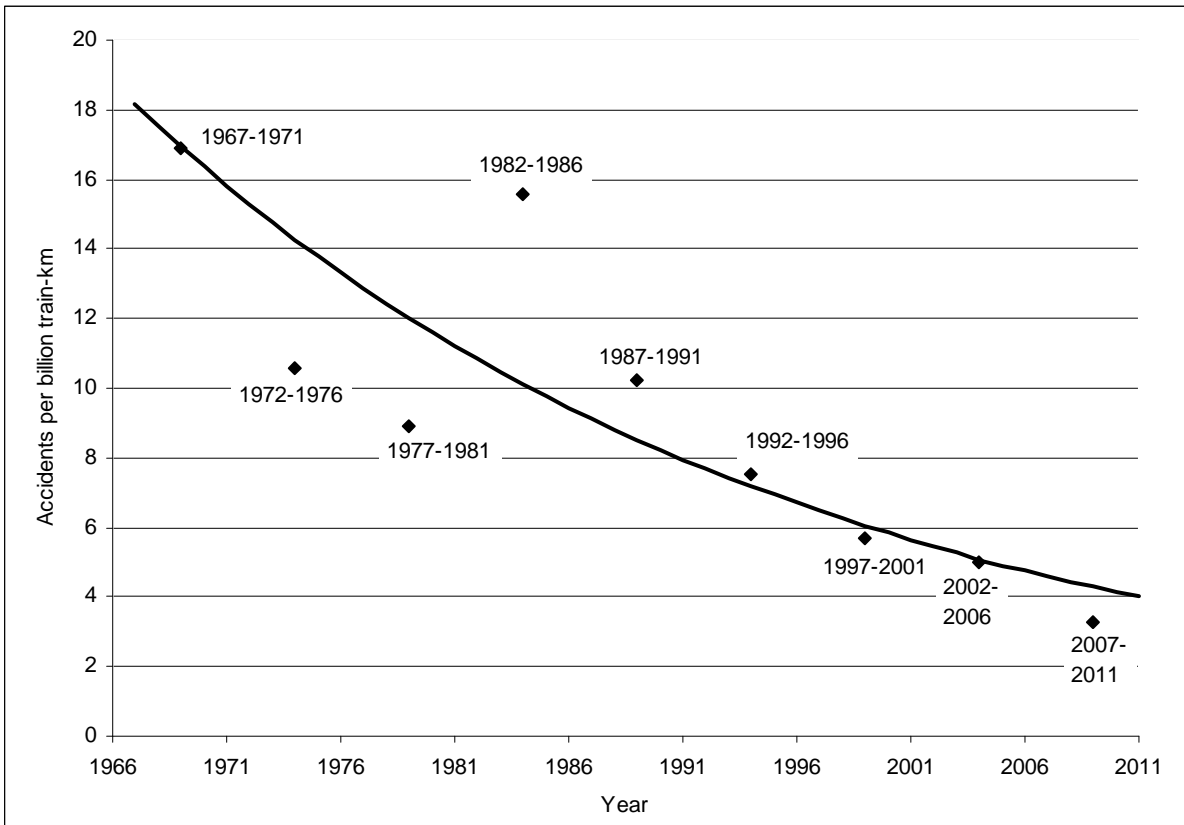
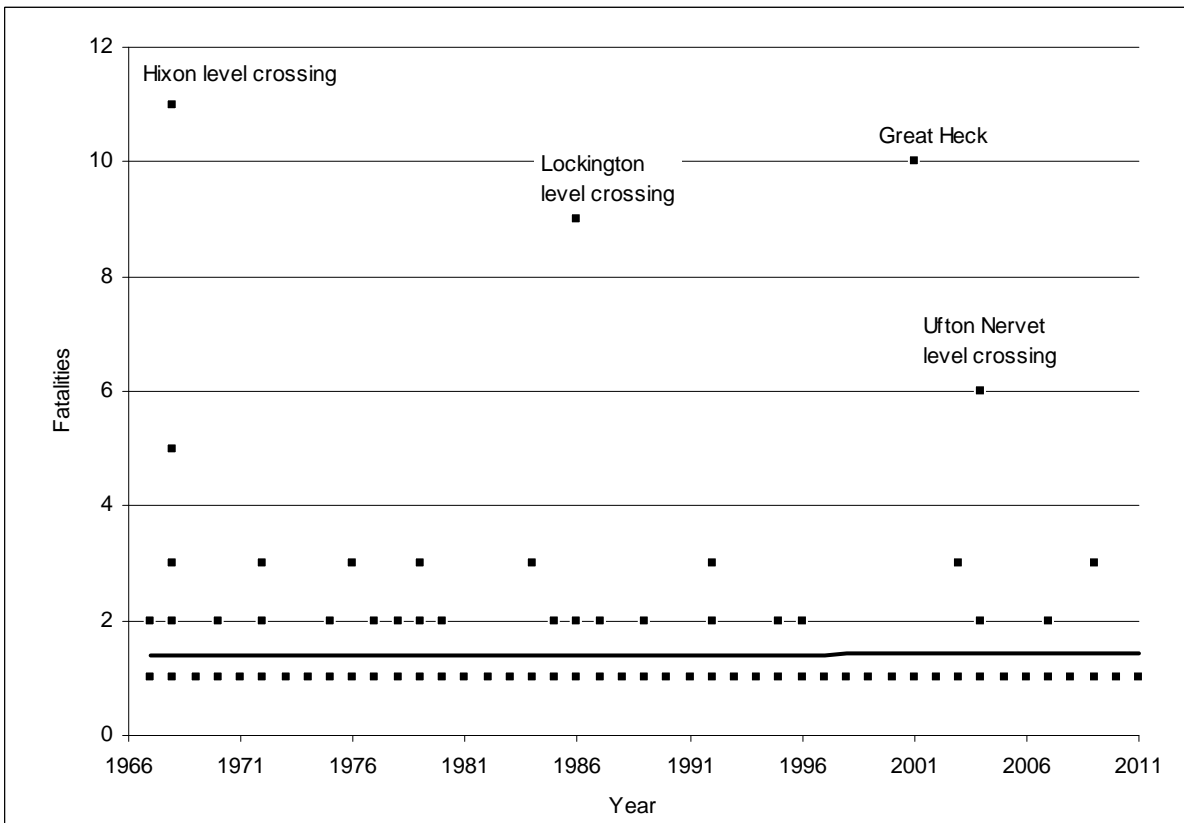


Figure 4: Fatalities in collisions between trains and road vehicles: 1967-2011



4.3 Accident consequences

Table 5 gives the distributions and averages of the numbers of fatalities in fatal collisions between trains and road vehicles by type of location. Although the observed average number of fatalities per accident differ between the types of location, the difference is not statistically significant.

Table 5
Distributions of fatalities in main line collisions between trains and road vehicles: 1967-2011

	Number of accidents with given number of fatalities									Total fatalities	Fatalities/accident
	1	2	3	5	6	9	10	11	All		
At level crossings	141	19	7	1	1	1		1	171	231	1.35
Not at level crossings	8	4	1				1		14	29	2.07
All	149	23	8	1	1	1	1	1	185	260	1.41

Figure 4 plots the fatalities in individual accidents over time; it should be noted that most of the points for one-fatality accidents represent several accidents. The ‘least squares’ trend line is shown; its slope is almost flat, and not statistically significantly different from zero.

In the light of these results, the mean number of fatalities per accident in collisions between trains and road vehicles is taken to be constant at 1.41 at both types of location. This is materially lower than the mean for train collisions, derailments and overruns because of the different nature of the accidents.

4.4 Estimated mean numbers of accidents and fatalities per year in 2011

Table 6 summarises the trends and estimated mean numbers per year of fatal collisions between trains and road motor vehicles in 2011, and the mean numbers of fatalities in these. The overall frequency of accidents is estimated to be 2.29 per year causing 3.21 fatalities per year.

Table 6
Fatal collisions between trains and road motor vehicles: 1967-2011

Accident Location	Estimated rate of change in accidents per train-km (with standard error)	Accidents per year in 2011	Fatalities per accident	Fatalities per year in 2011
At level crossings		2.07		2.91
Not at level crossings		0.21		0.30
All	-3.4% (se 0.6%) p.a.	2.29	1.41	3.21

5 SUMMARY OF PRINCIPAL RESULTS

Table 7 presents a summary of the estimated numbers of fatal accidents and fatalities per year in 2011 from earlier sections of this paper. Fatalities and weighted injuries are included, using the ratios of FWIs to fatalities discussed previously. Collisions between trains and road vehicles collectively present higher risks than train collisions, derailments and overruns.

**Table 7
Estimated mean numbers of fatal accidents and fatalities per year in 2011**

	Mean accidents per year in 2011	Mean fatalities per accident	Mean fatalities per year in 2011	FWI* per fatality	Mean FWI per year in 2011
Collisions, derailments & overruns	0.38	3.96	1.50	1.53	2.30
Train/road motor vehicle collisions	2.29	1.41	3.21	1.17	3.76

*FWI = fatalities and weighted injuries

6 EVOLUTION IN THE ESTIMATES OVER TIME AND COMPARISONS WITH THE SAFETY RISK MODEL

The Rail Safety and Standards Board has developed a detailed risk model, entitled the Safety Risk Model (SRM), for the purpose of estimating all risks of accidental fatalities and injuries on the main line railway. It does this by modelling the precursors and the consequences of about 120 accidental events. It uses a wide range of data on accidents and precursors, as well as expert judgement. The first two versions of the SRM were published in 2001; Versions 3 to 6 were published in February 2003 (Railway Safety 2003), February 2005 (RSSB, 2005), August 2006 (RSSB, 2006) and June 2009 (RSSB, 2009) respectively. Version 7 is currently the most recent and was published in August 2011 (RSSB 2011). Each version of the SRM uses data closing some months before its publication in order to allow time for its production. The SRM was reviewed by Bedford *et al* (2004); the review includes comment on the results of the SRM in relation to the type of analyses presented in this paper, which Bedford *et al* label the AEM (for Andrew Evans model); we adopt that label in this section.

Among many other outputs, the SRM estimates the same risks as those in this paper, but it does so in a different way, by the detailed modelling indicated above. It is possible to compare the estimates of the mean numbers of fatalities per year in train collisions, derailments and overruns and in collisions between trains and road vehicles from the two sources. However, it is not possible to compare the mean numbers of fatal accidents per year or fatalities per fatal accident, because the SRM works in terms of all accidents, not just the fatal ones, and the AEM considers just fatal accidents.

Table 8 presents the estimated mean numbers of fatalities per year in fatal train collisions, derailments and overruns for 2001-2011 from successive versions of the present paper for the AEM and from successive versions of the SRM. The year to which each version of the SRM is

attributed is that which is closest to end of the period of data used by that version. In particular, version 7 of the SRM was published in August 2011 and used data up to the end of September 2010; it is thus attributed to the year 2010, and compared with the “end-of-2010” version of the AEM. Table 8 shows two AEM estimates for 2003, one with and one without the Train protection and warning System (TPWS). Estimates before 2003 from both sources are without TPWS; estimates after 2003 are with TPWS.

Table 8 shows that both the AEM and the SRM have estimated reducing mean fatalities per year since 2001, to which TPWS made a major – though not the only – contribution. However, the SRM has consistently estimated higher mean fatalities per year than the AEM; it continues to do so.

Table 8: Estimated mean fatalities per year in train collisions, derailments and overruns: AEM and SRM: 2001 to 2011

Year	With TPWS?	AEM source	AEM estimate	SRM source	SRM estimate	Ratio SRM/AEM
2001	No	End-2001	4.3	Version 2	11.3	2.6
2002	No	End-2002	4.3	Version 3	6.7	1.6
2003	No	End-2003	4.1			
2003	Yes	End-2003	2.5			
2004	Yes	End-2004	2.4	Version 4	4.4	1.8
2005	Yes	End-2005	2.2	Version 5	3.6	1.6
2006	Yes	End-2006	2.0			
2007	Yes	End-2007	2.1			
2008	Yes	End-2008	2.0	Version 6	2.7	1.4
2009	Yes	End-2009	1.9			
2010	Yes	End-2010	1.6	Version 7	2.7	1.7
2011	Yes	End 2011	1.5			

Table 9: Estimated mean fatalities per year in collisions between trains and road motor vehicles: AEM and SRM: 2001 to 2011

Year	AEM source	AEM estimate	SRM source	SRM estimate	Ratio SRM/AEM
2001	End-2001	4.4	Version 2	5.8	1.30
2002	End-2002	4.4	Version 3	4.3	0.96
2003	End-2003	4.3			
2004	End-2004	4.4	Version 4	4.5	1.02
2005	End-2005	4.4	Version 5	3.8	0.87
2006	End-2006	3.9			
2007	End-2007	3.8			
2008	End-2008	3.6	Version 6	2.8	0.79
2009	End-2009	3.7			
2010	End-2010	3.4	Version 7	3.3	0.99
2011	End-2011	3.2			

Table 9 shows the corresponding estimated mean fatalities per year in 2001-2011 in collisions between trains and road motor vehicles from the AEM and the SRM. The table shows that both models agree that there has been a fairly slow reduction in these means in recent years, which is a reflection of recent safety performance. For these accidents the two models are in reasonably close agreement on the level of mean fatalities per year.

Technical note. The sources of the SRM results above are Table A1 of the Risk Profile Bulletin Issues 2 and 3 (Railway Safety 2001, 2003) and Table A2 of the Risk Profile Bulletin Issues 4 and 5 (RSSB 2005, 2006). The SRM’s hazardous events currently contributing to collisions, derailments and overruns are HET 01, HET 02, HET 03, HET 06, HET 26 (collisions), HET 09 (buffer stop overruns), HET 12 and HET 13 (derailments). The hazardous events contributing to collisions between trains and road vehicles are HET 04 (train colliding with object not derailing), HET 10 and HET 11 (level crossings). The reason for counting HET 04 here is that all the fatality risk from this type of accident is to road vehicle occupants that may be struck by trains not at level crossings. It may also be noted that the two models classify ‘Great Heck’ type accidents differently. These are the rare accidents in which trains are derailed by striking road vehicles not at level crossings. The present writer has classified these with train/road vehicle collisions; the SRM classifies them with derailments. The risk from such events is small (of the order of 0.1 fatalities per year, notwithstanding Great Heck).

SOURCES AND ACKNOWLEDGEMENTS

As noted in Section 3.1, the principal sources of information for this paper are the Railway Inspectorate (RI) annual reports and accident reports over the long term, and the Office of Rail Regulation (ORR, 2010) for recent years. The published RI reports are supplemented by RI computer records from 1984 and by data from the Rail Safety and Standards Board and the Rail Accident Investigation Branch. The author is grateful to these bodies, but is alone responsible for the contents of this paper.

LIST OF ABBREVIATIONS

AEM	Andrew Evans model
ATP	Automatic train protection
ATP-P	Automatic train protection-preventable
ECS	Empty coaching stock
FWI	Fatalities and weighted injuries
HMRI	HM Railway Inspectorate
HSE	Health and Safety Executive
LC	Level crossing
LH	Locomotive-hauled
MU	Multiple unit
NLC	Not at level crossing
ORR	Office of Rail Regulation
RAIB	Rail Accident Investigation Branch
RI	Railway Inspectorate
RSSB	Rail Safety and Standards Board
RTA	Road traffic accident
SPAD	Signal passed at danger
SRM	Safety risk model
TPWS	Train Protection and Warning System

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APPENDIX 1: DETAILED DATA TABLES

Table A1
Fatal collisions, derailments and overruns: national railway system: 1967-2011

Date	Location	Nature of accident	ATP*- preventable?	Rolling stock	Speed km/h	Fatal- ities
23. 2.07	Grayrigg	Derailment	No	Post-Mk1 MU*	153	1
10. 5.02	Potters Bar	Derailment	No	Post-Mk 1 MU	156	7
17.10.00	Hatfield	Derailment	No	Post-Mk1 LH*	185	4
5.10.99	Ladbroke Grove	Train collision, fire	Yes: C-SPAD*	Post-Mk 1 MU	209	31
19. 9.97	Southall	Train collision	Yes: C-SPAD	Post-Mk 1 LH	150	7
8. 8.96	Watford Junction	Train collision	Yes: C-SPAD	Post-Mk 1 MU	80	1
8. 3.96	Rickerscote	Derailment, then collision	No	Non-passenger	121	1
31. 1.95	Ais Gill	Derailment, then collision	No	Post-Mk 1 MU	97	1
15.10.94	Cowden	Train collision	Yes: C-SPAD	Mark 1 MU	108	5
25. 6.94	Branchton	Derailment	No	Mark 1 MU	75	2
13.11.92	Morpeth	Train collision	No	Non-passenger	40	1
21. 7.91	Newton	Train collision	Yes: C-SPAD	Mark 1 MU	97	4
8. 1.91	Cannon Street	Buffer stop collision	Yes: Overrun	Mark 1 MU	16	2
4. 8.90	Stafford	Train collision	No	Post-Mk 1 MU	32	1
20. 4.89	Holton Heath	Train collision	No	Non-passenger	60	1
6. 3.89	Bellgrove Junction	Train collision	Yes: C-SPAD	Mark 1 MU	48	2
4. 3.89	Purley	Train collision	Yes: C-SPAD	Mark 1 MU	56	5
27. 2.89	Warrington	Train collision	No	Non-passenger	16	2
12.12.88	Clapham Junction	Train collision	No	Mark 1 MU	56	35
11.11.88	St Helens	Derailment	No	Post-Mk 1 MU	37	1
19.10.87	Glanrhyd Bridge	Collapsed bridge; train fell	No	Mark 1 MU	24	4
19. 9.86	Colwich	Train collision	Yes: C-SPAD	Post-Mk 1 LH	157	1
9. 3.86	Chinley	Train collision	No	Mark 1 LH	48	1
4.12.84	Eccles	Train collision, fire	Yes: P-SPAD	Post-Mk 1 LH	56	3
3.12.84	Longsight	Train collision	No	Mark 1 MU	31	1
11.10.84	Wembley Central	Train collision	Yes: C-SPAD	Post-Mk 1 MU	92	3
30. 7.84	Polmont	Derailment	No	Post-Mk 1 MU	137	13
3. 2.84	Wigan	Train collision	No	Non-passenger	19	2
9.12.83	Wrawby Junction	Train collision	No	Mark 1 MU	19	1
3. 2.83	Elgin	Derailment	No	Post-Mk 1 LH	97	1
9.12.82	Linslade	Derailment	No	Mark 1 LH	68	1
27. 5.82	Alvechurch	Train collision	No	Mark 1 MU	64	1
11.12.81	Seer Green	Train collision	No	Mark 1 MU	48	4
8.12.81	Ulleskelf	Derailment	No	Post-Mk 1 LH	105	1
7.11.80	Crewe	Train collision	No	Non-passenger	44	2
14. 3.80	Appledore	Derailment	Yes: Excess speed	Mark 1 MU	97	1
22.10.79	Invergowrie	Train collision	Yes: P-SPAD	Mark 1 LH	97	5
16. 4.79	Paisley Gilmour St	Train collision	Yes: C-SPAD	Mark 1 MU	36	7
25. 2.79	Fratton	Train collision	No	Mark 1 LH	97	1
22.12.78	Milford LC*	Train/car collision	Yes: C-SPAD	Mark 1 MU	8	1
19.12.78	Hassocks-Brighton	Train collision	Yes: P-SPAD	Mark 1 MU	76	3
5. 9.77	Farnley Junction	Train collision	No	Mark 1 MU	64	2
9.11.76	Newton-on-Ayr	Train collision	Yes: C-SPAD	Non-passenger	Unknown	1
3. 1.76	Worcester Tunnel Jc	Train collision	No	Non-passenger	72	2
26.10.75	Lunan Bay	Train collision	No	Post-Mk 1 LH	40	1
11. 9.75	Corby	Train collision	No	Non-passenger	Unknown	1
24. 8.75	Carstairs	Train collision	No	Non-passenger	89	2
6. 6.75	Nuneaton	Derailment	Yes: Excess speed	Mark 1 LH	129	6
23. 1.75	Watford Junction	Derailment, then collision	No	Post-Mk 1 LH	109	1

*ATP = Automatic train protection; C-SPAD = Signal passed at danger protecting a conflicting movement; P-SPAD = Signal passed at danger protecting preceding train on same line; MU = multiple unit; LH = locomotive-hauled; LC = Level crossing.

Continued...

Table A1 (continued)
Fatal collisions, derailments and overruns: national railway system: 1967-2011

Date	Location	Nature of accident	ATP-preventable?	Rolling stock	Speed km/h	Fatalities
23.10.74	Bridgwater	Train collision	Yes: P-SPAD	Non-passenger	72	1
11. 6.74	Pollokshields E Jc	Train collision	Yes: C-SPAD	Mark 1 MU	48	1
19.12.73	West Ealing	Derailment	No	Mark 1 LH	113	10
30. 8.73	Shields Junction	Train collision, fire	Yes: P-SPAD	Mark 1 MU	80	5
27. 4.73	Kidsgrove	Train collision	Yes: P-SPAD	Non-passenger	19	1
6. 9.72	Leicester	Train collision	No	Non-passenger	48	1
11. 6.72	Eltham Well Hall	Derailment	Yes: Excess speed	Mark 1 LH	105	6
16.12.71	Nottingham	Train collision	Yes: C-SPAD	Non-passenger	72	3
6.10.71	Beattock	Train collision	No	Non-passenger	72	1
2. 7.71	Tattenhall Jc	Derailment	No	Mark 1 LH	109	2
21. 5.71	Cheadle	Derailment, then collision	No	Non-passenger	45	1
15. 4.71	Finsbury Park	Train collision	No	Mark 1 MU	64	1
26. 2.71	Sheerness	Buffer stop collision	Yes: Overrun	Mark 1 MU	20	1
18. 5.71	Middlesbrough	Train collision	No	Non-passenger	32	2
17. 7.70	Kirkstall	Train collision	No	Mark 1 MU	28	1
20. 5.70	Guide bridge	Derailment	No	Mark 1 MU	48	2
31.12.69	Road Junction	Derailment, then collision	No	Post-Mk 1 MU	117	1
30.12.69	Streatham Hill	Train collision	No	Mark 1 MU	32	1
18. 5.69	Beattock	Train collision	No	Mark 1 LH	16	1
7. 5.69	Morpeth	Derailment	Yes: Excess speed	Mark 1 LH	135	6
8. 4.69	Monmore Green	Train collision, fire	Yes: C-SPAD	Post-Mk 1 MU	72	2
8. 3.69	Ashchurch	Derailment, then collision	Yes: Excess speed	Mark 1 LH	48	2
4. 1.69	Paddock Wd-Marden	Train collision	Yes: P-SPAD	Mark 1 MU	109	4
9. 9.68	Castlecary	Train collision	No	Mark 1 MU	60	2
23. 3.68	Hatfield	Train collision	Yes: Excess speed	Non-passenger	48	2
11. 3.68	Peterborough North	Train collision	No	Non-passenger	32	2
5.11.67	Hither Green	Derailment	No	Mark 1 MU	113	49
27. 9.67	Didcot	Derailment	Yes: Excess speed	Mark 1 LH	105	1
15. 8.67	Copy Pit	Train collision	Yes: P-SPAD	Non-passenger	113	1
31. 7.67	Thirsk	Derailment, then collision	No	Mark 1 LH	80	7
5. 3.67	Connington South	Derailment	No	Mark 1 LH	118	5
28. 2.67	Stechford	Train collision	No	Mark 1 MU	97	9

Table A2

Fatal collisions between trains and road motor vehicles: national railway system: 1967-2011

Date	Location	Nature of accident	Fatalities		
			Train Occs	Road Veh Occs	All
Collisions at level crossings with one or more train occupant fatalities					
6.11.04	Ufton Nervet	Passenger train/car collision	6	0	6
26.7.86	Lockington	Passenger train/van collision	8	1	9
1.3.79	Naas	Passenger train/lorry collision	2	1	3
3.12.76	Chivers No 1	Passenger train/lorry collision in fog	1	0	1
15.7.70	Shalmsford St	ECS/lorry collision	1	1	2
??.70	Chivers Decoy	Passenger train/lorry collision in fog	1	0	1
6.1.68	Hixon	Passenger train/road transporter collision	11	0	11
Total	7 accidents		30	3	33
Collisions not at level crossings with one or more train occupant fatalities					
28.2.01	Great Heck	Car from M62/pass/freight train collision	10	0	10
15.3.76	Annan	Lorry fell from bridge; hit by pass train	2	1	3
Total	2 accidents		12	1	13
Collisions at level crossings without train occupant fatalities (summary)					
Total	164 accidents		0	198	198
Collisions not at level crossings without train occupant fatalities					
25.9.06	Copmanthorpe	Car crashed thro' fence at old LC; hit by train	0	1	1
28.2.02	Nocton, Lincs	Car crashed thro' old bridge wall; hit by train	0	1	1
15.8.01	Weeton	Car crashed thro' bridge approach; hit by ECS	0	1	1
8.6.97	Burbage Wharf	Car fell from bridge; hit by freight train	0	1	1
10.3.95	Balcombe Tun Jc	Car fell from M23; hit by pass train	0	1	1
21.8.93	Stourbridge	Car fell down bank; hit by train	0	1	1
6.12.91	Four Ashes	Car fell after RTA; hit by freight train, fire	0	1	1
3.8.87	Dunhampstead	Car fell from bridge; hit pass train	0	2	2
4.4.86	North Wembley	Car driven through fence; hit by ECS	0	2	2
??.81	Not known	Car crashed through fence; hit by train	0	1	1
24.10.79	Walkeringham	Car fell from bridge; hit by freight train	0	2	2
19.4.77	Cleland	Van driven thro' fence; hit by freight train	0	2	2
Total	12 accidents		0	16	16
All fatal collisions between trains and road vehicles					
Total	185 accidents		42	218	260
<i>Source: Extracted from Railway Safety (HSE, annual), HMRI train accident database, or RSSB</i>					
<i>Abbreviations: RTA = road traffic accident; ECS = empty coaching stock; LC = level crossing.</i>					

Table A3
Numbers of fatal collisions between trains and road motor vehicles: 1967-2011

	Number of collisions with given number of fatalities									Total fatalities	Fatalities/accident
	1	2	3	5	6	9	10	11	All		
1967-2011	149	23	8	1	1	1	1	1	185	260	1.4
2011	1								1	1	1.0
2010	1								1	1	1.0
2009	2		1						3	5	1.7
2008	2								2	2	1.0
2007	1	1							2	3	1.5
2006	1								1	1	1.0
2005	3								3	3	1.0
2004	1	1			1				3	9	3.0
2003	2		1						3	5	1.7
2002	3								3	3	1.0
2001	3						1		4	13	3.2
2000	3								3	3	1.0
1999	2								2	2	1.0
1998	4								4	4	1.0
1997	1								1	1	1.0
1996	1	1							2	3	1.5
1995	1	1							2	3	1.5
1994	4								4	4	1.0
1993	4								4	4	1.0
1992	2	1	1						4	7	1.7
1991	6								6	6	1.0
1990	2								2	2	1.0
1989	2	2							4	6	1.5
1988	4								4	4	1.0
1987	4	2							6	8	1.3
1986	10	2				1			13	23	1.8
1985	4	1							5	6	1.2
1984	2		1						3	5	1.7
1983	7								7	7	1.0
1982	3								3	3	1.0
1981	2								2	2	1.0
1980	1	1							2	3	1.5
1979	1	1	1						3	6	2.0
1978	3	1							4	5	1.2
1977	7	1							8	9	1.1
1976	11		1						12	14	1.2
1975	1	1							2	3	1.5
1974	1								1	1	1.0
1973	1								1	1	1.0
1972	4	2	1						7	11	1.6
1971	3								3	3	1.0
1970	10	1							11	12	1.1
1969	6								6	6	1.0
1968	8	2	1	1				1	13	31	2.4
1967	4	1							5	6	1.2

APPENDIX 2: STATISTICAL METHODS AND RESULTS FOR ESTIMATES OF TRENDS IN ACCIDENT RATES

For each of the accident types, the assumed basic model is that the number of accidents in period t is Poisson-distributed with mean θ_t given by

$$\theta_t = \alpha k_t \exp(\beta t)$$

where k_t = train-kilometres in period t , α is a scale parameter determining the general accident level, and β is a parameter measuring the long-term rate of change in accidents per train-km. The mean number of fatal accidents per train-km in period t is given by $\theta_t/k_t = \alpha \exp(\beta t)$. If $\beta = 0$, there is no long-term change in the mean accident rate.

Different types of accident and different variants of the accident models may have different values of the parameters α and β . The trends quoted in the main paper and in the tables below are estimates of the parameter β .

Table A4 gives the main statistical results and test statistics for variants of the model for the trends in the accident rates for collisions, derailments and overruns. Table A5 gives corresponding results for collisions between trains and road vehicles.

The scaled deviance in Tables A4 and A5 is the measure of goodness of fit of the model variants to the data; a large scaled deviance indicates a poor fit. If the data are indeed generated in the way presumed in the model (that is Poisson-distributed with a time-dependent mean), the scaled deviance can be assumed to be approximately χ^2 -distributed with mean equal to the number of degrees of freedom.

As noted in section 3.2, the model adopted for train collisions, derailments and overruns now combines all accident types, and is simple. The only variants considered of the model are variant (a) in which β is held at zero, and variant (b) in which β is estimated from the data. The large scaled deviance with $\beta = 0$ in Table A4 indicates that (a) is a poor fit, leading to the obvious conclusion that the trend is significantly non-zero. An interesting result from Table A4 is the small scaled deviance in variant (b), which is slightly smaller than the number of degrees of freedom, indicating that the model fits the data well.

As noted in section 4.1, the data used for the analysis of collisions between trains and road vehicles are for 1967-2011 for level crossing accidents and 1972-2011 for non-level crossing accidents. The adopted variant of the model is (b), that is a common trend for level crossing and non-level crossing accidents. The reduction in the scaled deviance of 36.4 between variants (a) and (b) is strongly statistically significant when tested against the χ^2 distribution with 1 degree of freedom, but the reduction of 0.8 between variants (b) and (c) is not. It follows that the trend is certainly non-zero, but the difference between the trends for accidents at level crossings and that for accidents elsewhere could be due to chance. Therefore we assume a common trend for both types of location. The residual scaled deviance of 18.7 in variant (b) with 14 degrees of freedom indicates a reasonably good fit of the model to the data.

**Table A4: Statistical results for variants of model for trends in accident rates:
all train collisions, derailments and overruns: 1967 to 2011**

Variant of model	Degrees of Freedom	Scaled Deviance	Estimate of trend parameter β (Standard error in brackets)
(a) No trend	8	60.1	Assumed zero for all accidents
(b) Common trend	7	6.7	-6.7% (1.0%) p.a. for all accidents

**Table A5: Statistical results for variants of model for trends in accident rates:
Collisions between trains and road motor vehicles: 1967 and 1972 to 2011**

Variant of model	Degrees of Freedom	Scaled Deviance	Estimate of trend parameter β (Standard error in brackets)
(a) No trend	15	55.1	Assumed zero for all accidents
(b) Common trend	14	18.7	-3.4% (0.6%) p.a. for all accidents
(c) Separate trends for LC* and NLC* accidents	13	17.9	-3.6% (0.6%) p.a. for LC accidents -1.6% (2.3%) p.a. for NLC accidents

*LC = level crossing; NLC = non-level crossing