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ABSTRACT

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Over the period from 1980 to the present, the economic status of the main line railway systems in many developed countries has changed, by privatisation or economic deregulation or both. The principal aims of such changes have been to improve the economic performance of the railways, and not to change the safety performance. Nevertheless, it is recognised that changing the organisational structure of railways might affect safety, particularly by increasing the number of operators, some of whom are new to the industry. Therefore the resources devoted to safety regulation have generally been substantially increased. This report examines evidence on the impact of restructuring on the safety performance of railways, of other transport modes, and to a small extent in other industries, using evaluation studies. The countries considered are Australia, Canada, the USA, Japan, the EU25 collectively, and Great Britain. The report includes a new analysis of the impact on train accidents of rail privatisation in Japan. The number of relevant studies is small. The available results show no evidence that rail restructuring as carried out had an adverse effect on safety. The report also discusses the regulatory frameworks, safety management systems, and the cost of railway safety measures.

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1. INTRODUCTION

Over the period 1980 to the present, the economic status of the main line railway systems in many developed countries has changed, by privatisation or economic deregulation or both. The principal aims of such changes have been to improve the economic performance of the railways, and not specifically to change the safety performance. Nevertheless, it is recognised that changing the economic structure of railways might affect safety, and many countries have wished to ensure that the generally good safety performance of railways did not deteriorate. It is therefore useful to examine the safety performance of railways during this period of change. This report considers the experience of Australia, Canada, the United States of America, Japan, the 25 member states of the European Union collectively as at 2005 (EU25), and Great Britain.

The specific content of railway restructuring has been different in different countries, depending partly on a country's initial structure. With the exception of the United States, the countries considered generally embarked on restructuring from a starting point with one or more major publicly-owned 'vertically-integrated' railway operators providing both infrastructure and train operation. The principal components of restructuring have been the reduction in economic regulation (in the United States), privatisation of all or some of the previously state-owned enterprises (Canada, Australia, Japan, some EU countries, Great Britain), the separation of the organisations providing the track and signalling from those operating trains (Australia, the EU25, Great Britain), and the provision of mandatory access to the tracks as train operators for suitably qualified new entrants, either as franchisees of passenger services or as commercial operators of freight or passenger services (Australia, the EU25, Great Britain).

Railway operation involves heavy vehicles moving on the surface at high speeds with long stopping distances. The safety risks of such operations have long been recognised, and elaborate control systems and technical standards have been developed to mitigate these risks. These risk controls are complex and had become deeply embedded in the structure of the railway organisations. Changing the organisational structure might therefore be expected to affect safety. Therefore safety and safety regulation have been a major concern throughout the railway restructuring process.

The safety risks that might be associated with privatisation or economic deregulation include the following.

- Activities that had previously been within the same organisation, such as infrastructure provision and train operation, might be separated, and the new safety responsibilities ill-defined or uncoordinated.
- Safety-critical information might be attenuated across organisational boundaries.
- New companies with little previous experience of safe railway operation might enter the industry and be less safe than more experienced operators.
- Changes in working practices were likely.
- Private operators might choose to spend less on safety than public operators in order to increase their profit.

An economic risk associated with safety is that:

- Incumbent operators might claim that potential entrants were unsafe, or prevent them gaining access to experience or information to be safe, as a means of protecting their markets.

The principal objectives of this project are the following:

1. Assess the manner in which rail safety performance can be seen to have been impacted by regulatory reform and structural changes within the industry;
2. Review the lessons learned where the regulatory framework for safety was not initially modified, or else inappropriately modified, and has subsequently to be changed adjusted to the new institutional and economic environment;
3. Analyse the outcomes of specific safety-enhancing policies that have been put into place during regulatory reform of railways (*e.g.* safety management systems); and
4. Make comparisons with regulatory developments in other sectors as far as appropriate (*e.g.* aviation, nuclear energy, etc).

The report continues as follows. Section 2 outlines the nature of railway safety performance data, and presents a high-level selection of such data from public sources for the countries in this study. Section 3 outlines all the studies known to the writer in which the effects of restructuring on safety have been examined empirically. This section covers railways, other transport modes and other industries. This section may be regarded as the core of this report. Section 4 considers options for safety regulatory frameworks, though there is insufficient data empirically to indicate whether some choices are better than others. Section 5 considers safety management systems. Section 6 briefly considers the cost of rail safety measures. Section 7 summarises the conclusions. References are listed at the end. There is an appendix with a new analysis of train accident data for the Japanese National Railway and its successor companies.

2. RAILWAY SAFETY PERFORMANCE DATA

2.1 Introduction

Railway safety performance data usually take the following form:

1. Counts of specified types of unwanted events, or “occurrences” in a system; and
2. Data related to safety management.

In addition, investigations are carried out into the serious accidents and those from which there are lessons to be learned, and the findings of these investigations also form part of safety performance data.

Railway safety occurrences are of many types. At the most serious end of the spectrum are multiple-fatality train collisions and derailments, which fortunately are rare. Next, there are less serious accidents of the same kind, which – either by safety defences or by good fortune – cause less harm or no harm. Next there are large numbers of personal accidents involving moving trains in which a passenger, member of staff, or member of the public is struck by or falls from a train, often fatally. In these accidents, members of the public may be subdivided between those who are legitimately on the railway, and those who are not, labelled “trespassers”. Next, many railway systems suffer a relatively large number of suicides; sometimes it may be difficult to determine whether a specific fatality was intentional (and therefore a suicide) or not. At the least serious end of the spectrum are large numbers of minor occurrences, including irregular train operation of various kinds without harm, infrastructure failures without harm, and minor slips, trips and falls by people on stations or elsewhere on railway property.

Therefore a reasonably complete set of safety performance data might include data on the kinds of events listed in Table 2.1. Railway operators monitor their own performance with such data, usually accompanied by verbal descriptions of the events. Some of these data are also reportable to safety regulators or to accident investigating bodies, who may then publish them. However, with the important exception of the United States, the amount of railway safety performance data in the public domain is limited. Furthermore, the data required and published by regulators and accident investigators are tailored to their own needs and history. In consequence they differ between countries.

Most of the data in Table 2.1 relate to unwanted events that have already happened. In consequence they are sometimes called ‘reactive’. Many observers – such as the Advisory Panel for the review of Canada’s Railway Safety Act (Lewis *et al* 2007, Chapter 6) or Hale (2000, page 11) – have commented that it would be helpful to have ‘proactive data’ or ‘leading indicators’ to give warning of deterioration in safety before accidents happen. Hale suggests a number of possibilities including near-misses and incident data, hardware failure data, behavioural monitoring, operational anomalies, inspection of the presence and working of safety measures, and audits.

Some of the indicators in the bottom half of Table 2.1 are examples of the kind of indicators from Hale’s list. However, as the quotation from Elvik later in this report suggests (Section 3.1.1), the validity of using incident data as a substitute for accident data can be questioned, because incident data it may be incomplete or biased, and changes in incident data might reflect changes in reporting practice and culture

as much as real changes in safety performance. For that reason, the analysis of data and the review of evaluation studies are based on accident data only.

Table 2.1. **Illustrative railway safety performance measures**

Casualties to persons
<ul style="list-style-type: none"> • Fatalities to passengers, staff, public non-trespassers, trespassers, suicides. • Serious (or major) Injuries to passengers, staff, public non-trespassers, trespassers, attempted suicides. • Slight (or minor) injuries to passengers, staff, public non-trespassers, trespassers, attempted suicides.
Accidents (unintended harmful events)
<ul style="list-style-type: none"> • Train collisions, derailments, overruns, and fires with fatalities or other casualties to passengers, staff or others – on running lines. • Train collisions, derailments, overruns, and fires with fatalities or other casualties to passengers, staff or others not on running lines – in yards, sidings or engineering possessions. • Train collisions, derailments, overruns, and fires without casualties but with other forms of loss – damage or disruption – on running lines. • Train collisions, derailments, overruns, fires without casualties but with other forms of loss not on running lines – in yards, sidings or engineering possessions. • Accidents to Persons involving moving trains. • Injuries on railway property not involving trains. • Accidents at level crossings. • Accidents involving carriage of dangerous good with and without release.
Incidents (events without harm but with potential for harm)
<ul style="list-style-type: none"> • Operations: Irregular working. • Operations: signals passed at danger. • Operations: loading irregularity. • Infrastructure: wrong-side signal failure. • Infrastructure: failure of level crossing equipment. • Infrastructure: failure of integrity of civil engineering. • Infrastructure: broken rails, buckled rails. • Rolling stock: broken wheels. • Rolling stock: hot axle boxes.
Indicators of technical safety
<ul style="list-style-type: none"> • Proportion of track or train-km fitted with automatic train protection. • Number of level crossings per km of track. • Proportion of level crossings fitted with automatic or railway-operated protection.
Indicators of safety management
<ul style="list-style-type: none"> • Number of safety audits carried out in total and as a proportion of intended audits. • Indicators of quality of safety culture.
Malicious acts
<ul style="list-style-type: none"> • Malicious acts to persons on railway property. • Malicious acts to trains: obstructions, missiles.

Table 2.2. Selected railway safety performance data: 2001-2006

	Australia	Canada	United States	Japan JR	EU25	Great Britain
Period covered	2002-2006	2002-2006	2002-2006	2001-2005	2004-2005	2002-2006
Train-km per year (10 ⁸)	1.811	1.490	12.359	7.422	37.346	5.287
Proportion of train-km that are passenger	60%	7%	12%	90%	..	89%
Fatalities per 100 million train-kilometres						
Non-trespassers:						
Passengers	..	..	0.5	..	2.0	1.9
Staff	..	..	2.2	..	1.4	0.9
Public non-trespassers	..	..	29.9	..	..	2.5
All non-trespassers	..	25.1	32.6	..	..	5.2
Trespassers	..	38.1	40.4	..	..	8.7
Non-tresps + trespassers	..	63.2	73.0	31.2	39.5	13.9
Suicides	..	..	..	..	..	38.2
All including suicides	25.1	..	..	..	..	51.1
Ratios of fatality rates						
Passengers and staff as % all non-trespassers	..	..	8.4%	..	..	52.9%
Trespassers / non-trespassers	..	1.52	1.24	..	..	1.66
Fatalities at level crossings (LCs)						
Fatalities per 100 million train-kilometres	7.5	22.3	29.0	10.1	11.1	2.1
LC fatalities as % of all non-trespasser fatalities	..	89%	89%	..	..	40%
Recorded train accidents per 100 million train-kilometres						
Different definitions used	154.8	701.4	248.3	1.3	218.7	196.8

Note: “..” means “not calculable from data source used”.

Sources and notes to data in Table 2.2

Australia

The primary source is *Australian Rail Safety Occurrence Data* published by the Australian Transport Safety Bureau (ATSB 2008). Train-kilometres are in Table 25. Fatalities are given in Table 1, but are not subdivided in any way by type of person or type of accident. A note in the *Australian Transport Statistics Yearbook 2007* published by the Bureau of Infrastructure, Transport and Regional Economics (BITRE, 2008) states that the fatality data include suicides. Train accidents are taken here to be the sum of Running Line Derailments (Table 3 of ATSB 2008), Running Line Collisions (Table 5), Collisions with Rolling Stock (Table 7) and Collisions with Infrastructure (Table 11). Fatalities at level crossings are given in a separate review of level crossings by the Railway Safety Regulators' Panel (RSRP, 2008) at www.rsrp.asn.au/files/publications/14_32..pdf.

Canada

The source is Addendum Table S3 to *Transportation in Canada 2007* published by Transport Canada, available at www.tc.gc.ca/pol/en/report/anre2007/add/table-s3.htm. Fatalities are divided into those at crossing collisions, those in trespasser accidents, and others, but the others are not subdivided by type of person or type of accident. Train accidents are here taken to include all those reported, except crossing collisions, trespasser accidents, employee accidents and passenger accidents.

United States

The source is *Railroad Safety Statistics 2006 Final Annual Report*, published by the Federal Railroad Administration (FRA 2008). Casualty data are taken from Tables 1.1, 1.2 or 1.3. The numbers of trespasser fatalities are here taken from Table 1.2, which excludes those at level crossings. All level crossing fatalities are therefore counted here as non-trespassers. Suicides are excluded, provided that this is determined by a coroner. Train accidents are as given in Table 1.1. Passenger train-km data are from Table 2.4.

Japan

Figures in the table are based on data provided personally to the author by the Institute of Land, Infrastructure, Transport and Tourism, Japan.

EU25

The data cover the 25 states of the European Union as in 2004-2005 and cover only those years. The sources are *Railway Safety Statistics year 2004* and *A Summary of 2004-2005 EU Statistics on Railway Safety*, published by the European Railway Agency at www.era.europa.eu/public/core/Safety/Documents/Safety%20performance/06-06-01ERA-Report.pdf and <http://www.era.europa.eu/public/core/Safety/Documents/Safety%20performance/07-05%20ERA-Report2.pdf> respectively. They are based on Eurostat data. The fatality data distinguish between passengers, employees, and others, but they do not distinguish trespassers from non-trespassers among the others. Suicides are excluded. Train accidents are here taken to be those reported to the EU as "significant accidents".

Great Britain

The source is the Annual Safety Performance Report 2006, published by the Rail Safety and Standards Board (RSSB 2007). This is an industry body rather than the regulator. The data used all come from Appendix 1 "Key safety facts". The RSSB's fatality data include assaults, but assaults have been excluded here. Data on suicides include suspected suicides as well as confirmed suicides. Train accidents are as reported by RSSB.

2.2. Selected international rail safety performance data

Table 2.2 gives a selection mainly from published sources of recent railway high-level safety performance data based on accidents for Australia, Canada (Federally regulated railways), the United States, Japan (JR railways only), the EU25, and Great Britain (National Rail only). The accompanying box gives notes and sources for these data. The purposes of Table 2.2 are:

1. To illustrate some aspects of the risk profile of different types of railway; and
2. To illustrate variations in the available data in different countries.

Table 2.2 contains a large number of symbols indicating “not calculable from data source used”. Such availability depends on the recording conventions adopted in different countries. The data in Table 2.2 should *not* be used to draw conclusions about relative railway safety performance in different countries, because most of the differences reflect different risk profiles or different recording conventions.

The top panel of Table 2.2 gives train-kilometres per year as a measure of scale of the railway operation, and the proportion of train-km that are passenger trains, which is an indicator of the type of operation. Of the railways in the table the EU25 has collectively the largest operation; then the United States; then Japan; then Great Britain; then Australia and then Canada. Canada and the United States are mainly freight operations, with only 7% and 12% respectively passenger; Australia has about 60% passenger; Great Britain and Japan have 89% and 90% passenger respectively.

The second panel of Table 2.2 gives railway fatalities per 100 million train-kilometres, and the third panel gives certain ratios among these fatality rates. The reasons for showing fatalities are first that they are important, and secondly that fatalities are fairly similarly defined in different countries (though not identically). All countries also record data on injuries, but they are not used here because of complications arising from differences in measuring the severity of injuries.

The fatalities are categorised into passengers, staff, public non-trespassers (mainly level crossing users, neighbours to railways, and visitors to railways), trespassers (persons illegally on the railway), and suicides. The large number of “not available” symbols in this panel indicates that different countries count different categories of fatalities, but the data are sufficient to illustrate the general patterns of railway fatalities. These patterns are the following:

1. The fatalities that are most directly within the railway operators’ control are those to passengers and staff. Of the countries considered, these fatalities are distinguished explicitly only in the United States, the EU25 and Great Britain. The numbers of such fatalities are small compared with other railway fatalities, but they are often high-profile, and they can be strongly affected by multi-fatality passenger train accidents, which are infrequent but have occurred in most countries. The numbers of staff fatalities exceed those to passengers in the United States, which is freight-dominated; the opposite is true for EU25 and Great Britain, which are passenger-dominated railways. Fatalities to passengers occur not only in train accidents but also in personal accidents such as falls when boarding trains.
2. Public non-trespasser accidents are also important. These are dominated by fatalities to the public at level crossings – both pedestrians and road vehicle occupants. The third panel of Table 2.2 shows that 92% of all non-trespasser fatalities in the United States were to the public, and the fourth panel shows that almost all of these were at level crossings. The proportion of non-trespasser fatalities that were to the public was smaller in Great Britain at 43%, but level crossing fatalities again dominate these.
3. The fourth panel indicates that level crossings are an important source of risk in all the countries considered. Several countries have mounted successful programmes to reduce level crossing accidents in recent years, but the large number of crossings and the opportunities for intentional or unintentional misuse by road users make the task difficult. Countries with large rural areas tend to have more level crossings per train-km than more higher-density countries,

and this leads to more accidents and fatalities per train-km, though to lower fatalities per crossing. The majority of fatalities at level crossings are to the road-using public, but occasionally accidents result in multiple fatalities to train occupants.

4. The numbers of fatalities to trespassers are greater than those to non-trespassers in all the countries for which these can be compared: there were 52% more fatalities to trespassers than non-trespassers in Canada, 24% more in the United States, and 66% more in Great Britain. As well as loss of life, they cause shock and distress to railway staff, and also disruption to services. Again, the railways mount programmes to discourage trespass.
5. Finally, there are many suicides on railways. Most countries do not regard suicides as railway casualties, and do not require confirmed suicides to be reported. However, suicides, as well as tragic for the person concerned, also cause shock and distress to railway staff, and also disruption to services.

The bottom panel in Table 2.2 presents accident rates to trains, such as derailments and collisions, taken directly from the data sources used, and adopting local definitions. The majority of these cause no casualties and little harm, but many of them have the potential to be more serious, and they may be taken as indicators of the performance of the operators in generally controlling their risks. It can be seen that the recorded rates vary enormously, reflecting not so much the relative safety performance of the differing countries, but their differing recording conventions. This illustrates the general point that different recording conventions, as well as different operating patterns, make international comparisons of railway safety performance extremely difficult. Burrows (2006) discusses the difficulties of international comparisons in more detail. Table 2. is a summary by the present writer of the main problems identified by Burrows.

Table 2.3. Problems in making international comparisons of rail safety performance data

Definitions of variables compared may be different, especially with regard to accidents.
Definitions of variables compared may be unclear.
Data may not be collected according to a precise definition.
Data may be at too aggregate a level.
Normalising data may not be available.
Fatalities may be differently defined in different datasets, especially with regard to trespassers and suicides.
Major and minor injuries may be differently defined in different datasets.
The reporting of non-injury accidents may be determined by a threshold monetary value of damage, but the value may vary between datasets or change its real value over time.
The operating environments of compared railways may be different Urban/ inter-city/ rural Predominantly passenger/ predominantly freight
Derailments and collisions in yards and sidings may or may not be separated from those on running lines.
Operators may be unidentified and their characteristics unknown.

Source: Present author, based on Burrows (2006)

It follows that the main prospect for the empirical investigation of the effect of railway restructuring on safety lies not in international comparisons, but in the analysis of time series of safety performance measures for specific countries, which have been collected under the same recording conventions over a long period of time.

Of the countries within this study, the United States, Japan and Great Britain all have long-term time series of safety performance data suitable for investigating the effects of restructuring, but the other countries and the EU25 do not. Therefore it is not surprising that the United States, Japan and Great Britain are the countries for which evaluation studies have been carried out. These are outlined in section 3.

Australia, Canada and the EU15 do not have suitable data for evaluation studies. In Australia the primary source of data is *Australian Rail Safety Occurrence Data*, assembled by the Australian Transport Safety Board (ATSB 2008), but data have been assembled using common definitions between the States only for 2001 to 2007. The Bureau of Infrastructure, Transport, and Regional Economics (BITRE) has published a series of rail fatalities covering 1979 to 2006 (BITRE, 2007, Tables 9.1b, 9.10), but this is impossible to interpret because of changes in coverage and definitions.

In Canada, safety performance statistics are currently assembled and published by the Transport Safety Board of Canada. The data from 1989 to 2006 were published and discussed in the Review of the Railway Safety Act by Lewis *et al* (2007), and in a research project for that review (CPCS Transcom Limited, 2007). There have been changes to the definitions and coverage of the data, which makes the statistics difficult to interpret. The writer has seen no data for Canada before 1989.

For Europe as a whole, occurrence data are assembled jointly by Eurostat and by the European Railway Agency (ERA). However, the data go back only to 2004 (ERA, 2006). The ERA is also assembling a database of accident reports. However, the formal starting data for that database is April 2006, and even now not all members of the EU are contributing. Therefore the ERA is near the beginning of its work as a source of data.

3. STUDIES OF EFFECTS OF RESTRUCTURING ON SAFETY IN TRANSPORT AND OTHER INDUSTRIES

3.1 Reviews of evaluation studies

The writer has identified two very useful general review papers evaluating the effects of deregulation or privatisation on safety performance in transport and in other industries. These are by Elvik (2006) and Egan *et al* (2007).

3.1.1 Elvik (2006) on deregulation in transport

Elvik (2006) carried out a synthesis of evaluations of the effects of deregulation on safety in all modes of transport, as part of Norway's Risk in the Transport Sector (RISIT) research programme.

Elvik notes that during economic deregulation, safety regulations are usually retained. These cover:

- Safety standards for vehicles (aircraft, rolling stock, road vehicles).
- Safety regulations for traffic operations (air traffic control, signal control of trains, speed limits for road transport, etc).
- Regulations for working conditions for employees (maximum working hours, minimum rest periods, professional qualifications etc).

For his synthesis, Elvik searched the JTRC/OECD Transport literature database for relevant papers. His criteria for the usability of papers included the ability to provide quantitative estimates of the effects on safety of deregulation or restructuring. Elvik found 25 studies in the database that met his criteria, but only two of these were on rail deregulation: one by the present writer on Great Britain (of which the final version is Evans, 2007), and the other by Savage (2003) on the United States. These are summarised below. Of the other papers in Elvik's review, 11 related to road transport, 10 to aviation and 2 were concerned with modal shift. No study was found concerning the effects of deregulation on maritime transport. Eighteen of the studies in Elvik's review related to the United States, 4 to Great Britain, 2 to New Zealand, and 1 to Norway.

Elvik notes that:

“Evaluating the effects of transport deregulation on transport safety is very complex. In the first place, obtaining reliable and valid safety data is difficult. Although major accidents are likely to be reported and included in official transport statistics, such accidents are few in number, at least in aviation and rail transport. ... Minor accidents are likely to be subject to incomplete and biased reporting. ... Incidents that are not classified as accidents such as signals passed at danger in rail transport ... are considerably more numerous than accidents, but are likely to be subject to incomplete and biased reporting. Moreover the validity of using incident reports as substitute for accidents can be questioned. Reporting a high number of incidents may not necessarily indicate a low level of safety, but could just as well be a sign of a high concern for

safety, which, if anything, one would expect to be associated with a good safety record in terms of accidents. All the evaluation studies that have been included in this paper have relied on official accident statistics to describe safety. All the studies are confined to fatal accidents or injury accidents. These data are probably the most reliable that can be used in evaluations of transport safety” (page 684).

“A major difficulty in evaluating the effects of deregulation on transport safety is to control for confounding factors. Essentially, controlling for confounding factors is trying to answer the question: what would have happened if deregulation had not taken place? ... The answer most studies give to the question of what would have happened in the absence of deregulation is that past long-term trends in accident rates would have continued. Provided the description of past long-term trends in accident rates is adequate, this is perhaps the most reasonable answer that can be given” (pages 684/5).

It may be noted that the analysis reported below of the effect of rail restructuring in Great Britain and Japan, and Figure 3.1 to Figure 3.4, rely on just this method for estimating what would have happened in the absence of restructuring.

Elvik’s overall conclusion is that “deregulation of transport does not appear to have adversely affected transport safety. Continued monitoring of the impacts of deregulation on transport safety is recommended, as the process of deregulation is still in its infancy in many countries, and is likely to continue for many years” (page 685).

On railways, he says “summary estimates of the effects of deregulation of railways indicate that safety has improved. There are, however, only two studies and both of them are observational. One should therefore regard the continued improvement of railway safety following deregulation as a statistical association only, not necessarily a causal relationship” (page 684).

3.1.2 Egan *et al* (2007) on health and safety effects of privatisation

Egan *et al* (2007) carried out a systematic review of papers evaluating the effects of privatisation (but not other economic reforms) in any industry on the health and safety of employees or the public, including transport passengers. Egan *et al* were concerned with evaluation studies that related to OECD countries at any time from 1945 up to 2005 and in any language. They searched a large number of databases, and initially identified 13 532 potentially relevant studies. However, in the end they found only 11 studies that met their evaluation criteria, of which 10 related to the United Kingdom and one to Portugal. Presumably, the reason why Egan *et al* found no studies from the United States is that restructuring in the United States generally took the form of deregulation rather than privatisation.

Of the 11 studies, only one was concerned with rail transport, and that was an early version of the present writer’s work. Three other UK studies were concerned with the effects of bus privatisation and deregulation in 1986, including one by the present writer (Evans 1994). The others were Astrop *et al* (1991) and White *et al* (1995). All these transport studies were concerned with the effects of restructuring on safety, measured by accidents or casualties. The seven other industries in Egan *et al*’s review were building, water, paper, cement, mining, electricity and gas. Three industries – gas, electricity and water – were considered in the same study (National Economic Research Associates, 1996). All except the gas and electricity industry studies were concerned with the health or safety of employees, rather than the public. The gas study was concerned with the frequency of gas explosions before and after privatisation, and the electricity study was concerned with electrical injuries to both employees and the public.

Egan *et al*'s substantive conclusions are the following:

“The most robust study found increases in the measures of stress-related ill-health among employees after a privatisation intervention involving company downsizing. No robust evidence was found to link privatisation with increased injury rates for employees or customers. In conclusion, public debates on the health and safety implications of privatisation have a poor empirical base, which policy makers and researchers need to address” (page 862).

The striking feature of Egan *et al*'s paper is the remarkable depth and width of their search (all OECD countries since 1945) and the small number of studies found, which led them to conclude that much of the privatisation debate “has been conducted in an empirical void” (page 867). Egan *et al* do not discuss the regulations and safety management systems related to the industries they consider.

3.2 Rail safety evaluation studies

The two studies of the effect of rail restructuring mentioned by Elvik are by Savage (2003) on the United States and an earlier version of Evans (2007) on the United Kingdom. A third study not mentioned by Elvik is by Clarke and Loeb (2005) on the United States. All three studies conclude that restructuring did not have an adverse impact on railway safety. Finally, the data on Japan provided to the author for the present study by the Institute of Land, Infrastructure, Transport and Tourism have enabled the author to carry out an analysis of the effect of rail privatisation on train accident rates in Japan. This is summarised below and more details are presented in the Appendix to the present report. This also concludes that privatisation did not have an adverse effect on safety.

3.2.1 Savage (2003) on United States

Savage (2003) considers the effects of rail legislative changes in the years between 1970 and 1980 on rail safety in the United States using data for 1960 to 2002. Railways have always been privatised in the United States, so the changes considered in Savage's evaluation are:

1. Economic deregulation – *i.e.* giving freedom to operators to fix their own prices and decide which traffic to accept; the previous economic regulation prevented railways from competing effectively with other modes.
2. The provision of stronger safety regulatory powers to the Federal Railroad Administration (FRA); and
3. Federal funding for the improvement of level crossings.

As noted in Section 2.2, the major groups suffering fatalities in the United States are staff, level crossing users, and trespassers. Savage's paper shows that following a worsening safety record in the 1960s, there were then reductions in the numbers of fatalities to each of these groups. On the worsening safety record in the 1960s, Savage says:

“The causes are not difficult to understand. ... Financial difficulties ... led to railroads disinvesting in their track and capital stock. The situation was made worse because new and heavier freight cars were being introduced. This led to a sharp rise in derailments that were caused by broken rails. These derailments became more of a public concern because of the expanded carriage of hazardous materials” (page 4).

After deregulation, the greatest improvement was for level crossing users, then employees, and the least improvement was for trespassers. Savage discusses the causes of these improvements. He suggests that they were partly because the improving financial position of the railways enabled more investment, and partly because the new enforcement and standard setting activities of the FRA ensured that the investment was made, both in infrastructure and rolling stock. In addition, the federal funding directly improved the safety of level crossings (of which there are about 230 000 in the United States (FRA 2008, Table 9.1)). The investment in track and rolling stock reduced train accidents, and benefited those at risk from train accidents, who in the freight-dominated railways of the United States are mostly on-train staff. Trespassers are likely to benefit least from these measures.

3.2.2 *Clarke and Loeb (2005) on United States*

Clarke and Loeb (2005) consider the effect of deregulation in the United States under the Staggers Act of 1980 on railway fatalities, using data over the period 1976-1992. They develop separate models for three different classes of fatalities: trespassers, level crossing users, and employees and passengers taken together. Their conclusions are similar to those of Savage:

“The statistical results ... do not support the hypothesis that deregulation of the railroad industry ... led to additional fatalities. ... The coefficients associated with deregulation in all three fatality equations were actually negative and tended to be statistically significant. We suspect that this reduction associated with deregulation is due to increased profitability of the railroads after the passage of the Staggers Act” (page 155).

3.2.3 *Evans (2007) on Great Britain*

Evans (2007) analyses the effect on safety performance of the privatisation of the main line railways in Great Britain from 1994, using official Railway Inspectorate data over the period 1967-2003. He considers four different types of accident:

1. Personal fatal railway accidents, excluding trespassers;
2. Fatal train collisions and derailments;
3. Fatal collisions between trains and road vehicles, mostly at level crossings; and
4. Significant, mostly non-fatal, train collisions and derailments.

The unified public rail operator British Rail had achieved long-term reductions in all four of the above categories of accident in the 27 years from 1967 until privatisation in 1994, and Evans takes the extrapolation of these favourable trends as the yardstick by which to judge the safety performance of the privatised railway. The downward trends in accident rates are the result of numerous improvements in rail technology and management taking place over a long period of time. They are not explicitly identified, but are proxied by the passage of time. Figure 3.1 and Figure 3.2 give examples of Evans' approach. The data points in Figure 3.1 give the annual numbers of personal fatal accidents (such as a person struck by a train) per million train-km in the period 1967 to 2002/03. The solid points are from the British Rail period in 1967 to 1993/94; the open points are from the privatisation period in 1994/95 to 2002/03. The solid curve is the trend fitted to the BR points, and shows that BR achieved a substantial reduction in accident rates, with the mean number of fatal accidents per million train-km falling at an estimated 3.6% per year (with a standard error of 0.3% per year). The dashed line is the extrapolation of the BR's trend, and is taken to be what would be expected if BR had continued. Figure 3.1 shows that the

actual accident rates were below BR's trend in every one of the 9 years after privatisation. Thus there is no evidence that privatisation increased personal fatal accident rates.

Figure 3.1. **Fatal personal railway accidents Great Britain: main line railways 1967-2002/03**

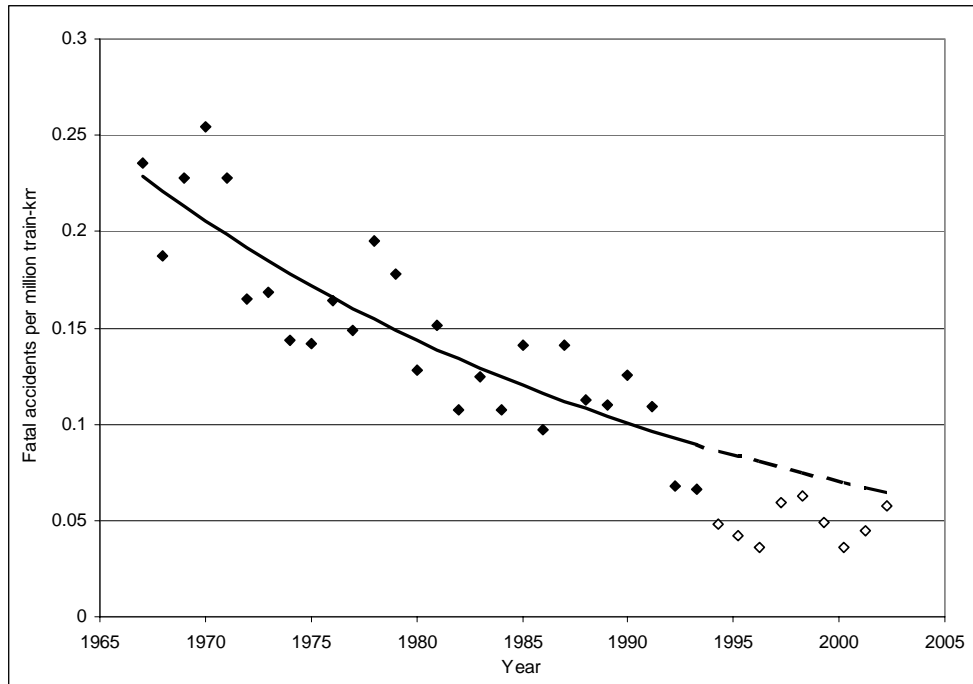


Figure 3.2. **Fatal train collisions, derailments and buffer overruns per billion train-km: Great Britain: national railway system: 1967-2003**

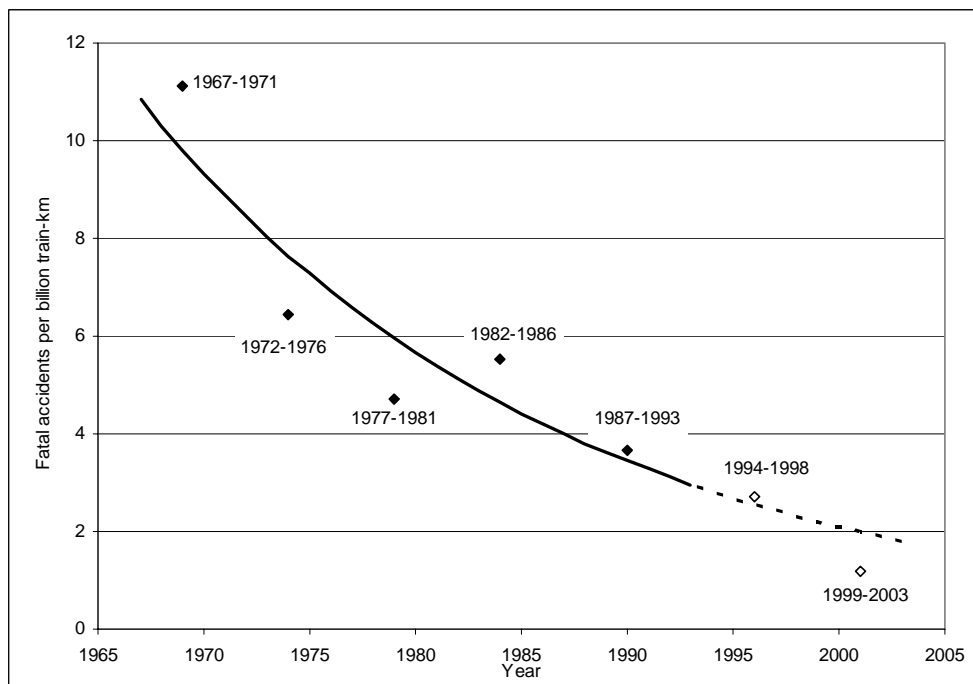


Figure 3.2 shows a similar analysis of the higher-profile fatal train collisions and derailments, which include such accident as Ladbroke Grove in 1999 and Hatfield in 2000. In this case, the accidents are grouped into mostly 5-year periods, because the numbers of fatal train accidents in single years are too small for separate analysis. Again BR had achieved a downward trend in the numbers of fatal accidents per billion train-km, in this case of 5.0% per year (with a standard error of 1.6% per year). Figure 3.2 shows that the actual accident rate in 1994-1998 was approximately on BR's trend, and the rate in 1999-2003 was below BR's trend. Thus there is no evidence to suggest that privatisation led to higher rates of fatal train collisions and derailments.

Similar results were obtained for the other major classes of accident: fatal collisions between trains and road vehicles, and significant train accidents.

Table 3.1. Summary of principal results from “Rail Safety and rail privatisation in Britain”

	Fatal personal accidents	Fatal train collisions, derailments and overruns	Fatal train/ road motor vehicle collisions	Fatal and non-fatal significant train accidents†			
Trends in accident rates							
Before privatisation*	-3.6% pa	-5.0% pa	-1.5% pa	-4.3% pa			
Numbers of accidents (accs) and fatalities (fats)							
	Accs	Fats	Accs	Fats	Accs	Fats	Accs
Before privatisation*	1 748	1 803	71	261	141	194	5 279
After privatisation*							
Actual, A	209	212	9	59	28	41	915
Expected, E	319	330	10.8	39.6	43.5	59.9	1 146
Actual – Expected (A–E)	-110	-118	-1.8	+19.4	-15.5	-18.9	-231
(Est standard error of A–E)	(26)	(27)	(5.0)	(28.9)	(11.4)	(16.8)	(55)

Notes

† For significant train accidents, the results apply to all railways in Great Britain, including metros; for all other types of accident, the results apply to the main line system only.

* For movement and non-movement accidents, 'before privatisation' means 1967–1993/94 (27¼ years) and 'after privatisation' means 1994/95–2002/03 (9 years); for train collisions, derailments and overruns, and train/road motor vehicle collisions, 'before privatisation' means 1967–1993 (27 years) and 'after privatisation' means 1994–2003 (10 years); for significant train accidents, 'before privatisation' means 1971–1993/94 (23¼ years) and 'after privatisation' means 1994/95–2002/03 (9 years). These periods are based on the available data and reporting periods.

Source: Evans (2007).

Table 3.1 summarises Evans' principal quantitative results. The four main columns in the table are the four classes of accidents analysed. We illustrate the structure of the table with reference to the first column, on fatal personal accidents. The trend given at the top of the column – in this case -3.6% p.a. – is the trend in accidents per train-km established in the BR era before privatisation, mentioned above. The next set of figures are the numbers of personal fatal accidents (1 748) and fatalities (1 803) in the BR era. The reason why the number of fatalities exceeds that of accidents is that some accidents have more than one fatality. The next row gives the actual numbers, A, of accidents and fatalities in the period after privatisation, 209 and 212 respectively. The next row gives the 'expected' numbers, E, of accidents and fatalities in the post-privatisation period, which were 319 and 330 respectively. The expected number of accidents is calculated from the extrapolated trend line in Figure 3.1; it is the number of accidents that

would have occurred if they had been exactly on BR's trend in the period after privatisation. The expected number of fatalities is the number of accidents multiplied by the estimated number of fatalities per accident, which is assumed constant at the BR rate of 1 803/1 748, or 1.04. The penultimate row gives the actual less expected ($A-E$) accidents or fatalities. A minus sign indicates that the actual number of accidents or fatalities was smaller than the expected number, and is thus favourable; a plus sign indicates that the actual number of accidents or fatalities was more than expected. Finally, the bottom row of figures in brackets gives the estimated standard errors of the preceding ($A-E$) differences. For a difference to be statistically significantly different from zero (at the 5% level of significance), its absolute value must be at least about twice its standard error.

It can be seen from the penultimate row of Table 3.1 that the actual numbers of accidents, as distinct from fatalities, were less than the expected numbers for all classes of accident. That is strong evidence against the argument that the frequencies of any class of accident were higher after privatisation than would have been achieved if BR had continued. In the case of fatal personal accidents and significant train accidents, the $A-E$ differences are statistically significantly different from zero, which implies that they are unlikely to be due to chance. However, it does not follow that the reductions in the frequencies of these accidents are due to privatisation, because they could be for other reasons. With regard to fatalities, as distinct from accidents, the penultimate row of Table 3.1 again shows negative $A-E$ differences for personal accidents and collisions between trains and road vehicles. However, in the case of train accidents the actual number of fatalities was 59, which was higher than the expected number of 39.6. The reason for the high actual number of fatalities is the severity of the train collision at Ladbroke Grove on 5 October 1999, in which there were 31 fatalities. This needs a little discussion.

Figure 3.3. **Fatalities in fatal train collisions, derailments and overruns
Great Britain 1967-2003**

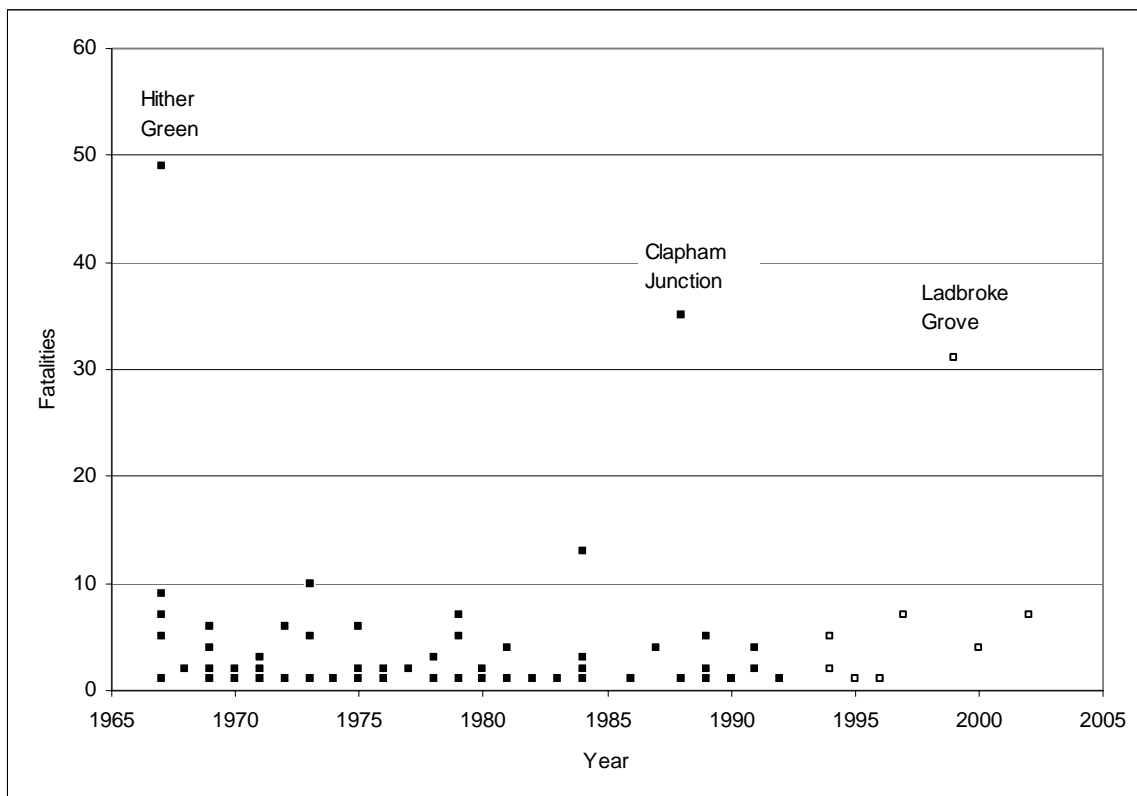


Table 3.1 shows the numbers of fatalities in all fatal train accidents in 1967 to 2003. It can be seen that the number of fatalities is very variable: most fatal accidents have a small number of fatalities, but a few have relatively large numbers. The overall average number of fatalities per fatal accident is 4.0, but there have been three accidents with more than 30 fatalities in the period, of which Ladbroke Grove was one. The variability in fatalities means that averages estimated over relatively short periods have high standard errors, and if the period in question includes a high-fatality accident, the period will have a higher-than-expected actual number of fatalities. That is why the actual number of post-privatisation fatalities was higher than the expected number, even though the actual number of accidents was lower than the expected number. It will be seen from Table 3.1 that although the *A-E* for fatalities in train accidents is positive, it is not significantly different from zero. That is, it could be due to chance. This raises the question of whether the high number of fatalities at Ladbroke Grove was linked to privatisation in some way. In this writer's view, there is no specific link; in particular, the types of rolling stock were the same as those which would have been operated by BR.

The principal counter-argument to Evans' conclusion that rail privatisation in Britain did not adversely affect rail safety is based on accounts of particular accidents, particularly those at Ladbroke Grove in 1999 and Hatfield in 2000 (see, in particular, Wolmar 2001). From detailed accounts of the events and actions leading to these accidents, Wolmar argues that they would not have occurred under BR. Evans (2007, section 5) agrees that such arguments about these accidents are plausible, even though by their nature, they are not provable. However, it is not sufficient to argue that particular accidents would not have occurred without privatisation, because if BR had continued, it is always possible that other accidents would have occurred. Therefore accounts of specific accidents are biased in the direction that change is for the worse: we know about the accidents that occur, but we do not know about the accidents that are prevented. One way of estimating how many accidents might have occurred if BR had continued is by means of a statistical model of the kind above.

A notable change that has occurred in British train accidents since Ladbroke Grove is a reduction in fatal accidents caused by signals passed at danger (SPADs). This change is linked not to privatisation, but to the deployment of the new Train Protection and Warning System (TPWS). In the decades up to the end of the 1990s, there were about 4 fatal SPAD accidents per decade. There have been none since Ladbroke Grove in 1999.

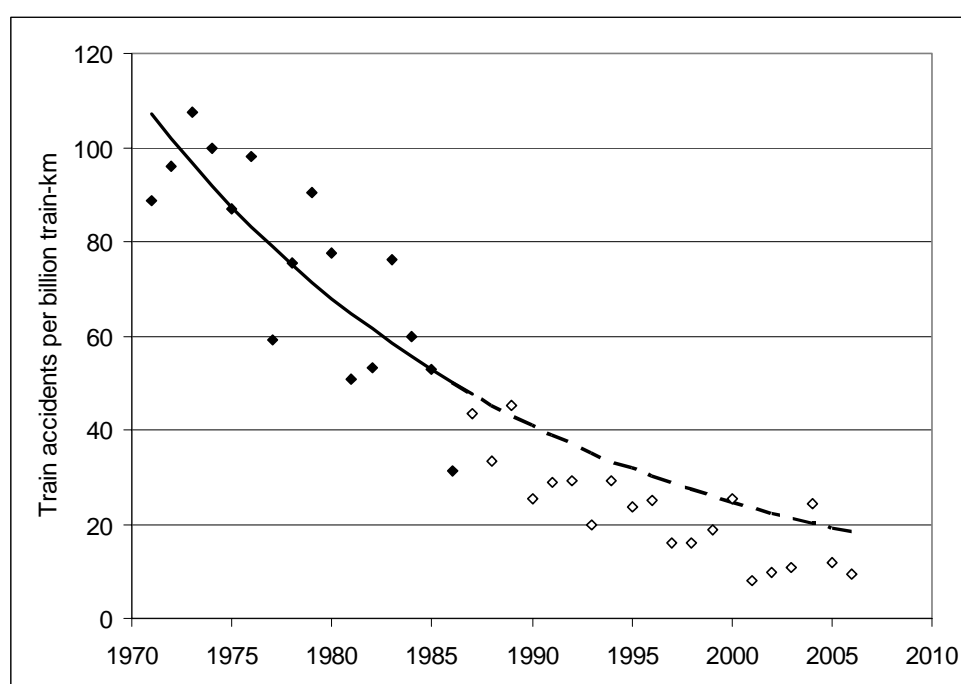
3.2.4 *Evans (2009) on Japan*

Evans (2009, Appendix to this report) has carried a similar analysis of train accidents on the JNR/JR system in Japan before and after privatisation in 1987. In this analysis, train accidents include train collisions, derailments and train fires, whether or not they caused casualties. Figure 3.4 presents the main results. The solid data points represent the observed annual train accidents per billion train-km before privatisation, and the open data points give corresponding data after privatisation. The solid line is the exponential trend fitted to the pre-privatisation data, reflecting the safety improvement being achieved by JNR; the estimated mean number of accidents per train-km fell at 5.0% per year with a standard error of 0.8% per year. The dotted line is the extrapolation of the pre-privatisation trend into the privatised era, and again may be taken to represent what would be expected if the JNR trend had continued. It can be seen that most – but not all – of the post-privatisation points fall somewhat below the extrapolated trend, indicating that the post-privatisation safety performance was slightly better than expected, though the appendix shows that this improvement was not statistically significant. However, this is evidence that JNR privatisation did not make safety worse.

The JNR/JR train operations include both conventional railways, including freight trains, and the Shinkansen standard-gauge high-speed passenger lines. During the period from 1971 to 2006 the

proportion of train-kilometres operated on the Shinkansen lines gradually increased from 5% of the total in 1971 to 18% in 2006. The Shinkansen lines have a very good safety record, and very few of the train accidents are on these lines. Therefore their increasing use will have contributed to the reduction in train accidents per train-km shown in Figure 3.4. It is therefore useful to consider whether the conclusion that privatisation did not affect safety still stands if the conventional JR railways are considered on their own. The answer is that the conclusion does still stand. The rates at which train accidents per train-km fell on the conventional lines were slightly lower when the Shinkansen are excluded, but there is no change to the conclusion that safety performance was slightly better after privatisation than would have been expected by extrapolating the pre-privatisation trend, albeit not statistically significantly so. Further details are in the Appendix.

Figure 3.4. Train accidents per billion train-km: Japan: JNR/JR: 1971-2006



3.3 Conclusions from evaluation studies

The amount of empirical evidence on the effect of restructuring on safety in any industry is limited. The three countries for which studies of the effects on safety of rail restructuring are available are the United States, Great Britain, and Japan; these are the countries for which at least some long-term official safety performance data are available.

The evidence from the studies of the United States suggests that reductions in fatality rates to staff, level crossing users and trespassers followed economic deregulation, the creation of the FRA and federal funding of level crossing improvements in the years between 1970 and 1980. This represents a reversal of the trends from the first half of the 1960s. Of the three groups, the greatest reductions in fatality rates were to level crossing users, then staff, and the reductions were least to trespassers.

The evidence from Great Britain and Japan is that there were downward trends in rail accident rates before restructuring, and that these continued afterwards. Any changes in accident rates at the time of

structuring were, if anything, favourable, but some of these are not statistically significant, and there is no convincing evidence that restructuring actually improved safety.

With regard to other transport modes, there have been studies of airline deregulation (all from the United States), bus deregulation (all from Great Britain), and road freight service deregulation (from several countries). The general conclusion from these studies is that economic deregulation did not adversely affect safety. In all modes, this result was broadly achieved by at least maintaining, and in some cases strengthening, the existing safety regulations and their enforcement. For example, the safety regulations were maintained unchanged throughout bus privatisation and deregulation in Great Britain in 1986, and Savage (2003, page 7) mentions additional legislation to tighten truck standards after deregulation in the United States.

The maintenance and enforcement of the existing regulations after restructuring often requires an increase in the resources devoted to the public bodies responsible for monitoring and enforcing safety. That is at least in part because of the larger number of transport operators encouraged by deregulation or privatisation, some of whom may be inexperienced; there is also a greater turnover of firms. Section 4.3 of this paper presents data on the increase in the staff of the British railway safety regulator as a consequence of rail privatisation. In Europe there has almost certainly been an increase in regulatory resources, as some organisations have been newly created. Other examples are mentioned by Savage (2003, page 9, quoted later in section 4.3 of this paper) who notes the enhancement of monitoring resources in all three of the modes he considers in the United States – road trucking, civil aviation, and railways. Astrop *et al* (1991, page 1) mentions that additional resources were added to the British Road Vehicle Inspectorate in anticipation of bus regulation in 1986.

With regard to other industries, Egan *et al*'s review mentions studies of privatisation in the building, water, paper, cement, mining, electricity and gas industries (mainly from the United Kingdom, with one from Portugal). They found no evidence that privatisation had adversely affected safety in these industries. However, they did report that a robust study had found increases in stress-related ill health among employees after a privatisation involving company downsizing. They do not discuss safety regulations or management systems.

4. REGULATORY FRAMEWORKS

4.1 Introduction

This section reviews the lessons learned where the regulatory structure was not initially modified or else inappropriately modified, and had subsequently to be adjusted to the new institutional and economic environment.

The previous section found that the empirical evidence indicates that, where it can be evaluated, rail restructuring as carried out did not have an adverse effect on railway safety performance. However, the empirical evidence is not sufficiently detailed to indicate how this favourable outcome was achieved.

In some countries regulatory structures or procedures were changed at the start of restructuring, with the intention of anticipating possible safety problems, and these changes may have helped prevent what might otherwise have been a deterioration in safety performance. In some countries the regulatory structures or procedures have subsequently been changed. Given the limitations on the available data, it is not possible to demonstrate empirically one way or the other whether specific changes in the regulatory structure have helped or hindered safety performance. However, we can note some of the changes that have been made, and note some arguments for or against these changes.

We consider three types of generic railway safety organisation:

1. The public railway safety regulator.
2. The accident investigation body.
3. The lead railway industry safety body.

4.2 Evolution of railway safety bodies in Great Britain

A country that has seen many detailed structural changes since rail privatisation in 1994 is Great Britain, and we use that country as a prompt for general questions about regulatory frameworks. Table 4.1 shows the evolution of each of three bodies (a) to (c) above in Great Britain from before the start of rail privatisation in 1994 until 2008. There has been much change from the original structure to that of today: none of the bodies created in 1994 still existed in the same form in 2008. Furthermore, Table 4.1 is confined only to safety bodies. If economic bodies were also included, they would show further change. The changes may be improvements on the original structure, but it is impossible to say how they have affected safety performance. Many of the issues were discussed at the public inquiry by Lord Cullen into the Ladbroke Grove accident in 1999 (Cullen, 2001), at which arguments on both sides of the cases for changes were presented. Jack (2007) gives a useful account of the British experience. Some of the information in Table 3.1 is based on his paper, and it is mentioned again below.

The discussion below raises a number of questions about the roles and relationships between the generic organisations above. However, it is likely that different countries will wish to answer the questions in different ways.

Table 4.1. **Evolution of regulatory framework for safety: national system: Great Britain**

Dates	Nature of railway safety organisation
Rail safety regulator	
Pre-privatisation	<ul style="list-style-type: none"> • The long standing safety regulator was the Railway Inspectorate (RI). Its history goes back to 1840. Functions included the following: <ul style="list-style-type: none"> • Inspecting new railways • Regulating staff safety • Investigating accidents and recommending safety improvements • Monitoring and reporting on safety generally. • The RI was part of the Government Department of Transport until 1 December 1990, when it moved to the Health and Safety Executive (HSE, the general industrial safety regulator) on 1 December 1990. A consequence was the more direct application of the general safety legislation to the railways than hitherto (the Health and Safety at Work Act 1974). • Before privatisation the Department of Transport and HSE prepared for privatisation with a document <i>Ensuring Safety on Britain's Railways</i> (1993), which recommended a Safety Case system, the forerunner of today's Safety Management Systems (SMSs). The recommended system was 'cascaded', under which the RI approved the Infrastructure Managers' (IM's) safety cases, and the IM approved the Railway Operators' safety cases. • The number of RI staff throughout the 1980s was about 35, and had risen to about 70 on 31 March 1994, partly in anticipation of privatisation, and partly in response to previous accidents.
1 April 1994 to 31 March 2006	<ul style="list-style-type: none"> • After privatisation, the Health and Safety Executive remained the railway safety regulator. The Railway Inspectorate retained its identity within HSE, and it was supported by other parts of HSE. • From 1994 to 2000, the RI and the HSE formally approved the IMs' safety cases, including their arrangements for accepting Railway Operators' safety cases. The IM approved the operators Safety Cases. From 2000 onwards, the RI approved both the IM and the operators' safety cases. • The HSE/RI retained powers of accident investigation, but in practice reduced the number of public reports. Two major accidents were subject to (non-RI) independent judicial inquiries. Independent accident investigation was transferred from the RI to the Rail Accident Investigation Branch (RAIB) on 17 October 2005. • Because of the increasing workload, the number of staff in the RI gradually rose from about 70 to 200 on 31 March 2006.
1 April 2006 to present	<ul style="list-style-type: none"> • On 1 April 2006 rail safety regulation and the Railway Inspectorate were transferred from the HSE to the Office of Rail Regulation (ORR), which was previously the economic regulator for the main line railways. • The ORR now combines economic and safety regulation. The ORR is an independent agency of the Department for Transport. • The RI has been absorbed into ORR without retaining a formal separate identity.

Independent accident Investigating body	
Pre-privatisation	<ul style="list-style-type: none"> • Before privatisation the independent accident investigator was the Railway Inspectorate. • The RI investigated all serious accidents and published an average of about eight reports per year on accidents of public interest.
1 April 1994 to 17 October 2005	<ul style="list-style-type: none"> • After privatisation, the RI within HSE continued to be the principal independent accident investigating body, both for 'learning lessons' and for possible prosecutions under health and safety law. • In practice, they did not publicly investigate as many accidents as in the past; this function was largely replaced by Formal Inquiries carried out by the industry itself (which were generally not published).
17 October 2005 to present	<ul style="list-style-type: none"> • The newly established Rail Accident Investigation Branch (RAIB), took over independent accident investigation from the RI on 17 October 2005. The RAIB is formally part of the Department for Transport. • It is independent, and does not attribute blame in its work. In its first years the RAIB has investigated about 45 accidents or near misses per year. The number of staff in 2007 was about 45.
Lead industry safety body	
Pre-privatisation	Before privatisation, the lead body was the British Rail Safety Directorate. It distributed standards as internal company documents.
1 April 1994 to 31 December 2000	<ul style="list-style-type: none"> • The Safety and Standards Directorate (S&SD) of Railtrack (the new infrastructure manager) took over the functions of maintaining the suite of standards relating to safety, and also of approving the safety cases of train operators using Railtrack infrastructure. • This entailed imposing legally binding standards on the railway operators. • Given this quasi-regulatory function, the S&SD was kept separate from the main commercial activities of Railtrack, but it remained part of Railtrack. • Railtrack was privatised on 20 May 1996.
31 December 2000 to 31 March 2003	<ul style="list-style-type: none"> • By the late 1990s, it was judged inappropriate that Railtrack S&SD as a commercial organisation should impose standards on operators with whom it had a commercial relationship. • Railway Safety was therefore set up temporarily as the lead safety body. It was no longer part of Railtrack, but was a subsidiary of Railtrack. At a similar time, the RI took over the approval of train operators' safety cases. • Railtrack itself was placed in administration on 8 October 2001. Railway Safety became a subsidiary of its successor, Network Rail.
1 April 2003 to present	<ul style="list-style-type: none"> • The newly-created Rail Safety and Standards Board (RSSB) took over the functions of Railway Safety on 1 April 2003. RSSB is an independent body funded by its members. • RSSB maintains national standards on behalf of both Network Rail and the train operators, and performs safety coordinating roles such as detailed safety performance monitoring and the development of a safety risk model. • RSSB also manages research, funded largely by the Department for Transport. • RSSB managed Formal Inquiries into accidents until creation of RAIB, but no longer does so.

4.3 The Rail Safety Regulator

With the exception of the United States, the starting points for rail restructuring were publicly-owned monopoly operators with vertically integrated systems providing both infrastructure and train

operation. The changes since then have seen privatisation in some countries and the access of new operators in others. Before restructuring, safety regulation by external bodies was either limited or in some countries non-existent. That was presumably because the operators were already in the public sector and were expected to regulate themselves. Furthermore, because they were self contained – at least within national borders – they could and did set their own technical and operational systems and standards for internal operations without reference to external bodies.

Britain was a country with an external regulator, the Railway Inspectorate (RI), but this was small and carried out its regulatory function mainly by persuasion rather than legal enforcement. The RI also inspected new infrastructure, carried out accident investigations in public, and published annual reports reporting in detail on safety performance.

The privatisation of railway operators – infrastructure managers or train operators – led to the need for a safety regulator to represent the public interest in safety that had previously been carried out by public bodies regulating themselves. A second effect was that because of the fragmentation of former monopoly operators, their previously internal systems and standards became public systems and standards, which had to be available to potential new operators, so that new operators could implement them alongside existing operators. The question arises as to what extent the new, or transformed, regulators should be responsible for these standards and to what extent they should remain the responsibility of the operators. The most commonly accepted principle is of “co-regulation”: the operators themselves should write their own rules and standards, because they are in the best position to do so, and the regulators should set general requirements, and monitor and oversee the operators’ processes and their outcomes. That in turn raises the question: if the rules and standards are to be written by the operators, who should determine those at the crucial interface between the infrastructure and train operation: should it be the infrastructure manager or the train operator? In Britain, that role was initially allocated to the infrastructure manager, but it is now performed by the industry-wide Rail Safety and Standards Board. The EU Safety Directive also places it as a joint function of Infrastructure Managers and Railway Undertakings (or train operators). In some other countries, the role remains with the Infrastructure Manager.

Should the safety regulator be free-standing or part of another body? In particular, should safety and economic regulation be carried out by the same body? In practice, the safety regulator is usually a division or an agency of a country’s Ministry of Transport, and so also is the economic regulator. In this respect they are similar to civil aviation authorities. In Britain the rail safety regulator had been transferred from the Department of Transport to the general industry safety regulator, the Health and Safety Executive (HSE), a few years before privatisation, and it remained in the HSE until 2006. Lord Cullen in his report of 2001 on the Ladbroke Grove accident supported the case for separate bodies for economic and safety regulation because “their functions are fundamentally different” (Cullen, 2001, paragraph 9.81). The argument for separation is that it allows the safety regulator solely to promote safety; the argument against separation is that the economics of safety measures have to be considered at some stage, and it is better for both safety and economics to be considered within the same organisation. When the safety and economic regulators were to be combined in Britain in 2005, the Government did not give reasons of principle for their decision; rather, it was a matter of unifying and simplifying the structure of regulation.

An issue for federal countries is whether safety regulation should be a federal or state/ province function. For main line railways the general view is that regulation should be at the federal level, mainly to provide uniform regulations for the benefit of operators, and also to make efficient use of regulatory resources. Of the countries considered in this review, only Australia has regulation at state level, but the National Transport Commission (2008) is consulting on whether it should be a federal function. For free-standing metros and local railways, regulation can be either at federal or state level.

Whatever the framework, it is clear from the British and US experience that the public resources needed to regulate a restructured railway industry are greater than those required before restructuring. Indeed the British government may have been too slow in increasing staff to meet the new demands. Table 4.2 shows the total number of staff of all grades in the Railway Inspectorate (RI) from 1982 to 2002 and in 2006. The table also shows staff in the Rail Accident Investigation Branch (RAIB), which began operation in October 2005, and took over the independent investigation of accidents from the RI.

Table 4.2 shows that the number of staff in the RI throughout the 1980s was in the range 30-40. That was the period well before privatisation. The number of staff increased in the early 1990s, partly in response to serious accidents in the late 1980s and partly in anticipation of privatisation. The number stabilised in the late 1990s in the range 80-90. It then increased again to reach about 200 in 2006 at the time of the transfer of the RI from the Health and Safety Executive to the Office of Rail Regulation (ORR). (It is not possible to extend this series, because the RI is no longer separately identified within the ORR.) In addition, the number of staff in the RAIB was 45 in 2006. Thus the total number of staff rose from 30-40 in the era of the nationalised railway to about 245 in 2006. Arguably, some of this increase would have occurred anyway, because of the increasing public interest in railway safety. However, it seems plausible that most of the increase is a consequence of rail restructuring: there are many more regulated railway organisations; there is more turnover among those organisations; and there are far more processes, documents and management systems to scrutinise. Nevertheless, the regulatory resources remain very small compared with those of the industry as a whole.

**Table 4.2. Staff in Rail Regulatory and Investigatory Bodies:
Great Britain: 1982-2007**

Date	Railway Inspectorate	Rail Accident Investigation Branch	Total
31 Dec 1982	35	0	35
31 Dec 1983	35	0	35
31 Dec 1984	36	0	36
31 Dec 1985	36	0	36
31 Dec 1986	32	0	32
31 Dec 1987	31	0	31
31 Dec 1988	31	0	31
31 Dec 1989	39	0	39
31 Dec 1990	45	0	45
31 Mar 1992	49	0	49
31 Mar 1993	62	0	62
31 Mar 1994	71	0	71
31 Mar 1995	85	0	85
31 Mar 1996	82	0	82
31 Mar 1997	85	0	85
31 Mar 1998	88	0	88
31 Mar 1999	98	0	98
31 Mar 2000	108	0	108
31 Mar 2001	145	0	145
31 Mar 2002	186	0	186
31 Mar 2006	About 200*	45	245
31 Mar 2007	..	45	..

Sources: Railway Inspectorate and RAIB Annual reports

*Number of staff transferred from the Health and Safety Executive to the Office of Rail Regulation on 1 April 2006 (ORR Annual Report 2005-2006, page 29).

The writer does not have corresponding data for other countries. However, with regard to railways, trucking, civil aviation in the United States, Savage (2003) says

“There is evidence in all three modes that the amount of safety monitoring and enforcement had to be enhanced. In part this is caused by the increase in the number of firms after deregulation. In addition there have been challenges in all modes from the entry of inexperienced firms, bankruptcy of established firms, and a constant turnover of firms that has taxed the government inspectorate and led to an increase in the inspection budgets” (page 9).

There is thus no reason to doubt the conclusion that rail restructuring leads to an increase in necessary regulatory resources, as co-regulation replaces self-regulation. In particular, the EU Safety Directive requires member states to have in place a rail safety regulator, or National Safety Authority (NSA), and an independent National Accident Investigation Body (NIB). Many European countries have had to create these bodies from scratch.

4.4 The accident investigating body

Should there be an independent accident investigating body? Almost all countries agree that there should be, and, as noted above, it is a requirement of the EU Safety Directive. The reasons for such a body are to provide independence from any interested party, including the regulator, and to provide blame-free investigations. The counter-argument, espoused by the RI for some years, was that combining investigation with regulation enables the findings of accident enquiries to be quickly fed into regulations and guidance documents.

Should the accident investigator be multi-modal or multi-industry? Different countries have different answers. Canada, the United States, Japan, some European countries and to some extent Australia have multi-modal investigators; other European countries, including the UNITED KINGDOM have single-mode bodies. The arguments for multi-modal bodies are that the modes can learn from each other, and that larger bodies tend to be more powerful than single-mode bodies, which are inevitably small. It may also be easier to manage the work flow in larger bodies, especially as even single-mode bodies need enough staff to be able to deal with major accidents, which by their nature are unpredictable.

Where they have discretion, the different accident investigating bodies vary greatly in the number of accidents they choose to investigate. This can be seen among other places in the European Railway Agency’s (ERA) public database of investigations carried out by the National Investigation Bodies (NIBs) http://pdb.era.europa.eu/pdb/safety_docs/naib/default.aspx. The European Railway Safety Directive 2001/14/EC requires the NIBs to investigate all of the most serious accidents, but gives discretion about other accidents. Some bodies investigate few accidents and some many; some confine themselves only to accidents and some include significant near-misses.

It should be noted that the railway operators themselves are always required by their Safety Management Systems (see Table 5.1) to carry out their own investigations of accidents and incidents, to learn their own lessons from all such events; such lessons may often be specific to a particular place or activity or organisation, and not necessarily have wider public import. Therefore the public accident investigation bodies tend to cover only the more important events, from which there may be general lessons to be learned.

4.5 Lead industry safety body

The issue of the lead industry body is raised here because the Rail Safety and Standards Board (RSSB) in Britain plays an important role in the safety system, but appears not to have close counterparts in other countries. RSSB's website gives its 2008 functions as:

- Railway Group Standards.
- Safety performance and risk.
- Research and development.
- National programmes.
- Vehicle acceptance bodies.
- Safety strategies.
- Learning from operational experience.
- European developments.
- Systems integration.
- Expertise to the industry.

As Table 4.1 shows, RSSB evolved from Railtrack's Safety and Standards Directorate, and ultimately from the British Rail safety directorate, but now has a much wider remit, including in particular environmental aspects of the rail industry. It does not have operational safety responsibilities, but it carries out a large number of industry-wide functions that could not effectively be carried out by the separate members of the industry. The writer has not found such a body in other countries. It may be that RSSB evolved because of the specific nature of Britain's privatisation, which took place very quickly and produced a large number of railway companies, many of which are powerful but none of which are dominant.

The closest counterparts in other countries are the railway associations, such as the Australian Railway Association (ARA) and the Railway Association of Canada (RAC), which represent the industry in regulatory discussions. The ARA indeed has a subsidiary company entitled the Rail Industry Safety and Standards Board (RISSB). However, the remit of the RISSB appears to be much narrower than that of the RSSB.

An earlier lesson related to the lead industry safety body was the abandonment of the 'cascade' system of safety case approval. From 1994 until 2000 the safety cases of train operators were approved by Railtrack's S&SD, and Railtrack's safety case was in turn approved by the safety regulator, including their arrangements for assessing train operators' safety cases. That might have been reasonable if Railtrack had remained for the medium term in the public sector, as was originally expected. However, Railtrack was privatised in May 1996, and by 2000 it was judged inappropriate that Railtrack should be the approver of the safety cases of operators with whom it had commercial contracts and relationships. Jack (2007) discusses this further. He makes the interesting point that when standards were imposed by Railtrack's Safety and Standards Directorate, they could be only the legal minimum, which is not

necessarily optimal, but when they are agreed jointly by the infrastructure manager and the train operators they may be closer to the optimum. It is one of RSSB's functions to facilitate such agreements.

4.6 Conclusions

There are many different possible ways of arranging the regulatory bodies in restructured railway systems. Some of these choices are indicated by the questions raised in the previous sections. The choices made by individual countries depend on their history, the nature of their restructuring, and the nature of the industry after restructuring. The available data are not sufficient to allow empirical conclusions in favour of one arrangement over another. However, it is clear that restructuring has led to a need substantially to strengthen the public safety regulator, even though this is at a time when the railways themselves have generally been getting safer.

5. SAFETY MANAGEMENT SYSTEMS

5.1 Origins and content

As noted above, before rail restructuring most countries had public-owned monopoly rail operators providing both infrastructure and train operation. Restructuring has seen some combination of privatisation, vertical separation of infrastructure provision and train operation, and the opening up of access to new train operators. This has led to stronger safety regulation to represent the public interest, the opening up of previously internal systems and standards, and arrangements to ensure that existing and new operators would operate safely and cooperate at their interfaces to ensure safety.

It is widely accepted that the principal responsibility for rail safety lies with the infrastructure providers and train operators themselves, because they are best able to control their risks. Therefore in the first instance it is for the operators to determine their own safety systems and comply with them. It is also for infrastructure managers and train operators to manage the interface between them. The function of the safety regulator is to oversee this process: to be satisfied that the railway operators' safety systems are suitable and sufficient for their purpose, and that they are being complied with. They may also specify certain broad standards, such as general requirements for signalling systems or level crossings. This combination of safety arrangements determined by operators and supervised by regulators is sometime labelled "co-regulation".

The generic label for the operators' safety arrangements is their "Safety Management System" (SMS). This phrase covers both the many safety systems themselves and the documentation of those systems.

The development of rail Safety Management Systems has another important and more generic origin. Over the last decades it has become accepted that many kinds of accidents or incidents in tightly controlled safety-critical systems such as railways are not simply the result of an immediate technical failure or human error, but may have their origins in the safety arrangements and culture of the organisation in which they occur. Accidents may stem from decisions and actions taken at times and places quite distant from the final accident (see, for example, Reason (1997); Turner and Pidgeon (1997); Hale (2000)). Therefore an effective safety management system must be embedded in the whole organisation and not just cover the arrangements for the immediate control of well-recognised hazards. Given the acceptance of the organisational nature of many types of accident, the railways would have adopted SMSs without the stimulus of rail restructuring. Other safety-critical industries, such as aviation and nuclear power have moved in the same direction, perhaps somewhat earlier.

Of the countries covered by the project, Australia, Canada, Japan, the EU (Safety Directive 2004/49/EC), and therefore the United Kingdom, all legally require railway operators to have in place documented safety management systems (SMS). Australia, Canada and the United Kingdom have published guidance on the production and contents of SMSs (National Transport Commission 2008, Transport Canada 2001, and Office of Rail Regulation 2007, respectively).

The European Railway Agency (2007) has published a review of experiences with SMS, both on railways and in selected other industries. The ERA review refers to the railway SMS in selected

European countries, and Australia and Canada among others, but it does not mention the United States or Japan. The ERA review is primarily a summary of various countries' requirements, but it is not evaluative, and does not assess the extent to which the SMS have been successful.

There is a reasonable degree of agreement on what an SMS should cover. Table 5.1 presents an example from the United Kingdom, based on the Railways and Other Guided Transport Systems (Safety) regulations 2006, which in turn is based on the 2004 EU Safety Directive.

Table 5.1. **Example of outline specification for Safety Management System**

General aims of SMS
<ul style="list-style-type: none"> • Define roles and responsibilities for safety. • Demonstration of how control of SMS by management at different levels is secured. • Involvement of workers. • Continuous safety improvement.
Content
<ul style="list-style-type: none"> • Safety policy statement, signed by Chief Executive, available to all staff. • Qualitative and quantitative targets, realistic and shared with all staff. • Methods for identifying relevant standards and procedures for meeting them. • Change-management process for identifying and controlling new risks. • Training programmes to ensure staff competence. • Management of safety-related information within and between organizations. • Control of layout of vital safety information. • Investigation of accidents and near-misses. • Emergency plans; liaison with emergency services. • Recurrent internal auditing of SMS.

5.2 Safety culture

An important part of the SMS is the idea of an effective 'safety culture'. The panel reviewing the Canadian Railway Safety Act said in 2007:

“The cornerstone of a truly functioning SMS is an effective safety culture. The Panel views such a culture as one in which safety values are firmly entrenched in the minds of managers and employees at all operational levels, and respected on a daily basis in the performance of their duties. It is demonstrated by the decisions, actions and behaviour of individuals.” (Lewis *et al*, 2007, section 5.3, page 68.)

In the context of the nuclear power industry, the UK Advisory Committee on the Safety of Nuclear Installations said:

“The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety

management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures.” (HSC, 1993, quoted by RSSB and also by Reason, 1997, page 194).

Research for the RSSB (Kiel Centre Ltd, 2004) has reviewed about 30 ‘toolkits’ for assessing the quality of safety culture in railway organisations, and RSSB has itself developed its own toolkit for assessing a railway organisation’s safety culture (see ‘safety culture network’ on the RSSB website). The approach is by questionnaire addressed to staff at all levels. The questionnaire comprises about 80 questions covering 11 factors in four groups. The groups are:

- Effective and appropriate safety management systems.
- Demonstrable management commitment to health and safety.
- Participation, involvement and workforce attitudes to health and safety.
- Organisational learning and continuous improvement.

SMSs and the improvement of safety culture are focussed on those aspects of railway safety that are under the railway operators’ control, especially the prevention of accidents that put passengers and staff at risk. They are necessarily less focussed on aspects that are less under the railways’ control, including the actions of level crossing users and trespassers, even though, as shown in Section 2, the latter account for the majority of railway fatalities.

There is a large literature on safety culture, which is outside the scope of this review. The requirement for SMSs and the evolution of organisational safety culture may well have contributed to the long term improvement railway safety performance noted in the first part of this report, but there is insufficient data to demonstrate this empirically one way or the other.

6. COST OF RAIL SAFETY MEASURES

Safety is so deeply embedded in the design and day-to-day operation of railways that it is impossible to separate the costs of safety from other costs of the provision of rail services. However, it is possible to consider the costs and the benefits of specific safety measures. As noted in section 2, railways are subject to many different kinds of hazards, and risks are mitigated by a wide variety of safety measures, ranging from minor local improvements such as lighting or fencing at specific places, to major system safety measures such as train protection.

Railway operators and regulators have long recognised that some safety measures represent better value for money than others, and that some safety measures may not be worthwhile, even though they would reduce accidents. However, the criteria for deciding what measures are worthwhile have not generally been very clear.

A cost benefit criterion for safety measures, like any other investment, would suggest that safety measures are worthwhile if their benefits exceed their costs, but not otherwise. The benefits of safety measures usually include the prevention of casualties, so the valuation of the benefits of safety measures requires the valuation of prevention of fatalities and injuries. Such valuations are well-established for road safety in most OECD countries, though the methods of determining the official valuations differ between countries. A recent review of European values is provided by the EU HEATCO project (Universität Stuttgart 2006, Table 5.2). The HEATCO project took it for granted that the same valuations for the prevention of casualties should be applied to rail as to road safety, and indeed to other transport modes, but with the exception of Great Britain there has been relatively little discussion of this. In Britain the RSSB has commissioned research (Oxford Risk Research and Analysis 2006 and 2008) on the rail value of preventing a fatality (VPF), and RSSB presents its own advice in “Taking safe decisions” (RSSB 2008). The researchers’ and RSSB’s conclusion is broadly that the rail VPF should be the same as the road VPF. That is in line with HEATCO’s implicit view.

The European Railway Agency held a conference on the “Economic Appraisal of Rail Safety related Interventions” in April 2009 (ERA, 2009), which presented an up-to-date snapshot of the use of cost benefit analysis (CBA) in railway safety. Generally, there is agreement among the professionals that CBA is a sensible form of analysis, but there are only very limited examples of the use of CBA in railway safety in practice. The most specific, albeit small, example presented at the ERA conference was by Hallden (2009) of Banverket, Sweden. This was of track surveillance cameras as a protection against suicides, trespassers and vandalism. Hallden’s conclusion was that the benefits of suitably located cameras exceed the costs. On a larger scale, but dating back to the 1990s, British Rail carried out a major cost benefit appraisal of Automatic Train Protection in Britain (see Evans 1996 for a succinct account). This came to the conclusion that the costs of ATP far outweighed its benefits, and this then contributed to the decision by the government not to pursue network-wide ATP. A presentational problem for privatised organisations carrying out cost benefit appraisals is that placing monetary values on the prevention of casualties is sometimes interpreted as putting “profit before safety”.

Two common requirements in organisational safety are that risks should be reduced to a level “as low as reasonably practicable” (ALARP), or that systems should be safe “so far as is reasonably practicable” (SFAIRP). These phrases neatly capture the idea that there are trade-offs in safety: it is

desirable to improve safety, but there are limits beyond which safety measures may not be practicable. The United Kingdom and Australia (NTC 2008) impose these as legal requirements on operators; the Lewis Advisory Panel (2007) recommended them for Canada; the 2004 Safety Directive of the European Union requires Member States to ensure that safety is maintained and “where reasonably practicable” improved (EU, 2004, article 4). In all these countries the same ALARP or SFAIRP requirement applies equally to public sector and private sector operators.

The problem with ALARP and SFAIRP is that they do not themselves indicate what safety measures should be regarded as practicable and what not. For many safety measures, ALARP and SFAIRP are interpreted as requiring the adoption of best practice, on the argument that good-practice safety measures must be reasonably practicable. For large or less tested safety measures, it is possible to interpret ALARP and SFAIRP through the cost benefit criterion, and define a safety measure to be practicable if its benefits exceed its costs, and not otherwise. Some railway organisations promote the interpretation of the ALARP or SFAIRP requirement in this way, notably RSSB in “Taking safety decisions” (2008). In practice there is a strong tendency in railways to adopt safety measures at the margin whose costs of preventing casualties exceed the roads values, especially for preventing passenger and staff fatalities.

Is there evidence that the privatised or restructured operators have adopted different and less stringent criteria for the adoption of safety measures than when they were public bodies? The evidence from section 3 of this paper, and the activities of safety regulators, suggest that they have not. A phrase sometimes used to summarise the counter-argument to “profit before safety” is “good safety is good business”. This is a reminder that private transport operators (in all modes) themselves have a strong incentive for safe operation, to avoid the costs and disruption of accidents and to protect their reputations. This is irrespective of the activities of regulators.

7. CONCLUSIONS

International railway safety performance data are useful and interesting for what they show about the nature of the operations and the risk profile of the railways in different countries. However, they cannot be used to assess comparative international safety performance, nor form a basis by which to evaluate different regulatory regimes. This is first because the railways are different in different countries, ranging from predominantly passenger to predominantly freight, and with very different densities and types of train operation. Secondly, the railways and regulators in different countries have adopted different definitions and recording conventions for safety data, so the different countries' data are often not comparable. What is measured in one country may not be measured in the same way in another.

It follows that the best available method for evaluating the effects of restructuring is by analysis of time-series data on safety performance within individual countries. It is then necessary to have data collected with consistent definitions over a period that is long enough to estimate risk levels and trends both before and after restructuring. This is fairly demanding, especially as restructuring may itself lead to changes in the coverage and definitions of safety performance data. Nevertheless, three countries do have data suitable for time series analysis. These are the United States, Great Britain and Japan. Analyses for the first two of these countries are already in the literature and are outlined in this report; a new analysis for Japan is presented in this report.

The evidence from the rail studies of the United States suggests that reductions in fatalities to staff, level crossing users and trespassers followed deregulation and other measures in 1980. The evidence from Great Britain and Japan is that there were downward trends in accident rates before restructuring, and that these continued afterwards. Any changes in accident rates at the time of structuring were, if anything, favourable, but some of these are not statistically significant, and there is no convincing evidence that restructuring actually improved safety.

With regard to other transport modes, there have been a fair number of studies of the effects on safety of airline deregulation and road freight deregulation in the United States, three on bus deregulation in the United Kingdom, and a small number of studies of road freight deregulation in other countries. The general conclusion is that deregulation of these modes did not have an adverse effect on safety. With regard to other industries, there is one major review of the effects of privatisation. This found no deterioration in safety to customers or staff, but it did report one finding of increases in stress-related ill-health among employees. That review is remarkable for its breadth: the authors searched for studies evaluating privatisation over a period of 60 years, in all OECD countries, and in all languages, but they found only 11 studies which met their criteria for review. Four of these were in transport, and overlap with results mentioned above.

The restructuring of railways has led to new roles for public rail safety regulators and raises questions about the organisation of the regulatory framework. Different countries have answered these questions in different ways, reflecting their constitution, history and their railway industries. The report discusses the roles of the public safety regulator, the accident investigation body, and the lead railway industry safety body, illustrated by their evolution in Great Britain, where none of the three bodies created after privatisation in 1994 existed in the same form in 2008.

The most common model for safety regulation after restructuring is “co-regulation”. In this model, the railway operators themselves are responsible for establishing an effective safety culture, and for writing their own safety systems, rules and standards, expressed in their Safety Management Systems. These must also provide for the cooperation at the railway interfaces, notably between infrastructure managers and train operators. It is for the safety regulator to make sure that the SMSs are fit for their purpose, and are being implemented on the ground. This has led to a need for larger and stronger regulatory bodies, illustrated by the 5/6-fold increase in the size of the British regulator between the 1980s and the mid-2000s. A new role is auditing SMSs and ‘safety culture’.

The final main section of the report discusses the cost of railway safety measures. The railways of several countries are required to ensure safety, so far as is ‘reasonably practicable’. In practice, railways appear to adopt safety measures at the margin whose costs of preventing casualties exceed the official values of preventing casualties on the roads, especially for passengers and staff. There are few examples of well-documented cost benefit analyses of railway safety measures in any country.

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ABBREVIATIONS

ALARP	As low as reasonably practicable
ARA	Australian Railway Association
ATP	Automatic Train Protection
ATSB	Australian Transport Safety Board
BITRE	Bureau of Infrastructure Transport and regional economics [of Australia]
BR	British Railways
CBA	Cost benefit analysis
ERA	European Railway Agency
EU	European Union
FRA	Federal Railroad Administration [of the United states]
HSE/C	Health and Safety Executive/ Commission [of the UK]
IM	Infrastructure Manager
IRSC	International Railway Safety Conference
JNR	Japanese National Railways
JR	Japanese Railways
JTRC	Joint Transport Research Centre [of OECD and ITF]
LC	Level crossing
ORR	Office of Rail Regulation [of the UK]
NIB	National Investigation Body [European term]
NSA	National Safety Authority [European term]
NTC	National Transport Commission [of Australia]
RAC	Railway Association of Canada
RAIB	Rail Accident Investigation Branch [of the UK]
RI	Railway Inspectorate [of the UK]
RISSB	Rail Industry Safety and Standards Board [of Australia]
RSRP	Railway Safety Regulators’ Panel [of Australia]
RSSB	Rail Safety and Standards Board [of Great Britain]
SFAIRP	So far as is reasonably practicable
SMS	Safety Management System
SPAD	Signal passed at danger
S&SD	Railtrack Safety and Standards Directorate
TSB	Transportation Safety Board [of Canada]
TPWS	Train Protection and Warning System [of Britain]
VPF	Value of preventing a fatality

APPENDIX: AN ANALYSIS OF THE EFFECT ON ACCIDENTS OF RAIL PRIVATISATION IN JAPAN

Introduction

As noted in Section 5, the writer is not aware of published empirical analyses of the effects on safety of railway restructuring for countries other than the United States and Great Britain. However, as part of the present project, the Japanese Institute of Land, Infrastructure, Transport and Tourism has provided data to the author, which enables such an analysis to be carried out for Japan. The method follows that previously adopted by the author for Great Britain (Evans 2007), though the accident coverage is less comprehensive.

The data provided to the author include the annual numbers of fatalities, train accidents (collisions, derailments, and train fires), level crossing accidents, passenger-km, freight-tonne-km, passenger train-km and freight train-km for periods from about fiscal year 1970 to fiscal year 2006, separately for the Japanese National Railways (JNR) and its successors (JR), and for the non-JNR/JR companies. The privatisation of the JNR took place at the start of 1987, so data from 1971 to 2006 provides 16 years pre-privatisation data and 20 years post-privatisation data.

From these data, we have chosen to analyse the series of total train accidents on the JNR/JR. The most obvious alternative would be the series of fatalities on the JNR/JR, but in general it is preferable to analyse accidents rather than outcomes of accidents, because accidents can be regarded as more independent events than fatalities. Fatalities are not independent, because several or many may occur in a single accident. Furthermore, the fatality data from Japan include those to trespassers, and they do not separate passengers, staff, the non-trespassing public, and trespassers.

Table A.1 gives the data on train accidents and also train-kilometres. The train kilometres are subdivided between those on the conventional railways, including freight train-kilometres, and those on the Shinkansen high-speed passenger lines. The proportion of train-km on the Shinkansen has risen gradually from 5% in 1971 to 18% in 2006. The horizontal line in Table A.1 indicates the date of privatisation of the JNR.

The train accident data in Table A.1 refer to the conventional and Shinkansen lines together. Full data separating them are available only for 1999-2006, and show that of the total of 88 train accidents in that period, 87 were on the conventional railways and one was on the Shinkansen. The Shinkansen accident was the derailment of a train moving at 200km/h due to an earthquake on 23 October 2004, fortunately without casualties. Press reports of that accident state that it was the first accident to a Shinkansen train since they began operating in 1964. It is therefore assumed that all the train accidents in Table A.1 except for the one in 2004 occurred on the conventional railways.

The main analysis below takes all JNR/JR operations together and does not distinguish between conventional and Shinkansen lines. However, we then carry out an analysis for the conventional lines alone.

Table A.1. **Train accidents and train-kilometres: JNR and JR: 1971-2006**

Year	Train	Train-kilometres (billion)			Shinkansen as % of al train- km l
	Accidents	conventional	Shinkansen	total	
1971	60	0.642940	0.033994	0.676934	5.0%
1972	66	0.648293	0.039463	0.687756	5.7%
1973	75	0.656356	0.041280	0.697636	5.9%
1974	69	0.650701	0.040896	0.691597	5.9%
1975	59	0.624275	0.053505	0.677780	7.9%
1976	68	0.635622	0.057290	0.692912	8.3%
1977	41	0.633426	0.058828	0.692254	8.5%
1978	51	0.616495	0.058541	0.675036	8.7%
1979	61	0.617073	0.058507	0.675580	8.7%
1980	51	0.599265	0.057015	0.656280	8.7%
1981	33	0.592517	0.055738	0.648255	8.6%
1982	34	0.577775	0.062563	0.640338	9.8%
1983	48	0.559436	0.069912	0.629348	11.1%
1984	37	0.547543	0.072141	0.619684	11.6%
1985	33	0.543336	0.080860	0.624196	13.0%
1986	20	0.552627	0.084074	0.636701	13.2%
1987	26	0.512558	0.085711	0.598269	14.3%
1988	23	0.593755	0.092267	0.686022	13.4%
1989	33	0.632314	0.098674	0.730988	13.5%
1990	19	0.645613	0.102642	0.748255	13.7%
1991	22	0.655296	0.105956	0.761252	13.9%
1992	22	0.646960	0.109278	0.756238	14.5%
1993	15	0.649495	0.109829	0.759324	14.5%
1994	22	0.642030	0.108316	0.750346	14.4%
1995	18	0.648405	0.111125	0.759530	14.6%
1996	19	0.647432	0.107728	0.755160	14.3%
1997	12	0.642051	0.114794	0.756845	15.2%
1998	12	0.638153	0.114217	0.752730	15.2%
1999	14	0.636557	0.114979	0.751536	15.3%
2000	19	0.631930	0.114171	0.746101	15.3%
2001	6	0.631674	0.118388	0.750062	15.8%
2002	7	0.603611	0.119653	0.723264	16.5%
2003	8	0.628402	0.121355	0.749757	16.2%
2004	18	0.614194	0.122298	0.736492	16.6%
2005	9	0.617107	0.134443	0.751550	17.9%
2006	7	0.620134	0.133153	0.753287	17.7%

The basic model of accident occurrence is that accidents are presumed to occur randomly in year t at a mean rate λ_t per year; λ_t is assumed to be given by

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

where:

k_t = train-kilometres in year t .

α is a scale parameter.

β is a parameter measuring the long-term annual rate of change in accidents per train-km.

This model assumes that the mean number of accidents per unit time is proportional to train-kilometres and to an exponential function of time, which represents the effects of the general improvements in railway safety taking place anyway. The basic model assumes that accidents are Poisson-distributed; we have also fitted the model assuming that the accidents have the more widely dispersed negative binomial distribution.

In order to test whether the accident rates or trends changed at the time of privatisation, four variants of model (1) were fitted, with different assumptions about the relative values of the parameters α and β before and after privatisation. The models were fitted using the STATA program, with a dummy variable used where required to distinguish the pre- and post-privatisation periods. The models assume that accidents are Poisson-distributed, with each of the following assumptions about the parameters α and β :

- a. No trend and no change at the date of privatisation (common α throughout; $\beta = 0$).
- b. Single trend and no change at the date of privatisation (common α and β throughout).
- c. Single trend with step change in accident rate the date of privatisation (different α 's before and after the date of privatisation and common β).
- d. Separate models before and after the date of privatisation (different α 's and β 's before and after the date of privatisation).

The results are reported in Tables A.2 and A.3 below: Table A.2 gives the results for all railways combined; Table A3 does so for the conventional railway alone.

Tables A.2 and A.3 give for each variant of the model the degrees of freedom, scaled deviance, reduction in scaled deviance from the previous variant, and estimates of selected parameters with their standard errors. The scaled deviance is the measure of goodness of fit of the model variant 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 mean given above), the scaled deviance would be approximately χ^2 -distributed with mean equal to the number of degrees of freedom. Each variant of the model has 1 less degree of freedom than its predecessor, so a statistically significant improvement in the fit of a variant from its predecessor would be a reduction in the scaled deviance that was significant when tested against χ^2_1 (whose upper 5% value is 3.84).

The first result from Table A.2 – which is also obvious from a glance at the data – is that model variant (b) fits much better than variant (a); therefore there is a clear downward trend in the accident rate. The common rate is estimated at –6.5% per year, with a standard error of 0.3%. However, model variant (c) does not fit significantly better than variant (b) and variant (d) does not fit significantly better than variant (c). Therefore there is no evidence that privatisation affected either the train accident rate or the trend. If anything, the accident rate was somewhat lower after privatisation than before – indicated by

negative step change in the rate at the time of privatisation in variant (c), but it is not statistically significant, so no benefit from privatisation should be claimed. However, it is evidence against the hypothesis that privatisation increased accidents.

Figure 3.2 in the main report illustrates these results in a different way. It plots accidents per billion train-km before and after privatisation, and the trend estimated from the pre-privatisation data in model (d). It can be seen that in most of the post-privatisation years, the actual accident rate bettered the extrapolation of the pre-privatisation trend, but not significantly.

Table A.2 shows that even for the best fitting model variants (b) to (d) the scaled deviance substantially exceeds the scaled deviance, implying that scatter or dispersion of the numbers of accidents is greater than would be expected if they really were Poisson-distributed. For that reason we have also fitted the model assuming the accidents have a Negative Binomial distribution. The results with the Negative Binomial distribution do not differ materially from those quoted above with the Poisson distribution. In particular the estimates of the parameters α and β in each model variant are very similar, and the conclusions regarding statistical significance are the same.

Table A.3 gives results corresponding to Table A.2 when the model is applied to the conventional railways alone. The general pattern is the same. There is no evidence that privatisation led to a deterioration of safety on the conventional railway.

Table A.2. Statistical results for variants of model for trends in train accidents per billion train-km: Japan National Railway/Japan Railway companies Conventional and Shinkansen trains: fiscal years 1971-2006

Variant of model	Degrees of freedom	Scaled deviance	Reduction in scaled deviance	Estimates of selected parameters (Standard error in brackets)
(a) No trend	35	527.2		Trend assumed zero
(b) Single trend throughout	34	50.9	476.3	Trend in accident rate: -6.5% (0.3%) p.a.
(c) Common trend with step change in level at end-1986	33	48.4	2.5	Trend in accident rate: -5.7% (0.6%) p.a. Step change at end-1986: -18% (10%)
Separate models before and after end-1986	32	46.8	1.6	Trends in accident rate: Before end 1986: -5.0% (0.8%) p.a. After end-1986: -6.7% (1.0%) p.a.

Table A.3. Statistical results for variants of model for trends in train accidents per billion train-km: Japan National Railway/Japan Railway companies: Conventional trains only: fiscal years 1971-2006

Variant of model	Degrees of freedom	Scaled deviance	Reduction in scaled deviance	Estimates of selected parameters (Standard error in brackets)
(a) No trend	35	469.4		Trend assumed zero
(b) Single trend throughout	34	50.3	416.9	Trend in accident rate: –6.1% (0.3%) p.a.
(c) Common trend with step change in level at end-1986	33	47.9	2.4	Trend in accident rate: –5.3% (0.6%) p.a. Step change at end-1986: –18% (10%)
Separate models before and after end-1986	32	45.3	2.6	Trends in accident rate: Before end 1986: –4.5% (0.8%) p.a. After end-1986: –6.6% (1.0%) p.a.

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