# FATAL TRAIN ACCIDENTS ON BRITAIN'S MAIN LINE RAILWAYS: END OF 2019 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 2019, based on fatal accident data over the 53-year period 1967 to 2019. There were no fatal train collisions, derailments or overruns in 2019 for the twelfth consecutive calendar year. That continuing good performance contributes to a further reduction in the estimated mean frequency of such accidents from 0.20 per year in 2017 to 0.17 in 2019. The estimated mean number of fatalities per year in such accidents fell from 0.81 in 2017 to 0.69 in 2019. There was one accidental fatal collision between a train and a road motor vehicle in 2018 with two fatalities, and none in 2019. This was in line with recent past performance. The estimated frequency of such accidents fell from 1.77 per year in 2017 to 1.60 per year in 2019, with 2.45 fatalities per year in 2017 compared with 2.23 in 2019. However, it should be noted that this paper does not include fatalities to pedestrians at level crossings. The long-term rate of reduction in the accident rate per train-kilometre is estimated to be 7.4% per year for train collisions, derailments and overruns, and 3.8% per year for collisions between trains and road motor vehicles. The paper examines the evolution of these 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 more fatalities per year than this paper.

**Keywords**

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

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**CONTENTS** page

## 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 53-year period from 1967 to 2019. 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 2017, and was dated June 2018 (Evans, 2018).

This paper incorporates:

(1) data on fatal train collisions, derailments and overruns for 1967-2019;
(2) data on fatal collisions between trains and road motor vehicles for 1967-2019;
(3) data on train-kilometres to the end of 2019.

The main statistical results presented are:

(1) estimates of the mean frequencies of fatal train collisions, derailments and overruns in 2019, 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 2019 and of their trends; and
(3) estimates of mean fatalities per year in 2019.

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 fatal accidents, either all together or of a specified type, are presumed to occur randomly at a rate of $\lambda$ per billion train-kilometres. Once an accident has occurred, the number of fatalities is also random, and has a probability distribution with mean $\mu$. 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 the fatality risks λμ 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 λμ.

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 of 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 1967-2019. There have been no such accidents since 2007, so Table A1 is unchanged since 2008. 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 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 ten five- and one three-year period covering 1967 to 2019. 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 eleven data points. The estimated rate of reduction in accidents per train-kilometre over the whole period is 7.4% per year, with a standard error of 0.9% per year. The right-hand end of the curve gives the estimated mean number of accidents per billion train-kilometres in 2019, which is 0.289. There were 0.603 billion train-kilometres in 2019 (figure provided by RSSB), which implies that the estimated mean number of fatal accidents per year in 2019 was 0.0.289*0.603, or 0.174.

Table 3 shows these results. The table also shows the result of combining the estimated mean of 0.174 fatal accidents per year in 2019 with the estimate of 3.96 fatalities per fatal accident discussed in the Section 3.3, to give an estimated mean of 0.689 fatalities per year in 2019 in collisions, derailments and overruns.

**Table 1: train-kilometres; fatal train collisions, derailments and overruns; and accident rates: national railway system: 1967-2019**

| Period | Years | Train-kilo-metres (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 |
| 2012-2016 | 5 | 2.89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2017-2019 | 3 | 1.76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1967-2019 | 53 | 25.31 | 15 | 8 | 9 | 49 | 81 | 0.6 | 0.3 | 0.4 | 1.9 | 3.2 |

**Table 2**
**Fatalities in main line collisions, derailments and overruns: 1967-2019**

| Type of accident | Number of accidents with given number of fatalities | | | | | | | | | | | | | | Total fata-lities | Fata-lities/ 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 2019**

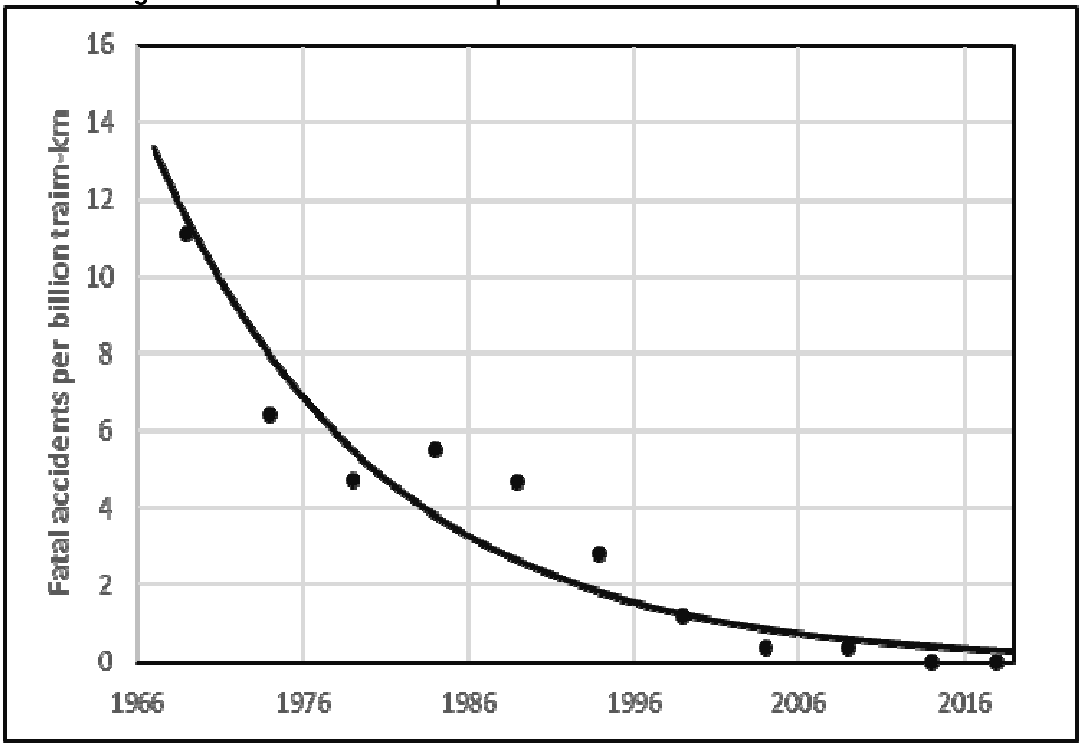


**Figure 2: Fatalities in train collisions, derailments and overruns: 1967-2019**

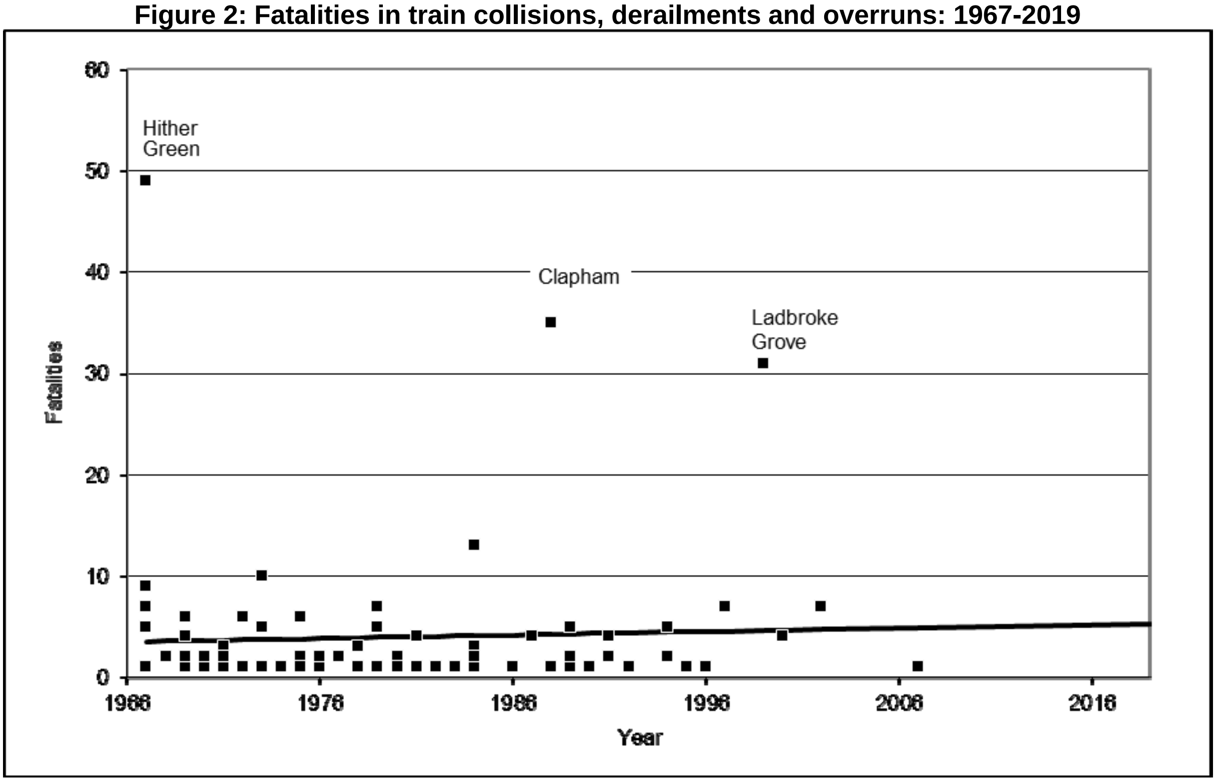

**Table 3**
**Fatal train collisions, derailments and overruns: 1967-2019**

| Form of model | Estimated rate of change in accidents per train-km (with standard error) | Estimated mean accidents per year in 2019 | Fatalities per accident | Estimated mean fatalities per year in 2019 |
|---|---|---|---|---|
| Single trend | -7.4 (se 0.9%) p.a. | 0.174 | 3.96 | 0.689 |

### 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 2019

Table 3 (above) gives the estimated mean number of fatalities per year in 2019. 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 2019 is 0.69, compared with 0.81 in 2017. The evolution of these results since 2001 is given in Table 8.

## 4 FATAL COLLISIONS BETWEEN TRAINS AND ROAD MOTOR VEHICLES

### 4.1 Data

There was one fatal accidental collision between a train and a road motor vehicle in 2018, with two fatalities. It was at a level crossing. There were none in 2019. That is a fairly typical performance for recent years. It should be noted that in recent years there have been more fatalities to pedestrians or pedal cyclists at level crossings than to occupants of road vehicles. In particular, there were five such fatalities in the two years 2018-2019, all in different accidents. These are excluded from the present analysis because they are not classified as train accidents.

There were 196 fatal main line accidental collisions between trains and road motor vehicles between 1967 and 2019. Of these, 182 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 175 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 196 accidents caused a total of 273 fatalities, of which 42 were train occupants and 231 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 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 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 84% of fatalities in train/road vehicle collisions are road vehicle occupants and 16% are train occupants, the overall ratio of equivalent fatalities to actual fatalities is 1.170.

### 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 eleven 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 3.8% per year for accidents both at level crossings and not at level crossings, with a standard error of 0.5% per year. 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 2019 are 1.46 per year at level crossings and 0.14 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 observed 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 motor vehicle collisions and accident rates: national rail system 1967-2019**

| 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 |
| 2012-2016 | 5 | 2.89 | 8 | 0 | 8 | 2.8 | 0.0 | 2.8 |
| 2017-2019 | 3 | 1.76 | 3 | 0 | 3 | 1.7 | 0.0 | 1.7 |
| 1967-2019 | 53 | 25.13 | 182 | 14 | 196 | 7.2 | 0.6 | 7.7 |

*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: 1967-2019**

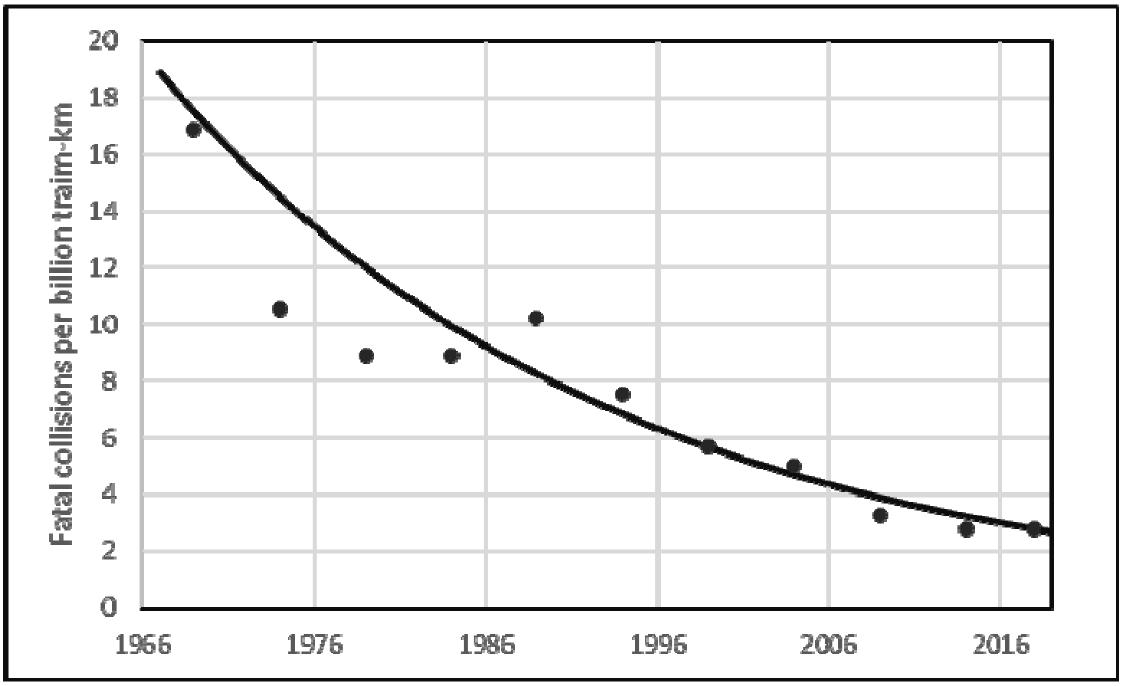


**Figure 4: Fatalities in collisions between trains and road vehicles: 1967-2019**

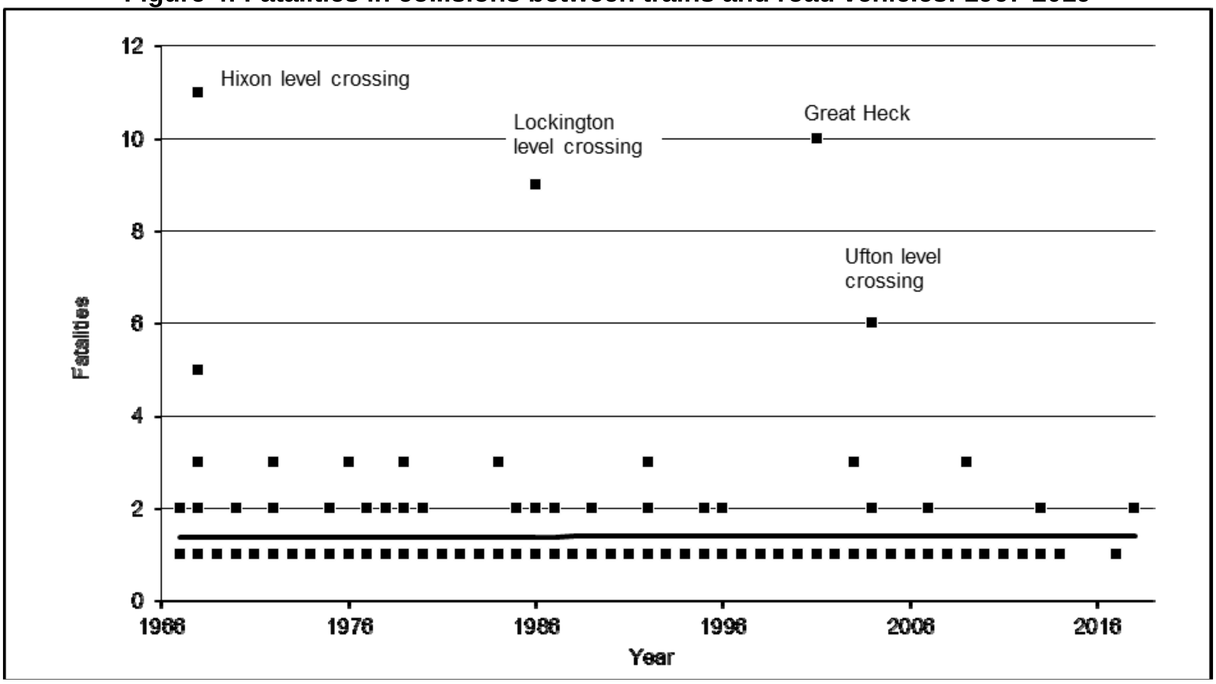

Table 5 gives the distributions and averages of the numbers of fatalities in fatal collisions between trains and road vehicles by type of location. Although the observed average number of fatalities per accident differ between the types of location, the difference is not statistically significant.

**Table 5**
**Distributions of fatalities in main line collisions between trains and road vehicles: 1967-2019**

| | Number of accidents with given number of fatalities | | | | | | | | | Total fata-lities | Fata-lities/ accident |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **5** | **6** | **9** | **10** | **11** | **All** | | |
| **At level crossings** | 150 | 21 | 7 | 1 | 1 | 1 | | 1 | 182 | 244 | 1.34 |
| **Not at level crossings** | 8 | 4 | 1 | | | | 1 | | 14 | 29 | 2.07 |
| **All** | 158 | 25 | 8 | 1 | 1 | 1 | 1 | 1 | 196 | 273 | 1.39 |

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 1.39 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 2019

Table 6 summarises the trends and estimated mean numbers per year of fatal collisions between trains and road motor vehicles in 2019, and the mean numbers of fatalities in these. The overall frequency of accidents is estimated to be 1.60 per year causing 2.23 fatalities per year. The corresponding estimates for 2017 were 1.77 accidents per year and 2.45 fatalities per year.

**Table 6**
**Fatal collisions between trains and road motor vehicles: 1967-2019**

| Accident Location | Estimated rate of change in accidents per train-km (with standard error) | Accidents per year in 2019 | Fatalities per accident | Fatalities per year in 2019 |
|---|---|---|---|---|
| At level crossings | | 1.46 | | 2.03 |
| Not at level crossings | | 0.14 | | 0.19 |
| All | –3.8% (se 0.5%) p.a. | 1.60 | 1.39 | 2.23 |

## 5 SUMMARY OF PRINCIPAL RESULTS

Table 7 presents a summary of the estimated numbers of fatal accidents and fatalities per year in 2019 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 2019**

| | Mean accidents per year in 2019 | Mean fatalities per accident | Mean fatalities per year in 2019 | FWI* per fatality | Mean FWI per year in 2019 |
|---|---|---|---|---|---|
| Collisions, derailments & overruns | 0.17 | 3.96 | 0.69 | 1.53 | 1.06 |
| Train/road motor vehicle collisions | 1.60 | 1.39 | 2.23 | 1.17 | 2.60 |

*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 130 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 8 were published in February 2003 (Railway Safety 2003), February 2005 (RSSB, 2005), August 2006 (RSSB, 2006), June 2009 (RSSB, 2009), August 2011 (RSSB 2011) and December 2014 (RSSB 2014) respectively. Version 8.5 is currently the most recent and was published in March 2018 (RSSB 2018). Each version of the SRM uses data closing some months before its publication in order to allow time for its production. For example, SRM version 8.5 uses data up to February 2017, and is therefore attributed to 2016 in Tables 8 and 9 below. 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 motor 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 2001-2019 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 8.5 of the SRM was published in March 2018 and used data up to the end of February 2017; it is attributed to the year 2016, and compared with the "end-of-2016" 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 far from 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 2019**

| 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 | | | |
| 2012 | Yes | End 2012 | 1.4 | | | |
| 2013 | Yes | End-2013 | 1.2 | Version 8 | 2.4 | 1.9 |
| 2014 | | | | | | |
| 2015 | Yes | End 2015 | 1.0 | | | |
| 2016 | Yes | End-2016 | 0.9 | Version 8.5 | 2.3 | 2.6 |
| 2017 | Yes | End-2017 | 0.8 | | | |
| 2018 | | | | | | |
| 2019 | Yes | End-2019 | 0.7 | | | |

Table 9 shows the corresponding estimated mean fatalities per year in 2001-2019 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, which reflects safety performance. For these accidents the two models are in reasonably close agreement on the level of mean fatalities per year.

**Table 9: Estimated mean fatalities per year in collisions between trains and road motor vehicles: AEM and SRM: 2001 to 2019**

| 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 | | | |
| 2012 | End-2012 | 3.2 | | | |
| 2013 | End-2013 | 3.1 | Version 8 | 3.5 | 1.13 |
| 2014 | | | | | |
| 2015 | End-2015 | 2.8 | | | |
| 2016 | End-2016 | 2.5 | Version 8.5 | 2.0 | 0.80 |
| 2017 | End-2017 | 2.5 | | | |
| 2018 | | | | | |
| 2019 | End-2019 | 2.2 | | | |

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

The principal sources of information for this paper are the Railway Inspectorate (RI) annual reports and accident reports for older data, and the Office of Rail and Road, the Rail Safety and Standards Board (RSSB) and Rail Accident Investigation Branch (RAIB) for more recent years. 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 and Road |
| 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: 1967-2019**

| 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: 1967-2019**

| Date | Location | Nature of accident | ATP-preventable? | Rolling stock | Speed km/h | Fatal-ities |
|---|---|---|---|---|---|---|
| 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 | Roade 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: 1967-2019**

| Date | Location | Nature of accident | Fatalities: Train Occs | Fatalities: Road Veh Occs | Fatalities: All |
|---|---|---|---|---|---|
| **Collisions at level crossings with one or more train occupant fatalities** | | | | | |
| 6.11.04 | Ufton | 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 | 175 accidents | | 0 | 211 | 211 |
| **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 | 196 accidents | | 42 | 231 | 273 |

*Source*: Extracted from *Railway Safety* (HSE, annual), HMRI train accident database, or RSSB
*Abbreviations*: RTA = road traffic accident; ECS = empty coaching stock; LC = level crossing.

**Table A3: Numbers of fatal collisions between trains and road motor vehicles: 1967-2019**

| | Number of collisions with given number of fatalities | | | | | | | | | Total fatalities | Fatalities/ accident |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 5 | 6 | 9 | 10 | 11 | All | | |
| 1967-2019 | 156 | 25 | 8 | 1 | 1 | 1 | 1 | 1 | 196 | 273 | 1.4 |
| 2019 | | | | | | | | | 0 | 0 | |
| 2018 | | 1 | | | | | | | 1 | 2 | 2.0 |
| 2017 | 2 | | | | | | | | 2 | 2 | 1.0 |
| 2016 | | | | | | | | | 0 | 0 | |
| 2015 | | | | | | | | | 0 | 0 | |
| 2014 | 2 | | | | | | | | 2 | 2 | 1.0 |
| 2013 | 2 | 1 | | | | | | | 3 | 4 | 1.3 |
| 2012 | 3 | | | | | | | | 3 | 3 | 1.0 |
| 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 $\lambda_t$ given by

$$\lambda_t = \alpha\, k_t \exp(\beta t)$$

where $k_t$ = train-kilometres in period $t$, $\alpha$ is a scale parameter determining the general accident level, and $\beta$ 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 $\lambda_t/k_t = \alpha \exp(\beta t)$. 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 $\alpha$ and $\beta$. The trends quoted in the main paper and in the tables below are estimates of the parameter $\beta$.

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 motor 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 $\chi^2$-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 $\beta$ is held at zero, and variant (b) in which $\beta$ 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 about equal to 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 1967-2019 for level crossing accidents and 1972-2019 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 53.7 between variants (a) and (b) is strongly statistically significant when tested against the $\chi^2$ distribution with 1 degree of freedom, but the reduction of 0.1 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 20.9 in variant (b) with 18 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 2019**

| Variant of model | Degrees of Freedom | Scaled Deviance | Estimate of trend parameter β (Standard error in brackets) |
|---|---|---|---|
| (a) No trend | 10 | 96.0 | Assumed zero for all accidents |
| (b) Common trend | 9 | 10.8 | -7.4% (0.9%) 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 2019**

| Variant of model | Degrees of Freedom | Scaled Deviance | Estimate of trend parameter β (Standard error in brackets) |
|---|---|---|---|
| (a) No trend | 19 | 74.5 | Assumed zero for all accidents |
| (b) Common trend | 18 | 20.9 | -3.8% (0.5%) p.a. for all accidents |
| (c) Separate trends for LC* and NLC* accidents | 17 | 20.8 | -3.8% (0.5%) p.a. for LC accidents<br>-3.5% (2.0%) p.a. for NLC accidents |

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