The Southall and Ladbroke Grove
Joint Inquiry into
Train Protection Systems

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QC FREng

The Rt Hon Lord Cullen
PC
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THE JOINT INQUIRY INTO TRAIN PROTECTION SYSTEMS

Preface

This Report comes between the Report into the Southall rail accident, published in February 2000, and the Report into the Ladbroke Grove accident, to be published shortly. Unusually, the Public Inquiry from which this Report results was not concerned with the facts of either accident, but with broader questions of safety on the railways in the light of developments before and since these tragic accidents.

The Joint Inquiry was established shortly after the Ladbroke Grove accident and during the course of the Southall Inquiry. Its terms of reference, established by the Health and Safety Commission with the consent of the Deputy Prime Minster, were to consider the following:

(i)  Train Protection and Warning Systems
(ii) future application of Automatic Train Protection Systems
(iii) SPAD prevention measures

taking account in particular of

the Southall accident on 19 September 1997
the rail accident at Ladbroke Grove Junction on 5 October 1999
the technical assessment for the Deputy Prime Minister of Rail Safety Systems by Sir David Davies

with a view to making general recommendations with regard thereto.

The report of Sir David Davies was published on 24 February 2000. It has given rise to a large amount of public debate and has been extremely valuable in
focusing attention on the issues which called for further debate. Sir David Davies agreed to give evidence to this Inquiry so that his views, along with other experts from within and from outside the rail industry, could be considered in the context of our particular terms of reference.

Although it was urgent to make progress with the Joint Inquiry, by Spring 2000 all parties involved in the Ladbroke Grove Inquiry, including its Chairman, were fully engaged in it. For the Joint Inquiry, we were fortunate to be able to call upon most of the team which had organised and managed the Southall rail accident inquiry, principally David Brewer as Secretary to the Inquiry and Laurence O’Dea of the Treasury Solicitor’s Office. Ian Burnett QC and Richard Wilkinson were instructed as Counsel to the Inquiry, now joined by Dominic Adamson. Major Anthony King OBE, was appointed Technical Assessor. That team was able to work independently of the Ladbroke Grove team so that it was possible to programme the Joint Inquiry hearings to begin on 18 September. We were able to conclude the hearing of evidence on 13 October and oral submissions on 27 October 2000.

The issues in the Joint Inquiry gave rise to technical evidence of some complexity, extending beyond the technical capabilities of train protection systems and into their statistical performance, as well as the financial costs and benefits arising. We have tried in this report, to set out the issues and our conclusions in largely non-technical language because we believe that it is important for the travelling public to appreciate as fully as possible the extent of risks still involved in rail travel and the steps being taken to minimise those risks. While the numbers of annual fatalities from rail accidents is small - making rail travel by far the safest form of land transport - the public remains rightly concerned about the possibility of further catastrophic accidents.
The safety systems and procedures considered in this report will reduce, but not eliminate, the risk of a catastrophic accident occurring during the next decade or more through a signal passed at danger (SPAD). But most of that risk will be removed when the railway system is fitted with the European Train Control System (ETCS), which is first to be installed on the West Coast Main Line. Fitment to the remainder of the network will inevitably be gradual, involving, as it does, great cost and resources.

For the present, existing train protection systems, including the Train Protection and Warning System (TPWS), must continue to be supplemented by other measures to reduce or mitigate the effect of SPADs. For the future, our greatest concern is that nothing should impede the fitment of ETCS and the achievement of the best possible level of train protection. The rail industry has a poor record in meeting its objectives. We believe that the measures we have recommended, coupled with adequate funding and resources, should enable this important objective to be met.

John Uff                                          W. Douglas Cullen
### Glossary of Terms

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<th>Abbreviation/Term</th>
<th>Definition</th>
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<td>AEA Technology</td>
<td>Technical Consultants</td>
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<td>ALARP</td>
<td>As Low As Reasonably Practicable</td>
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<td>ATC</td>
<td>Angel Train Contracts</td>
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<td>ATOC</td>
<td>Association of Train Operating Companies</td>
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<td>ATP</td>
<td>Automatic Train Protection</td>
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<tr>
<td>Audit</td>
<td>Procedural Check e.g. on Maintenance or Safety Provisions</td>
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<td>AWS</td>
<td>Automatic Warning System</td>
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<td>BR</td>
<td>British Rail</td>
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<td>BR-ATP</td>
<td>British Rail version of ATP</td>
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<td>BTP</td>
<td>British Transport Police</td>
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<td>CBA</td>
<td>Cost Benefit Analysis</td>
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<td>CIRAS</td>
<td>Confidential Incident Reporting and Analysis System</td>
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<td>CRUCC</td>
<td>Central Rail User’s Consultative Committee</td>
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<td>CTRL</td>
<td>Channel Tunnel Rail Link</td>
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<td>DETR</td>
<td>Department of the Environment, Transport and Regions</td>
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<td>DM</td>
<td>Driver Manager</td>
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<td>DRA</td>
<td>Driver Reminder Appliance</td>
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<td>DSM</td>
<td>Driver Standards Manager</td>
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<td>DSD</td>
<td>Driver Safety Device</td>
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<td>DVD</td>
<td>Driver Vigilance Device</td>
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<td>ECML</td>
<td>East Coast Mainline</td>
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<td>EEB</td>
<td>Enhanced Emergency Braking</td>
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<td>EQE</td>
<td>Technical Consultants</td>
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<td>EROS</td>
<td>Emergency Restriction of Speed</td>
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<td>ERTMS</td>
<td>European Rail Traffic Management System</td>
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<td>ETCS</td>
<td>European Train Control System</td>
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<td>EWS</td>
<td>English Welsh and Scottish (freight operator)</td>
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<td>FGW</td>
<td>First Great Western</td>
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<tr>
<td>Group Standard</td>
<td>Mandatory documents defining minimum requirements to ensure system safety and safe inter-working on the railway.</td>
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<td>GSM-R</td>
<td>Global System for Mobile Communications – Railways</td>
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<td>GWML</td>
<td>Great Western Main Line</td>
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<td>HMRI</td>
<td>Her Majesty’s Railway Inspectorate</td>
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<td>HSC</td>
<td>Health and Safety Commission</td>
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<td>HSE</td>
<td>Health and Safety Executive</td>
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<td>HST</td>
<td>High Speed Train</td>
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<td>HSWA</td>
<td>Health and Safety at Work etc Act 1974</td>
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<tr>
<td>ILG</td>
<td>Industry Liaison Group (TPWS)</td>
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<tr>
<td>ISO</td>
<td>International Standards Organisation</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>LRM</td>
<td>Layout Risk Method</td>
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<tr>
<td>LUL</td>
<td>London Underground Limited</td>
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<tr>
<td>Mark I</td>
<td>Old Slam Door Rolling Stock</td>
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<td>Mark III, IV</td>
<td>Post 1974 Rolling Stock on the railway</td>
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<td>MOLA</td>
<td>Master Operating Lease Agreement</td>
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<td>ORR</td>
<td>Office of the Rail Regulator</td>
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<td>OTDR</td>
<td>On Train Data Recorders</td>
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<td>OSS</td>
<td>Over Speed Sensor</td>
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<td>Overlap</td>
<td>Distance beyond signal to fouling point</td>
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<td>PSR</td>
<td>Permanent Speed Restriction</td>
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<tr>
<td>Railway Group</td>
<td>Group comprising Railtrack and duty holders of Railway Safety</td>
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<tr>
<td>Rail Regulator</td>
<td>Individual appointed to enforce Railway Group Standards and the Track Access Conditions.</td>
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<tr>
<td>Reverse STM</td>
<td>Reverse standard transmission module</td>
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<tr>
<td>ROSCO</td>
<td>Rolling Stock Company</td>
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<tr>
<td>RSC</td>
<td>Railway Safety Case</td>
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<td>S&amp;SD</td>
<td>Safety and Standards Directorate (Railtrack)</td>
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<td>Safety Case</td>
<td>Formal statement of competence</td>
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<tr>
<td>SMIS</td>
<td>Safety Management Information System</td>
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<td>SPAD</td>
<td>Signal Passed At Danger</td>
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<td>SPADRAM</td>
<td>SPAD Reduction and Mitigation</td>
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<td>SRA</td>
<td>Strategic Rail Authority</td>
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<tr>
<td>STM</td>
<td>Specific Transmission Module (see para 3.13 et seq)</td>
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<td>TEN</td>
<td>Trans-European Network</td>
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<tr>
<td>TOC</td>
<td>Train Operating Company</td>
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<td>TPWS</td>
<td>Train Protection and Warning System</td>
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<tr>
<td>TPWS-A</td>
<td>Train Protection and Warning System Basic Model</td>
</tr>
<tr>
<td>TPWS+</td>
<td>Train Protection and Warning System plus (additional OSS)</td>
</tr>
<tr>
<td>TPWS-E</td>
<td>Train Protection and Warning System with Eurobalise</td>
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<tr>
<td>Track Access Conditions</td>
<td>Agreement for track use between Railtrack and train operator</td>
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<tr>
<td>TSI</td>
<td>Technical Specification for Interoperability</td>
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<tr>
<td>TSR</td>
<td>Temporary Speed Restriction</td>
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<td>TVM430</td>
<td>French Railways ATP system</td>
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<tr>
<td>VPF</td>
<td>Value of Prevented Fatality</td>
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<tr>
<td>WCML</td>
<td>West Coast Main Line</td>
</tr>
<tr>
<td>Wrong Side</td>
<td>Failure to an unsafe condition</td>
</tr>
<tr>
<td>WSA</td>
<td>WS Atkins Rail</td>
</tr>
<tr>
<td>WTP</td>
<td>Willingness to pay</td>
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1. Two separate Public Inquiries have been conducted into the rail accidents which occurred at Southall in September 1997 and at Ladbroke Grove in October 1999. Both Inquiries had, within their terms of reference, consideration of train protection systems, intended to prevent trains passing signals at danger. In November 1999, the Health and Safety Commission (HSC), with the consent of the Deputy Prime Minister, established a Joint Public Inquiry into train protection systems and related issues, taking account of both the Southall and the Ladbroke Grove accidents and the Report of Sir David Davies, which was published in February 2000. The Joint Public Inquiry took place in September and October 2000.

2. This Report reviews and assesses the value of all train protection systems which are currently or will shortly be available, and considers other means of preventing signals being passed at danger or of mitigating the effects.

3. The risk from SPADs measured in terms of past statistics is not large in comparison to overall casualties on the railways and equates to an average of two fatalities per year. SPADs, however, also give rise to the much more significant danger of a catastrophic accident in which many tens of fatalities might occur. The elimination of SPADs therefore deserves a high priority.
4. The only train protection system generally fitted on the UK network at the present time is the Automatic Warning System (AWS). This provides a warning and potential brake application at each signal set to red or yellow, but may be cancelled by the driver. Great Western and Chiltern Lines additionally have the benefit of the BR-Automatic Train Protection System (BR-ATP) installed in about 1990 but only recently having become fully effective. Both AWS and BR-ATP now represent old technology. Up to 1999 some experts considered that BR-ATP should be extended across the whole network despite the very great cost. As a result of other systems now being developed there is no longer any serious demand for general fitment of BR-ATP. We recommend that BR-ATP should be maintained on Great Western and Chiltern Lines but should be extended only to the extent of filling gaps in the present system.

5. Since 1994 BR and Railtrack have been developing the cheaper and simpler Train Protection and Warning System (TPWS). As a result of slow progress, TPWS fitment in 1999 was made mandatory as from 2004, which was accelerated following the Ladbroke Grove crash to 2003. TPWS has significant shortcomings in that its capacity for stopping a train approaching a red signal is limited to speeds of up to 74mph, and provided that the train is fitted with the best currently available braking system. Many trains currently have braking systems falling significantly below the best available and many of these travel at speeds significantly greater than 74mph. Despite its limitations, we recommend that the current mandated fitment of TPWS should not be reversed.
6. Alternative and enhanced versions of TPWS may be available, although further development and testing is still required. TPWS+ involves additional Over Speed Sensors (OSS) in advance of the signal and TPWS-E involves an alternative system capable of migration and incorporation into other train protection systems. We recommend that TPWS+ should be further tested and fitment should be considered. The decision whether to develop TPWS-E should be left to the railway industry.

7. Since 1996, European law has required the fitting of a modern ATP system known as the European Train Control System (ETCS) which exists as three separate levels of specification. Level 3, the most advanced system, has the potential to increase track capacity. ETCS is currently undergoing preliminary trials in Europe and is being fitted at Levels 1 and 2 to the current WCML upgrade.

8. The European Directive presently applies only to high speed Trans European Network (TEN) lines but will presently become a requirement for a significant proportion of conventional lines. It is required to be fitted only when signalling systems are renewed or upgraded. ETCS has the capability to fulfill the early aspirations of BR-ATP but with more modern and adaptable technology. There are, however, justified concerns that the fitment of TPWS will delay ETCS. We recommend a phased programme of ETCS fitment, to be supported by Regulations, after appropriate consultation.
9. For lines not involving high speed running or large volumes of traffic and not covered by present or future European Directives, other cheaper train protection systems may be appropriate including TPWS or TPWS-E if its development is commercially justified. Alternatively, ETCS Level 1 may be found appropriate.

10. Until ETCS is generally available on UK lines the risk of a catastrophic accident following a SPAD remains. This will continue to be the case after fitment of TPWS in respect of a significant proportion of trains. Consequently, the maintenance and development of the SPAD Reduction and Mitigation (SPADRAM) initiative remains a high priority. It is recommended that particular attention is given to multi-SPAD signals, research into human factors and use of the Drivers’ Reminder Appliance. It is also recommended that research into other means of stopping trains, including enhanced emergency braking (EEB), should be pursued vigorously.
1.1 This report concerns Train Protection Systems and other means of preventing the occurrence of Signals Passed at Danger (SPADs). It is appropriate at the start to take note of the part played by SPADs in overall rail safety. Taking figures from the last complete Annual Report on Rail Safety from HM Chief Inspector of Railways, for 1998/99 (excluding the Ladbroke Grove accident), total railway fatalities for the past 6 years have remained at a level of around 40 per annum (with a range of 48 to 25). Numbers are significantly lower than those in past decades. Fatalities resulting from train accidents (including collisions) have represented only a small proportion of the total, typically 10 per annum (range 1 to 12). Passenger fatalities from train accidents represent an average of about four per annum. All these figures cover both passengers and railway staff but exclude significant numbers of casualties to trespassers, which annually exceed 100 (including a number of children under 16) and suicides, which also annually exceed 100.

1.2 While annual numbers of casualties from train accidents remain low, making rail travel by far the safest form of land transport, the numbers of fatalities have significantly increased as a result of catastrophic accidents which have occurred at irregular intervals. Those at Southall in 1997 and at Ladbroke Grove in 1999, which gave rise to this Joint Inquiry, each resulted from signals being passed at danger. However, catastrophic accidents have occurred from other causes as well. The collision at Clapham Junction in 1988, which resulted in 35 deaths, was caused by an error in signal wiring which led to a wrong signal aspect being presented to the driver. The collision at Eschede in Germany in 1998, which resulted in over 100 deaths, was caused by a fractured steel tyre. More recently, the accident at Hatfield in October 2000 in which 4 people died, was caused by a rail which fractured as the train passed over it;
and the accident near Selby at the end of February 2001 appears not to involve any failure of the railway system.

1.3 Ensuring that trains comply with signals at danger thus plays an important part in overall rail safety. The numbers of fatalities which are thought to be capable of being prevented by the avoidance of SPADs can be calculated by averaging past statistics. This produces an average figure of about two fatalities per annum. However, this should not be seen as limiting the significance of SPAD prevention. Primarily this is because SPADs continue to have the potential for catastrophic consequences, the more so in the light of the general increase in speed of trains and the growth in traffic. Statistics based on averages cannot be a guide to the consequences of any particular event in the future. In addition, SPAD prevention should be seen as part of a general safety culture in which the possibility of fatal accidents should become increasingly remote.

Public attitude to safety

1.4 No one can be unaware of the strength of publicly expressed opinions about current safety issues, whether they concern railways, road traffic, industrial accidents or any other activity which poses a risk to the safety of the public. Equally, anyone who has followed public attitudes for a decade or more cannot be unaware that this is a relatively recent phenomenon. In the past railway crashes, even very major ones, did not produce the level of public reaction which currently results from any rail accident involving casualties. Changes in public attitude have been reflected in, and perhaps influenced by, major changes in the law and practice relating to safety. The modern attitude to safety owes a great deal to the reforms recommended by Lord Robens which were given effect in the Health and Safety at Work Act 1974 (HSWA). This has led to major and progressive changes in the safety practices at all levels of industry and in almost all walks of life. New safety codes and procedures have been introduced in many industries. On the railways this coincided with the new safety regime introduced at privatisation during the mid-1990s.
Government and industry have striven to create awareness of safety issues. It is, therefore, not surprising that the public should respond by showing heightened awareness of safety issues, particularly those affecting risks to individuals.

1.5 At the same time, there are certain difficulties involved in seeking to take account of the public’s attitude to safety. First, the attitude of the public can only be expressed through public channels such as the news media or pressure groups. In the case of the rail industry, the recent public inquiries have also provided a platform for views expressed on behalf of particular groups of people. In assessing the weight of all such opinions, we must take into account the circumstances in which such views are given and the fact that the weight to be given to public opinion is ultimately, along with many other competing issues, a matter for the democratically elected government and Parliament.

1.6 We must also take account, in assessing the public attitude to safety, of various bodies of research and expertise aimed specifically at gauging and applying public attitudes, for example to the priority to be given to safety-related expenditure. It has been necessary, historically, for central and local government spending departments to form judgments about such priorities. In relation to rail safety issues, as will be seen in Chapter 4 of this report, advice to Ministers on safety issues has been formulated between experts at the Health and Safety Executive (HSE) and within the DETR. Those experts have been assisted by statistical and sociological research which will also be reviewed later. It is clear that considerable effort is expended in seeking to determine and to reflect public attitudes to safety in the decisions which are made. These decisions are of such importance that it is appropriate that they be exposed to scrutiny. Nevertheless, the sums which can be devoted to safety issues are necessarily limited and other demands on public funds mean that questions of priority must be addressed. Those decisions are ultimately to be made at a political level but we are conscious of the reliance that may be placed on a
report such as this. We therefore seek to assess and take into account the public attitude to safety and to weigh this appropriately, along with other relevant factors, in the recommendations that we make.

Who pays for safety on the railways?

1.7 We have already referred to public expenditure on rail safety. The UK rail industry, which was formally nationalised in 1947, was progressively privatised under the Railways Act 1993 between 1994 and 1996. All the relevant assets are now owned by public limited companies (plcs) with wide share ownership. The principal asset holders are Railtrack (track, signals, depots and stations) and the rolling stock owning companies (ROSCOs) from which train operators generally lease their equipment during the period of their franchise. There are some exceptions, notably freight operators which generally own their own rolling stock. Thus, the public’s perception may include the expectation that expenditure on rail safety should come from the coffers of the private companies which “own” the railways. Their failure to expend adequate sums is seen as “putting profits before safety”. For a number of reasons, this concept can give a misleading impression.

1.8 Although rail assets (and liabilities) are held by shareholders of the private railway companies, the industry remains heavily dependent on the injection of public funds. The financial structure of the rail industry is considered in more detail in Chapter 4. For the present, it is noted that, in common with other privatised utility industries, the rail industry is subject to a tailor-made system of economic “regulation” by which statutory controls are exercised in the public interest, not over the day-to-day running of the industry, but over the performance delivered. At the time of privatisation, these controls were seen as necessary to maintain services at a reasonable level, reflecting a general expectation that privatisation would result in a reduction in the quality of service. In recent years, other aspects of performance have become more prominent, notably in seeking to promote punctuality.
1.9 It is the role of the regulating bodies (Office of the Rail Regulator and, now, the Strategic Rail Authority) to ensure that adequate funds (as determined by them) are available to rail companies. Their function does not extend to determining how or when these funds are expended. That is a matter for the commercial operation of the companies involved. Hence, decisions about the timing of track repair or replacement are for Railtrack. The Rail Regulator can do no more than reflect his opinion about Railtrack’s performance in his periodic decisions about track access charges and authorised borrowings, as well as in the imposition of penalties. This is the essence of regulation which seeks to uphold the public interest, while allowing the industry to be operated in accordance with the principles of private enterprise.

1.10 In regard to safety expenditure, while relevant contracts will generally be entered into by Railtrack and the ROSCOs (and freight operators) and payments will be made by them, the source of funding is more complex. None of the privatised rail asset holding companies possess the means to fund the next generation of rail safety measures from their own resources. Accordingly, public funding in some form is essential for these measures to be carried out. One of the primary concerns of Railtrack, as the principal spending body involved in current rail safety issues, has been to ensure that public funding will be available, whatever measures are determined to be required.

Complexity of the network

1.11 One of the difficulties faced by the privatised UK rail network is its great size and complexity which creates a natural resistance to rapid change. This takes a number of different forms. In terms of size, the current extent of the network amounts to over 10,000 miles and the total length of lines to well over twice that figure. Just under one third of route mileage is electrified, being further divided into third rail DC and overhead AC traction systems. There are some 25,000 signals on the system, all of which are potential, if not actual candidates for train protection measures. Rolling stock includes electric locomotives and
multiple units (MUs) confined to electrified lines; and diesel and diesel-electric MUs with diesel electric locomotives. The traditional trains of locomotive-hauled coaches and HSTs with a power car at each end are now being replaced by fixed formation train sets and MUs with all coaches powered and capable of increasingly high speeds.

1.12 There are currently some 180 different classes of locomotive and MU, often with variations within classes. There are several different types of signalling and interlocking systems. The fitting of a new safety system to the rail network, thus involves not just the development of the system itself, but its adaptation to fit the huge variety of existing equipment on which it is to be installed. The fitting of new systems to existing track and rolling stock (referred to as “retro-fitting”) is substantially more difficult and expensive than fitting at manufacture or at major re-signalling. It is typically fraught with teething difficulties which require considerable resolve to overcome, as demonstrated clearly through the experience of First Great Western (FGW) with their BR-ATP pilot.

1.13 In addition to the complexity of the system itself, and perhaps as a consequence of it, the UK rail network is currently faced with a number of different train protection systems, some already fitted, others in various stages of development. The broad question to be addressed in this report is what is the best way forward? At present, virtually the whole of the passenger network is protected by the AWS which provides an audible and visual alarm and the possibility of brake intervention at each warning and stop signal encountered. AWS, however, (because it can be overridden by the driver) does not intervene to prevent the driver passing a signal at danger. ATP is designed to achieve this. A version, which is referred to in this report as BR-ATP, is currently fitted on parts of the Railtrack Great Western and Midland zones used by FGW and Chiltern. The alternative TPWS which has been under development since 1994 is now effectively mandated by Regulation. In addition, both high speed
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lines and conventional lines will, in future, be subject to European Directives requiring the fitment of train protection systems based on the European Rail Transport Management System (ERTMS). Neither BR-ATP nor TPWS will comply with the Directives. The circumstances on different lines within the UK network vary very greatly in terms of speed, capacity and types of traffic. The appropriate safety systems, both mandatory and non-mandatory, may also vary.

1.14 Whatever safety systems are to be fitted for the future, it is clear that, with a few exceptions, no train protection system beyond the existing AWS will be operational until 2003 at the earliest. Furthermore, in the light of experience, it should be accepted that further delays in the fitting of train protection are not unlikely. The SPADRAM (SPAD reduction and mitigation) project, introduced in 1994 as an alternative to ATP, included also a range of measures directed towards reducing the numbers of SPADs. Given the inevitable delay before any further train protection becomes available, it is not merely a matter of prudence but of clear necessity to take all possible measures to avert the possibility of future accidents resulting from SPADs.

1.15 If TPWS is to be installed on a network-wide basis and become the principal means of protection against SPADs, it is important to note the limitations of the system, which will not deliver full ATP protection. These relate primarily to the speed of the train but there are other limitations, including the fact that many signals will not be fitted. In these circumstances, it will remain important to pursue and develop the SPADRAM measures to minimise further the possibility of accidents resulting from SPADs which cannot be prevented by TPWS.

The Joint Inquiry

1.16 This report follows a Joint Public Inquiry held under section 14(2)(b) of the Health and Safety at Work Act 1974. The Inquiry is unique in not having been
generated by a single accident or event. The issues which the Joint Inquiry has dealt with were originally included within the terms of reference of the Southall rail accident inquiry, Chaired by Professor Uff QC. The Southall rail accident, in which seven people were killed and a large number injured, occurred on 19 September 1997. After a substantial delay as a result of criminal proceedings brought against the driver and the Train Operating Company, the Inquiry hearings commenced on 20 September 1999. Just over two weeks after the start, on 5 October 1999, the rail accident at Ladbroke Grove occurred in which 31 people lost their lives and many were injured. Lord Cullen PC was appointed Chairman of the Public Inquiry into the Ladbroke Grove accident and was given wide terms of reference which included the issues of Train Protection Systems and SPAD Prevention Measures. Initially, it was decided that the Southall Inquiry would not deal with these duplicated issues. Subsequently, however, it was proposed that the issues be dealt with through a further Joint Inquiry and this was established by Mr Bill Callaghan, Chair of the Health and Safety Commission, with the consent of the Deputy Prime Minister, by letter dated 5 November 1999 (Annex 01).

1.17 In October 1999, in the course of much public concern about SPADs and their consequences, Sir David Davies FREng, FRS, President of Royal Academy of Engineering, was appointed by the Deputy Prime Minister to prepare a report on train protection systems. The report was published in February 2000 and its contents have been widely reported and debated. Sir David Davies’ report was presented to the Joint Inquiry and he attended to give evidence on his report and to be cross-examined by the parties at the Inquiry. Sir David’s report and evidence to the Inquiry are referred to further in the body of this report.

1.18 The Southall Inquiry continued its hearings in October 1999, but excluding issues now within the Joint Inquiry’s terms of reference. The Southall Inquiry completed its hearings on 20 December 1999. The report of the Chairman was published on 24 February 2000 and a subsequent action plan was issued by
HSC, after consultation with all parties, on 22 May 2000. Implementation of the Southall recommendations continues. The Ladbroke Grove Inquiry was divided into two sections. Part I, dealing with the circumstances of the accident commenced on 10 May and was concluded on 14 September 2000. Part II, dealing with the regulation and management of safety on the railways, commenced on 30 October and was completed on 20 December 2000. The reports following the Ladbroke Grove Inquiry will be published in due course.

1.19 The Joint Inquiry hearings commenced on 18 September 2000. The proceedings were adjourned on 19 September and again on 5 October so that relatives and victims of the two accidents and members of the Inquiry could attend the memorial services arranged on the anniversary of each accident. The evidence was concluded on 13 October and final oral submissions were heard on 27 October 2000, after the service of written submissions of the parties. A list of the parties and their representatives who appeared at the Inquiry is included as Annex 02. An alphabetical list of witnesses at the Inquiry is at Annex 03. A full list of the Inquiry personnel is set out at Annex 04. The Chairmen permitted televising of the proceedings following the same protocol as that developed for the Southall Inquiry.

The pace of change

1.20 This report comes between two major accident inquiries. Its scope is specific and limited. The report must, however, take account of wider aspects of rail safety and of public perceptions and expectations as clearly reflected in responses to the accidents at Southall and Ladbroke Grove. We must also take into account, when formulating any recommendations, the rapid changes which are occurring within the UK rail industry. After the Southall Inquiry was set up, the Government introduced a new Transport Bill which has recently been enacted as the Transport Act 2000. This sets up the Strategic Rail Authority with wide new powers to control and direct investment into the rail industry, as well as taking over the powers of the former Franchising Director. The Rail
Regulator, Mr Tom Winsor, who was appointed in July 1999 has introduced new policies and priorities which are progressively having effect. As part of the transport debate, the Government has introduced a 10 year plan providing for investment of £49 billion in the rail system over the next decade, which will make possible the introduction of the protection system which this report considers.

1.21 Rail safety technology can also be seen to be developing at a rapid pace. The effects of change are nowhere more clearly seen than in the case advanced before the Joint Inquiry on behalf of the Passengers’ Group. The case that had been put forward at the Southall Inquiry, only one year earlier, sought a recommendation for network-wide fitment of BR-ATP. The case presented to the Joint Inquiry, in contrast, was for rapid fitment of the new European ETCS system. Plainly, we must take these developments into account so that this report is relevant at the date of its issue and for some time thereafter. We must therefore take into account also changes which are likely in the future. The Joint Inquiry presents a great challenge, but one which is matched by the importance of the issues of future safety on the railways.

Questions to be addressed in this report

1.22 In the following chapters we address many individual and detailed issues. The principal questions for consideration by the Joint Inquiry have, however, been identified by Counsel to the Inquiry and they are as follows:

1. Should the current plan to install trackside and train-borne TPWS be continued, curtailed or aborted?

2. (a) Should TPWS+ be subject to trials?
(b) If the trials are successful should TPWS+ be installed anywhere on the network and if so where and in what circumstances?
3. (a) Should TPWS-E be subject to trials?
   (b) If the trials are successful should TPWS-E be installed anywhere on the network and if so where and in what circumstances?

4. To what extent should ETCS be installed on the network, in what order and to what timetable?

1.23 Other questions addressed in the report are:

5. What should be the future of BR-ATP on Great Western and Chiltern Lines and the Heathrow Express?

6. What priority should be given to SPAD reduction and mitigation measures?

7. What measures should be taken to ensure compliance with decisions about train protection measures?

1.24 Question 1 is the subject of Chapter 6. Questions 2 and 3 are assessed in Chapter 7 Question 4 is considered in Chapter 8 and question 5 in Chapter 9. Question 6 is considered in Chapter 10 and question 7 in Chapter 5. The options are evaluated in Chapter 11 and our recommendations set out in Chapter 12.

1.25 In addressing these questions we should take note of the part played by rail safety in transport generally. Although detailed statistics were not introduced, parties made numerous references to road transport and we cannot fail to be aware of the general level of fatalities and injuries on the roads, which exceed those on the railways many times over. The priority conventionally given to rail safety is dealt with in Chapter 4. We put on one side the disproportionate reaction of the media to rail mishaps of any kind. On the basis of submissions on behalf of rail users as well as the views of experts from HSE and DETR, we
believe that the real concern of the public lies in the possibility of further catastrophic accidents involving multiple fatalities, in circumstances where the passengers have no control over events, and the public have only limited knowledge of who is in charge of safety on the railway system.

1.26 The issues dealt with in this Report cover, in part, similar ground to the report of Sir David Davies. For the Joint Inquiry, however, we have had the benefit of a public oral hearing and access to many more documents. We have also had the opinions of many experts including Sir David himself, and we have had the opportunity to weigh many different views put forward on behalf of different industry participants.
2.1 The great majority of the UK rail network presently operates without any form of train protection capable of preventing SPADs, and will continue to do so for at least the next two years. It is therefore important to understand what lies behind the numbers of SPADs, which have been regularly reported in the press and rightly give rise to great concern. The numbers occurring annually (still significantly in excess of 500) bear little relation to the numbers of fatal accidents resulting from SPADs (less than one accident every two years). Nevertheless, both the Southall and the Ladbroke Grove crashes resulted directly from SPADs and the potential for catastrophic consequences is plain.

2.2 There are many different means of preventing SPADs or of avoiding or reducing their consequences. The different systems and procedures overlap to a very high degree such that, in the case of any potential SPAD, there will be two or more systems and many different procedures in place, all directed towards the same end. Only when all systems and procedures fail at the same time will there be the possibility of a SPAD leading to a collision. The principal concern which this report addresses is of such a combination of failures having the potential to lead to a catastrophic accident. Each of the individual systems and procedures under discussion is to be viewed in this context.

SPADRAM Project

2.3 SPAD Reduction and Mitigation (or SPADRAM) was the name given to an initiative launched in 1994 jointly between BR/Railtrack and HMRI. The SPADRAM project effectively replaced the earlier policy of BR for nation-
wide fitment of ATP. The project included the new train protection and warning system (TPWS), although it was not to be submitted to trials until 1997. SPADRAM also included a range of measures aimed at reducing the numbers of SPADs and mitigating their effect, including early versions of some of the measures currently being pursued. The SPADRAM Project represented the first concerted attempt to address all aspects of SPADs and their avoidance.

2.4 There were no fatal accidents resulting from SPADs during the period immediately after rail privatisation. In August 1996, a collision occurred at Watford, resulting in the death of one passenger. The collision followed a SPAD in which the driver failed to bring the train to a halt within the reduced overlap. An internal HMRI Inquiry made the following recommendations relevant to SPAD issues:

2. Railtrack should review their procedures for convening Signal Sighting Committees so that, following multiple SPAD incidents, an assessment of all risk factors could be considered.

4. Railtrack should identify signals with reduced overlaps, carry out risk assessments and take appropriate action.

5. Railtrack should adopt a track layout risk assessment method to identify risks of collision resulting from SPADs.

10. TOCs should audit their own SPAD management systems.

11. Railtrack should develop the SPAD Management Programme and instigate studies into human and other factors.

12. Railtrack should ensure that all TOCs using a route are informed of a SPAD incident on that route.

2.5 On 19 September 1997 a crash occurred at Southall, west London, in which seven people lost their lives. This was the first modern high-speed collision
following a SPAD involving multiple fatalities. A passenger train collided with an empty freight train at a relative speed of over 80mph. The report of the delayed public inquiry into the accident, which was published in February 2000, made the following recommendations relevant to SPADRAM issues:

1. Evidence should be collected for reliable research into human behaviour studies relating to driver performance.

5. Testing of driver competence should be extended to include abnormal driving situations permitted by the Rules.

6. Drivers should be encouraged to report all actual or suspected faults, whether through formal fault reporting procedures or through CIRAS.

7. A national qualification and accreditation system for drivers should be established.

Categories of SPADS

2.6 SPADs are categorised in terms of their gravity so that they may be properly investigated and appropriate management action taken. A category ‘A’ SPAD is one when a stop signal (and any preceding cautionary signal) was displayed correctly and in sufficient time for the train to be stopped safely at the signal. Categories ‘B’, ‘C’ and ‘D’ are defined in Annex 05 which also lists “severity ratings” and “hazard rankings” which are to be assessed for each SPAD. Railtrack is responsible for ensuring that every Category ‘A’ SPAD is investigated in a way that establishes the full facts and determines the immediate and underlying causes. Normally a formal inquiry or investigation will be conducted unless all parties are satisfied with an alternative process. Railtrack are responsible for the input of data to SMIS. All members of the Railway Group are required by the Group Standards to have processes in place to take management action resulting from the investigation. Guidance Notes
provide for data collection forms to be completed by the Infrastructure Controller, Train Operator and others.

Category ‘A’ SPADs are required to be Hazard Ranked by the Railway Group member responsible for the person causing SPAD. The Index derived is used to aid management decisions for future action.

**HMRI SPAD report**

2.7 During 1998 and 1999 HMRI made inspections of the management systems in place covering SPADS. Their audit focused on a number of key areas to determine whether or not the risks of SPADs were being reduced as far as reasonably practicable and to examine the effectiveness of SPAD management systems. This initiative came during the two years following the Southall accident and some four years after the introduction of the SPADRAM Project. While noting the importance of general measures for avoiding SPADs (including signal sighting and driver training), the audit focused on specific measures for implementing corrective action, particularly in two key areas namely

(a) the prompt investigation of SPADs so as to find the root cause, including the taking of effective action and communicating findings to relevant parties; and

(b) putting into place effective measures to stop repeat SPADs at the same signal.

2.8 The HMRI report noted the following matters:

- SPADs probably give rise to the highest safety risk facing the rail industry.

- It was a matter of concern that SPADs had increased during 1998/99.
• HMRI were encouraged to note that the industry was now addressing the necessary issues in a robust manner.

• 22 actions were identified, many of which the industry was already working towards implementing.

2.9 HMRI gave a presentation of their SPAD report on 2 September 1999, although copies of the report were not available until some weeks later. Because HMRI believed the industry to be responding positively, enforcement action was not proposed and none was taken until after the tragic accident at Ladbroke Grove, which occurred some weeks after publication of the report.

Numbers of SPADs

2.10 The statistics published in HMRI Annual Reports reveal a progressive decrease in recorded numbers of SPADs from 1994/5 (771), 1995/6 (729) and 1996/7 (688) to 1997/8 (639). In 1998/9 the number rose to 664 but the figure for 1999/2000 has dropped again to 596. During the course of the Inquiry it emerged that the figures provided by Railtrack were some 5% higher than those reported to HMRI. The difference is due to Railtrack’s inclusion of SPADS from sources (e.g. shunting) not required to be reported to HMRI. The difference is of no significance since the trends in both sets of figures are the same. Railtrack and HMRI are taking steps to harmonise their database to ensure that figures in future will be directly comparable.

2.11 Numbers of SPADs can be analysed as between different train operators covering a wide range of different types of service. Figures can be produced showing best and worst records. The differences between passenger operators are not significant, however, and we are satisfied that train operators and ATOC itself are all aware of the need for continued attention to SPADs. A question was raised as to the relative contribution to the overall number of SPADs of freight as against passenger services. Existing data on SPADs between 1994 and 2000, grouped by sector, suggested that freight companies
(principally EWS, as by far the largest freight operator) were responsible for a higher proportion of more severe SPADs than in the case of passenger services. This conclusion was, however, challenged by EWS who drew attention to the following factors likely to result in higher numbers:

- Freight trains are more frequently held up by red signals
- Shunting operations, which can lead to SPADs, are more frequent
- Freight – passenger junctions are a particular source of SPADs
- The running of ballast trains for engineering works, where signals are not in normal operation, can lead to SPADs

SPAD rates for individual freight drivers were shown to be equal to or better than those of passenger drivers and we do not consider that any adverse conclusion is warranted in the case of freight services.

2.12 Concern over continuing numbers of SPADs is now such that all operators seek to draw lessons from their own SPAD experiences for the purpose of ongoing training. An example is the Heathrow Express Company which, even with the benefit of ATP, has experienced 5 SPADs. Two were on lines without ATP and one followed an isolation. In both the other cases, the train was brought to rest well within the overlap. Each had involved a critical lapse of concentration by the driver in the 10 seconds prior to the signal.

2.13 The average SPAD rate per driver across the network remains at the figure of only one SPAD in 17 years. But while this might appear near the limit of what is achievable, every SPAD is preventable and it remains a high priority to reduce the numbers yet further.
Statistics and trends

2.14 The incidence of different categories of SPADS is regularly analysed in order to provide statistical data. One particular use of statistics is to assess the extent to which anti-SPAD measures are successful, or alternatively, require further attention. Such analysis is largely confined to year on year figures and does not seek to draw long term conclusions. In the case of accidents involving fatalities and serious injuries, however, longer term statistical analysis provides material upon which the effects of train protection systems can be assessed in terms of the prevention of fatalities and injuries. Such analyses are carried out in purely mathematical terms using historical data to predict future numbers of accidents and fatalities. The mathematical processes are limited to the analysis of data in order to establish past trends, which are then assumed to continue into the future, an assumption which has been borne out by events since the analysis was first carried out. The results of the analysis can then be further developed by adding additional assumptions e.g. as to the growth in traffic and as to many other factors.

2.15 Professor Andrew Evans, London Transport Professor of Transport Safety at the Centre for Transport Studies, University College and Imperial College, London, who is a leading authority on rail safety statistics, gave evidence to the Joint Inquiry. Professor Evans, with Neville Verlander, were the authors of a paper published in October 1994 on the prediction of fatalities from rail accidents. This paper, produced at the time of the debate about the future of BR-ATP, estimated the number of fatalities to be expected on the basis of past rail accidents, and the numbers that could be expected to be saved by the installation of BR-ATP. The paper noted that most fatal accidents had only a small number of fatalities, but a few had many – a conclusion which has also been borne out by subsequent events.

2.16 In May 1999, Professor Evans wrote a major paper for the Journal of the Royal Statistical Society on Fatal Train Accidents on Britain’s Main Line Railways.
The paper noted a high rate of decline in both ATP-preventable and non-ATP-preventable accidents, but a lower rate of decline in SPADs generally. The Ladbroke Grove accident occurred before publication, and a postscript was added to update the conclusions. Even after allowing for the Ladbroke Grove accident, the paper estimated that the mean frequency of fatal train accidents from all causes was just over one per year, and the average number of fatalities just under four per year. The paper also noted the reduction in numbers of casualties resulting from the introduction of more modern rolling stock.

Professor Evans published a series of further papers in 1999 and 2000, including a commissioned report on the speeds of trains in fatal accidents, in response to Recommendation 43 of the Southall accident report. In addition to Professor Evans’ papers and submissions to the Joint Inquiry, an assessment of the statistical evidence was presented to the Inquiry by Dr Simon Walker, Reader in Computational Mechanics at Imperial College London, which confirmed Professor Evans’ methods of analysis. However, Dr Walker pointed out the essential shortcomings of the statistical methods employed. Thus, the use of smoothed-out graphs for the purpose of analysis could be misleading to the extent they suggested a trend which was more regular than actual events showed. Furthermore, the paucity of data meant that predictions were more dependent on individual events, such as the Ladbroke Grove crash. Nevertheless, Professor Evans himself has noted the surprising stability of overall figures for fatalities.

Professor Evans’ updated Royal Statistical Society paper presented a new statistical analysis of fatal accidents resulting from SPADs. It was concluded that the data now shows a clear and differential trend between fatal accidents resulting from plain line SPADs, which are shown to be decreasing at 10% per annum, and those resulting from conflicting movement SPADs (junctions), which are shown to be increasing at 1.4% per annum. These figures, however, require further qualification. The numbers of fatal accidents resulting from
plain line SPADs is now extremely small, the last such accident having occurred in 1984. Around 95% of fatal accidents resulting from SPADs are associated with conflicting movements (junctions). The suggested 1.4% per annum increase in conflicting movement SPADs is subject to a standard statistical error of ± 2.8% so that the future projected figure may lie anywhere in the range +4.2% to -1.4%. None of the witnesses at the Inquiry were able to suggest a reason for a statistical increase, if that is a correct interpretation of the figures. The rate of increase was not itself statistically significant but, conversely, the clear difference between plain line and conflicting SPADs was statistically significant. These figures are at least consistent with the continuing high overall numbers of SPADS of all types. It is also clear that junction SPADs remain the major source of risk.

Fatalities in rail crashes

2.19 As stated above, after taking into account the Ladbroke Grove crash, the average number of passenger fatalities resulting from train accidents equates to about four per annum. This may cause some surprise. How is it that a crash involving 31 fatalities and many serious injuries can have so little effect on future predicted accidents and fatalities? The answer is that recent fatal accidents involving multiple fatalities, (Southall, Ladbroke Grove and now Hatfield) form part of a surprisingly consistent trend. Passenger fatalities on the railways, seen over a lengthy period of time, represent an underlying and relatively small annual figure, subject to occasional serious accidents in which a large number of fatalities may occur. Such events are few and far between and are rightly viewed by the public with abhorrence, but the number of fatalities in a particular accident remains a matter of chance, depending on the particular circumstances. The Ladbroke Grove crash did have a material affect on the statistics by increasing the average number of fatalities per accident from approximately 2.4 to 4.10. The occurrence of the crash, although tragic and unpredictable, was not statistically unlikely. It remains probable that multi-
fatality accidents will continue to occur in the future, the actual numbers of fatalities being highly uncertain.

2.20 Different types of accidents are not reflected in the smoothed out graphs that are the product of Professor Evans’ work. Nor do the graphs take on any noticeably different form when other factors are taken into account, such as increased traffic, additional operational safety measures and safer rolling stock. These factors produce only different average future trends with no indication of the distribution of the predicted numbers of fatalities.

2.21 An alternative approach to this issue was presented by Professor Mathias Beck of Glasgow Caledonian University, as part of his report on Cost Benefit Analysis presented on behalf of the Passengers’ Group. Professor Beck made use of the so-called Monte Carlo Analysis to calculate the future probability of accidents of different severity, falling within the overall standard statistical predictions. This method makes use of simulated random numbers for the calculation of the probability of accidents of different severity, using a large number of computerised simulations. The analysis can then be incorporated into a different form of cost benefit analysis, using the predicted rates of occurrence of accidents of different severity, which is considered further in Chapter 4. This method of analysis can generate, in place of the average future rate, the probability of a severe accident occurring within a period of, say, 30 years. Such calculations form an equally valid part of the statistical analysis and provide some information, at least, on the likelihood of multi-fatality accidents occurring in the future.

2.22 Any prediction as to numbers of SPADs and their consequences depends upon assumptions which are made as to the circumstances which will apply at the time of any future accident. Professor Evans’ predictions for average future equivalent fatalities are based exclusively on what has happened in the past, assuming that past trends will continue. These figures can be adjusted to take into account new factors, although it should be emphasised that little or no
statistical data exists from which actual figures can be predicted. Indeed, some factors may produce different effects, alternatively tending to increase or decrease statistical numbers. The principal factors needing to be taken into account are set out in the following paragraphs.

**Increase in traffic**

2.23 This is assumed to result in trains running at closer intervals, thereby increasing the numbers of red signals encountered and therefore the likelihood of SPADs. In addition, higher numbers of passengers on a train are likely to result in more casualties in the event of an accident. Historical data on the effect of increased road traffic is unlikely to be a reliable guide to rail travel, where very different circumstances exist.

**Increase in speed**

2.24 This has been the subject of a separate report by Professor Evans. It had earlier been reported that numbers of fatalities increase in a linear fashion with speed of collision. However, as Dr Ian Murphy pointed out, the kinetic energy dissipated in a crash (through damage or dispersal) is proportional to the square of the speed, so that a higher speed would be expected to have disproportionately severe consequences. The effect on fatalities may, of course, be masked by other factors. Professor Evans found the mean number of fatalities did indeed rise with the impact speed, although the relationship was not close and the number of fatalities in individual accidents was very variable. Professor Evans also found, however, that there has been no statistically significant upward trend in the speeds of trains involved in accidents. Consequently, no statistical data was available from which the effect (should it occur) of increasing collision speed could be judged.
Crashworthiness

2.25 There is an undoubted beneficial relationship between crashworthiness of vehicles and numbers of fatalities. Improved designs of both coaches and couplings have led to predictable increases in safety. Such a conclusion can be reached from a comparison of the consequences of individual accidents, rather than from statistics. HMRI considered this issue to be of such importance that they pressed for the mandated withdrawal of Mark I rolling stock, now required by the Railway Safety Regulations 1999. These improvements are, however, included in existing statistics as a result of the progressive introduction of Mark III and IV rolling stock.

Increased use of multiple units

2.26 The effect is to place passengers at the front and rear of a train, without the protection of a substantial locomotive. Plainly, the effect of this will be dependent on the particular circumstances of an accident: some may be unaffected, yet others may be substantially affected in a way and to an extent that cannot be predicted.

Multi-SPAD signals

2.27 A multi-SPAD signal is defined as one which has been passed at danger more than twice in 12 months, or more than three times in 3 years. HMRI drew attention to multi-SPAD incidents at particular signals in their report into the accident at Watford South Junction in August 1996 (Recommendation 2). The issue was raised again in the HMRI SPAD report of September 1999, where specific action was required including the collaborative risk assessment of all multi-SPAD signals. The recommendation in the Watford report, to ensure that all TOCs using a route were informed of a SPAD on that route, was repeated. It was subsequently calculated that multi-SPAD signals, as redefined in the reissued Group Standard 3252, accounted for around 36% of all SPADs, which suggested this as an area requiring urgent attention.
2.28 After the Ladbroke Grove crash, HMRI drew up a list of the top 22 multi-SPAD signals which were ranked in order of numbers of SPADs. For the purpose of the Inquiry Dr Ian Murphy, whose work on layout risk analysis was considered in the Southall Inquiry, was invited to apply his analysis to multi-SPAD signals and, in particular, to the list drawn up by HMRI. Dr Murphy had already produced a report for the Joint Inquiry in which he drew conclusions as to the significance of different types of SPAD, pointing out that the crucial factor was the existence of a collision opportunity rather than the SPAD itself. In his report, No 102, Dr Murphy considered the risk of collision involved in each of the top 22 multi-SPAD signals identified by HMRI.

2.29 Dr Murphy’s initial conclusions were that 14 of those signals had immediate collision potential following a SPAD, while 8 had relatively benign consequences. Of the 14 signals of particular concern, these fell into further categories where the potential was for head-on collision (10 signals) or where the potential was for side-on collision (4 signals). Dr Murphy then analysed each of the signals using his FT (Fouling and Timing) method. This involves calculation of the probability of the occurrence of a fouling SPAD or the time intervals between occurrences. The analysis is based on the following data:

- Average number of SPADs per year
- Proportion of SPADs which are fouling
- Percentage of occasions when signal at red is protecting a conflicting move.
- Length of vital interval (i.e. the period of time within which a collision is possible).
- Time for which signalled route is set.

2.30 Dr Murphy’s analysis led to a significant re-classification of signals deemed most at risk, through assessment of the frequency of a predicted collision,
together with a separate “Severity Index” representing the consequences of such a collision. The order of risk in which Dr Murphy’s analysis placed the 22 signals in question was quite different from that based on the numbers of SPADs and clearly illustrated those signals most in need of review. These included signal SN109 involved in the Ladbroke Grove crash. We understand that Railtrack are pursuing this alternative method of analysis with Dr Murphy, with a view to extending it to other signals within the network in order to identify those most urgently in need of attention. We endorse this course of action.

2.31 A variety of remedial measures have been identified to mitigate the risk from multi-SPAD signals. In the severest cases, alteration to the track layout or signalling may be called for to avert or mitigate the collision opportunity. In less severe cases, the following measures are available:

- Rapid dissemination of information about the signal
- Warning signboards on the trackside
- Banner repeater signals
- Speed restrictions
Chapter 3

Review of Train Protection

3.1 This chapter gives an overview of train protection in order to show the context in which individual systems are to operate. The term “train protection”, as used in this Report, refers to the means of preventing the passing of a signal at danger and over-speeding. Traditionally, the responsibility for stopping the train before a signal at danger rested with the driver. But since the early years of the 20th century mechanical and electro-magnetic systems have been developed to improve safety. Initially, these delivered a warning to the driver but more recently, train protection systems have been developed which are capable of taking control of the train to ensure that the brakes are appropriately applied. Currently, a warning system known as AWS (Automatic Warning System) is fitted to rolling stock operating on all passenger and most freight lines. This system was installed by British Rail between the 1950s and 1980s and has undoubtedly been responsible for averting many accidents and for preventing many fatalities and injuries.

3.2 Train Protection Systems were first proposed for general use on the UK network in the mid-1980s. This led to the recommendation by Mr Anthony Hidden QC, in the report on the Clapham Junction accident (para 46), that ATP (Automatic Train Protection) should be fitted to the rail network after initial pilot schemes on Great Western Trains and Chiltern Railways. In 1994/5 it was decided not to proceed with network-wide fitment of BR-ATP on the ground of cost, and to proceed instead with an alternative package of measures known as SPADRAM. This included the alternative and less effective train protection system known as the TPWS (Train Protection and Warning System). Between 1995 and 1999 TPWS was developed and tested on a number of lines, while on Great Western Trains and Chiltern Railways BR-ATP continued to be used. During 1998 and 1999 BR-ATP finally became fully effective on Great Western and Chiltern lines.
3.3 Before reviewing train protection systems it should be noted that the Passengers’ Group appearing at the Joint Inquiry was highly critical of the train protections systems currently available and contended that the UK lagged “a long and shameful distance behind” the rest of Western Europe. They were supported by Mr Anthony Howker, an expert with many years of railway experience who considered the UK to be “just about the only country left in the world that runs high-speed trains and mixed traffic without the benefit of modern ATP systems that prevent the driver passing signals at danger”. While this Report is concerned with the future and not with the past, such contentions are not to be disregarded as hyperbole. They reflect the fact that the present state of train protection in the UK has been the product of decisions made over the past 20 years under widely differing regimes of management, with little evidence of long term planning. One of the principal tasks of this report is to identify the path towards the fitment of train protection systems appropriate to a modern railway system.

Automatic Warning System

3.4 AWS was reviewed in the public inquiry into the Southall accident. Its development and current performance were considered in Chapter 12 of the Report, together with the rules and practices governing its use. Evidence to the Inquiry gathered by the BTP, and subsequently re-analysed by FGW, revealed widespread and inadequately documented isolations of AWS. It was concluded that AWS faults on Great Western services were running at the rate of almost 10 per week in the period preceding the Southall accident. Concern was expressed as to arrangements for both servicing and renewing AWS equipment. Recommendations were made for improvement of maintenance procedures and for changes to operating rules to minimise the running of trains without operational AWS.
3.5 AWS is of direct relevance to the functioning of TPWS, which uses much of the existing AWS system. Evidence to the Joint Inquiry concerning TPWS also dealt with the reliability of the AWS equipment that will remain to form part of TPWS. The evidence presented suggested that current AWS equipment, on the rail system generally, is no more reliable than was revealed at Southall in the case of FGW, and possibly even less reliable. A number of witnesses expressed serious concern about this situation. We consider these issues further in Chapter 6 below in relation to TPWS. During the period that AWS remains as the only warning system available on a large part of the network, it must be strongly reaffirmed that the equipment should be adequately maintained, renewed and serviced in order to provide at least a basic level of protection against SPADs. Evidence of unsatisfactory AWS equipment which has emerged during the fitting of TPWS has not given us any confidence that this is yet being achieved. Renewal of AWS equipment is to be preferred but this is seen by Operators as an expensive option.

Automatic Train Protection

3.6 The fitment and development of BR-ATP on Great Western Lines was also reviewed in the Southall Inquiry and considered in Chapter 13 of the Report. Up to the date of the Southall accident, there existed neither the willpower nor the commitment to take the steps necessary to bring BR-ATP into full operation. The Pilot Scheme on Great Western Lines came close to being abandoned and it was only as a result of the Southall accident that FGW found the effort and investment required to bring the system into full operation. Ironically, it was as a result of the Ladbroke Grove accident and consequent restriction of services, that FGW were first able to commence operation with 100% BR-ATP. Since then, they have operated a policy of “No ATP No Go”. HMRI finally gave approval to BR-ATP on the Great Western lines on 25 September 2000. Nevertheless, FGW continue to experience reliability
problems with BR-ATP which are reviewed further in Chapter 9 below, where consideration is given to its use on other lines including those over which Chiltern Railways operate.

3.7 Both AWS and BR-ATP now represent old technology dating respectively from the 1950s and 1980s. Both have continuing reliability problems. A valuable lesson to be learned from the fitment of BR-ATP is that retro-fitment of relatively sophisticated equipment to older locomotives not designed for such equipment is likely to lead to problems not only of fitment but also of continuing reliability. Problems can be solved individually, but collectively they may render such systems unsatisfactory. TPWS potentially faces the same difficulties. Major improvements in reliability of train protection systems can be best fully realised when the systems are incorporated in re-signalling schemes and fitted to trains which have been designed to accommodate them.

Train protection and warning system

3.8 TPWS was conceived as a simple, cheap and quickly available means of providing train protection. It was intended to fill the gap left by abandonment of nation-wide fitment of BR-ATP. A draft of the European Directive on Interoperability was issued in 1994 and the likelihood of full ATP being required by European law was known about from 1991, so that TPWS was always seen as having a limited life span. TPWS uses much of the existing AWS equipment, which will continue to operate as an additional warning system. TPWS will provide an automatic train stop at a red signal and an additional speed trap located in advance of the signal, where line-side equipment is fitted.

3.9 Since its original conception, TPWS has developed a number of teething problems during trials which, while progressively overcome, have led to greater complication of the equipment. The principal issue concerning TPWS
which has now emerged is whether even more complex variants on the system should be developed and put into use. Related to this issue is the question of limitations on the ability of the system to provide effective train protection and what measures should be taken to improve its effectiveness. TPWS issues are considered in Chapters 6 and 7.

### European train protection

3.10 In 1996, the European Commission and Council issued Council Directive 96/48/EC on interoperability for the Trans-European high speed rail network (TEN). The UK lines covered by this Directive are the Great West Main Line (London – Cardiff), West Coast Main Line (London – Glasgow), East Coast Main Line (London – Edinburgh) and the Channel Tunnel Rail Link (Folkestone-London) which is currently under construction. The Directive requires the fitting of a compatible train protection system under the European Rail Transport Management System (ERTMS). Such a system, known as ETCS, will function in a manner similar to BR-ATP but using entirely new and non-compatible technology. Subsequently, a further draft Directive was issued by the European Commission covering conventional lines. This Directive will apply to a significant proportion of the remainder of the UK network. When fully in force, the Directives will require a version of the ERTMS system to be fitted. The European Directives and their effects are considered further in Chapter 8.

3.11 Neither the BR-pioneered ATP (BR-ATP) nor TPWS will comply with the requirements of the European Directives. Both will require to be replaced on lines covered by the Directives. The area of uncertainty lies in the timing of ETCS, the type of equipment to be fitted and the feasibility of transitional measures (see annex 06 for details of ETCS trials).
The Davies’ report

3.12 Within days of the Ladbroke Grove crash, the Deputy Prime Minister appointed Sir David Davies to prepare a report on train protection systems. The report was published on 22 February 2000. After reviewing the systems available to the UK rail network, Sir David concluded that TPWS offered the advantage of short term protection before the expected availability of ETCS. Recommendations were made for development of enhanced versions of TPWS which might satisfy safety requirements on particular lines. It was recognised that, in order to run both on ETCS-fitted lines and on TPWS-fitted lines, trains would require dual fitment. It was emphasised, however, that the future lay with one of the three levels of ETCS train protection.

Specific transmission module

3.13 This refers to a train-borne device (STM) which will allow the train, when fitted with a European ETCS system, to run on lines fitted with non-compliant systems, such as ATP loops. STMs are likely to be in widespread use throughout Europe as transition measures, during the introduction of ETCS systems, given that the majority of European lines are already fitted with some form of train protection. In the case of UK lines, an STM could be developed to allow ETCS-fitted trains to use the BR-ATP-fitted Great Western lines. The STM, which is still under development, would allow the train protection system to read and use information transmitted by the line-side equipment.

3.14 A variant on this approach may apply in the case of non-ETCS-fitted trains using ETCS-fitted lines. Where the train is fitted with a non-compliant train protection system such as BR-ATP a “reverse STM” could be devised to allow the trains to make use of their ATP equipment by reading information transmitted by the ETCS track equipment. It should be emphasised that these
devices will be transitional, and intended to allow the maximum protection which the train and track in combination can generate.

**SPAD prevention**

3.15 With the exception of the BR-ATP systems on the Great Western and Chiltern Lines, and TPWS trial sections on lines used by Thameslink, Connex and EWS, there is no system of train protection currently in operation on the main UK rail network. While TPWS will be fitted progressively to track and trains, the earliest date for general deployment of TPWS is the beginning of 2003; and fitment of other systems will be substantially later. Consequently, SPAD prevention for at least the next 2 years will be dependent on more conventional measures.

3.16 The SPADRAM Initiative, launched in 1994 in the face of inevitable delay in the fitting of any general train protection system, included procedures directed towards reduction in the numbers of SPADs and the mitigation of their consequences. The procedures included, particularly, driver performance. From 1995 onwards the SPADRAM measures have been pursued and developed by the UK rail industry and the safety regulators (notably HMRI) with increasing vigour. The Southall rail accident in September 1997 heightened concern about SPADs and accelerated the SPADRAM programme; and the extreme public concern following the Ladbroke Grove accident in October 1999 gave even more impetus to the avoidance of SPADs pending the introduction of Train Protection Systems. This topic is developed in Chapter 10.

**Implementation of new safety measures**

3.16 We conclude this chapter by referring again to submissions from the Passengers’ Group about the way in which new safety systems have been introduced on the UK railway system. They referred to the “grudging and
reluctant way in which the railway industry (whether in public or private hands) has implemented” new safety measures. Even the horror of accidents had been “supplanted by a penny-pinching concern that performance must not be adversely affected”. While we appreciate the frustration engendered by lack of quick action following the identification of major shortcomings in the system and recommended solutions (usually following major accidents), there are reasons for the delays which have occurred which are not always to be traced to concerns about money or performance. Foremost among these is the complexity, size and inertia of the railway system (see Chapter 1) and the difficulty of identifying the right solution at a time of continuing evolution and change.

3.17 In retrospect, while the introduction of AWS was plainly appropriate, although implemented too slowly, the decision to introduce BR-ATP pilot schemes and the decision in 1994 to replace BR-ATP with TPWS were more questionable. In terms of implementation, both government and industry have sought to demonstrate a new resolve backed up by the provision of funding and legislation, which are considered in the following two chapters. It is clear that the future of train protection lies with ETCS. The fitment programme on WCML, despite early set backs, represents a major commitment to rail safety which will influence development of the UK rail network in decades to come.
CHAPTER 4

THE COST OF SAFETY

4.1 Before we consider the detailed safety systems and the sums which will need to be expended, it is appropriate to consider the source of those funds, everyone is happy in principle, to see money being spent on safety. However if the expenditure is to be reflected in the cost of rail travel, or if it prevents money being spent on other measures, the expenditure may come in for more scrutiny.

Funding and Regulation

4.2 Under the current structure of the rail industry all commercial activities are undertaken by public limited companies which are subject to the law and practice of commerce. The activities which they undertake are also governed by the statutes under which the rail industry was privatised, which create the particular regulatory system through which the rail industry is, in part, controlled. The regulated rail industry shares some aspects of its operation with other regulated industries, such as water and the energy sectors. The detailed regulatory structure is, however, unique to the railway industry and involves two separate levels of regulation: first, through the Office of the Rail Regulator, currently Mr Tom Winsor; and secondly, through the Strategic Rail Authority (SRA) of which the new Chairman is Sir Alastair Morton. Their functions and the relevant sources of funding will be briefly explained.

4.3 The Strategic Rail Authority has taken over the functions of the Franchising Director, including the right to award franchises. The programme for replacing many of the current franchises is underway and is a competitive process. The SRA has wide powers of financial assistance which were not available to the Franchising Director.
4.4 The government’s current 10-year investment package for the rail industry amounting to £49 billion includes an expected £34 billion of private finance. The breakdown of the total investment is broadly;

- £38 billion of enhancement and renewals investment for passenger services. This figure encompasses projects such as the West Coast Mainline, CTRL, Thameslink 2000 and East London line extensions as well as passenger subsidy. £500 million is allocated for TPWS.
- £7 billion investment in new and replacement passenger rolling stock over the next ten years
- £4 billion investment in European funding of rail freight including new rolling stock

Railtrack has been allocated European funding of 63.8 million Euros to date and expects to receive more for the WCML upgrade.

Funding of Railtrack

4.5 Railtrack plc occupies a central role in the UK rail industry as the owner of all the major fixed assets, principally track and signalling, together with depots and stations. They are the main “investors” in new safety systems. At privatisation, Railtrack acquired British Rail’s infrastructure assets as well as part of their debt, which became designated as the “Regulatory Asset Base”. As part of the regulatory system, Railtrack are permitted to add approved expenditure to the Regulatory Asset Base, upon which they are allowed to recover, as part of their income, interest at the weighted average cost of capital, to service the increasing debt. Approved expenditure will include, for example, renewal of signalling systems, where this amounts to an upgrade. One of the
issues of concern to Railtrack is how far future capital expenditure will be approved by the Regulator.

4.6 Some 85% of Railtrack’s revenue derives from track access charges and rentals from franchise operators. Income is set by the Regulator at 5-yearly intervals. The second 5-yearly review was issued in October 2000. The duty of the Regulator under the Railways Act 1993 and the Network Licence is to promote efficiency and economy and specifically to set charges at such a level as to allow Railtrack to carry out its functions “in a timely, economic and efficient manner”. In doing so, the Regulator calculates the gross revenue required during the period in question, from which are deducted “single till revenues” i.e. other income available to Railtrack. Gross revenue requirements include operating costs and maintenance costs. Other sources of income include receipts from freight operators (6.2%) from property transactions (5.3%) and from other sources. A contentious issue remaining from privatisation is the incentive for Railtrack to expand and improve the infrastructure from their normal regulated revenue.

Funding of train operators

4.7 Passenger train operating companies (known as TOCs) are generally not required to hold substantial assets. Companies seeking to become TOCs must bid for the award of their franchise and, upon award, must enter into a regulated Track Access Contract under which charges are payable to Railtrack for line access. Most TOCs at present lease rolling stock from ROSCOs under a standard Master Operating Lease Agreement (MOLA), which was drawn up at the time of privatisation. TOCs receive income from passenger fares and from government subsidy via the SRA, presently of the order of £900 million per annum. Currently 75% of TOC income is from fares and 25% from subsidy. If the Regulator allows track access charges to increase, that increase
is funded by the SRA and ultimately by the public purse. ROSCOs are not in receipt of direct public funding.

4.8 Freight operating companies are not subject to franchising. They own their own locomotives and rolling stock. Capital support is provided through Freight Facilities Grants and revenue support through Track Access Grants which currently amount to £54 million per annum. Government policy is to support the movement of freight onto rail. 85% of freight on the UK network is operated by EWS.

**Funding of safety systems**

4.9 New safety systems involve substantial capital expenditure in varying proportions on both track and rolling stock. Costs of track installations will be met exclusively by Railtrack. This will be funded, if regarded as mandatory, either by direct public subsidy via the SRA, or by indirect subsidy via the Regulator. The Regulator may allow an increase in the regulatory asset base funded by an increase in track access charges, which may in turn result in additional subsidy to TOCs. Mandatory (but not non-mandatory) modifications to current rolling stock are dealt with under the MOLA, pursuant to which TOCs pay 10% of the costs. ROSCOs pay the remaining 90% up to a ceiling of £20 million in any one year beyond which the government contributes 60% of the excess and the ROSCOs the balance of 30%. These arrangements will continue until about 2004 but will be reviewed in new leasing agreements that will accompany the next franchising round.

4.10 The extent to which any part of the costs may not be covered by such subsidy and may result in increases in fares, remains uncertain. However, the costs of the safety measures currently under consideration will be met substantially from the public purse. The issue of priorities as between one form of safety expenditure and another remains and is considered below in the context of cost benefit analysis. It needs to be emphasised, however, that public subsidy
substantially distorts the attitude of operators, including Railtrack, to the fitment of safety systems. The costs and benefits to them are quite different to the costs and benefits to the public at large. The interests of the public are represented most closely by HMRI and the Regulatory bodies and, in this Joint Inquiry, by the Passengers’ Group.

**Decisions about safety**

4.11 No transport system can be entirely free of risk and safety can never be absolute. Risk can be measured in terms of statistical probability, but this means only that adverse consequences are predicted to occur at some time within a stated period. The prediction that an event may happen once in 100 years does not mean that it will not occur for 100 years. The element of uncertainty means that it may happen immediately. Only over a long period should the average conform to the probability.

4.12 This report is concerned with the avoidance of SPADs. If they are to be avoided by resort to a train protection system, this will be achieved only if the train protection system operates correctly, if the brakes are applied in sufficient time to stop the train and if the brakes then operate correctly. Each of these stages inevitably involves some risk that can be quantified, but never entirely eliminated. Furthermore, as noted in Chapter 1, SPADs represent only part of the risk associated with the railway system. Decisions on the fitting of train protection systems must take these considerations into account.

**Reasonable practicability**

4.13 The legal responsibility for safety on the railway system is, in general, governed by the underlying principle of what is “reasonably practicable”, in accordance with the Health and Safety at Work Act 1974. The Railways Act 1993, which is the founding legislation of the privatised rail system, does not deal with safety issues; all current railway safety regulations are made under
the 1974 Act. The HSE, through The Railway Inspectorate, may normally take enforcement action only by reference to what is reasonably practicable.

4.14 The meaning of this term was considered by the Court of Appeal in Edwards v. National Coal Board [1949] 1KB 704, where Asquith LJ stated that:

‘“Reasonably practicable” is a narrower term than “physically possible” and seems to me to imply that a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other; and if it be shown that there is a gross disproportion between them, the risk being insignificant in relation to the sacrifice – the [person on whom the duty is laid] discharges the onus on them [of proving that compliance was not reasonably practicable].’

This case continues to be regarded as an accurate expression of the law: see Redgrave’s Health and Safety 3rd edition, para 2.55. Cost Benefit Analysis (CBA) is thus a component of assessing what is reasonably practicable. CBA is considered below.

4.15 Railtrack’s Safety Case imports reasonable practicability, which must be given effect by creation of new Group Standards or amendment or abolition of existing Standards. Representation and participation by all operators is required and new safety requirements cannot be imposed unless they satisfy the requirements of reasonable practicability.

4.16 This is not, however, the only approach to safety. It is well recognised by decision makers, particularly Ministers and their advisers, that the approach to risk must also take into account public reaction to the consequences. Some consequences are regarded as so abhorrent and intolerable, that the risk of such occurrence must be reduced whatever the cost. Examples are the possibility of escape of nuclear contamination or the spread of CJD. Risks involved in rail
travel are not generally regarded in this way, but public reaction to catastrophic rail accidents is a matter which should be, and is taken into account, in the making of decisions about rail safety.

4.17 Given that neither Railtrack cannot impose safety requirements beyond those which satisfy the test of reasonable practicability and cost benefit, how are safety systems to be imposed where these criteria are not clearly satisfied? Before privatisation this question did not arise. British Rail sought to maintain the rail system in a safe condition by gradual evolution and the introduction of new technology subject to the availability of funding. The time taken to achieve full fitment of AWS between the 1950s and 1980s shows the BR system as inadequate. The experience of introducing ATP on Great Western and Chiltern Lines during the 1990s shows the system which replaced it to be equally wanting in this respect.

Regulation for safety

4.18 In the UK rail industry as presently constituted, safety measures going beyond the conventional safety yardstick might be adopted in response to commercial pressure, particularly if they involve material benefits. However, for the new safety systems currently under consideration, the only means of ensuring fitment is through regulation coupled with the assured provision of adequate funding. This has been the approach adopted by HSE in the case of TPWS, through the Railway Safety Regulations 1999. These regulations, which are considered in more detail in Chapter 5, represent a new approach to the introduction of safety measures, which was not envisaged at the time of rail privatisation. We are asked to review those regulations and we do so, but bearing in mind that both HSE and DETR have already come to their own informed decisions on the issue.
4.19 For the introduction of ETCS, regulations must be issued by HM Government to comply with the European Directives. Neither the Directives nor the regulations to be issued are open to review in this Inquiry. We are, however, asked to recommend the bringing forward of ETCS on both high speed and conventional lines, for the achievement of which domestic regulations are one possibility. Given that funding is a necessary requirement for the introduction of any major new safety system, regulation as opposed to mere recommendation has the further attraction of putting the availability of funding beyond doubt.

4.20 It follows that cost benefit analysis, unless so mandated, should not be taken as the only criterion for making a decision on safety issues. It is, however, generally accepted, and we accept, that CBA is a factor to be taken into account when reaching a decision on the introduction of train protection systems. CBA itself, in relation to safety issues, has proved controversial in terms both of the costs and the benefits which are to be assessed. CBA in relation to the present issues is now briefly reviewed.

Cost benefit analysis

4.21 Cost benefit analysis (CBA) requires comparison of the present and future costs against future benefits, rendered into the common currency of money and adjusted to present comparable values. It thus involves assessment of future benefits and their reduction to monetary values, including the prevention of injuries and fatalities. Experts called by the rail unions considered the method to be flawed. To put a value on fatalities is particularly controversial, since it suggests that human life has a particular value and no more. Understandably, this is a concept which those who have been bereaved in rail accidents find difficult to accept. But viewed in terms of priorities, the issue can be expressed in a simpler and less emotive way. No one should take offence at being asked whether an available sum of money should be spent on one project or another; nor would a decision based on the greatest reduction of risk cause any surprise.
Perhaps the terms in which cost benefit analysis is conventionally performed need to be changed. In essence, however, the process is concerned with achieving the best overall result in terms of preventing fatalities and injuries that might otherwise occur.

4.22 We do not need to review the history of cost benefit analysis, which has undergone a number of changes of approach. CBA was applied for the first time in relation to a substantial railway safety proposal in 1993/4 when British Rail undertook a reappraisal of the decision, made some 5 years earlier, to introduce ATP. The analysis then carried out, and subsequent comments on the data and methods employed, were presented to the Joint Inquiry in great detail. We made it clear that the Inquiry intended to look primarily to the future and saw no purpose in reappraising past decisions. Nevertheless, certain rules and practices emerged from the analysis then carried out which are still relevant to decisions made today and it is right that they should be examined.

Value of prevented fatalities

4.23 Central to the appraisal of any safety system is its potential to prevent crashes and consequent injuries and fatalities. A value must be put on this benefit which is now conventionally referred to as the value of a prevented fatality (VPF). The numbers of “equivalent fatalities” in any accident are estimated by counting numbers of major and minor injuries which are then aggregated into an equivalent fatality by counting ten major injuries or two hundred minor injuries as equivalent to one fatality. The figures have little basis other than convention and it needs to be emphasised that they represent equivalent fatalities avoided and in no sense represent the value of a life which has been lost nor that of any injury suffered. The concept of VPF has long been in use by the DETR for road projects and is subject to periodic review. The VPF figure is increased to reflect the value of other benefits of preventing an accident, although these are small compared to the saving of life. The current (June 2000) VPF figure used by the DETR is, at least in theory, £1.15 million.
4.24 Underpinning the DETR’s determination of an appropriate VPF figure is research carried out to determine the public’s willingness to pay (WTP) for safety projects. By both direct and indirect methods, researchers seek to ascertain the amount of money which the public is prepared to spend to achieve a particular safety benefit. The methods include revealed preference studies in terms of wage differentials and consumer market decisions. Alternatively, stated preferences can be ascertained through the testing of individuals’ decisions on the monetary value of changes in risk. This is the preferred method of the DETR and has been broadly adopted by the HSE.

4.25 Figures for VPF have been included in Railtrack’s Safety Case since 1994, corresponding to those used by DETR for road safety. However in the case of risks regarded as close to the limit of tolerability, an additional factor of 2.8 is applied, creating in effect a differential between rail and road safety. This approach was first adopted in the reappraisal of ATP in 1993/4 and has been justified by DoT (now DETR) and HSE on the basis of societal concerns about the consequences of major rail accidents. The factor is considered to reflect extreme public reaction to accidents involving multiple fatalities, including the fact that the victims have no control over events. The current VPF figure for fatalities arising from rail accidents, accepted by both Railtrack and the HSE, is £3.22 million.

4.26 A major research project was commissioned in 1995 by the HSE in conjunction with the Department of Transport, the Home Office and HM Treasury, and undertaken by departments from the universities of Newcastle upon Tyne, Wales, York and Sussex. A final report was issued in early 2000. The major object of the research was to examine whether the differential applied as between road and rail safety, was supported by direct survey of public opinion in which fire risks were also included. The results, surprisingly, afforded little or no support for the differential between road and rail safety. Surveys were repeated after the Ladbroke Grove crash and substantially confirmed the
original opinion. Professor Jones-Lee of Newcastle University gave evidence
to the Inquiry confirming the results of the project. We take note of the wide
variance between this research and the conventional approach, which HSE and
DETR still favour. We believe that the research project must be seen in the
context of the particular methods and questionnaires employed. We are not,
however, required to resolve the differences which have emerged, which
dictate the need for further consideration by those supporting each position.

4.27 The report presented to the Inquiry by Professor Beck of Glasgow Caledonian
University took a different approach to accident prediction, as noted in Chapter
2. For the assessment of benefits the report considered a range of studies
including the Jones-Lee research. This approach revealed a wide range of
possible figures from which a weighted average could be derived. The point of
Professor Beck’s alternative approach to CBA was to apply the analysis to
particular types of simulated “future” accident, of which the probability could
be calculated, including catastrophic accidents. Professor Beck generally
supported the DETR’s current figure for VPF and sought to demonstrate that a
CBA test for an ATP system could be satisfied over a range of possible future
events involving different types of accident, rather than average figures.

4.28 It is to be noted that all methods of analysis involve “discounting” future
benefits so as to bring all figures to a common base. The discount rates used
are, in some cases, contentious. We do not feel it necessary to express any
view on these issues, which are of narrow compass, in the light of major
differences of approach which have emerged.

4.29 Any future ATP system will entail expenditure at levels many times higher
than that indicated by any approach based on CBA. Despite its cost, there
appears to be a general consensus in favour of ATP. The expenditure of
massive sums of public money on ATP rather than on other rail or road safety
schemes, or any other causes, is a matter for Government, including the
European Commission.
Judgments to be made

4.30 We have been presented with, and have reviewed, a range of approaches to decision making in the context of rail safety based on costs and benefits. We have noted the approach to decision making embodied in Health and Safety practice and in Railtrack’s Safety Case. However, the train protection systems to which this report is primarily addressed are (in the case of TPWS) or will in the future be (in the case of ERTMS), mandated by law. In both cases provision has been made for public funding. We are not, therefore, called on to come to any judgment on whether these systems satisfy a cost benefit analysis. We believe that our function in these respects is to ensure that relevant issues have been addressed and that adequate transparency is afforded to the expenditure of the very large sums of public money involved, and that the recommendations made reflect the broad interests of the public.
5.1 Privatisation of the rail industry brought with it a new approach to safety based on Railway Safety Cases and more detailed Group Standards. These in turn are based on duties under Safety Regulations (having effect under the Health and Safety at Work Act 1974) and under Railtrack’s Network Licence, which incorporate the concepts of best practice and the maintenance of risk as low as reasonably practicable (ALARP). The duty to maintain safety is, thus, not absolute. For the maintenance of the existing railway system, these general obligations could reasonably be translated into specific duties, and any failure could be the subject of enforcement action by HMRI, using their powers under the Health and Safety Act. For the introduction of new equipment, including the fitting of new safety systems, however, the application of these obligations in practice was unclear, as was the provision of funding for them.

5.2 Some years before the process of privatisation began, two important safety measures were the subject of recommendation in the 1989 report on the Clapham Junction crash. Paragraph 46 of the Recommendations was for implementation of ATP Pilot Schemes and paragraph 56 for withdrawal of the old Mark I rolling stock. Both were to be pursued by BR and both, having begun, should have been passed on to the new privatised owners in 1995/6. The fate of both recommendations illustrates the difficulty of achieving compliance under the original non-statutory scheme.

5.3 As regards the BR-ATP Pilot Scheme on Great Western lines, the initial fitment of trains and track was carried out and funded by BR. Railtrack, however, were not placed under any specific obligations to proceed with the Pilot Scheme. The operating franchise granted to Great Western Trains in February 1996 did not place them under a duty to proceed with BR-ATP to any
particular timetable and there was doubt as to whether they were obliged to proceed at all. At the same time, the Hidden recommendation that Mark I rolling stock should be replaced by 1999 fared even worse. It had been formally dropped by BR/Railtrack and was not transferred to the newly created ROSCOs.

5.4 The fates of both the BR-ATP Pilots and of Mark I rolling stock were raised by the Parliamentary Transport Select Committee in July 1996 when HSE gave evidence. This led to HSE themselves considering regulation to enforce compliance, initially in regard to Mark I rolling stock only. This received a favourable response from the Secretary of State in early 1997. With the added impetus of the Southall crash and with continued support from the new Minister, HSE pursued the issue of regulations to cover both Mark I rolling stock and TPWS, the future of which was otherwise considered to be very uncertain. HSC published a formal consultation document in May 1998. After considering responses, the Commission submitted draft regulations to the Deputy Prime Minister in December 1998. These were laid before Parliament in August 1999 mandating both the fitment of TPWS and conditional withdrawal of Mark I rolling stock by 2004. The effect of the regulations is considered further below.

5.5 It needs to be emphasised that the path of prescribing for these changes by regulation represented a substantial departure from the concept of “reasonable practicability” as enshrined in the Health and Safety Work Act. Use of the test of reasonable practicability may lead to the conclusion that many available safety measures might be rejected or not proceeded with on the ground that their cost exceeds the quantifiable benefits. As has already been seen, the “benefits”, in terms of the prevention of injuries and fatalities, may also reflect extreme public concern about rail safety in comparison to other perceived risks. But the position of train protection systems, up to 1997, was that they were not perceived by the rail industry or HSE as being reasonably practicable and
neither ATP nor TPWS would have been fitted without other incentives, including regulation.

5.6 Where regulations are introduced they will be given effect through the courts in accordance with their terms. The Railway Safety Regulations 1999 are expressed in terms of mandatory requirements as to the fitting of equipment in the absence of which it will become unlawful to operate. Regulations may, however, be framed in any terms thought to be appropriate and may contain provisions for allowing derogation.

System Authorities

5.7 The report into the Southall accident noted the detrimental effect, particularly on the ATP programme, of the absence of any System Authority to oversee the project. It was noted that rights and obligations in regard to safety equipment such as ATP were generally not defined in legal terms. Recommendation 63 called for the creation of System Authorities to oversee new and existing projects.

5.8 For the TPWS programme, an Industry Liaison Group (ILG) had been set up at the instigation of Railtrack, chaired by Brian Clementson, a former Director of Virgin Trains. The ILG is an ad hoc group that performs a useful function in disseminating information and securing views of the companies involved i.e. ROSCOs and train operators. Mr Clementson noted that TPWS had been evolved by Railtrack without reference to ROSCOs or train operators, but cooperation had now been achieved. It appears that the ILG is now generally regarded as equivalent to a TPWS System Authority. However, it has no contractual or statutory status and has not been vested by its members with any power or authority.

5.9 It should be stated clearly that the ILG is not the “System Authority” contemplated by Recommendations 57 to 64 of the Southall report. These recommendations called for the creation of legally enforceable rights and
obligations. The ILG, while performing a useful function of liaison, would be wholly unequipped to enforce the fitting of TPWS without the backing of mandatory regulations. Without such regulation, any System Authority without power to enforce its decisions would be of little value, particularly when faced with companies having different commercial interests. The failure of the rail industry so far to put in place any legally enforceable rights and obligations in regard to common safety equipment leads inevitably to the conclusion that such equipment is unlikely to be fitted without the use of regulation.

**Railway Safety Regulations 1999**

5.10 These regulations apply to a “Train Protection System”, which is defined (Regulation 2) as:

“equipment which -

(a) causes the brakes of the train to apply automatically if the train -

   (i) passes without authority a stop signal such passing of which could cause the train to collide with another train, or

   (ii) travels at excessive speed on a relevant approach.”

5.11 This definition corresponds to the (i) train stop and (ii) speed trap (or over-speed sensor) elements of TPWS. The Regulations contain significant exemptions, some of which are considered below. TPWS will comply with the stated requirements but other systems could also comply. A Train Protection System may alternatively comprise (where reasonably practicable to install) -

“equipment which automatically controls the speed of the train to ensure, so far as possible, that a stop signal is not passed without authority and that the permitted speed is not exceeded at any time throughout its journey”.
This is, in effect, a reference to ATP which, where fitted to both train and track, will automatically comply with the regulations. There will not be compliance, however, where an ATP-fitted train runs on non-ATP-fitted track, nor when non-ATP-fitted trains run on ATP-fitted track. Thus, in practice, both Great Western lines and BR-ATP-fitted trains will require to be fitted with TPWS. ATP may, however, remain as the exclusive Train Protection System on lines used only by the Heathrow Express and, possibly, on Chiltern Lines also, subject to further extension of ATP coverage which is considered in Chapter 9.

5.12 The regulations do not make the fitment of Train Protection Systems mandatory as such, but prohibit (Regulation 3) the operation of a railway without train protection. The prohibition applies from 1 January 2004, but also requires that a programme for the installation and bringing into service of train protection has been approved by the HSE “and is being implemented”. Appropriate programmes have been submitted to and approved by the HSE. If it transpired that the industry was failing to implement those programmes, the regulations would, in theory, prevent further operation of the railway from the date of such failure. In any event, these dates have now been brought forward following the Ladbroke Grove crash, as considered further in Chapter 6.

5.13 The regulations contain a number of significant exemptions. They do not apply to London Underground and to similar metro systems in Tyne and Wear and Strathclyde, nor to the Manchester Serco Metrolink, provided that there is in place an automatic train stop, such as the London Underground “tripcock” system. These railways will, therefore, comply with the “train stop” element of TPWS but need not comply with the “speed trap” element, which will generally be unnecessary in view of the limited speed of operation. The regulations do not apply to a tramway (as defined) or to a railway which does not exceed 25mph. There are also provisions for the granting of Exemption Certificates.
5.14 The “relevant approach” to which the speed trap or Over Speed Sensor (OSS) is to be applied means (Regulation 2) -
(a) an approach to a stop signal (unless a train travelling at maximum speed can be stopped by the train stop system before the fouling point)
(b) an approach to a speed restriction (beyond specified limits)
(c) an approach to a buffer stop.

As regards the fitting of signals with a train stop, this is required (Regulation 2(4)) only in the case of signals protecting junctions and not those on plain track. When a Train Protection System is in operation, the regulations make detailed provisions as to withdrawal from service after a failure of the system (Regulation 3).

5.15 The same regulations mandate the withdrawal from service of Mark I rolling stock by 1 January 2003, unless rebodied or modified, and withdrawal of rolling stock with hinged doors without central locking by 1 January 2005.

European law requirements

5.16 In the early 1990s, the European Commission began to consider the use of Directives which would apply across the European Community to harmonise the operation of railway systems in inter-connected member states. International railway services have been in existence for many decades, not only between the countries of mainland Europe but, to a more limited extent, between Great Britain and the Continent. The opening of the Channel Tunnel has greatly expanded direct rail travel between Great Britain and Northern Europe. Very little attention has been paid, historically, to achieving conformity between different national systems. Generally, Europe has adopted (with a few exceptions) the same track gauge, based on the original railways developed in England. The loading gauge (i.e. clearance to structures) is not common and both signalling and safety systems have, for a very long period, developed almost independently. Thus, signalling systems differ in their basic
concepts (the UK system being based on distance from a point of conflict); and many different national train protection systems have been developed. Only in the past two decades have control systems been developed which are capable of being fitted on an international basis. An example of this is the ATP systems selected for the Great Western and Chiltern Line pilots, both of which had been developed and used on Belgian lines.

5.17 In 1996, the European Council adopted the High Speed Train Interoperability Directive 96/48/EC, providing for interoperability of the high speed Trans-European Network, generally known as the TEN lines. In the UK, this will apply to the following lines:

- Great West Main Line (GWML)
- West Coast Main Line (WCML)
- East Coast Main Line (ECML)
- Channel Tunnel Rail Link (CTRL)

These lines will, in the future, be upgraded (or in the case of CTRL built) for speeds of 200km/h (125mph) or 250km/h or greater. When upgraded, the Directive requires fitment of a Train Protection System.

5.18 The Directive defines the “essential requirements” which are to be met by the new high-speed systems, including control-command and signalling sub-systems. The essential requirements are to be met by the adoption of “Technical Specifications for Interoperability” (TSIs) which are intended to ensure both the achievement of appropriate function and compatibility. The Directive came into force on 8 October 1996 and member states were required to implement the Directive no later than April 1999. Many member states, including the United Kingdom, have not done so. The TSI for control-command and signalling sub-systems is still in draft form and expected to be adopted and published early in 2001.
5.19 The Train Protection Systems required to be fitted under the Interoperability Directive will come within the European Rail Transport Management System (ERTMS) and are generally referred to as the “European Train Control System” (ETCS). Although the specification documents are still in draft, preliminary trials have already commenced and others will follow with a view to progressive fitment to TENs across Europe during the coming decade. The current position in the UK and elsewhere in Europe is reviewed in Chapter 8.

5.20 In addition to the High Speed Interoperability Directive, the European Commission published a draft Directive on interoperability of conventional railways in 1999, the latest draft being dated June 2000. Further consultation is to be carried out with a view to publishing a final version of the Directive for adoption by the end of 2001. The broad scheme of the Conventional Interoperability Directive follows that of the High Speed Directive. The routes covered by the two Directives will cover a major portion of the UK rail network, but will fall short of full national coverage.

Effect on Railway Safety Regulations 1999

5.21 The submissions and evidence presented to the Joint Inquiry on behalf of Rail Unions included an opinion on the effect of Council Directive 96/48/EC on the Railway Safety Regulations 1999. That opinion concluded that the Regulations conflicted with European law because they did not comply with the obligations set out in Directive 96/48/EC. The obligations are triggered by the carrying out of upgrade operations, but the Regulations permit a train protection system not compliant with ERTMS. This conclusion would be fortified if TPWS were also shown to compromise the installation of an ERTMS system. Subsequently, the Joint Inquiry was provided with further legal opinions on these issues, on behalf of the Passengers’ Group and on behalf of Railtrack, together with further supplementary opinions and submissions. Both Railtrack and the Passengers’ Group disputed the basic premise of the opinion on behalf of Rail Unions. However, both Unions and the Passengers’ Group were in
agreement that fitting TPWS to high speed lines would trigger an obligation to install ETCS, at least after the relevant TSIs had been published. The opinion on behalf of Railtrack disputed both propositions. All parties recognised that a derogation to allow the installation of TPWS on high speed lines could be granted if the criterion set out in article 7(a) of Council Directive 96/48/EC is met. This article requires that the project for upgrading an existing line for high speed should be at “an advanced stage of development when the TSIs in question are published”. The Passengers’ Group submitted that this criterion could not, in fact, be met. There was at least tacit agreement that the derogation in question was a matter for the United Kingdom Government and not the European Commission.

5.22 Counsel to the Inquiry provided an additional opinion on the effect of Directive 96/48/EC on the Railway Safety Regulations 1999 and on the opinions and submissions provided to the Joint Inquiry. The opinion of Counsel to the Inquiry was that it could not be successfully argued that Directive 96/48/EC imposed an immediate obligation on member states to install ETCS on existing high speed lines, so that there was no current incompatibility between the Directive and the Regulations. Counsel further considered that there was no evidential basis for the additional argument that installation of TPWS would compromise the installation of an ERTMS system. The Railway Safety Regulations 1999 did not specifically require the installation of TPWS and did not prevent the installation of ETCS. However, Counsel considered that the contention advanced by the Passengers’ Group, that TPWS would amount to an upgrade so as to trigger the requirement to fit ETCS, was arguable. Railtrack’s contrary argument that TPWS did not constitute upgrading was likewise considered to be arguable. Counsel submitted that it was neither necessary nor desirable for the Inquiry to purport to resolve this dispute, which was a matter for the appropriate court; nor did Counsel indicate a view on the questions which were regarded as arguable. Counsel pointed out, however, that the practical consequences of the position suggested by the Passengers’ Group and
Rail Unions would lead to an odd result. A project to improve safety by fitting TPWS would be unlawful unless at the same time ETCS was put in, notwithstanding that ETCS was not immediately available whereas TPWS was.

5.23 We accept and adopt the position proposed by Counsel to the Inquiry and do not attempt to resolve or give any view on the rival opinions put to the Inquiry. We consider that the issues of whether the Railway Safety Regulations 1999 are in conflict with European law, whether the fitting of TPWS will trigger a requirement also to install ERTMS, and whether a derogation under article 7 is available, should be resolved, if necessary, in an appropriate forum as soon as possible.

Transport Act

5.24 Finally, in this review of relevant statutory provisions, note should be taken of the Transport Act 2000 which was before Parliament for many months. It contains important new provisions affecting the railway system. These include setting up of the Strategic Rail Authority, which operated as the shadow authority for more than a year with Sir Alastair Morton as Chairman. The functions of the Franchising Director are transferred to the SRA along with administration of substantial new funding for the railways, as already noted in Chapter 4.
Origins of TPWS

6.1 TPWS grew directly out of the decision, formulated during 1994 and finally announced in 1995, to abandon nation-wide fitment of ATP. Since the mid-1980s, it had been apparent that a form of train protection should be fitted to the UK railway system. From 1994 the task, originally of BR, was to find an interim solution to reduce the risk of SPADs, until a suitable ATP system could be found to meet reliability and affordability criteria. From the earliest days of the TPWS Initiative, it was apparent that European requirements would ultimately dictate the form of ATP which would be fitted in the future, at least to high speed lines. A draft of the Interoperability Directive had been issued in 1994. A SPADRAM working group was established in 1994, charged with investigating ways of reducing or mitigating the consequences of SPADs, taking into account experience up to that point with BR-ATP.

6.2 One of the particular problems that had been experienced with BR-ATP was with odometry (i.e. mechanical measurement of distance travelled), which persisted throughout the 1990s. The working group recommended a number of options, one of which was an enhanced version of AWS to provide a Train Stop and Over Speed Sensor (OSS) otherwise known as a “speed trap”, to be fitted to high risk signals. This proposal did not require odometry. The use of the existing AWS system would solve the problem of creating space in rolling stock for fitment of the equipment and would minimise changes and additions to wiring. Railtrack’s letter to the Secretary of State dated 21 November 1995 included a commitment to develop TPWS and to install it on a pilot basis. The initial time scale was for trials to begin in mid-1996 with installation to start in
1997. As with other rail projects, this programme was to prove seriously over-optimistic.

How TPWS works

6.3 TPWS works in a manner similar to AWS in that a track signal, picked up by the passing train, is enabled to apply the brake. In the case of AWS, the brake application applies to every signal set to danger or warning i.e. red, yellow or double yellow, but the brake application is delayed, giving the driver the opportunity to cancel the warning signal and thus avert a brake application. AWS, in fact, very rarely operates to apply the brake but warns the driver who, having cancelled the signal, should apply the brake in the normal way. In the case of TPWS, the brake application is selective, but if applied it cannot be cancelled by the driver. AWS is operated by permanent and electro-magnets which operate electrical reed switches through which warnings and, if necessary, the brake application are delivered. In the case of TPWS, communication between the track and train is by low frequency radio signals from loops placed in the track. TPWS loops operate in pairs. First, the “arming” loop, operating at one specific frequency starts a timer on the train. This is followed by a “trigger” loop at a different frequency. If the trigger loop is encountered before the timer has completed its sequence (indicating excess speed) a brake application is generated.

6.4 The basic TPWS model (now referred to as TPWS-A) comprises two sets of loops. The first which the train encounters is the “Over Speed Sensor” (OSS). This has its loops set a precise distance apart, depending on the critical speed at which a brake application is to be generated. The second part of the TPWS-A system is the “train stop” which has a further pair of loops located at the signal and overlapping. The train stop is energised when the signal is set to danger, and will cause a brake application at any speed. The OSS is likewise energised when the signal is set to danger but will only generate a brake application if it is passed at an excessive speed. The capability of TPWS to prevent a potential
collision depends upon the ability of the braking system to bring the train to a halt after the brake application and within the overlap i.e. the system aims to mitigate rather than prevent a SPAD.

6.5 The position of the OSS has been under review during the development of TPWS. It is now located at about 350 metres before the signal (the precise distance depends on the gradient), so that it will be encountered before meeting the AWS magnet. If the train is travelling within the speed limit to which the OSS is set, so that no brake application occurs, the train will receive a normal AWS warning at the magnet (183 metres before the signal), which will need to be cancelled. The train stop, located at the signal, initiates a brake application if the train passes the signal when set to danger. The system is designed not to operate when the train travels in the reverse direction on the same line. TPWS-A can be permanently energised, as it is in the case of buffer stops or speed restrictions.

6.6 The timer on passenger trains is nominally set to one second, and that on freight trains to 1.2 seconds, so that the same OSS will provide a brake intervention at a proportionately lower speed on freight trains, to reflect their lower braking performance. Communication between track loops and the train is via a train-mounted antenna. Otherwise the electronic equipment is all contained within the same metal housing which currently contains the AWS. Much of the original AWS equipment remains, including the brake application mechanism. The system is designed to self-test when energised in the driving cab. TPWS is non-intrusive and, if the train is driven within permitted operating speeds and brought to a stop before any red signal, the system will not intervene. In these circumstances, the driver will carry out exactly the same driving functions, including use of the DRA and AWS, as at present. TPWS operates as a last resort intervention system.
Development of TPWS

6.7 In 1995 Railtrack, which was then still a publicly owned company, invited tenders for the development and manufacture of TPWS train-borne equipment. Tenderers were provided with a detailed performance specification that included a requirement for TPWS to be capable of use on all types of rolling stock and to use common equipment across the whole Railtrack infrastructure. Tenders were invited in July 1995 from twelve international companies, eight of whom returned formal proposals. Railtrack prepared an evaluation of the proposals in December 1995 in which the tenders of GEC Alstom and Redifon MEL were shortlisted for full evaluation. Further review led to the selection of Redifon as the preferred supplier and further technical development of TPWS has been restricted to this single company. The tender process needs to be further reviewed in the context of TPWS-E, which is considered in Chapter 7.

6.8 Having selected the preferred tenderer, both Railtrack and HMRI became involved in the detailed design development of the system in order to meet the proposed programme for trials and fitment. In February 1996 Railtrack appointed Redifon to design and supply the track equipment also, which potentially eliminated any problems of compatibility between the two parts of the system. AEA Technology and W S Atkins, each of whom had experience of train protection systems, were commissioned to assist in the evaluation of various design options and subsequently to advise on the development of TPWS. The design has been optimised with the intention of preventing the maximum number of potential accidents.

6.9 The later stages of TPWS development have involved identification and solution of a number of specific design problems. Also calculations have been made as to the predicted rate of occurrence of different failure modes. Reliability is of particular concern. Given that TPWS makes use of substantial elements of the old AWS system, which is now known to possess substantial reliability problems, it is important that TPWS should not inherit the same
underlying level of unreliability. One of the features of TPWS is that when an automatic brake application is generated, it occurs independent of any action which the driver can take. If a train that is automatically braked is not stopped within the overlap, it may come to rest in a position which fouls a junction. Assessment of the reliability and performance of TPWS is therefore an important aspect of its design.

TPWS trials

6.10 The date for commencement of trials given by Railtrack in November 1995 and announced to the House of Commons by the Minister was mid-1996. Trials were to be carried out first on Thameslink but were progressively put back and had not commenced at the date of the Southall crash. Trials were then put in hand urgently and eventually started on 26 October 1997, just over a month later.

6.11 Early problems developed with the compatibility of the AWS Receiver, which resulted in TPWS failures. The problem was associated with the changeover circuit between AC and DC running on Thameslink trains. The train circuit design was amended and the problem overcome. The trials were successively extended during 1998, to address further technical development of the system and to allow extended fitment. Trials eventually included fitment of all 66 Thameslink Class 319 units and 20 Class 421 units running on the Thameslink and Tonbridge-Hastings routes, as well as 2 Freightliner Class 57 locomotives running on the East Anglia zone. Trials included track fitment to signals but not to speed restrictions.

Mandating TPWS

6.12 During the course of the tests, HMRI began to doubt the ability of the industry to fit TPWS speedily on a voluntary basis. In April 1998, HMRI announced their intention to propose additional regulations to accompany those which
were to mandate the withdrawal of Mark I rolling stock. A consultative document was issued in May 1998. Mandating of TPWS was opposed by EWS on the grounds that it offered no advantage over AWS and was subject to design deficiencies. TPWS was supported by others but this must be seen in the context of the continuing pressure for wider fitment of the more expensive ATP and the increasing likelihood that European regulation would mandate ETCS over much of the network. The Railway Safety Regulations were produced in draft in late 1998 and finally signed on 10 August 1999 mandating the introduction of a Train Protection and Warning System by 2004.

**Acceleration of TPWS programme**

6.13 Two days after the Ladbroke Grove accident, following a meeting with the Deputy Prime Minister, Railtrack put in hand plans for acceleration of the TPWS programme aimed at bringing fitment forward by 12 months. A more detailed programme was drawn up on 26 November 1999 and Railtrack set about the necessary liaison with those involved in implementing TPWS. A TPWS industry liaison group was established which has conducted monthly meetings.

6.14 In January 2000 Railtrack produced documents setting out proposals for the implementation of the 1999 Regulations and consisting of a specification for selection of TPWS locations, a specification for installation of transmitter loops and a programme for installing and bringing into service track-based elements of TPWS.

**Reliability of TPWS**

6.15 Initial trial results on TPWS in 1998 indicated comparable reliability with AWS. Extended testing in 1999, on Thameslink routes and on East Anglia and Southern zones, suggested that TPWS had not yet achieved reliability
comparable to that of AWS, but the achievement of parity was anticipated. The reliability of TPWS is currently under review at a theoretical and practical level. Theoretical work includes analysis of failure modes and their effects, as well as risk assessments. Practical data on the performance of TPWS is being obtained from continuing trials.

6.16 Performance of TPWS is now regulated by Group Standard GK/RT0090. The results of investigations and trials of TPWS to date have raised a number of technical concerns with both train-borne and trackside equipment. Some of the figures suggest that the Group Standard reliability targets are not being complied with. However, Redifon who are responsible for the design and development of TPWS have found solutions to all technical problems which have arisen so far. It should be emphasised that, although TPWS is substantially less sophisticated than ATP, it remains a mainly “retro-fitted” system that is likely to suffer (like BR-ATP) from unforeseen interfacing problems. Given that BR-ATP has been made to work on the two Pilot Schemes, there is no reason, in principle, why TPWS should not continue to overcome any problems which may emerge. Undoubtedly, there will be many class-specific problems as the basic system is adapted to the many different types of train to be fitted. HSE were sufficiently confident with the reliability of TPWS to give type approval to the Redifon track and train equipment and we do not regard questions of reliability as having any material impact on the question of its future fitment.

6.17 There are, however, a number of aspects of the technical performance of TPWS which do give rise to continuing concern. In terms of its operation, TPWS is not “fail safe” in that any malfunction will necessarily result in a more safe response. If the system fails to operate there will, generally, be no brake application where it would otherwise occur and this may be without prior warning to the driver. If the system fails to operate, the Railway Safety Regulations 1999 (Regulation 3) already require a withdrawal from service,
and this will be backed up by more detailed operating rules which are likely to reflect the parallel position of AWS. Until the driver is aware of a malfunction, such rules are of no effect. However, the issue has been investigated by W S Atkins for ATOC and the risk is assessed as low.

6.18 A second technical aspect of TPWS reliability concerns its dependence on AWS components and the questionable reliability of those components. The extent to which different operators intend to replace and renew AWS parts which will remain in service with TPWS varies. The problem of AWS reliability has emerged comparatively recently. Most parties expressed surprise at what was revealed in the course of the Southall Inquiry, since when the position has, if anything, become more worrying. More than one expert at the Joint Inquiry expressed concern at the continuing unreliability now revealed. Given the cost of the components it is surprising that any readily replaceable AWS element should be allowed to remain. Nevertheless, this is a matter of practical installation, and we recommend that AWS parts should be replaced where the option is available. The ATOC TPWS Executive (see para 6.29 below) is to produce a standard for AWS equipment, a move which we endorse.

6.19 In the course of more recent development, a number of improvements have been identified. These include reducing the incidence of failure modes not revealed to the driver and, in the event of a trackside fault, providing for the previous signal to revert to red. Against this, Mr Cooksey of HMRI expressed concern about “creeping elegance”, by which he meant the avoidance of delay to a good system by improvements of questionable benefit. We note that some improvements have already been rejected on behalf of the ROSCOs on the ground that the risk of further delay exceeds the risk which the modifications seek to avoid. We believe that this is an appropriate response which is also in keeping with Mr Cooksey’s more practical approach.
6.20 HMRI have also expressed concern about the emerging picture of AWS unreliability. It is important that TPWS should be significantly more reliable than AWS currently is, particularly in the light of the disturbing evidence which emerged in the course of the Southall Inquiry (Report, Chapter 12).

Effectiveness of TPWS

6.21 The basic model of TPWS is assessed to be capable of stopping a train travelling at up to 74mph within a standard overlap distance of 200 yards (184 metres) from a red signal provided the train can achieve braking at a rate of 12%g. The effectiveness of the system in preventing accidents depends on the proportion of future potential accidents which fall within these parameters. Approximately one third of the total UK rail mileage allows trains to exceed 75mph. Many trains will travel at speeds substantially in excess of 75mph – currently up to 125mph in the case of HSTs. Sir David Davies expressed discomfort at recommending TPWS for lines operating at speeds far higher than 75mph. In addition, many trains, including HSTs, do not achieve 12%g braking. Some overlaps are less than 200 yards, although many exceed this length, sometimes substantially. Plainly, it is impossible to predict within any degree of certainty what will be the statistical effect of TPWS. A system which protects slower but not faster trains may be seen as less than satisfactory. What can be said, at least, is that whatever the speed and braking capacity of the train, TPWS will reduce the collision speed to some extent.

6.22 The effectiveness of TPWS was considered at the beginning of the SPADRAM project by AEA in their report in 1994. Their first estimate, at a time when TPWS existed only as a concept, was that it would prevent up to 68% of equivalent fatalities caused by SPADs. This early assessment is open to substantial criticism. AEA prepared a second report in 1996 in which, taking
into account the DRA, the effectiveness of TPWS was discounted to around 55% which was expressed as subject to wide uncertainty. The report also noted that most of the benefits of TPWS could be gained by fitment of a limited proportion of signals, perhaps as low as 20%.

6.23 During 1998, when TPWS trials had re-started after the Southall crash, a number of further reports were commissioned. In March 1998 AEA prepared a report on the effect of partial fitment on fatalities prevented. In June 1998 AEA produced an analysis of the effect of TPWS on accident casualties in the period 1985 to 1997. Taking account of the uncertainty of available data, the report concluded that the overall effectiveness of TPWS in the accidents examined was 60% but with a substantial range of possible variation. At the same time, W S Atkins were commissioned to prepare a cost benefit analysis in which the 1994 BR-ATP data was updated. Their analysis of prevented fatalities led to the conclusion that TPWS would be 65% effective in saving ATP-preventable fatalities.

6.24 These reports have been subjected to criticism and reassessment. Sir David Davies, in his report of February 2000 quoted a figure of 65% for the overall effectiveness of TPWS, as compared to ATP, noting that this was “likely to be a low estimate” (para A 5.2). This assessment was criticised on the basis that Sir David Davies had not had access to the full range of reports. Nevertheless, it is clear that Sir David was well aware of the variations, in both approach and data, in the reports which he considered. In our view, an assessment of the order of 60% for the effectiveness of TPWS in preventing fatalities as compared to ATP remains justified, bearing in mind the inherent and unavoidable uncertainty in the data under consideration. What is being assessed is the long term effectiveness of TPWS. The effect on individual accidents and on short term statistics is, however, unpredictable because of the large and inevitable variations of individual accidents. All that can be said is that TPWS will reduce the likelihood of fatalities occurring from SPADs by
about two thirds. No more exact prediction is appropriate or even possible. The question we have to consider is whether there is sufficient justification for proceeding with TPWS.

6.25 Chapter 7 considers the possible application of variants which may enhance the performance of TPWS. It is relevant here to mention other possible means of enhancing the performance of the basic model, TPWS-A. Enhanced emergency braking (EEB) and improved adhesion devices are considered in Chapter 10. These will improve the performance of any train control system and would tend to improve the statistics analysed by AEA. Likewise, the possibility of altered track layouts to increase the length of overlaps will directly improve the chance of stopping a train short of the point of collision. Sir David Davies, in his main report, suggested the possibility of improving the effectiveness of TPWS by the use of train regulation to avoid, or reduce the frequency of, red signals being presented to trains which could not be stopped by TPWS within the overlap. Sir David Davies quoted a possible risk reduction of 5%. This proposal is further evaluated in Chapter 11.

Fitment of TPWS

6.26 TPWS was always envisaged as a system which could be fitted at selected signals, although all trains using the line in question would need fitment. A study carried out by AEA Technology in 1997 showed that 90% of the risk would be removed by fitment of between 15 and 18% of signals. The actual number to be fitted was proposed at a higher level. However, for the purpose of the Railway Safety Regulations 1999, it was decided that all signals protecting junctions would be fitted, representing between 40 and 50% of the total number of signals on the network. The actual number to be fitted will be approximately 11,000. This is the programme currently being carried out in order to comply with the regulations, and this is likely to absorb all or most available resources, particularly taking into account the acceleration of the statutory programme. A number of witnesses drew attention to examples of
plain line signals which posed material risks where TPWS should also be fitted. Railtrack’s present intention is to embark on risk analyses of plain line signals so that fitment can proceed to these as soon as the obligations under the regulations are satisfied.

6.27 The fitment of signals involves relatively standardised control equipment and the installation of appropriate loops and wiring. The positioning of loops needs to be carried out with accuracy, particularly in the case of the Over Speed Sensor, where the exact positioning of the loops is essential to the correct triggering of a brake application. Otherwise, while signal installation requires to be carried out during a possession, the work is relatively straightforward. Railtrack have placed the contract for supply of trackside equipment with Redifon. Fitment is being carried out by the appointed signalling contractors.

6.28 In the case of on-train equipment, the need to fit TPWS to many different types of train poses many different problems. Railtrack have selected Redifon for the design and development of the TPWS model. Each operator and ROSCO is intended to enter into a turnkey contract for the supply of on-train equipment by Redifon, with the option of fitment either by Redifon or by the TOC. The total UK passenger stock comprises 5432 cabs, of which 1889 may be exempt under the 1999 Regulations. The current programme envisages fitment of 90% of the cabs to be fitted, by the end of 2002. Redifon are currently supplying equipment for new-build manufacturers.

6.29 The TPWS programme is currently being overseen by the TPWS Industry-Liaison Group (ILG) chaired by Brian Clementson. In addition, train operators have formed the ATOC TPWS Executive chaired by Richard Lockett. The TPWS Executive meets weekly and members are also free to attend the 4-weekly meetings of the ILG. The TPWS Executive has its own expert advice from AEA Technology. Primary responsibility for safe operation of TPWS will lie with TOCs under the Railway Safety Regulations 1999. TOCs will be
responsible for maintenance of train-borne equipment and Railtrack for track equipment.

Cost of TPWS

6.30 In March 1996, almost two years after the idea of TPWS was first launched, the cost of fitment to the whole fleet was estimated at £12 million with £21 million for fitment to 5,000 signals. By the date of the 1999 Regulations these costs had risen to approximately £40 million and £80 - £105 million respectively. By October 1999, the total estimate had risen again to some £160 million with a further £30 million to be added for the cost of acceleration. Sir David Davies was given updated figures of £50 million and £193 million for train and track equipment. During the course of the Inquiry figures of £37 million (fleet fitment) and £373 million (track fitment) were given, together with other costs estimated at £46 million. The total currently estimated cost of over £450 million on any view greatly exceeds the figures on the basis of which TPWS was launched.

6.31 It is to be noted that part at least of the escalation in figures is accounted for by the numbers of signals requiring fitment. This has grown from the initial 5,000 to some 11,000 approximately now included within the Railway Safety Regulations 1999. The figure will grow further as attention is given to plain line signals, speed restrictions and buffer stops. As regards enhanced TPWS, considered in Chapter 7, the cost of additional loops and wiring necessary for TPWS+ is uncertain but has been suggested as lying in the range £70-86 million. The cost of TPWS-E is unknown but figures of £466 million for network-wide and £203 million for partial fitment have been suggested. In the light of experience with TPWS-A, very little reliance could be placed on these figures.
7.1 There are significant limitations on the capability of TPWS-A, which are reviewed in Chapter 6. These have led to the proposal of additional or alternative measures which can be considered as enhancements to the original system. Two principal enhanced versions are considered. TPWS+ (TPWS plus) addresses the limited speed at which TPWS-A is fully effective, namely 74mph at 12%g braking force, by providing an additional Over Speed Sensor (OSS) which aims to make the system effective at higher speed and/or lower braking capacity. TPWS-E addresses the “dead-end” aspect of TPWS by replacing track loops, which have no purpose beyond TPWS, with Eurobalise, which have the capability of migration to ETCS. Other means of adding to the performance of TPWS-A are reviewed in Chapters 6 and 10.

7.2 At the date of this report, trials have been underway with TPWS-A for some two years. Trials of TPWS+ and TPWS-E are planned, but further work is needed for their implementation. While the essential question concerning TPWS-A is whether the system should be fitted in accordance with the current Regulations and programme, the questions to be considered with regard to these variants is whether, if TPWS-A is to proceed, there should be tests on one or both and, if successful, whether and where they should be fitted.

7.3 While many parties at the Inquiry generally supported the enhancement of TPWS, it was not supported by the Rail Unions and the Passengers’ Group was sceptical, having been initially opposed to TPWS itself. The main ground of opposition was that both TPWS+ and TPWS-E would divert resources and were unlikely to bring serious benefits. EWS, who were not enthusiastic about TPWS because of its lower effectiveness on freight, nevertheless supported the enhanced protection of TPWS+. The SRA were flatly opposed to any enhancement, which Mr McCullough regarded as retrograde.
TPWS+

7.4 The basic operation of TPWS-A is described in Chapter 6. The placing of the Over Speed Sensor (OSS) is such that a train travelling at excess speed will have its brakes applied only from a point some 350 metres in advance of the red signal, giving a maximum available stopping distance of about 533 metres, assuming a standard overlap. Many trains need a much longer stopping distance. For example, the HST involved in the Southall crash braked at some 1200 metres before signal SN254 at red and collided at a speed of about 70mph, some 410 metres beyond the signal. TPWS+ consists simply of an additional OSS which can be placed at any convenient point in advance of the signal. Calculations have shown that for a train protected by TPWS-A up to 74mph, additional loops placed approximately 800 metres before the red signal can offer full protection up to 100mph. These figures apply to a train having emergency braking capability of 12%g. Trains with different braking characteristics and travelling at different speeds will be protected in varying degrees, depending upon the position of the second Over Speed Sensor (OSS2). AEA Technology have carried out theoretical calculations as to the optimum placing of OSS2 so as to extend the range of protection to the maximum extent for a chosen range of train types. Yet further protection can be provided by fitting additional loops, OSS3 etc.

7.5 A major advantage of TPWS+ is that it may be fitted selectively to particular signals and has no effect on the train-borne equipment which will continue to operate on the same standard setting. The OSS can be made to operate at a higher speed by placing the loops further apart. A disadvantage of TPWS+ is that loops which are placed to arrest the speed of trains with lower braking characteristics will unnecessarily reduce the speed also of trains with higher braking capacity. The cost of TPWS+ was quoted by Sir David Davies as £70m, but the final cost will depend on the extent of fitment.
7.6 Where additional loops, OSS2 etc, are to be located far in advance of the red signal, the possibility arises of attaching the additional Over Speed Sensor to the yellow signal. This would, however, involve a fundamental change in UK signalling practice, from “distance to go” to speed control, and the universal view is that all additional loops should be served by, and activated solely by, the red signal.

**TPWS-E**

7.7 In contrast to TPWS+, this involves major changes to both the track and trainborne equipment as compared to TPWS-A. The principal feature is the use of Eurobalise fitted to the track in place of loops. Once installed, the balise would be capable of operating ETCS equipment so as to facilitate the progressive “migration” from one system to another. TPWS-E equipment is based on modern digital technology. Eurobalise can be programmed to cover different speeds and braking curves for different trains. TPWS-E can operate with different signal aspects (not just red) and at much higher speed than TPWS-A.

7.8 At the start of the Inquiry, TPWS-E was characterised as a “major opportunity lost” (Davies’ report para 4.4.2) which, had it been actively considered in around 1996, might have solved the “dead-end” problem of TPWS. The industry might then have been able to embark on a cost-saving migratory path to full ATP under European Regulations. The Passengers’ Group also criticised this as “a golden opportunity thrown away” which had left Britain with a second rate system wholly incompatible with the European Directive. As the Inquiry progressed this issue took on other aspects. First, the assertion by Railtrack (which had not been based on any documentary research) that the original TPWS tender round had not produced any proposals based on the Eurobalise, turned out to be untrue. At least two of the tenders received were based on an embryo design that would use a form of Eurobalise. The Redifon proposals were selected largely on the basis of cost, without evaluation of the
potential benefit of the Eurobalise. Sir David Davies had not been aware of these facts when writing his report.

7.9 In response to criticism, particularly from the Passengers’ Group, Mr Rod Muttram of Railtrack S&SD (and now Chief Executive Designate of Railway Safety Limited) produced an additional statement in which he gave details of the TPWS bidding procedure and of Railtrack’s approach. Mr Muttram stated that bidders had been encouraged to offer a Eurobalise-based solution in the oral presentations to bidders, although the documentation was based on performance alone. Railtrack were keen to receive such a bid from ADtranz, who had the relevant technology. Two bids were received based on Eurobalise from Siemens and Ansaldo, but they failed to comply with requirements as to timescale, cost and risk. They were eliminated and received no substantial consideration. At this time (1995), the TEN Directive for high-speed lines was still in preparation and the conventional Directive had not been suggested. The Eurobalise had not been developed or trialed and the final specification was not fixed until late 1999. It was highly unlikely that a Eurobalise solution chosen in 1995 would have been compatible with ERTMS standards as they have emerged. Having, in 1995, just rejected ATP on the ground of cost, Mr Muttram thought there was no chance of securing funding for a TPWS solution involving the same order of cost.

7.10 Additionally, as the possibility of migration was examined through the evidence presented to the Inquiry, the picture which emerged was somewhat different to what had been anticipated. As regards the re-use of Eurobalise, this would require substantial further installation work, including reprogramming, even though there would be a saving in materials. The on-train equipment needed for TPWS-E differs entirely from that required for TPWS-A and TPWS+, involving a larger and more expensive processor. As regards the availability of TPWS-E, Sir David Davies had envisaged the carrying out of trials urgently (para 4.13) so that vital opportunities would not be lost. It is
now clear that no tests can be performed in less than six months. The total period required, assuming successful tests, before TPWS-E would be available is of the order of 2½ years, which effectively precludes this as an alternative to TPWS-A. While the costing of TPWS-E is highly uncertain, in the absence of further development work, it will be substantially in excess of the cost of TPWS-A.

7.11 The operational advantage of TPWS-E lies in its ability to transmit a wide range of signals to different trains so as to avoid the unnecessary retarding of trains with higher braking capacity. Siemens, as a prospective manufacturer, are now promoting the adoption of TPWS-E and have offered to loan equipment for a preliminary test. The initial expectation for TPWS-E was that it had the capability of providing more effective protection on high-speed lines. Contrary to that view, both Mr Muttram and Mr Fenner (Railtrack’s Engineering Manager for Train Protection) considered that TPWS-E had potential application for secondary lines that would not be fitted with ERTMS, particularly where lightly trafficked, and their view was shared by Mr Cooksey of HMRI. In the light of this, it seems clear that TPWS-E, whatever its true advantages, is no longer the priority which it seemed during the early part of the Inquiry. Elements of TPWS-E are currently undergoing trials in Switzerland and Portugal. These should be evaluated as part of the assessment process to determine whether TPWS-E has a viable future.

Why enhanced?

7.12 Implicit in the above discussion is that TPWS needs to be enhanced on account of its significant limitations. In considering whether enhancement should be the subject of recommendations, it is relevant to reflect on why, at this comparatively late stage, more than 12 months after TPWS-A became mandatory, consideration is being given to improvements. TPWS-E, as noted
above, could not be introduced for some 2½ years, largely because it involves different technology requiring a full testing programme. Even TPWS+, involving only an extension of the same basic technology, has not yet been subject to trials.

7.13 We believe that it is important to keep well in view the original objective of TPWS, which was to provide a quick and cheap stop-gap solution. The gap in question was that left by abandonment of national fitment of BR-ATP in 1994. What has happened since then is that the characteristic delay of the rail industry in implementing any non-mandatory system has allowed and perhaps encouraged the development of more sophisticated design features, now including the two “variants”. What is unfortunate, but not unpredictable, is that TPWS now threatens to overlap the availability of ETCS. The risk that the partially effective system (TPWS) may delay implementation of the fully effective system (ETCS) can only be exacerbated by deployment of enhanced TPWS systems. More than one expert at the Joint Inquiry expressed the view that TPWS was becoming too complicated for the benefits it could produce. This applies with even more force to the proposed TPWS variants.

7.14 Our conclusions, which are considered in Chapter 11, are that TPWS+ should be pursued on a trial basis at present. We believe that TPWS-E, however, is a project which the rail industry should explore and should itself not be the subject of any recommendation from the Inquiry.
CHAPTER 8

UK AS PART OF EUROPE

8.1 The European Rail Traffic Management System (ERTMS) was initiated by the European Commission in 1989 with the intention of developing a harmonised train command and control system to further the objective of interoperability on the European rail networks. ERTMS covers a range of issues but train control is presently the main area of interest through the European Train Control System (ETCS) which was set up in 1991. The aim of this project is to prepare specifications (TSIs) with which individual systems must comply.

8.2 Railways were first developed commercially in England during the second decade of the 19th century, where the “standard” gauge of 4ft – 8½ in (1.435m) was selected. During the remainder of the 19th century railways and rail technology developed rapidly throughout the world. The influence of British engineers and British technology was considerable and standard gauge was adopted over most of Europe, making interoperability a practical possibility. However, engineers in different European countries rapidly developed their own equipment and systems, particularly for control and safety purposes. European conflicts during the 20th century promoted the development of national, rather than international standards and practices. The general decline of railway industries throughout the world following the Second World War further stifled the creation of international standards.

Development of train protection

8.3 Within the UK industry two catastrophic accidents during the 1950s led to the nation-wide fitment of the Automatic Warning System (AWS), which was the first means of preventing SPADs not based on mechanical contact (see Southall Report Chapter 12). On the continent of Europe, similar experiences in different countries led to the adoption of other safety systems. When BR decided, in the late 1980s, to install ATP Pilot Schemes on Great Western and
Chiltern Lines, no UK-designed system was available and it was decided to purchase two alternative Belgian systems, designed by ACEC and GEC AS/SEL respectively. Other European countries, notably France, Germany and Holland had each adopted their own forms of ATP, in the case of France, following a major ATP-preventable accident at Argenton-sur-Creuse in 1985. In December 1997 Railtrack commissioned a report from AEA on the status of ATP implementation throughout Europe.

8.4 The present situation throughout Europe is well illustrated by the multiple Train Protection Systems fitted to Eurostar trains since the opening of the Channel Tunnel to public service in 1994. Eurostar trains are fitted with the TVM 430 system which is fitted to high-speed lines in France, Belgium and in the Channel Tunnel. This involves continuous signal transmission through the rails with full in-cab signalling. In addition, the trains are fitted with AWS for UK lines and BRS, a similar system used on French non-high speed lines; also with KVB, a unique French ATP system fitted to Classique lines following two signalling accidents on SNCF in the early 1990s; and with TBL1, a Belgian Train Protection System similar to the BR-ATP Pilots (which will migrate to a full ATP system known as TBL2 during 2001). The trains are fitted with the UK Drivers’ Reminder Appliance and it is intended shortly to fit TPWS also.

8.5 The Eurostar systems are highly redundant and duplicate their functions several times over. They have been rationalised by combining different functions in the driver’s control systems so that, for example, the same override button is used for each system. Drivers are provided with three radio systems, which are automatically selected through the TVM 430 equipment. Drivers are required to be bi-lingual (English-French). It is salutary to recall that Eurostar, having avoided any fatal crashes, has suffered a SPAD at Ashford owing to poor adhesion in November 1999 and a derailment in France in June 2000, the cause of which is under investigation by SNCF.
8.6 As noted in Chapter 5 the European Commission, pursuant to its powers under the Treaty of Rome, articles 154 and 155, decided during the 1990s to take action to secure interoperability between inter-connected national rail networks. Directive 96/48/EC applies to high speed TEN lines and this will shortly be followed by a Directive (of which a draft was issued in June 2000) applying to a large proportion of UK conventional lines. The result will be to mandate the fitment of ETCS which will, accordingly, progressively replace the plethora of train protection systems currently in existence throughout Europe. The current Directive does not set a timetable but requires that fitment is carried out when qualifying work is undertaken, principally comprising renewal or upgrading. The impact of the Directive on the fitment of TPWS has been considered in Chapter 5. The principal questions considered in this chapter are how fitment of ETCS will impact on the UK rail network, when ETCS is likely to be fitted, and whether the present situation calls for recommendations for change.

Description of ETCS

8.7 The new European Train Control System will make use of new radio communications technology to create an entirely new command and control system for the railway. Communication is via digital GSM-R radio, similar to modern cell-phone technology. Coverage will be provided alongside railway lines to communicate directly with the driver’s cab to display movement authority for the vehicle. Full Automatic Train Control through supervision of the speed of the train is a relatively simple addition to the system, which will be operated from a centralised control point without the need for lineside signals. The version described is known as ETCS Level 3. A particular advantage of the system is that it can be fitted at two earlier stages known as Levels 1 and 2 which are each capable of being “migrated” to the next level without wholesale replacement of equipment. ETCS level 3 represents a major step-change in railway technology.
8.8 Railtrack had intended that their current upgrading of the West Coast Main Line (WCML) should install ETCS Level 3 and dispense with lineside signals. In 1999, however, a decision was made to switch to the installation of Levels 1 and 2 initially, involving the considerable additional expense of renewing lineside signals. At the Inquiry, proponents of ETCS advocated the rapid adoption of Level 3 while others were more cautious. A major element of the current Train Protection debate is whether the installation of TPWS will hold up the fitment of ETCS, either through shortage of resources or through reducing the incentive to fit a further train protection system once TPWS is available.

8.9 The three levels of ETCS and their functions are as follows:

- **Level 1**: this provides full ATP with continuous speed supervision and intermittent transmission from track to train, based on the Eurobalise which is linked to a Lineside Electronic Unit (LEU) and conventional signals. The operation of trains remains based on conventional fixed block track-circuit system.

- **Level 2**: lineside signals are now replaced by the very high integrity GSM-R radio network covering both lines and tunnels. Movement authorities are transmitted direct to the train and displayed in the cab. Continuous speed supervision and continuous track to train communication is provided but operation and train position is still based on fixed track blocks.

- **Level 3**: The train calibrates its position by reference to Eurobalise and informs control by GSM-R radio. The control sends messages to the train giving speed and distance in which to stop. Trains can be operated closer together with the advantage of increased track capacity and increased speed of recovery from disturbance.
8.10 ETCS Level 3 does not yet exist as a working system. Trials are currently proceeding or are planned in the near future on ETCS Levels 1 and 2 in Germany, Switzerland, Italy and Spain. The first successful demonstration of ETCS Level 1 was on the Vienna-Budapest line in November 1999, the equipment being based on Class P, a preliminary specification. Tests are currently underway using Class 1 specification. Other tests are planned for Holland. Details of current and planned ETCS trials are set out in Annex 06.

8.11 Before ETCS equipment can be fitted to main line tracks, trials on a test line need to be carried out. For this purpose, a section of line in Leicestershire, known as the Old Dalby Test Track, is being re-signalled, upgraded and fitted with ETCS Levels 1 and 2 trackside equipment. It is anticipated that high-speed trials will begin in 2002, although it has recently emerged that some delay may result from the discovery of rare flora (the Deptford Pink Orchid) growing near the track. Tests will be necessary whatever the outcome of continental trials, in order to investigate the performance of ETCS equipment in the different environment of UK railways, which typically involve different levels of mechanical, electrical and electronic loading as compared to other systems. It is important that “teething problems” are not encountered in service, so far as avoidable.

**Fitment to UK lines**

8.12 The first UK line that will receive ETCS equipment is the West Coast Main Line (WCML) which is currently undergoing modernisation as part of its normal economic life cycle. It is intended that this will be followed by other high-speed TEN lines i.e. East Coast and Great Western, and by conventional lines later. There is little hard evidence of the likely cost of ETCS. Railtrack have suggested that the indicative cost of fitting all routes with a line speed of 70mph or more would be £1.9 billion, but the true figure will remain uncertain for some considerable time.
UK AS PART OF EUROPE

8.13 West Coast Main Line

WCML is Europe’s busiest mixed-traffic railway and represents an ETCS installation vastly greater than any of the trials so far carried out in Europe. WCML involves some 650kms of main line between London Euston and Glasgow carrying some 2,000 trains per day in total. The line currently operates at a maximum speed of 110mph and was last modernised in the early 1970s. Following a review in 1998 Railtrack took the bold decision to install ETCS Level 3. In 1999 they were forced to abandon this proposal because of potential delays which would have prejudiced obligations undertaken for the introduction of a high-speed service by 2005. Railtrack now plans to install ETCS Level 2 south of Crewe and Level 1 northwards. This change has resulted in a substantial increase in cost of some £1.5 billion, of which the cost of re-signalling is estimated at £600 million. Upgrading plans include increasing line speed initially to 125mph and subsequently to 140mph. The current programme envisages completion of ETCS fitment by 2007. The upgrade to 125mph will include the introduction of tilting trains, which will be controlled by Eurobalise fitted as part of the ETCS system. Railtrack regard the present timetable as achievable but challenging. There are two substantial incentives to timely completion. First, Railtrack have entered into contractual commitments with Virgin to allow faster and more frequent trains, with Virgin undertaking to replace the WCML fleet. Secondly, undertakings have been given to the Regulator as to the provision of additional train paths for other operators. Failure to meet the timetable will therefore have serious financial consequences.

East Coast Main Line

8.14 On ECML Railtrack have considered three different options for fitment of ETCS. If left until normal economic replacement of facilities, the majority of the line would not be fitted until at least 2010 and completion might not occur until 2030. This option could not be regarded as being acceptable. Two
alternative options involve overlaying ETCS on the existing system between 2006 and 2008, or alternatively, bringing the work forward to the period 2003 to 2005. While Railtrack accepted that the third option should be the aim, the available capacity of the supply industry gives rise to doubt as to whether this is possible. There are suggested compensating advantages in the longer programme in that the relevant technology would have been developed and trialed on the WCML such that it would be possible to move directly to ETCS Level 2 using GSM-R radio. Earlier fitment of ETCS would, however, be required if tilting trains were to be introduced by 2005 as planned. There are presently two rival bidders for the ECML franchise which makes it undesirable, if not impossible, to predict at the present time what should be the optimum solution. Whatever programme is to be followed for ETCS, fitment of TPWS is intended to proceed in accordance with the Regulations on both WCML and ECML.

Great West Main Lines

8.15 On GWML the position is complicated by the existence of BR-ATP, which is now fully operational. The future of BR-ATP is considered in Chapter 9. FGW are presently procuring new Class 180 trains fitted with BR-ATP and there are plans similarly to fit existing Class 47 locomotives. The high speed TEN line runs from London to Bristol Parkway, where BR-ATP is fitted, and on to Cardiff. The future fitment of ETCS in compliance with Directive 48/96 is dependent on when the line is upgraded. Lines between London and Bristol will be capable of being used by ETCS-fitted trains carrying an STM.

Other lines

8.16 The CTRL line, which is presently under construction, will be fitted with TVM 430 (see para 8.4 above). Eurostar trains using the line will already be fitted with ATP and other train protection systems capable of reading a wide variety of track signals. As regards other lines, including those covered by the Draft
Conventional Directive, ETCS fitment will be considered as lines are upgraded or renewed. By this time, there will be greater experience of ETCS fitment within the UK network and the planning of the work will be more certain. At the same time, the performance of TPWS, assuming that it will be fitted, will provide further data on the benefits of further train protection where not mandatory. Enhanced braking performance will also be a factor in considering whether further protection is justified.

8.17 Some 12% of the network has a line speed of 35mph or less and a further 55% has line speed between 40 and 75mph. A case for ETCS fitment, where not mandatory, will be difficult to sustain unless supported by operational advantages or the need for interchangeability. In the case of new trains, however, the position is somewhat clearer. As already recommended by Sir David Davies, all new stock should be provided with at least the physical capability of accommodating ETCS. It is also to be expected that the future design of traction units will take account of the needs and sensitivities of the new generation of electronic control and protection systems.

GSM-R radio

8.18 This new digital radio system, which forms part of ETCS level 2 and 3, is at the heart of the new generation of train control technology. It provides the opportunity for secure speech or data communication with train and driver, in addition to the train protection facility. GSM-R radio may be installed as a separate system in advance of ETCS level 2, and has been characterised as Level 1.5. Given the enormous potential advantages of the system, it needs to be considered as a separate option.

ETCS fitment in Europe

8.19 In Chapter 3 we noted strong criticism levelled at the rail industry for its slow implementation of new safety measures, leaving the UK lagging behind the rest of Europe, in contrast to the leading role of a century ago. While these
comments have much to justify them it needs to be said that, despite earlier severe under-investment by comparison with other European countries, as noted by Sir David Davies, the UK is presently playing a full part in the development of ETCS. It is true to say that all the trials of ETCS and its components have so far been conducted in other European countries, but these have been predominantly at Level 1 (Annex 06). Railtrack’s earlier proposal to install ETCS Level 3 on WCML would have put the UK in the forefront of development in Europe. The current more modest scheme to install Levels 1 and 2 ETCS will still be substantially larger than any other European scheme.
9.1 The ATP Pilot Schemes installed on Great Western and Chiltern Lines now stand as a monument to the fine intentions but somewhat opaque management style of British Rail during the 1980s. At the time it was accepted without demur that a Train Protection System would be needed in the future, to avert collisions following SPADs of the type which occurred shortly after the Clapham Junction crash, at Purley and at Bellgrove. No cost benefit analysis had been carried out and the project was, in any event, subject to the provision of adequate public funding, which would depend upon the economic climate at the time of installation.

9.2 The recommendation of the Hidden report for the introduction of ATP was coupled with a requirement for the study of appraisal procedure for safety elements of investment to take account of cost effectiveness (Recommendation 48). The 1989 Hidden report (para 15.12) quoted costs for ATP installation of £380 million for comprehensive fitment, or £140 million for the preferred selective fitment. When ATP was reappraised by BR and HMRI in 1994, the cost was put at £475 million. A cost benefit analysis carried out by BR led to a cost per equivalent fatality avoided of £13.9 million, or £7 million for partial fitment. While these figures were revised downwards by HSE, and the detailed figures remain somewhat controversial, the inevitable result was that the two pilot schemes were left stranded while nation-wide fitment of ATP was placed on permanent hold.

9.3 Between 1995 and 1997 the painfully slow development of BR-ATP on Great Western Lines was followed intermittently in the specialist press, but came into public focus again as a result of the Southall crash. During the following two years there was a major escalation of commitment on the part of FGW which eventually led to the Great Western Pilot achieving virtually full operation, at
the same time as the Chiltern Pilot which had experienced not dissimilar difficulties. Meanwhile, BR-ATP had become fully operational on the Heathrow Express service using the Great Western line from Paddington, opened from 1998. Ironically, 100% ATP operation on Great Western Lines was achieved only after and partly as a result of the Ladbroke Grove crash, because the number of services to and from Paddington was restricted.

Nation-wide fitment of BR-ATP

9.4 At the Southall Inquiry the primary case advanced on behalf of the Passengers’ Group was for a recommendation for the nation-wide fitment of ATP, then seen to be fully operational on Great Western and Chiltern Lines. This part of the Inquiry was put on hold following the Ladbroke Grove crash and its public inquiry, which included train protection issues within its terms of reference. The common interest of these two inquiries in train protection led to this Joint Inquiry being established to deal specifically with Train Protection Systems and related issues.

9.5 By the time of the opening of the Joint Inquiry, one year after the opening of the Southall Inquiry, and with the benefit of a substantial body of further expert evidence, the case put to the Joint Inquiry on behalf of the Passengers’ Group was for the early fitment of ETCS, recognising that nation-wide fitment of ATP was no longer an option. In addition to the fact that BR-ATP will not comply with the European Interoperability Directives, the cost estimated in 1994 (£475 million) had risen by 1999 to an estimated £953 million (John McMorrow, AEA Technology). The present cost of national installation including maintenance and further work on the Pilot Schemes is estimated over a 20-year life at £3.1 billion or £4.7 billion for a 30 year total life. In addition, despite the current level of use on Great Western and Chiltern Lines, HMRI continue to regard these installations as not providing a reliable system matched to the operating needs of the railway. This has indeed been borne out by continuing reliability problems, particularly in the form of start-up faults.
9.6 Evidence was presented by GEC-Alstom, both to the Southall Inquiry and to the Joint Inquiry, as to the practicability of extended fitment of BR-ATP, which remains technically feasible. ETCS-fitted trains would be able to run on BR-ATP-fitted lines using an STM and BR-ATP-fitted trains may be able to run on ETCS-fitted lines using a reverse STM. While these devices were not yet developed, their essential technology was not considered to be groundbreaking. STMs were likely to be required for Belgian and Dutch Railways at least. GEC-Alstom also considered that the existing BR-ATP systems could be migrated progressively to ETCS. However, the continued fitment and renewal of BR-ATP equipment to rolling stock on Great Western and Chiltern Lines was proving difficult and costly. Chiltern had even had difficulty in persuading manufacturers to fit BR-ATP as part of the original equipment, and had to resort to retrofitting of their new Class 168 trains.

9.7 It must be borne in mind that BR-ATP represents old technology which will become increasingly difficult to replace or service, as reflected in the escalating projected cost of maintaining the system. Despite the very considerable commitments of FGW to the successful running of BR-ATP, the system continues to have reliability problems on FGW, largely due to the original need for retro-fitting the equipment. This is borne out by fewer problems experienced on Chiltern where BR-ATP was fitted to more modern rolling stock. Before the start of the Joint Inquiry, some representatives of Railtrack advocated the removal of BR-ATP. At the Inquiry, all parties (including Railtrack) supported retaining the existing BR-ATP installations until replaced by an equally effective Train Protection System (Recommendation 66, Southall Report), but there were no parties within the Inquiry advocating the fitment of BR-ATP to lines other than those currently fitted. We endorse this judgment, which represents the inevitable conclusion to be drawn from the current situation. In these circumstances, it becomes necessary to consider whether,
during its remaining life, BR-ATP should be extended on the lines currently fitted, or what alternative action should be taken in these cases.

Extended fitment on Great Western

9.8 On Great West Lines, there remain gaps in ATP coverage. The main line is fitted from Paddington to Bristol Parkway and to a position short of Bristol Temple Meads. A section of relief line is fitted where used by the Heathrow Express. The two short platforms, Nos. 13 and 14 at Paddington are not fitted, likewise the line between Reading and Newbury is only partially fitted. There is a gap between Bath and Bristol Temple Meads. Filling those gaps requires the fitting of ATP loops to 46 signals. It would also be possible to fit the relief lines with between 20 and 60 signals and to fit fully the line through Bedwyn. The cost of these additions is estimated by Alstom at approximately £7 million. A second package for which the cost is estimated as £5.5 million involves trackside fitment to extend protection to Severn Tunnel Junction and the lines from Swindon to Kemble and from Reading to Oxford.

9.9 These alternatives need to be evaluated in the broader context of other train protection systems which are, or will in the future, become mandated. No proposals currently exist for more extensive fitting of BR-ATP on Great Western Lines west of Bristol, nor beyond the Severn Tunnel and on to Swansea. In both cases, there are lines involving speeds of up to 110mph. The cost of BR-ATP fitment would be very considerable and we do not propose further inquiries in this regard.

Extended fitment on Chiltern

9.10 Chiltern operate on two lines from London Marylebone, a southern line to Birmingham Snow Hill via Aynho Junction, and a northern line to Aylesbury. BR-ATP is fitted on the southern route between London Marylebone and Aynho Junction. Chiltern wish to extend ATP coverage from Aynho Junction to Birmingham Snow Hill. This substantial length of 48 miles could be fitted
with BR-ATP. Alternatively, it could be fitted with ETCS Level 1 equipment, for which purpose Chiltern trains would need to be fitted with a reverse STM. ETCS-fitted trains would be able to read ATP trackside equipment using an STM. Some doubt remains as to whether train-borne BR-ATP equipment can be made to read ETCS. Chiltern’s existing Class 165 trains, which are owned by ATC, would not be retrofitted with ETCS and would operate only on existing ATP-fitted lines. The new Class 168 trains which could be ETCS-fitted are owned by Porterbrook.

9.11 Chiltern Lines have other unique features. Traffic is almost exclusively Chiltern on the southern line, with the exception of two freight trains per day. The section of line between Bicester and Aynho is single track and has a particular need for ATP. In addition, Chiltern’s northern route is shared with London Underground from Harrow on the Hill to Amersham. This section is fitted with the LUL train stop ATC system and Chiltern trains using this section are fitted with “tripcocks”. The proposals for extension of BR-ATP or alternative fitment of ETCS Level 1 are limited to the southern section. Plans for future operation on Chiltern Lines are complicated by the current round of bidding for a new 20-year franchise. At the time of the Inquiry, Chiltern Trains did not know the outcome, but it has since been indicated that they are a preferred bidder.

Fitment to other trains

9.12 Given that BR-ATP will remain on Great Western lines for some years before replacement by ETCS, and that several other operators (Thames, EWS, Virgin and Wales and West Trains) use the lines, there is a possibility of providing enhanced protection for these operators by fitment of ATP to the trains which operate on Great Western Lines.

9.13 This issue has arisen in the Ladbroke Grove Inquiry with regard to Thames Trains. It is considered here solely in terms of the future. The Passengers’
Group made a strong plea for the Joint Inquiry to recommend the fitment of Thames Trains with BR-ATP. We consider that any recommendations for wider fitment of BR-ATP to trains would have to be justifiable in the light of the following factors:

(i) BR-ATP represents old technology which is unlikely to achieve full reliability.

(ii) Retro-fitment to different classes of train is likely to generate problems not previously encountered on Great Western or Chiltern Lines.

(iii) Wholesale fitment to all stock will be very costly, while selective fitment will impose limitations on use of stock.

(iv) TPWS protection will be available within a timescale which is likely to be earlier than that which could be achieved by BR-ATP.

(v) Additional protection on BR-ATP fitted lines is likely to be available by the early fitting of trains with ETCS, together with an STM. This would have clear economic advantage where ETCS will be required in the future.
10.1 If Automatic Train Protection were to be fitted on the whole UK rail network, it would take a number of years to complete, even if it were possible to start now. Actions to reduce the numbers of SPADs and to mitigate their consequences would remain a matter of top priority in the interim. If TPWS is to be fitted, and to form the first line of SPAD defence over a major part of the network, the avoidance of a proportion of potential collisions will remain dependent on SPAD reduction and mitigation. In approximate terms, if TPWS is capable of eliminating up to two thirds of ATP-preventable fatalities, SPAD reduction and mitigation must be relied upon to avert the rest. Furthermore, the cost of these measures probably represents better value for money than any train protection system. SPAD reduction and mitigation is, however, not automatic and depends upon many different human resources for its effectiveness.

10.2 The SPAD reduction and mitigation measures which are currently being promoted grew out of the original 1994 SPADRAM Initiative. This included, in relation to locomotives and their performance, an “Enhanced Automatic Warning System” which became TPWS, and also the Driver Reminder Appliance (DRA). Also included were proposals for improved braking performance, including measures to enhance adhesion. Other measures for the reduction and mitigation of SPADs addressed:

- Driver performance
- Crashworthiness
- Conflicting movements
- Track layout risks
These initiatives have undergone very considerable developments in the past five years. The following specific issues have also been added to the SPADRAM list:

- Defensive driving
- SPAD Management and Analysis
- Human factors generally
- Confidential Incident Reporting and Analysis System (CIRAS)
- On-Train Data Recorders (OTDR)
- Use of simulators

Crashworthiness was dealt with in both the Southall and Ladbroke Grove Inquiries. It remains an important topic but is not developed here. CIRAS was covered in the Southall report and received additional impetus from the two post Ladbroke Grove “rail summits”, in October and November 1999. CIRAS remains on course for national implementation in the near future. The use of data recorders and simulators was the subject of recommendations in the Southall Report which are still in course of implementation.

Signal sighting

As the rail industry contemplates the next step-change in operating speeds to 140mph and above, it is universally accepted that signal communications by the visual sighting of coloured light signals is effectively limited to the current maximum running speed of 125mph. This represents, in effect, the limit of human capability for safe operation. The next speed increase must therefore be accompanied by a move to cab signalling, which will form part of an ATP system. The acknowledgement of this limit on human performance must also lead to the realisation that the visual perception of signals at 125mph involves a
greater risk of mis-reading or failing to perceive a signal than does travel at lower speeds. As other parts of the network move to 125mph running, the development and pursuit of SPADRAM issues, particularly those relating to driver performance, becomes the more critical.

10.5 The issue of signal sighting was regarded by drivers, through their unions and advisers, as being of central importance. We accept and endorse their concern that signal sighting should be carried out with the aid of all the best available practices including expertise on human behaviour, with the objective of maximising the visibility and comprehensibility of signals to the driver. This should include review procedures as well as greater encouragement to drivers to provide feedback on signals which are regarded as providing less than optimum visibility. The addition of more lineside apparatus will be bound to create conflicts where it is important that signal visibility should be regarded as an absolute priority.

10.6 The Joint Inquiry considered a report dated 9 July 2000 produced by signal sighting experts for Railtrack. The report addressed the general signal sighting issues. The Joint Inquiry was invited to make recommendations for the clarification of applicable Group Standards, where these were considered still to be ambiguous, for revision of signal sighting times and for particular consideration of gantry-mounted signals and their appropriate sighting distance. Since this topic has been more fully covered in the Ladbroke Grove Inquiry, we believe that recommendations should be confined to that report.

Drivers’ Reminder Appliance

10.7 This was originally part of the 1994 SPADRAM initiative which was introduced, in accordance with the programme requirement, in December 1998. The DRA is intended to prevent drivers starting off against a red signal, a surprisingly common cause of SPADs. The device, where manual, is activated by the driver pushing a button after the train has been brought to a halt at a red
starting signal at a station or at a red signal encountered between stations. When activated the button becomes illuminated and isolates the traction control, preventing the train from moving under power. When the red signal has cleared, the driver pulls the button, the illumination disappears, and the traction current is restored. The Rule Book (which operates as a Group Standard) requires the driver to set the DRA on each occasion that a train comes to a stand, either at a signal at danger or at a platform.

10.8 During 2000 it came to light that drivers on Thames Trains and other companies were using the DRA in a way not envisaged by the Group Standard, by setting the DRA on the move at a yellow signal, as a way of removing traction, and as a supplement to AWS in reminding the driver of the signal at caution. This practice was not prohibited but was risk assessed on behalf of Railtrack. It was concluded that the balance of risk was against this practice which is, as from December 2000, prohibited. An alternative automatic version of the DRA is to be made available where the device comes into operation without intervention of the driver, but must be switched off manually in order to allow the train to start.

Driver management

10.9 This topic was covered in the Southall report which contains recommendations which are currently being implemented. In addition ATOC, during the course of 2000, has developed a programme for driver management which has involved the production of six codes of practice covering the following matters:

- Transfer of safety performance information
- Monitoring driver systems
- Basic training assessment and monitoring
• Driver Standards Managers’ competence

• Driver recruitment and selection

• Audit of driver selection process

10.10 Railtrack are currently considering, in conjunction with ATOC, the incorporation of these codes into the Group Standard, subject to a risk assessment. ATOC are also considering further work to follow up recommendations of the Southall Report relevant to driving.

**Driver selection and training**

10.11 Since the 1980s, driver selection has involved psychometric testing as part of the suitability assessment process. In 1993, BR introduced a new driver selection and training package which was given the title “Driver 2000”. This included “at risk” assessment for existing drivers, with designation into 3 categories. Driver performance became a permanent feature of the SPADRAM project from 1994 and has developed since then, with increasing emphasis on human behaviour issues.

10.12 Driver selection and training is now covered by Group Standard GO/RT 3251. This also covers driving techniques and is of particular importance to driving with TPWS. The Standard covers selection and the conducting of tests and also contains the component parts of a driver-training syllabus. The particular emphasis to be placed on various components is left to individual operators, who have responsibility for training their own drivers.

10.13 A defensive driving package was produced in December 1999. While some drivers considered that it impugned their professionalism, most accept defensive driving as a significant element of safety. It may be questioned whether defensive driving is necessary to overcome inadequacies of the
signalling system. Some drivers consider defensive driving to be in conflict with pressure to achieve targets and the Chief Inspector of Railways has referred to tension between safe driving and timetable. HSE is considering research on whether any conflict exists between defensive driving and punctuality.

10.14 The Joint Inquiry received some evidence on the approach to driver training and SPAD avoidance by individual operators. The Heathrow Express operator lays particular stress on train operation in a “degraded mode”, in this case, with ATP isolated. Conversely EWS, as the major freight operator, faced different problems arising from long journey times with relatively low performance braking. They laid particular stress on fatigue management and had commissioned advice from the US consultant Circadian Technology. There are differences between TOCs on their attitude to simulators. Some operators (Virgin and Eurostar) have installed simulators, which have the support of HMRI, who consider them to have great potential particularly for route learning. Other operators, including SWT, take the view that simulators cannot be a substitute for time spent in practical handling of trains. While it remains important that drivers should acquire all round skills applicable to all types of driving, it is clear that particular operators must also ensure that their drivers have the specific skills and aptitude needed for the type of work to be undertaken.

Recent SPAD reduction measures

10.15 SPAD reduction measures have progressively grown since privatisation with greatly increased activity after the Ladbroke Grove crash. The principal measures now in place, all of which are promoted or supported by Railtrack, are the following:

- National SPAD Focus Group, with wide representation across the industry.
• Regular SPAD workshops organised by Halcrow Rail, who also publish a SPAD newsletter, Red Alert.

• Annual SPAD Conferences.

• Provision of root cause investigation training to SPAD investigators.

10.16 Publications aimed at SPAD control include:

• The Anti-SPAD toolkit

• SPAD Management Handbook (with interactive CD)

• Quarterly progress reports following the HMRI SPAD Report

10.17 Research commissioned by S&SD has examined factors consistent with higher SPAD rates, which have been found to include the driver’s age (36 - 46), drivers in their first year of driving and the period 2 to 4 hours into the driver’s shift. Some classes of recently employed drivers have also been found to experience higher SPAD rates.

10.18 Specific actions taken by Railtrack and operators include the following:

• Annual SPAD reports have to be supplemented by monthly, weekly and even daily reports.

• All Category A SPADs are now investigated and actioned appropriately.

• SPAD data, including multi-SPAD signals, is now entered on the SMIS system.

• Group Standard GO/RT3252 on SPAD investigation has been reviewed and re-issued.

10.19 Individual operators have taken their own anti-SPAD measures. For example, EWS has taken 19 SPAD measures since the Ladbroke Grove crash, all aimed at the achievement of enhanced driver performance. The SPAD reduction
measures listed above clearly overlap to a high degree. As already noted, a SPAD will occur only when every preventive measure fails. Nevertheless, the lesson of recent history is that all these measures are likely to be needed to avoid the possibility of a further catastrophic crash.

**Human factors**

10.20 The Joint Inquiry received a substantial body of evidence from a number of experts called on behalf of different parties. Evidence on this topic had been given previously in both the Southall Inquiry and the Ladbroke Grove Inquiry. The evidence is relevant to a number of topics, particularly to SPAD avoidance. The Inquiry is grateful to Dr Deborah Lucas, Principal Psychologist at HSE who co-ordinated the evidence of the different experts and produced for the Inquiry a joint statement which was also signed by Professor Neville Moray, Professor John Groeger, Professor Helen Muir and Emma Lowe of Railtrack. The joint statement is appended as Annex 07 to this report.

**SPAD mitigation**

10.21 While much of the recent activity has been addressed to SPAD reduction and prevention, mitigation or even avoidance of the effect of a SPAD is of equal importance in the prevention of injuries and fatalities. If a train has failed to comply with warning signals so that a SPAD is likely, there remain the possibilities of prevention by Over Speed warnings with intervention (TPWS) or of emergency intervention by the signaller via radio or setting of other signals to danger. Where a SPAD occurs, its effect will depend on the braking force and rail-head condition, the length of overlap and the provision of mitigation beyond the overlap, including diversionary and trapping arrangements. The range of mitigation options has been usefully analysed in a report to the Joint Inquiry by Westinghouse Signals, following their contributions to the work of Sir David Davies.
Signal regulation

10.22 This was raised at the Southall Inquiry as having the potential for SPAD reduction, in the context of Layout Risk analysis, through the evidence of Dr Ian Murphy of Glasgow University. Following the recommendations of the Southall report, Dr Murphy attended meetings with A D Little, the originator of the LRM Analysis. The results of their joint review are still awaited. While changes to layout design principles represent a longer term solution to SPADs, Dr Murphy’s work has led to a re-analysis of the multi-SPAD signals identified in the HMRI SPAD report of September 1999. This work was recognised as a material advance in the understanding of SPADs and their consequences. Dr Murphy has also suggested some short term layout improvements to deal with multi-SPAD signals, which are being actively followed up by Railtrack. We regard this work as extremely promising and to be followed up urgently.

10.23 With regard to the specific issue of regulation changes to reduce the likelihood of SPADs, Sir David Davies referred to a proposed new approach to deal with the limitations of TPWS whereby signal regulation, in the case of conflicting movements, should be directed towards stopping trains which could be brought to a halt within the overlap by TPWS rather than those (currently including high speed trains) which could not. A figure of 5% was suggested for possible risk reduction. This proposal is given further consideration in Chapter 11.

Stopping the train

10.24 Fundamental to SPAD avoidance and mitigation is availability of adequate braking capability, coupled with adequate adhesion. Turning first to the available braking capability, this is conventionally measured as a percentage of “reverse acceleration” represented by gravity (g). The best conventional braking capability currently available, known as enhanced emergency braking (EEB), can produce braking force equivalent to 12%g. This is achieved by the rapid application of brakes and increased braking effort. EEB represents an
improvement of about one third on conventional braking with corresponding reductions in stopping distances, although the actual effect of braking depends on many factors, particularly the speed and weight of the train and the gradient.

10.25 While a few trains are capable of exceeding 12%g braking force (for example, London Underground trains), many classes of heavy rail vehicle do not presently achieve 12%g, notably including high speed trains. It is important to note that the limitations on the effectiveness of TPWS (which is said to be capable of stopping a train within the standard overlap from a speed of 74mph) is calculated for braking capacity of 12%g. Trains with lower braking capability will be stopped only from a lower speed or within an increased stopping distance.

10.26 Current Group Standard (GM/RT 2044) specifies classes which are exempt from the EEB programme, including classes of train which do not exceed 75mph. The exemptions are under review by Railtrack, who have been advised by W S Atkins. It is proposed to remove classes 158, 159 and 442 from the list of exemptions. This is to be welcomed. There are, however, physical limitations on the ability to retro-fit EEB to locomotives which are not designed to accommodate it. Such braking imposes significant stresses on the structure of the locomotive. Urgent consideration is being given to modification of HSTs to permit achievement of increased braking effort. Presently, 60% of locomotives and MUs are not fitted with EEB. The table at Annex 08 summarises the current position on the current UK fleet. Annex 09 sets out a comparative table of stopping distances for different braking systems, with an indication of the effectiveness of TPWS at different speeds.

10.27 Enhanced emergency braking operates through conventional disc brakes which are now fitted to all new trains and the majority of old rolling stock. Their effect depends upon the achievement of adequate adhesion between wheels and rail. Adhesion problems caused by leaves and other contaminants have been well publicised as have the counter measures adopted by Railtrack involving
special vehicles to remove leaves etc from the rails and the application of a gel containing an abrasive. Occasionally, these measures have been seen to fail and to result in SPADs, usually during the autumn. We understand that leaf problems are dealt with in other countries by the relatively ruthless clearance of trees and vegetation from the vicinity of the lines. This is not regarded as an acceptable solution within the UK and other measures must be adopted.

10.28 In addition to rail clearance measures, a number of countries, including the UK, have developed “sanders” i.e. devices fitted to the train to apply sand ahead of the wheels in order to enhance or maintain adhesion. A number of different devices are available and have been fitted to some classes of DMUs. Materials other than sand have been tried out, notably in Japan. Research on sanders continues.

10.29 An additional option which has been considered is magnetic track brakes, which provide additional contact with the rail independent of the wheels. The limitation on use of such devices is the detrimental effect of severe retardation on both the train and occupants and on the rails. Some limited testing has been carried out on magnetic track brakes, but it is considered they would require fitment of extensive additional equipment and do not presently form a realistic option.
In this chapter we review the issues which have been set out and discussed in earlier chapters with a view to reaching decisions which will form the basis of recommendations to be set out in Chapter 12. Before doing so, there are a number of factors which need to be kept in mind when evaluating the competing arguments.

**Background to evaluation**

First should be mentioned the cost of the measures under consideration. The proposed new train protection systems will involve substantial cost. By contrast, many of the measures falling under the umbrella of SPADRAM constitute management procedures which involve relatively modest cost. But some of the SPADRAM measures, such as data recorders, simulators and changes to track layout, will involve material cost. All such measures have in the past been regarded as subject to cost-benefit criteria to determine whether, in terms of health and safety legislation, they are “reasonably practicable”. This approach has previously prevented or inhibited the pursuit of specific safety measures, including wider fitment of BR-ATP. The fitment of on-train data recorders is still regarded as controversial on the basis of cost-benefit analysis (CBA).

The use of cost benefit analysis was endorsed by the Clapham Junction and Southall accident reports and its use as a management tool is not in question. In the case of rail safety issues, however, it needs to be recognised that the application of CBA using the financial quantification of the benefit of preventing “equivalent fatalities” is controversial on a number of grounds. These include the very concept of seeking to put a value on human life. It needs to be re-stated that calculations of this sort are unavoidable, given that
priorities as between one form of expenditure and another must be confronted. There is a temptation to equate the value of a statistical fatality capable of being prevented, with the value to be placed on a life of an individual which has been lost. This is understandable but misplaced. Lives which have been lost in preventable disasters are better recognised by seeking more appropriately to use available funding to save lives in the future. But, while cost benefit analysis can be a powerful management tool, decision making depends on wider considerations. It needs also to be clearly stated that cost benefit analysis is only one element in the process of arriving at the most appropriate decision.

11.4 While cost benefit analysis determined the course of development in Train Protection Systems in the UK in 1994-5, the passing of the Railway Safety Regulations has pre-empted any such decision in relation to both the fitment of TPWS and the withdrawal of Mark I rolling stock. Likewise, the current European Directive 96/48/EC requiring ETCS on high speed lines and the impending Directive on conventional lines will similarly render further considerations of cost benefit irrelevant. The Government’s 10 year Transport Review, including the provision of public funding for these measures, renders inappropriate any further consideration of their justification on cost grounds.

11.5 Two related matters which remain of concern are, first, the availability of adequate resources within the UK and European rail industry and, secondly, the achievable timetables for fitting of the major items of train protection under consideration. As to resources, the UK is known to have a total availability of only some 700 adequately experienced signal designers. Signalling technicians needed to oversee track fitment are also in limited supply, as seen in a number of recent projects. In particular, progress on commissioning of the Willesden and Leeds resignalling projects has been dictated by the availability of signal technicians. Numbers may be enhanced by overseas recruitment, but the limited availability of key personnel indicates that the programmes for fitment
of new train protection systems may be dictated by resources rather than finance or management decisions. This will apply particularly to the fitment of ETCS Level 1 and 2.

**Extension of BR-ATP**

11.6 Short sections of Great Western Lines were omitted as part of the original Pilot Scheme in order to observe the effect of passing from fitted to non-fitted lines. No purpose is served by maintaining those gaps and they should be infilled together with other omitted sections to provide full coverage between Paddington and Bristol Temple Meads and Parkway. As regards the additional fitting of relief lines and other parts of the Great Western Zone, we were not persuaded that these should be the subject of recommendations, in the light of the limited future for BR-ATP. These lines will be fitted with other Train Protection measures in the future, and the better operational solution may be to bring forward the fitting of other measures. In reaching this conclusion, we bear in mind that the lines in question are used by other operators whose trains are not fitted with BR-ATP.

11.7 There was virtual unanimity among parties to the Inquiry that any extension of train protection on lines presently fitted with BR-ATP should be by fitment of ETCS. There are many factors which support this view, including the ability of ETCS to migrate to higher levels against the inability of BR-ATP; also the fact that BR-ATP now represents 1980s technology which will become increasingly more difficult and more expensive to maintain. We would add to this the continuing marginal unreliability of ATP, which still exhibits faults beyond what should be expected of a relatively new system. While valuable lessons are to be learned from the two BR-ATP Pilots, they do not justify further extension to the existing systems.

11.8 Specifically, we do not consider that the case for fitting BR-ATP on Thames Trains using Great Western Lines is established in terms of the criteria set out
in para 9.13 above. Our considerations take account of the additional protection likely to be available through TPWS and ETCS, the former within a timescale not incompatible with the time likely to be required to achieve full operation of retro-fitted BR-ATP. As regards ETCS, there will be a need to select sections of the network for the early trial and fitment of train-borne equipment. Thames Trains could be appropriate for the early trial of the STM which may be fitted for trains using Great Western Lines, thereby affording early ATP protection.

**Train Protection and Warning System**

11.9 Divided views exist on the advantages and disadvantages of TPWS. In terms of performance, its benefits are plainly limited and, despite the substantial expenditure that it represents, TPWS will still permit a proportion of ATP-preventable accidents to occur. The consequence of any accident that does occur following a SPAD may be mitigated by reduction in speed. But in the case, for example, of the Southall accident, TPWS would have had no additional effect, since the driver had applied the brakes before the point at which the Over Speed Sensor would have cut in. Conversely, the Ladbroke Grove collision would have been entirely averted, since the speed of the train that passed SN109 at red was modest and the overlap long. In cases between these two extremes, the effect of TPWS will depend upon brake performance and the length of the overlap. Mr Cooksey, on behalf of HMRI saw specific advantage in TPWS as a stand-alone system i.e. if more sophisticated systems failed or were delayed, it would remain; and Railtrack saw positive advantage in two systems operating in tandem.

11.10 In the months before the start of the Joint Inquiry and at the opening of the Inquiry itself, a strong case was made out, particularly on behalf of Passengers’ Group for TPWS to be abandoned in favour of earlier fitment of ETCS. This was seen as the successor of BR-ATP, which the Passengers’ Group had promoted at the Southall Inquiry. Throughout the year 2000 and for some time before that, the rail industry and Railtrack in particular had been actively
pursuing the now mandated fitment of TPWS. The programme of trials was substantially completed and, while development of the system continued, orders for the supply of equipment had been placed. The Railway Safety Regulations 1999 came into force on 30 January 2000 by which date the fitment programme required by the Regulations had also been approved. The move to fit TPWS was characterised as being unstoppable, despite assurances received from DETR that the recommendations of the Joint Inquiry would be complied with.

11.11 We do not accept that any decision about TPWS is inevitable. But we do not believe that its cancellation would advance the date by which ETCS can be introduced. Given the discretion that exists over the dates for fitment of ETCS and limitations of resources, our concern is that fitment of TPWS should not be permitted to delay the fitment of ETCS. That is, however, dependent also on other factors, particularly progress on other aspects of the WCML upgrade which will form the first commercial fitment of ETCS, and also progress on trials at the Old Dalby test track. The consequences of delay to ETCS fitment are of such importance that the situation should be independently monitored. For this purpose an appropriate firm of consultants should be nominated by HMRI and appointed by Railtrack with instructions to provide reports to HMRI at intervals of not more than 6 months.

11.12 We believe that the original objectives of TPWS, to provide a relatively cheap and quickly available stop-gap, in place of nation-wide fitment of BR-ATP, remain proper and viable aims. TPWS was designed with the intention that it would be replaced within a limited period. TPWS has been delayed by a number of factors, mostly technical, but so has ETCS. Optimistic forecasts of equipment availability are a characteristic of the railway industry. Nevertheless, delayed TPWS still fits reasonably into its originally intended slot.
11.13 After weighing the issues carefully, we are left with considerable reservations about the effectiveness of TPWS. Its true level of performance was not known with accuracy at the date of its adoption as part of railway safety policy in 1994/95. Its limitations have become more apparent as its cost has escalated. We doubt that it would have been adopted had both of these factors been known more reliably at the outset. There have been various attempts to “talk up” the theoretical effectiveness of TPWS. We give only limited weight to the figures presented, since the consequences of any accident which occurs in the future on a TPWS-protected train are quite unpredictable. The suggestion, mentioned by Sir David Davies, of a change in signal regulation rules to avoid presenting red signals to trains which could not be stopped by TPWS, involves such a fundamental change in policy as to require thorough investigation. We were not offered any such investigation or analysis of its consequences beyond the suggestion that it could enhance the effectiveness of TPWS by 5%. There was no support for this figure nor could there be without knowledge of the alternative regulation policy proposed. In the light of the many difficulties surrounding regulation (see the Southall Report, Chapter 4) we do not regard this possibility as one which should influence our conclusions.

11.14 We remain concerned that the effectiveness of TPWS is least where the risk is greatest i.e. on high-speed trains with braking capability falling well below the optimum. We have referred in Chapter 1 to the real concern of the public lying in the possibility of further catastrophic accidents. TPWS will not remove that concern.

11.15 Despite our misgivings, we accept that TPWS offers a material degree of reduction in SPAD risks. Operators were generally in favour and there will be parts of the network in which TPWS can offer a relatively permanent train protection system. As a result of events which have occurred independently of any of the present Inquiries, the industry is now largely committed to the implementation of TPWS and the government, with the support of HSE, has
made its fitment mandatory. Counsel for the Passengers’ Group conceded at the end of the Inquiry, that “by the time the Joint Inquiry makes its recommendations the process of TPWS fitment would be irreversible”. While we have not accepted that our hands are tied, we conclude that the evidence has not persuaded us that the fitment of TPWS should now be reversed.

11.16 Concern remains over the decision simply to fit TPWS to all junction signals with plain line signals awaiting a later risk assessment. While this is a matter for the balancing of resources and the efficient management of the TPWS programme, we would prefer to see fitment generally based on risk assessment and resources being concentrated on those signals most in need of protection. Undoubtedly, there exist a number of junction signals which do not require TPWS fitment and a number of plain line signals which do. All multi-SPAD signals should be fitted unless they present no risk. In the remaining time available under the Regulations urgent steps should be taken to ensure that resources are devoted to signals most in need of protection. This should include the possibility of exempting signals which are covered by the Regulations but where the risk is minimal.

11.17 We have noted that the industry was persuaded, after the Ladbroke Grove crash and in the light of strong public criticism of railway management, to accelerate by one year the programme for track fitment set only months before under the Railway Safety Regulations 1999. While it has not been suggested that the accelerated programme is unachievable and we have not been asked to make any recommendation in relation to it, it should be observed that the original programme was that which the HSE considered to be the best achievable. The accelerated programme will affect the employment of resources throughout the industry as well as distorting the programme of design and development previously agreed within the industry. Some concerns were expressed as to whether the accelerated programme was achievable. We consider that the accelerated programme should be kept under review to ensure that any adverse
consequences do not outweigh the benefit of accelerated fitment. Of perhaps
greater importance is the need to allocate resources so as to co-ordinate the
fitment of track and train-borne equipment such that TPWS protection can be
achieved at the earliest date.

TPWS variants

11.18 We consider first TPWS-E, which represents a material advancement on
TPWS-A, involving both different lineside and different on-train equipment.
Sir David Davies recommended, in February 2000, an early programme of
testing, the results of which would be available for the Joint Inquiry
commencing in September 2000. In the event, no such tests were carried out,
partly as a result of a failure to agree on funding. Once this issue was resolved,
it became apparent that trials of TPWS-E could not be put in place until the
first half of 2001 and that, if successful, the further process of development and
testing would mean that TPWS-E could not be available for some 2 ½ years.
Thus, the only decision which could be taken at the present time is whether
TPWS-E should be pursued at all. It is clear that TPWS-E does not represent a
priority given the inevitable progress of TPWS-A in the meantime.

11.19 The arguments in favour of TPWS-E remain its greater flexibility and ability to
provide protection to trains with different characteristics, together with the
possibility of migration to ETCS. The disadvantages remain its present
unavailability and the now inevitable consequence that it would have to be
fitted alongside TPWS-A, since the majority of the fleet and the majority of
lines will already have been fitted with TPWS-A. It will also involve
substantial additional cost beyond the cost of TPWS-A. HSE have concluded
that TPWS-E is unlikely to be of significant use on the UK rail network. While
it will remain open to the industry to explore the possible development and use
of TPWS-E, we are not persuaded that it should be the subject of any
recommendation.
11.20 TPWS+, however, is a “bolt on” option which can be added selectively and at any time to provide protection at higher speeds. It involves no additional technology and involves little more than the provision of additional pairs of track-mounted loops, wired back to the signal. TPWS+ has the full support of HSE, who recognise the limitation of TPWS-A. The potential advantage of TPWS+ is apparent and we recommend its continued development. The use of more than one additional OSS should also be investigated. We remain concerned, however, that the lack of flexibility inherent in TPWS will lead to additional loops creating operational problems for trains with different braking characteristics. These problems will, again, potentially revive the issue of regulation and priority as between different classes of train. The seriousness of these problems remains to be established by trials, and we are not convinced that TPWS+ can presently be regarded as more than a theoretical improvement to the basic capability of TPWS. Should TPWS+ prove successful, its fitment should be concentrated on lines carrying high-speed trains and on lines carrying other trains which cannot be stopped by TPWS-A.

European Train Control System

11.21 Fitment of ETCS Levels 1 and 2 is already in course as part of the current WCML modernisation. That programme is driven by important commercial pressures and no recommendations are appropriate. This will be followed by upgrading of ECML. The work to be carried out presently remains contingent on the next franchise decision. We are satisfied that Railtrack’s present intention is to proceed with this work in a timely fashion. They are not, however, subject to the same stringent commercial pressures and possibility of substantial slippage remains very real.

11.22 We are also concerned, in regard to the initial fitment of ETCS, with the continuing fragmentation of the industry and the well-publicised difficulties of achieving co-operation between different participants in the same project. This was considered at some length in the Southall Report and was the subject of
recommendations for the setting up of System Authorities. The organisation currently overseeing TPWS has already been commented on in Chapter 6 above. For the implementation of ETCS, we consider that the parallel activities of trials to be carried out at the Old Dalby test track, the WCML rebuild and the commissioning and introduction into service of new rolling stock will impose far greater requirements on the industry. There are a host of factors which may delay the implementation of ETCS and we consider that urgent steps should be taken to make provision for their resolution before any actual delay is caused. The need for a means of resolving inter-company issues is, in our view, a high priority. We note that the form of and means of setting up System Authorities has been the subject of specific attention in Part II of the Ladbroke Grove Inquiry. In making a recommendation for the creation of a System Authority for ETCS we intend that further account should be taken of Recommendations in that Report covering such bodies.

11.23 The remaining high-speed TEN route is that on Great Western Lines. This will require fitment of ETCS when they are next upgraded. The lines to be covered by the draft Conventional Directive, will require fitment when they are next upgraded or renewed. The concern expressed, particularly by the Passengers’ Group, was that, in the absence of compulsion, the fitment of TPWS would be a major disincentive to both Railtrack, Operators and Owners to bring forward the considerable costs of ETCS fitment. The most economical solution would be to fit ERTMS at the end of the natural life cycle of signals and/or rolling stock. This might result in the risk of postponing general fitment of ETCS for perhaps a further 30 years. Faced with this uncertainty and armed with considerable historical knowledge of the performance of the railways in the introduction of new safety systems, we are not persuaded that ETCS can safely be left to the industry in its present fragmented state. The decision of HMRI to propose and the Government to accept regulation as a means of achieving the timely fitment of TPWS leads us to conclude that such a course is equally appropriate to ensure the fitment of ETCS, where decisions will need to be
made and enforced concerning priorities and the safe operation of individual lines.

11.24 During the course of the Inquiry it was made clear that HSE now considers that regulations are essential to secure the timeous fitment of ETCS to a phased programme. In its final submissions, Railtrack greatly welcomed this decision, as did other parties. While Railtrack maintained that ETCS fell far short of meeting the test of “reasonable practicability”, regulation has the added advantage of making public funding the more secure. It is also significant that the current round of franchising offers the opportunity to make provision for the cost of fitment of ETCS to rolling stock, to the extent there may be an issue. The precise drafting of regulations will require lengthy and detailed consultation. The broad outlines, however, are clear.

11.25 Having reviewed the evidence as to the current state of development of ETCS, the availability of resources and other commitments which the industry faces, we conclude that regulations should provide that all trains running at over 100mph should be protected by ETCS by the year 2010. Within this overall requirement ETCS should be fitted on WCML in accordance with the current timetable, with ECML and GWML being fitted by 2006. All lines carrying trains at over 100mph should be fitted by 2008, with trains running at over 100mph being fitted by 2010. Regulations should also contain powers to require the fitting of ETCS progressively to routes with line speeds above 75mph, and above 60mph if justified on safety grounds. We include as Annex 10 a detailed list of requirements and objectives to be achieved by Regulations.

11.26 We remain concerned that the fitment of TPWS may, in fact, delay the introduction of ETCS. Some parties were concerned to establish that the two projects would operate independently, but we consider it would be unrealistic to suppose that there could be any overlap, except in the case of WCML where both systems are to be installed as part of the upgrade. We consider that maintaining the present accelerated TPWS programme has the potential
advantage also of minimising delay to the subsequent fitment of ETCS. Conversely, any extensive fitment of additional TPWS systems will have the opposite effect.

11.27 Subject to carrying out pilot tests on ETCS equipment, there is no reason why early fitment should be limited to the major upgrades on WCML and ECML. Two alternative pilot schemes have been identified during the course of the Inquiry which should be further investigated. First, the proposal to extend ATP coverage on Chiltern Lines from Aynho Junction to Birmingham Snow Hill could be achieved with ETCS Level 1 or 2. Secondly, the proposal to allow Thames Trains using Great West Lines to benefit from ATP could be satisfied by early fitment of ETCS train-borne equipment with an STM. We have no doubt that other pilot schemes could be identified which have the advantage both of providing early feedback on performance of the new systems and of providing additional train protection. In these cases, however, unlike the BR-ATP pilots, the equipment can be retained and upgraded when appropriate. Other pilot schemes utilising ETCS or ETCS components should be considered. Particularly, there may be advantage in the early fitting of GSM-R radio in advance of ETCS equipment.

Mixed systems

11.28 The present complexity of the UK rail system is such that virtually all lines carry traffic from more than one operator and in most cases the trains involved will be fitted with more than one train protection system. It is a matter of long term strategy whether a greater degree of uniformity and simplicity can be imposed on the system. For the present, it seems inevitable that lines and trains will need to be fitted so as to use alternative systems. In principle, trains should be able to make use of the highest degree of information transmitted by
track equipment, for which purpose trains will need to be fitted with STMs and reverse STMs depending upon the lines which they use.

11.29 In the long term, the objective should be to replace all command and control equipment with ETCS level 3. Short of that, however, the long term objective of simplifying the remaining systems on the network should be pursued at the time that any particular system reaches the limits of its life.

SPAD reduction and mitigation

11.30 It has been pointed out already that, whatever action is taken to fit automatic train protection to UK lines, there will be several years at least during which no protection is available beyond the existing Automatic Warning System. In these circumstances, the measures outlined and discussed in Chapter 10 are a necessity. They will continue to be so even after fitment of TPWS because of the numbers of ATP-preventable accidents which will not be averted by this system and the plain line signals not fitted with TPWS. Even fitment of enhanced TPWS will still leave a significant gap in its coverage.

11.31 The response of the railway industry to SPAD reduction and mitigation measures has been general and without reservation. It is not, however, a matter for commendation since any such change inevitably begs the question why it should be made only after two serious accidents and much public pressure. However, the fact that these measures might have been taken earlier can only add to their importance. Now that it can clearly be seen that the ability of a train running at 125mph to stop at a red signal is dependent upon the perception and reaction of the driver, aided by warnings in the cab, practical measures to sustain and enhance the driver’s performance can be seen as commanding a high priority. The view of HSE is that we are already close to what can be expected of human response in the cab or signal box, a view with which we agree.
11.32 We therefore endorse the many separate programmes and procedures and mention only the following as being of particular significance.

- Research into multi-SPAD signals should remain a top priority including the wide dissemination of information about specific signals regarded as high risk and the design and implementation of mitigation measures at such signals.
- Specifically, analytical methods (including that of Dr Ian Murphy) should be developed and verified in order to identify those signals where the greatest risk lies.
- Driver selection, training and management should continue to be developed in accordance with current research into human factors issues.
- Signal sighting issues should be kept under continuous review, particularly in the case of signals known to present visibility problems.
- Use of the Driver’s Reminder Appliance should be standardised and work on the automatic version pursued.

11.33 The proposals in the report of Sir David Davies for a new approach to signal regulation has already been considered in terms of the effectiveness of TPWS. The proposal has serious commercial implications and also represents a reversal of signalling policy as developed over the past two decades. A convincing case would need to be made for such a change to be implemented and the safety gain would need to be beyond question. Although the proposal came originally from Railtrack’s own consultant, they were opposed to its further pursuit. We have seen no analysis justifying the suggested safety gain and we do not consider that this proposal presently merits inclusion within the SPADRAM measures.

11.34 The present programme of extending the availability of enhanced emergency braking clearly has great potential for the avoidance of collisions, and should be pursued with vigour, as should the continued fitment of sanders. Magnetic
track brakes, conversely, have not been established as a viable addition to the list of SPADRAM measures.

Evaluation of sectors

11.35 We include in Annex 11 network maps showing what we see as the future evolution, in terms of train protection systems, of each of the major lines, together with accompanying notes.
12.1 In this chapter we set out the courses of action which we recommend as necessary in the light of the material appearing in Chapters 1 to 10 and the discussion and evaluation in Chapter 11. We also set out the matters of significance on which we make no recommendation.

12.2 In formulating these recommendations we have been greatly assisted by the submissions of the parties appearing at the Inquiry and of Counsel to the Inquiry. Our proposals have been reviewed by the technical assessor to the Inquiry, Major Anthony King OBE, and we have taken his views into consideration.

12.3 During and after the Inquiry hearings, views were exchanged on whether the identity of the party to whom recommendations were addressed (the “Owner” of the recommendation) should be the subject of comment from the parties themselves. We have considered the views put forward and believe that, in relation to the present Joint Inquiry, no such consultation is appropriate. We have identified in relation to each recommendation the party or parties to whom they are addressed and the appropriate period for compliance.
12.4 **Extension of BR-ATP**

These recommendations apply to the ATP system currently in use on Railtrack Great Western and Midland Zone lines used by First Great Western and Chiltern Trains.

1. Gaps which were left on original fitment of BR-ATP track equipment should be infilled to provide full continuous coverage between Paddington and Bristol Temple Meads and Marylebone and Aynho Junction (para 11.6).

2. No recommendation is made for fitment of BR-ATP to other lines on Great Western or Midland Zones or to relief lines (para 11.7).

3. No recommendation is made for fitment of BR-ATP to trains run by any other operating company (para 11.8).

12.5 **Train protection and warning system (TPWS)**

4. The current mandated fitment of TPWS-A to trains and track should not be reversed (para 11.15).

5. Track fitment should include all multi-SPAD signals unless they present no risk (para 11.16).

6. Risk assessments should be carried out on plain line signals, initially on those considered by TOCs to pose significant risk (para 11.16).
7. Track fitment should include plain line signals where the risk from SPADs is established to be significant (para 11.16).

8. Risk assessments should be carried out to identify junction signals where the risk from SPADs is insignificant. Consideration should be given to obtaining exemptions for such signals from track fitment (para 11.16).

12.6 TPWS+

9. Trials should be carried out on TPWS+ using single and multiple additional Over Speed Sensors (OSS) with the aim of drawing up a design standard and measuring the effect of additional OSS on different types of train and on driving techniques (para 11.20).

10. If proved to be feasible, a full appraisal of the effect of one or more additional OSS on all traffic passing a signal should be carried out before fitment of additional OSS (para 11.20).

11. Fitment of TPWS+ should be concentrated on lines carrying High Speed Trains and on lines carrying other passenger trains which cannot be stopped within the normal overlap by TPWS-A (para 11.20).

12.7 TPWS-E

12. No recommendation is made for continued testing or fitment of TPWS-E (para 11.19).
RECOMMENDATIONS

12.8 TPWS fitment

13. Fitment of TPWS-A should continue in accordance with the currently accelerated programme (para 11.17).

14. All parties should co-operate in the production and updating of a resource allocation programme directed towards the matching of track and rolling stock fitment, in order to maximise the early attainment of TPWS protection (para 11.17).

15. The accelerated programme should be reviewed and updated to ensure that it is compatible with the early attainment of TPWS protection and that any adverse consequences do not outweigh the benefit of accelerated fitment (para 11.17).

16. Steps should be taken to ensure that TPWS fitment is completed in such time and manner as not to delay fitment of ETCS (see Recommendation 27 below) (para 11.11).

17. For the fitment of train-borne TPWS, AWS components should be replaced to the maximum extent practicable. For this purpose the ATOC TPWS Executive should draw up a standard for the replacement of AWS in train-borne TPWS equipment (para 6.18).

12.9 European Train Control System (ETCS)

18. Fitment of ETCS to lines covered by Directive 96/48/EC (TEN lines) and the draft Directive on Conventional lines should be supported by Regulations (para 11.24).
19. Regulations should be in absolute terms and not dependent on reasonable practicability (para 11.24).

20. HSE should establish a programme for consultation and drawing up of Regulations for the fitment of ETCS with the objective of Regulations being in force within three years (para 11.24).

21. The requirements and objectives to be achieved by Regulations in relation to major lines should be those set out in an Annex 10 of this report (para 11.24).

22. Pilot schemes using ETCS or ETCS elements should be carried out. These should include the following three Recommendations to the extent they are feasible (para 11.27).

23. Fitment of ETCS Levels 1 or 2 should be considered between Aynho Junction and Birmingham Snow Hill (para 11.27).

24. Fitment of ETCS train-borne equipment should be considered on Thames Trains using Great Western Lines, together with an STM to allow use to be made of BR-ATP track equipment (para 11.8, 11.27).
25. The selective fitment of GSM-R radio in advance of ETCS fitment to trains should be considered. For this purpose lines should be identified for the early fitment of ground and track equipment, to be followed by train-borne equipment (para 11.27).

12.10 ETCS fitment

26. A System Authority should be established to oversee and direct the timely fitment of ETCS, including the current programme for the Old Dalby test track (see Annex 10(m)), (para 11.22).

27. For the purpose of avoiding delays, fitment of ETCS should be independently monitored with reports being submitted at intervals of not more than 6 months, stating whether fitment of ETCS has been delayed or impeded by work on TPWS fitment (para 11.11).

28. All new rolling stock should be compatible with ETCS and GSM-R fitment (Davies Recommendation 11).

12.11 SPAD reduction and mitigation

29. All SPADRAM measures should be continued unless and until HMRI are satisfied that they are unnecessary (para 11.32). The following measures should be pursued in particular.
30. Research into multi-SPAD signals and into the cause of multiple SPADs should be continued (para 11.32).

31. Procedures for the dissemination of information and for the design and implementation of mitigation measures following multiple-SPADs should be kept under review (para 11.32).

32. Analytical methods (including that of Dr Ian Murphy) aimed at identifying signals which pose the greatest risks should be pursued with urgency (para 11.32).

33. Research into human factors should continue with particular emphasis on its application to driver selection, training and management and signal sighting issues (para 11.32).

34. HMRI should implement the proposal for research into the possibility of conflict between defensive driving and punctuality. (para 10.13)

35. Use of the Drivers’ Reminder Appliance should be standardised and work on the automatic version pursued (para 11.32).
12.12 Stopping trains

36. The programme for the development and retro-fitting of Enhanced Emergency Braking (EEB) should be continued with urgency, including the identification of any further classes which it is not appropriate to exempt (para 11.34).

37. Improvement of braking on HSTs and other rolling stock running at speeds in excess of 100mph should be regarded as a priority (para 11.34).

38. The use of sanders to maintain and enhance adhesion should be pursued and a programme of trial fitment drawn up (para 11.34).

39. No change in regulation policy to avoid presenting red signals to trains not capable of being stopped by TPWS should be considered without a full assessment and analysis of the consequences (para 11.33).
## LIST OF ANNEXES

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The Rt Hon Lord Cullen PC
Ladbroke Grove Rail Inquiry
Romney House
Marsham Street
London
SWIP 3RA

Professor John Uff QC
Southall Rail Accident Inquiry
New Connaught Rooms
61-65 Great Queen Street
London
WC2

5 November 1999

Ladbroke Grove Rail Inquiry
Southall Rail Accident Inquiry

The Health and Safety Commission has considered the inter-relation of these inquiries which were established under section 14(2)(b) of the Health and Safety at Work etc Act 1974.

In his letter of 19 February 1999, Professor Uff set out a list of issues arising from the Southall Rail Accident to which he was minded to direct his inquiry. Following the tragic accident at Ladbroke Grove Junction, which will clearly give rise to further evidence on a number of these issues, Professor Uff informed parties in his letters of 12 and 19 October how he was minded to proceed. In particular he stated that he did not propose to deal with certain of the matters which he had listed earlier.

The Commission supports the determination expressed in Professor Uff’s letter of 19 October that the Southall Inquiry should not be held up by the investigation into the accident at Ladbroke Grove Junction. At the same time, the Commission is anxious that all the issues which were originally identified by Professor Uff should be properly and comprehensively considered, and that victims of the Southall accident should have the opportunity to be heard in an inquiry into them.

The Commission therefore supports the view taken by Professor Uff, as set out in his letters of 12 and 19 October 1999, that the Southall Rail Accident Inquiry should not deal with the subjects set out in the letter of 19 February which are detailed below. However, it considers that in view of the interest of Southall victims in these subjects, they should be the subject of a joint inquiry chaired by both of you. The Commission is therefore, with the consent of the Deputy Prime Minister, appointing you jointly for this purpose under Section 14(2)(b) of the 1974 Act.
The Commission expects that you will each deal separately with whatever you consider it appropriate to investigate within each of your existing terms of reference, subject to the exception in each case of matters which you are to deal with jointly. You will sit together to consider the following subjects, namely:

(i) Train Protection and Warning Systems
(ii) the future application of Automatic Train Protection systems
(iii) SPAD prevention measures

taking account in particular of:

- the Southall rail accident on 19 September 1997;
- the rail accident at Ladbroke Grove Junction on 5 October 1999,
- the technical assessment for the Deputy Prime Minister of rail safety systems by Sir David Davies

with a view to making general recommendations in regard thereto.

Having regard to the wide ranging remit of Lord Cullen, the Commission considers it appropriate that wider matters within issue 6 of Professor Uff’s letter of 19 February 1999 to the Southall Parties should be dealt with by Lord Cullen; and that the Southall Inquiry should consider issue 6 matters only in the direct context of the Southall accident.

No doubt Professor Uff will draw to the attention of Lord Cullen any matters arising in Professor Uff’s own inquiry which would be more appropriately taken forward by Lord Cullen.

Yours sincerely,

[Signature]

Bill Callaghan
Chair
Agreed by the Chair and signed in his absence
Sarah Gawley
Acting Commission Secretary
### Parties and Representatives

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<tr>
<th>Party/Group</th>
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<tr>
<td>Inquiry counsel</td>
<td>Ian Burnett QC, Richard Wilkinson, Dominic Adamson, Laurance O’Dea, Treasury Solicitor</td>
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### ALPHABETICAL LIST OF PERSONS PROVIDING EVIDENCE TO THE INQUIRY

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<td>Jones-Lee</td>
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<td>Dr Bernard</td>
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<td>Laycock</td>
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<td>09/10/2000</td>
</tr>
<tr>
<td>Lee</td>
<td>Nigel</td>
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<td>03/10/2000</td>
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<td>Lockett</td>
<td>Richard</td>
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<td>Lucas</td>
<td>Dr Deborah</td>
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<tr>
<td></td>
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<td>McCullough</td>
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<td>Roderick Ian</td>
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<td>Nelson</td>
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<td>Ian</td>
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<td></td>
<td>11/10/2000 R</td>
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<td>Preston</td>
<td>Graham</td>
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<td>27/09/2000</td>
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<tr>
<td>Raven</td>
<td>Brian</td>
</tr>
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<td></td>
<td>06/10/2000 R</td>
</tr>
<tr>
<td>Robb</td>
<td>Sean</td>
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<td>Robinson</td>
<td>William</td>
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<td>20/09/2000 R</td>
</tr>
<tr>
<td>Sadler</td>
<td>Michael</td>
</tr>
<tr>
<td></td>
<td>11/10/2000 R</td>
</tr>
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<td>Sawyer</td>
<td>David William</td>
</tr>
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<td>26/09/2000</td>
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### ALPHABETICAL LIST OF PERSONS PROVIDING EVIDENCE TO THE INQUIRY (CONT.)

<table>
<thead>
<tr>
<th>Name</th>
<th>Evidence presented or read on</th>
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<tbody>
<tr>
<td>Sayce</td>
<td>Adrian 22/09/2000 R</td>
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<tr>
<td>Sharpe</td>
<td>Andrew 11/10/2000 R</td>
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<tr>
<td>Shaw</td>
<td>C A 27/09/2000</td>
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<td>Shooter</td>
<td>Adrian 09/10/2000</td>
</tr>
<tr>
<td>Smallwood</td>
<td>Dr Robert 21/09/2000</td>
</tr>
<tr>
<td>Smith</td>
<td>John 06/10/2000</td>
</tr>
<tr>
<td>Spackman</td>
<td>Michael 22/09/2000</td>
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<tr>
<td>Stamp</td>
<td>Chris 04/10/2000</td>
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<tr>
<td>Sutton</td>
<td>Allan 11/10/2000</td>
</tr>
<tr>
<td>Taylor</td>
<td>Frank 09/10/2000</td>
</tr>
<tr>
<td>Thomas</td>
<td>Peter 27/09/2000</td>
</tr>
<tr>
<td>Thomas</td>
<td>Peter 06/10/2000</td>
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<tr>
<td>Tunley</td>
<td>John D 11/10/2000 R</td>
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<td>Wadey</td>
<td>Chris 06/10/2000 R</td>
</tr>
<tr>
<td>Walker</td>
<td>Dr Simon 20/09/2000</td>
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<td>Walley</td>
<td>Donald 28/09/2000</td>
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<tr>
<td>Weston</td>
<td>Bruce 10/10/2000</td>
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<tr>
<td>Wilkins</td>
<td>Steve J 11/10/2000 R</td>
</tr>
<tr>
<td>Worsley</td>
<td>Tom 22/09/2000 R</td>
</tr>
</tbody>
</table>
List of Inquiry Personnel

Joint Chairmen
Rt Hon. Lord Cullen PC
Professor John Uff QC

Technical Assessor
Major AGB King OBE BSc

Inquiry counsel team
Ian Burnett QC
Richard Wilkinson
Dominic Adamson
Mandy McClean

Inquiry Solicitor
Laurance O’Dea

Inquiry Secretary
David Brewer

Inquiry Administration
Mike Carless
Monica Garcia
Annie Johnston
Paul McGuiness
Claire Mullord
Darren Putland
Jansen Versfeld
Annex 05

SPAD definitions

SPAD Category A
Any occasion where a train passes a signal at danger without authority, other than defined below as Category B, C or D.

SPAD Category ‘A’
A numerical rating from 1 - 8 based on the actual consequences of the SPAD.

Severity ratings

<table>
<thead>
<tr>
<th>Severity Categories 1 to 2:</th>
<th>Severity Categories 3 to 8:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Overrun 0 to 25 yards, overrun not exceeding overlap, and no damage, injuries or death</td>
<td>3 Overrun greater than overlap plus all overruns greater than 200 yards and no damage, injuries or deaths</td>
</tr>
<tr>
<td>2 Overrun 26 to 200 yards, overrun not exceeding overlap, and no damage, injuries or deaths</td>
<td>4 Track damage only with no casualties</td>
</tr>
<tr>
<td></td>
<td>5 Derailment with no collision and no casualties</td>
</tr>
<tr>
<td></td>
<td>6 Collision (with or without derailment) and no casualties</td>
</tr>
<tr>
<td></td>
<td>7 Injuries to staff or passengers with no fatalities</td>
</tr>
<tr>
<td></td>
<td>8 Fatalities to staff or passengers</td>
</tr>
</tbody>
</table>

SPAD Category 'B'
Any occasion where a train passes a signal at danger without authority because a stop aspect or indication was not displayed with sufficient time for the driver to stop safely at the signal:
• because of a failure of signalling or level crossing equipment, or
• because it was returned to danger in error.

SPAD Category 'C'
Any occasion where a train passes a signal at danger without authority because a stop aspect or indication was not displayed with sufficient time for the driver to stop safely at the signal because it was returned to danger in an emergency in compliance with rules and regulations.

SPAD Category 'D'
Any occasion when vehicles without any traction unit attached or a train which is unattended run away past a signal at danger.

SPAD Hazard Ranking
Each incident is ranked to reflect the seriousness of the SPAD and thereby assist the prioritisation of management actions. The ranking consists of recurrence factors and potential consequence. Serious Hazard Ranked SPADs are those ranked with either 1 or A or a.

<table>
<thead>
<tr>
<th>Consequences of the incident</th>
<th>1 Serious</th>
<th>2 Moderately serious</th>
<th>3 Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recurrence factors equipment and environmental</td>
<td>A Very important</td>
<td>B Moderately important</td>
<td>C Of minor importance</td>
</tr>
<tr>
<td>Recurrence factors human - driver/other staff responsible</td>
<td>a Major</td>
<td>b Moderate</td>
<td>c minor factor</td>
</tr>
</tbody>
</table>

Multi SPADed Signal
A signal that has had 2 or more Category A SPADs in the last 5 years.
### Annex 06

**Table to show the stages of ERTMS trials in Europe**

<table>
<thead>
<tr>
<th>Country</th>
<th>Line</th>
<th>Track</th>
<th>Locos</th>
<th>ETCS Level</th>
<th>Project Type</th>
<th>Expected Commencement</th>
<th>Contractor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Vienna – Budapest (Hungary)</td>
<td>45km</td>
<td>2</td>
<td>L1</td>
<td>Feasibility</td>
<td>Autumn 2002* Early 2003*</td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>L96 (Brussels – Leuven)</td>
<td></td>
<td></td>
<td>L1 &amp; L2</td>
<td>Feasibility</td>
<td>2003</td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Plodiv – Burgas</td>
<td>150Km</td>
<td>100</td>
<td>L1</td>
<td>Commercial</td>
<td>End 2001</td>
<td>Alcatel SEL</td>
</tr>
<tr>
<td>Czechoslovakia</td>
<td>Prague – Dresden</td>
<td></td>
<td></td>
<td>L1/2</td>
<td>Feasibility</td>
<td>By 2003</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>Barreau interconnexion “Ille de France”</td>
<td>25km</td>
<td>5</td>
<td>L1 &amp; L2</td>
<td>Feasibility</td>
<td>Mid 2001</td>
<td>Alstom</td>
</tr>
<tr>
<td></td>
<td>Paris-Est - Sezanne</td>
<td>9km</td>
<td>5</td>
<td>L1</td>
<td>Feasibility</td>
<td>2000</td>
<td>Alstom</td>
</tr>
<tr>
<td>Germany</td>
<td>Juterborg - Berlin Halle to Leipzig</td>
<td>118km</td>
<td></td>
<td>L1 &amp; L2</td>
<td>Feasibility</td>
<td>Late 2002 Jan 2003</td>
<td>Siemens Alcatel</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Plodiv – Burgas</td>
<td>150Km</td>
<td>100</td>
<td>L1</td>
<td>Commercial</td>
<td>End 2001</td>
<td>Alcatel SEL</td>
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<td>Czechoslovakia</td>
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<td>L1/2</td>
<td>Feasibility</td>
<td>By 2003</td>
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<td>France</td>
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<td>25km</td>
<td>5</td>
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<td>Feasibility</td>
<td>Mid 2001</td>
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<td>Feasibility</td>
<td>2000</td>
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<td>Germany</td>
<td>Juterborg - Berlin Halle to Leipzig</td>
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<td>L1 &amp; L2</td>
<td>Feasibility</td>
<td>Late 2002 Jan 2003</td>
<td>Siemens Alcatel</td>
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<tr>
<td>Hungary</td>
<td>Budapest – Vienna (Austria)</td>
<td>45km</td>
<td>2</td>
<td>L1</td>
<td>Feasibility</td>
<td>Early 2003</td>
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<tr>
<td>Italy</td>
<td>Florence – Arezzo</td>
<td>85km</td>
<td></td>
<td>L1, L2 &amp; L3</td>
<td>Feasibility</td>
<td>End 2000</td>
<td>Ansaldo/Alstom</td>
</tr>
<tr>
<td>Rome – Naples</td>
<td>New</td>
<td></td>
<td></td>
<td>L2</td>
<td>Commercial</td>
<td>Early 2004</td>
<td>Ansaldo/Alstom</td>
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<tr>
<td>Luxembourg</td>
<td>Luxembourg – Belgium Whole Network</td>
<td></td>
<td></td>
<td>L1</td>
<td>Feasibility</td>
<td>2002</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>Albacete – Villar Chinchilla Madrid – Seville Madrid - Barcelona</td>
<td>30sigs 35km</td>
<td>2+5 63loco</td>
<td>L1</td>
<td>Feasibility</td>
<td>2002</td>
<td>Siemens Adtranz Both above</td>
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<tr>
<td>Switzerland</td>
<td>Chur – Zurich Olten Lucerne Berne – Olten (new hi-speed line) Whole Network</td>
<td>30sigs 35km</td>
<td>2+5 63loco</td>
<td>L1</td>
<td>Feasibility</td>
<td>Ongoing (2yrs) Early 2001 End 2004</td>
<td>Siemens Adtranz Both above</td>
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<td>Netherlands</td>
<td>Herlen – Maastricht Meppel – Leeuwarden Amsterdam – Utrecht Betuwe Line</td>
<td>New freight</td>
<td></td>
<td>L1, L2 &amp; L3</td>
<td>Feasibility</td>
<td>2002*</td>
<td>Ether Alstom / Adtranz</td>
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<tr>
<td>UK</td>
<td>Old Dalby (test track) WCML</td>
<td>32km 650km</td>
<td>L1 &amp; L2</td>
<td>Feasibility</td>
<td>2002/2003 2005</td>
<td></td>
<td></td>
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</table>

* Indicates dates which have not been verified

**SEE NOTES OVERLEAF**
Annex 06 cont.

NOTES ON EUROPEAN TRAIN PROTECTION SCHEMES

Netherlands
Fitting of the NGATB system commenced in 1996. It uses balises and is described as having a functionality similar to Level 1 ETCS, however it is not compatible with ETCS and will require an STM.

Dutch National Railways have commenced the BEV21 project (Safety for the 21st century) designed to implement ERTMS signalling specifications. The first phase is feasibility with two pilot lines followed by phase two, commercial operation. There are four lines planned for fitment, the two already in the table and a further two high speed lines south and east to Belgium and Germany which are to have level 3 fitted.

Mainlines are planned to be fitted with ETCS Level 3 between 2010 and 2020 (project BB).

France
There are two commercial projects in the planning stages; TGV Est, a line from Paris – Strasbourg, which is expected to be completed in 2005, level 2 or possibly 3 and the TGV Sud-Est, Paris – Lyon with the expected replacement of existing TVM300 by level 3 ETCS.

Level 2 ETCS may also be installed on TGV Mediterranean.

Germany
GSM-R radio system being fitted nationwide, for 2002 by Mannesmann Arcor. 170km of new railway between Koln – Frankfurt is to be fitted with LZB with the capacity to upgrade to level 2 by 2002. Along with Nurnberg – Ingolstadt.

Eventually all ‘LZB’ installations will be upgraded to ETCS Level 2 by the end of 2002

Switzerland
The ongoing test between Chur – Zurich is using a combination of ZUB vehicle equipment and Eurobalise technology to transmit the data. This test has been in operation for over three years now and will now be implemented on all trains which won’t be receiving ETCS cab signalling.

Article in rail international states that Olten Lucerne must be operational by autumn 2000.

Italy
The first country to provide a successful demonstration of ETCS level 2 on the Florence Arezzo line.
The following is the text of a Joint Report on Human Factors prepared for the Inquiry.

Southall and Ladbroke Grove Joint Inquiry: Human Factors

1 Purpose of this document

This document has been prepared for the Southall and Ladbroke Grove Joint Inquiry. That Inquiry has asked those human factors experts who have already presented evidence to establish common areas of agreement and disagreement. This document does not repeat the evidence already presented to the Southall and Ladbroke Grove inquiries or submitted to the Joint Inquiry. Instead the aim is to give general principles to which all the human factors experts listed in (2) below are in agreement.

2 Human Factors experts who have contributed to this document

The following psychologists and ergonomists have contributed to this document:

Professor Neville Moray, University of Surrey (ASLEF/RMT/TSSA)
Professor John Groeger, University of Surrey (ASLEF/RMT/TSSA)
Professor Helen Muir, University of Cranfield (ATOC)
Ms Emma Lowe, Railtrack Safety and Standards Directorate
Dr Deborah Lucas, HSE

3 Scope of this document

The Inquiry have requested that the human factors experts consider four aspects:

a) issues that have been identified as significant in human factors terms which are of potential relevance to SPAD prevention
b) what can be done to give practical effect to matters that have been identified as significant
c) areas where further research is required
d) the anticipated effect of human factors development on future SPAD risk
Annex 07 cont.

4 Consensus principles

We agree that the following principles apply to those significant human factors issues which are relevant to reducing the number of signals passed at danger.

DESIGN ISSUES

HF1 Human factors aspects of train driving cover not only the characteristics of the driver (e.g. route knowledge, alertness, etc) and the equipment (e.g. signalling, train controls and instruments, etc.), but also the interface between the driver and the equipment. Full evaluation of this human-machine combination is vital for the reduction of opportunities for human failures. Human errors do not cause problems unless the characteristics of the equipment allow them to. This analysis should be done by incorporating knowledge about human information processing, human reliability, and good ergonomic principles into the design and evaluation process. It is a serious weakness if well established principles of ergonomics are ignored. (Moray, Lucas, Groeger, Lowe)

HF2 When implementing a fully (or a partially) automatic protection system such as TPWS and ETCS it is essential that its evaluation should include
(i) whether the operators (signallers, drivers) fully understand how the system works
(ii) whether they understand its limitations (eg in terms of speed, operating conditions)
(iii) whether a study has been made of its failure modes and how the operator will respond when the system fails. Sooner or later all hardware and electronic systems fail. Operators must be taught what will happen when the system fails, what are the symptoms that show it has failed or is failing, and what actions they must take. (Moray)

HF3 The design process for new equipment eg cabs, interfaces of equipment in control rooms should consider human factors issues explicitly. Building the needs of the users of systems into design prevents human errors from arising. This requires early incorporation of human factors thinking and involvement of future users of the equipment in the design process. (Lucas, Moray, Groeger)

SIGNAL SIGHTING

HF4 Signal sighting principles and practice and signalling design must consider the limitations of human physiology and anatomy in particular:
(i) the reliability of colour discrimination in the periphery of the retina
(ii) the dynamics of visual attention especially where there are several objects in a visual field and
(iii) the impact of temporary interruptions of previews of the signal caused by changes of visual attention (eg between track, signal and in-cab instruments), signal obscuration, and changes in signal position on approach (eg when approaching a signal on a curve) (Moray, Groeger)
HF5 Complex signal and track layouts impose higher demands on drivers' route knowledge and attention. The designers of signals and signal sighting arrangements must recognise that more complex designs and minimal compliance with such standards as currently exist (eg GK/RT0031) impose additional demands on drivers and lead to more opportunities for human failures. Presenting information in a consistent and straightforward manner, avoiding anomalies, and reducing other visual distractors at signals should be the normal good practice for all signals. The principle should be that it should be possible to identify a signal directly and uniquely. (Moray, Groeger) There should be a requirement for an ergonomic assessment of the 'driveability' of a route for new signalling layouts. This is particularly necessary when such layouts are complex. (Lowe) The process for derogations or authority for non-compliance with such standards should consider carefully such human factors issues. (Groeger (eg use of theatre boxes and numerical route indicators), also from Wilkins (WS Atkins) and Bell (ASLEF))

WARNING DEVICES

HF6 Warning devices should be designed according to known 'best practice' ergonomic principles. This would ensure that it is clear to drivers what the warnings are signifying and what action should be taken. The inability of AWS to distinguish between cautionary and danger aspects is an example of an ergonomic design problem. (Groeger, Muir) The design of the current AWS system should be reviewed and an evaluation carried out of the technical feasibility of designing the system so that the auditory and visual signs directly indicate the signal aspect.

HF7 The use of existing warning devices to warn of other situations must be considered very carefully (eg using AWS to warn of other non-signal situations such as speed restrictions) since this may reduce its effectiveness as a primary warning to the driver of the need to stop the train. (Lucas) It is also important to consider the impact of other systems on existing warning devices, for example, on the introduction of TPWS or more advanced systems (Lowe). Warning devices which are fitted in cabs to alert drivers to signals can give rise to a level of dependence on the device. Such dependence, and the risks associated when it is not provided, should be considered for existing systems and during the design and risk assessments of new warning devices. (Groeger and Lucas)

TRAINING AND ROUTE KNOWLEDGE

HF8 A driver's knowledge of a number of 'routes' is a key element in the prevention of signal reading problems particularly for complex layouts. Human memory has known limitations. These limits need to be recognised and, where possible, other means of support given to drivers to reduce high demands on memory. The training and assessment of such 'route knowledge' would benefit from increased rigour, interactive, computer-based instruction and assessment rather than relying on verbal reports for the assessment of competence. (Groeger)
HF9 Drivers will rarely experience certain abnormal or degraded situations (eg driving with warning devices isolated) or emergencies (eg detraining passengers). Regularly encountering such situations in a simulated environment will assist them in dealing more effectively with any real-life occurrences. Simulators are becoming more widely used across many industries for initial and refresher training and for assessment of some elements of competence. Their use in the rail sector would be beneficial. The selection of the appropriate fidelity of simulation for such training should be based on a suitable analysis of driver training and assessment needs. (Southall inquiry, Groeger, Lowe, and Muir)

ALERTNESS AND FATIGUE

HF10 Reduced alertness due to the effects of fatigue or the repetitive nature of a task is one of a number of influences on the human performance of all safety critical staff. Good practice guidelines on shiftwork and the timing of breaks within shifts exist and should be used more widely within the rail industry. (Southall, Lucas)

DEVELOPING HUMAN FACTORS CAPABILITY IN THE RAIL INDUSTRY

HF11 Risk assessments should continue to consider those human failures which may initiate incidents or mitigate the consequences of accidents. Safety cases should consider fully the risks from human failures and their associated control measures. The further development, and use of, existing human reliability methods within the rail industry would be advantageous. The numbers of staff in the rail sector with sufficient knowledge of human factors would need to be increased for such assessments. (Lucas)

HF12 Signal sighting committees should be able to call on expert human factors assistance when complex layouts and signalling situations are in question. (Muir) Investigators of incidents should also have access to suitably trained and experienced specialists (Groeger).

INCIDENT INVESTIGATION

HF13 The investigation of incidents of signals passed at danger should be informed by human factors theories cast in appropriate investigatory tools. The causal analysis of such incidents and accidents should consider possible combinations of human factors relating to individual and system/equipment aspects and to the interface between individuals and systems. (Groeger) The information provided by on train monitoring recorders should routinely be investigated following a SPAD. Statistical analysis of data from such accidents and incidents should build on research already published including that on the influence of organisational and managerial factors on incidents. (Muir, Lucas) Suitable caution should be exercised when the attributed cause of a serious SPAD is solely dependent on the recollection of those involved.
Information reported by traumatised individuals can be unreliable and should be supported by other information sources (Groeger).

INCREASING THE AWARENESS OF HUMAN FACTORS

HF14 There is an awareness of the potential threat to safety caused by human factors. In order to understand the issues in more detail it is advised that information about the causes of error, the influence of different types of stress and workload on performance and the potential for fatigue, health, communication, etc. to limit performance is included in the training of safety critical staff and their managers. Such a requirement for awareness training is already in operation for pilots in the aviation industry. (Muir)

CONFIDENTIAL REPORTING

HF15 The confidential reporting of safety related incidents provides an important additional source of information to learn from and should be encouraged. Such systems of reporting also maintain a certain level of safety awareness among staff. There are clearly benefits in the expansion of the ScotRail CIRAS system to a nationwide scheme. (Muir)

MANAGEMENT OF DRIVERS

HF16 There are also issues around the management of drivers, particularly those who have been identified as 'at risk'. The use of the on train monitoring recorders (OTMR) to proactively evaluate the driving styles of such drivers would be a useful information source. (Lowe) The management of new drivers, especially those who have been recruited from outside the rail sector, is also a key area. Evaluation of the suitability of training and assessment regimes for this category of driver is recommended. (Groeger)

5 Benefits

In proposing these principles we are fully aware that they cannot eliminate all signals passed at danger and that a technical solution which would prevent those human errors which lead to serious consequences is needed. The design of any such technical solutions needs to consider human factors in order to avoid introducing additional risks (Groeger, Moray, Lucas) However, applying the above human factors principles should reduce the variability in the occurrence of SPADs between signals and between drivers and should therefore reduce SPADs overall. We are not currently able to quantify the likely extent of this reduction. However, we anticipate that paying attention to key human factors issues would prevent a proportion of SPADs which are currently categories as being due to ‘inattention', 'misread signal' and 'disregard signal'. The latter category include many SPADs which have had serious consequences.
6 Future research

R1 There should be a planned programme of human factors research supported by all parties in rail industry. The new human factors group within the Rail Industry Advisory Committee may be a suitable channel for steering this research programme. This programme should build on the review of existing work which has been collated by Railtrack S&SD. The review should also fully consider recent developments in the fields of ergonomics and psychology through consultation with appropriate experts. (Groeger). Insights from other industrial sectors should also be sought. A key goal of this research should be to develop pragmatic solutions to issues where there is already a body of evidence. (Lowe, Lucas, Southall) Dissemination of the results of human factors research through appropriate channels is needed. One example of this would be a regular seminar for the rail industry. Open publication and peer review of research sponsored in the rail sector should be another goal (Lowe, Lucas).

R2 Mechanisms for evaluating the effectiveness and practicality of any SPAD reduction measures proposed should be set up. Similarly there should be a process of risk assessing any such measures. (Lowe)

R3 Simulators should be used to collect empirical data on human factors issues where currently there is reliance on 'expert judgement'. An example of this would be the collection of eye movement data from drivers to explore the dynamics of visual attention in the driving task (Southall, Moray, Muir, Lucas, Groeger). Eye movement data should also be collected in real train driving situations to validate the simulator data although the risks involved must be carefully considered. (Moray, Groeger)

R4 Research to look at the extent of, and limitations of, route knowledge could lead to new ways of testing competence or methods of improving the effectiveness of route learning or associated job aids. Such research may also clarify what route knowledge is actually learned by drivers, its limitations, and the way it is applied. This would have implications for signal design, route knowledge training and retraining, and assessment (Groeger).

Ms Emma Lowe
Dr Deborah Lucas
Professor John Groeger
Professor Neville Moray
Professor Helen Muir

3.10.00
## Braking capability of rail fleet

<table>
<thead>
<tr>
<th>Serial</th>
<th>Class</th>
<th>Type</th>
<th>Service Brake (%g)</th>
<th>Emergency Brake (%g)</th>
<th>Note</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>315, 317, 318, 319, 320, 321, 322, 323, 325</td>
<td>AC/EMU</td>
<td>8.5</td>
<td>12.0</td>
<td>14, 13</td>
</tr>
<tr>
<td>2</td>
<td>455, 456, 465, 466, 442</td>
<td>DC/EMU</td>
<td>8.5</td>
<td>12.0</td>
<td>13, 3</td>
</tr>
<tr>
<td>3</td>
<td>310, 312</td>
<td>AC/EMU</td>
<td>7.5</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>313, 314</td>
<td>AC/EMU</td>
<td>8.5</td>
<td>10.0</td>
<td>1, 10</td>
</tr>
<tr>
<td>5</td>
<td>507, 508</td>
<td>DC/EMU</td>
<td>8.5</td>
<td>11.0</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>302, 303, 304, 305, 308, 309</td>
<td>AC/EMU</td>
<td>7.0</td>
<td>7.5+</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>411, 412, 421, 422, 423</td>
<td>DC/EMU</td>
<td>7.0</td>
<td>7.5+</td>
<td>8, 4</td>
</tr>
<tr>
<td>8</td>
<td>141, 142, 143, 144</td>
<td>DMU</td>
<td>7.0</td>
<td>7.5+</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>150, 153, 155, 156</td>
<td>DMU</td>
<td>7.0</td>
<td>7.5+</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>158, 159</td>
<td>DMU</td>
<td>8.5</td>
<td>10.5</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>165, 166, 168</td>
<td>DMU</td>
<td>8.5</td>
<td>12.0</td>
<td>13</td>
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<tr>
<td>12</td>
<td>Locomotives, 43, 87, 90, 91</td>
<td>Diesel and Electric</td>
<td>8.0</td>
<td>10.0</td>
<td>6, 11</td>
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<tr>
<td>13</td>
<td>Locomotives, 20, 31, 37, 47, 56, 58, 59, 60, 73, 86, 92</td>
<td>Diesel and Electric</td>
<td>6.5</td>
<td>7.5</td>
<td>6, 12</td>
</tr>
</tbody>
</table>

See notes overleaf…
General note

Most trains have some small improvement in braking performance if “emergency” is selected.

DMUs and EMUs built in the last 25 years have a three-step brake control. There is a further position “emergency” but this does not deliver an improvement in braking performance. Enhanced emergency braking (EEB) is intended for DMU/EMU with three step braking and disc brakes. EEB provides additional braking capacity when “emergency” is selected. All MUs built since 1994 have EEB fitted.

Notes

1. Could achieve 11.0\%g. Class 313 is probably exempted by the Group Standard
2. Merseyrail Rolling Stock
3. Class 442 has stepless brake control and a rate of 10\%g but is being considered for EEB
4. Slam door stock
5. EEB being considered
6. Stepless or 7-step brake control make it difficult to achieve 12\%g. Class 43 (HST) is being reviewed
7. Maximum speed not exceeding 75mph
8. Maximum speed 90mph
9. Class 309 maximum speed 100mph
10. Currently has an exemption from the Group Standard
11. Maximum speeds 110 – 125mph
12. Maximum speeds do not exceed 100mph
13. Classes 323, 465 and 168/9 are capable of 100mph or more and built with 12\%g braking capacity
14. Some of classes 317, 319, 321 and 322 have less than 12\%g braking capability and a maximum speed of 100mph. Retrofitting of EEB is possible.
Effectiveness of TPWS-A
position of signal and end of safety overlap in relation to stopping point

Speed on approach to over speed sensor

<table>
<thead>
<tr>
<th>Speed</th>
<th>&lt;41mph</th>
<th>74mph</th>
<th>100mph</th>
<th>125mph</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSS 1</td>
<td>187</td>
<td>576</td>
<td>950</td>
<td>1452</td>
</tr>
<tr>
<td>TS</td>
<td>217</td>
<td>636</td>
<td>1119</td>
<td>1722</td>
</tr>
<tr>
<td>End of Overlap</td>
<td>257</td>
<td>766</td>
<td>1379</td>
<td>2122</td>
</tr>
</tbody>
</table>

Tripped at TS
Tripped at OSS1

Distance in metres

Effectiveness of TPWS +
position of signal and end of safety overlap in relation to stopping point

Speed on approach to advance over speed sensor

<table>
<thead>
<tr>
<th>Speed</th>
<th>&lt;41mph</th>
<th>74mph</th>
<th>100mph</th>
<th>125mph</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSS 1</td>
<td>187</td>
<td>526</td>
<td>950</td>
<td>1452</td>
</tr>
<tr>
<td>OSS 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS</td>
<td>217</td>
<td>636</td>
<td>1119</td>
<td>1722</td>
</tr>
<tr>
<td>End of Overlap</td>
<td>257</td>
<td>766</td>
<td>1379</td>
<td>2122</td>
</tr>
</tbody>
</table>

Tripped at OSS1
Tripped at OSS2

Distance in metres
## Figures for Braking Rates and Stopping Distances

<table>
<thead>
<tr>
<th>Approach Speed</th>
<th>8%g</th>
<th>10%g</th>
<th>12%g</th>
</tr>
</thead>
<tbody>
<tr>
<td>41mph</td>
<td>257m</td>
<td>217m</td>
<td>187m</td>
</tr>
<tr>
<td>74 mph</td>
<td>766m</td>
<td>636m</td>
<td>526m</td>
</tr>
<tr>
<td>100 mph</td>
<td>1379m</td>
<td>1119m</td>
<td>950m</td>
</tr>
<tr>
<td>125 mph</td>
<td>2122m</td>
<td>1722m</td>
<td>1452m*</td>
</tr>
</tbody>
</table>

These figures are assuming:

- The train stop loops are at the signal
- A standard overlap of 183m from the signal
- An Over Speed Sensor placed 350m before the signal
- Distance from OSS to end of overlap is 533m
- The second OSS (TPWS+) is shown as 500m in advance of the standard OSS but this distance will be determined by trials yet to take place.

The use of 12%g braking may be limited by the rate at which energy can be dissipated. A rate of 9%g or 10%g maybe more realistic – with the consequently extended braking distance.

The figures in the graph indicate the distance travelled by the train after braking has been triggered by the TPWS.
Requirements and Objectives of Regulations for Fitment of ETCS to Major Rail Lines

(a) A requirement that trackside ETCS on the WCML is completed according to the current timetable;

(b) A requirement that trackside ETCS on the ECML is completed by 2005 or 2006;

(c) A requirement that full ATP protection is provided on the GWML by 2006 with the possibility of requiring a reverse STM for the FGW fleet;

(d) A requirement that all lines that carry trains above 100mph are fitted with ETCS by a date not later than 2008;

(e) A requirement that routes with a line speed between 75mph and 100mph are risk assessed within a specified time to establish the order in which ETCS should be fitted to them.

(f) A power vested in the HSE or Secretary of State to require that lines falling within (e) are fitted with ETCS;

(g) A requirement that routes with a line speed of between 60mph and 75mph are risk assessed to enable a decision to be made as to whether ETCS is justified on safety grounds;

(h) A power vested in the HSE or Secretary of State to require that lines falling within (g) are fitted with ETCS;

(i) A requirement that all new trains are fitted with ETCS to whatever extent is possible at the time they are built;

(j) A requirement that the current fleet is retrofitted with ETCS according to a realistic timetable, taking account of the speed of the trains, and where they operate;

(k) A prohibition against running a non-ETCS fitted train over an ETCS fitted line after 2010, unless TPWS provides equivalent protection;
Annex 10 cont.

(i) A prohibition against running any train over 100mph after 2010, unless it is protected by ETCS or other full protection.

(m) A requirement to establish a System Authority with powers to manage the installation of track and train equipment.

(n) A power to grant exemptions and amendments
Annex 11

Line-speeds and Fitment of train protection systems on the UK rail network

The map (Annex 11A) shows the distribution of line-speeds on the rail network. Annex 11B shows a possible arrangement for train protection systems in the UK, but this, like any arrangement, will be subject to many variables. The outcome and timings will be dependent on a number of factors. Key factors are line and route speed, traffic frequency and freight movements. Other factors are noted below.

1. The age and state of the signalling equipment on each route may influence the type of ETCS adopted.
2. The arrangement of the franchises and routes
3. The form of the regulations made for ETCS fitment by the UK Government
4. The form and interpretation of the European Directives
5. The resources available for signalling work
6. The need to equip routes which may have sections of line with speeds between 75 and 125mph rather than just the sections of routes with the higher speeds
7. The satisfactory completion of trials of ETCS equipment on both track and train
8. The satisfactory development of STM and reverse STM
9. That the TPWS fitment is completed to timetable
10. The satisfactory development of TPWS+
11. That an ATP risk assessment is completed prior to any major line speed increases.

Notes on the network schematic

The schematic is not to scale. It shows a possible distribution of train protection systems throughout the UK in the period 2010 – 2020.

i) West Coast Main Line – a mixture of ETCS Levels 1 and 2
ii) East Coast Main Line – ETCS Level 2
iii) Great Western Main Line, Midland Zone (Chiltern Railways) – BR ATP, similar to ETCS Level 1
iv) Lines not assessed for fitment with ETCS before 2010 will be equipped with a mix of TPWS, TPWS+ or RETB
v) Midland Mail Line will be fitted with ETCS Level 2
Rail network showing line speeds
An option for Train Protection System on the UK rail network by 2010 - 2020

ANNEXES

ANNEX 11B

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