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Train Protection - Review of economic aspects of the work of the ERTMS Programme Team

Prepared by **NERA**
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Train Protection - Review of economic aspects of the work of the ERTMS Programme Team

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This report presents the findings of the Economic Review Team that has assessed the economic components of the work of the European Rail Traffic Management System Programme Team (EPT) which has been reviewing different options for the implementation of ERTMS, which includes automatic train protection, in Great Britain. In particular the report covers the EPT "Final Report" of April 2002, and subsequent work up to December 2002. The report has been written by a team led by NERA, and including Professor Andrew Evans of UCL, Sedgwick Wharf and Corus Rail Consultancy. The report covers the choice of baselines for appraisal and options, impacts on railway capacity and railway operation, overall impacts on railway safety, inter-modal impacts, costs of installation, the risks of the project, and the role of cost-benefit analysis in the appraisal. The report endorses the main conclusion of the EPT April 2002 report that it would not be appropriate to implement ERTMS to the timetable proposed by the Joint Inquiry into Train Protection. However, it also concluded that the economic analysis in the EPT report contains many weaknesses and seriously over or understates important quantitative impacts.

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EXECUTIVE SUMMARY

Introduction and Methodology

This report is the Economic Review of the work of the ERTMS Programme Team (EPT), in particular of their "Final Report" (EPTFR) of April 2002 and of our understanding of subsequent work carried out by them since then. The review has been led by NERA, drawing on major contributions on transport safety from Professor Andrew Evans of University College London, from Adam Sedgwick of Sedgwick Wharf on railway safety and the railway industry, and from a team from Corus Rail Consultancy on unit costs.

In undertaking the review we have held five substantial meetings with the EPT and their consultants, and also had meetings with the SRA, Railtrack, *Df*T, the ROSCOs, and the Railway Industry Association. We have had extensive access to the unpublished background material used by the EPT in writing their report and reaching their conclusions. We have been in close touch with the HSE throughout our project, and have also had some liaison with the team undertaking the parallel Technical Review.

We have approached this study as a constructive review and not as an "audit". An audit would in some respects be too demanding, as it would be unrealistic to examine all of the very extensive work of the EPTFR, let alone subsequent work, for economic rigour. However it would also be too narrow, in that we have inquired not only into what has been done, but also into broader issues of policy analysis, such as the rationale underlying the assumptions, and the choice of options.

The EPT Reports and Ongoing Work

The Joint Inquiry into Train Protection Systems chaired by Professor Uff and Lord Cullen, following the Southall and Ladbroke Grove accidents, reported in March 2001, and recommended that the European Train Control System (ETCS) should be installed on the British main line network. Uff/Cullen also recommended that regulations should be made requiring that ETCS should be installed to a certain timetable. (ETCS is an element of ERTMS, and provides automatic train protection (ATP).)

Railway Safety and the SRA have subsequently set up and co-chair an ERTMS Programme Board (EPB), with wider industry representation, and with the HSE, ORR and *DfT* as observers. The EPB appointed the cross-industry EPT to produce an industry plan for ERTMS implementation, to be submitted to the Health and Safety Commission. The EPT work "has been done on the basis that ERTMS will be implemented in accordance with EC Directives".

Preceding the EPTFR were two earlier, unpublished reports: a Preliminary Report in August 2001, and an Interim Report in January 2002. The Interim Report considered five options for ERTMS implementation. Following this, the EPB asked the EPT to focus on Option 1 (the Joint Inquiry timescale) and a refined version of Option 4 (Option 4R – focused on a more advanced, radio-based version of ERTMS). The EPTFR compares each of these two options against a common baseline with no ERTMS, modelled and appraised over a 40 year period.

The EPTFR explains that there are three main reasons for implementing ERTMS: ***capacity and performance; interoperability;*** and ***safety.***

The EPTFR concludes that, relative to the TPWS baseline and at present traffic levels, fitting ERTMS, by reducing the number of ATP-preventable accidents, is likely to save on average around 1 equivalent life per annum initially. This rises to 2.8 equivalent lives per annum by 2042. However, because Option 1 reduces rail capacity, it would shift some traffic from rail to road, with a consequent increase in overall transport fatalities. The EPTFR estimates an increase of about 700 road fatalities over 40 years.

The Joint Inquiry timescale (Option 1) is estimated in the EPTFR to reduce the capacity of the rail network by 12.5 per cent, leading to a loss of 1 in 8 train paths, while Option 4R is estimated to increase capacity by up to 10 per cent (with complementary investment).

Option 1 is estimated to involve significantly more risk than Option 4R, primarily because of the rapid implementation period.

The EPTFR concluded that ERTMS should be implemented over a significantly longer timescale than that recommended by the Uff/Cullen Joint Inquiry.

Baselines and Option Choices

The baseline is the alternative, or "counterfactual", against which a proposal is compared. Baselines are often defined as "do nothing" or "do minimum" options, against which a selection of more proactive options is compared. This is essentially the convention adopted by the EPT: they compare ERTMS options against the current, programmed implementation of TPWS, with no subsequent ERTMS.

The use of this train protection baseline of TPWS means that measures of the effectiveness of ERTMS are dependent on estimates of the effectiveness of TPWS, which have varied markedly over time and between documents, though they now appear to be more stable. The extra safety benefit provided by ERTMS is likely to be further reduced by the installation of TPWS+ which is variously estimated to add a further benefit in the range of 3 to 8 per cent. At present, the EPT analysis excludes any consideration of this effect of TPWS+ because it is outside its formal remit.

Baselines for traffic and capacity over time were not developed in the EPTFR. The commercial analysis assumed a growth or contraction of traffic which exactly corresponded to the presumed capacity impact of the ERTMS systems installed. The consequent revenue effects emphasised the benefits of the more advanced systems. The safety analysis assumed 10 Year Plan traffic growth to 2010, and slower growth thereafter to give a doubling of traffic in 2043 relative to 2000.

It is becoming widely accepted that TPWS has had an adverse effect on capacity: if so this will have an impact on estimates of the capacity impact of ERTMS. This has not yet been considered by the EPT.

The selection of option choices in the EPTFR was designed to compare the Joint Inquiry timescale with a later timescale. For that function it served its purpose well, even though the reasons presented for preferring a later programme are in our view flawed because of explanations provided later in the report. It did not consider any other alternative options.

The EPT Interim Report considered a range of options, from which Option 4 was constructed, and then further refined to construct Option 4R. However if the case is accepted that Option 4R is a better choice than the Joint Inquiry timescale, this does not mean that Option 4R is the *best* choice. We believe that the industry should be encouraged to develop a range of plausible options for train protection, although many options are outside the remit of the EPT. These include the option of speed restriction until ERTMS is reliably available.

Railway Capacity and Railway Operation

The current EPT position is that, relative to the no-ERTMS baseline, ERTMS Level 1 will reduce signalling capacity by 5 to 15 per cent. This is materially different from the message given to the Joint Inquiry, which was led to understand that Level 1 would have no impact on signalling capacity. However, we believe that the EPTFR over-estimates the impact on system capacity. The effects of non-signalling constraints, intelligent placing of extra balises and substituting for TPWS all reduce the net capacity impact.

All of the EPT capacity modelling has used existing modelling tools, which are designed to model the use of trains on a given network. They have been the only models available to EPT, but they are not particularly well suited to modelling the effects of a change in the signalling system. It has also been assumed that very little adaptation of signalling rules and procedures will be feasible until trackside signalling is removed, although we believe that some early reoptimisation might greatly reduce the negative impacts of System B.

Railway Safety

The EPT's estimates of future railway safety risks are at present based on fault-tree analysis, in the form of Railway Safety's Safety Risk Model. This type of model has an important role in technical safety analysis and for some industrial activities it is the only way to estimate the absolute risk of accidents. However for the British railway system we are satisfied that, on the evidence currently available, the underlying level of ATP-preventable risk should be estimated from past accident data. On this basis we estimate that the EPT overestimates the absolute risks of ATP-preventable accidents by a factor of about 2.5.

Our own estimate is that the risk, at today's traffic levels, with TPWS and TPWS+ but without ERTMS, is one fatal ATP-preventable accident in about ten years, with an average fatality rate of four fatalities per accident. With ERTMS this falls to one ATP-preventable accident in about every sixty years. Allowing for the impact of capacity changes on rail travel demand and transfers to other modes, our estimates of annual changes in actual fatalities at 2001 traffic levels are set out in Table 1. These allow for reductions in ATP-preventable accidents due to installation of ERTMS, changes in other rail fatalities as a result of changes in rail traffic levels, changes in fatalities accessing rail stations, and changes in road fatalities due to changes in road traffic consequent on changes in rail traffic.

Table 1 Expected fatalities and changes in expected fatalities per year, at 2001 traffic levels

		Change in fatalities with ERTMS, and rail activity		
	Total fatalities with TPWS, but no ERTMS	***Reduced by 3%***	***Unchanged***	***Increased by 3%***
ATP-preventable fatalities	0.5	-0.5	-0.5	-0.5
Other rail fatalities	28.3	-0.9	0	+0.9
Rail access fatalities	Included below	-1.4	0	+1.4
Road fatalities	3,450	+5.4	0	-5.4
Total expected fatalities per year	**3,479**	**+2.6**	**-0.5**	**-3.7**

Unit Costs

A difficulty in assessing the realism of ERTMS cost estimates is that they are based on manufacturers' estimates of costs of equipment that are not yet being commercially produced. A further matter of considerable concern is the large increases in the costs of automatic train protection equipment, as is illustrated in Table 2. These cost increases are consistent with a general problem that costs of rail infrastructure have increased sharply in recent years.

Table 2 ATP installation costs (supply and fit), £2002 prices

		1993/94 BR-ATP Report	*1997 review*		*April 2002 (supplied by EPT)*	
		£'000	***£'000***	***Rise from 1993/94***	***£'000***	***Rise from 1997***
GW: Retrofit - 1 cab per vehicle	Train/cab*	50	80	68%	352	340%
	Track/signal	10	15	41%	72	380%
Chiltern: New – 2 cabs per vehicle	Train/cab*	30	56	83%	272	386%
	Track/signal	6	17	169%	72	324%

** The cost of a complete new multiple unit vehicle is about £750k (Modern Railways, September 2002, page 18).*

Capital costs are presented in the EPTFR as the sum of two components: "unrisked capital", and "risk on capex up to P80". The first of these is the basic estimate of capital costs, while the second is an estimate of an additional level of capital cost, allowing for risk, which is not expected to be exceeded with an 80 per cent probability. For Option 1, base capital costs are £3.4 billion and the risk element £2.6 billion. For Option 4R, base capital costs are £2.7 billion and the risk element £0.9 billion.

Our review of unit costs notes that in constructing these costs:

- Labour costs have been largely based on day rates, whereas for such a large scale project it is likely that lower rates could be negotiated for long term contracts; and

- Project management costs in the EPTFR are high, though these estimates have since been somewhat reduced.

Cross-Modal Impacts

We believe that the EPTFR considerably over-estimates the increase in road deaths arising from Option 1, and the decrease from Option 4R, mainly because they assume that all the reduction in rail capacity translates directly into a switch of passengers to road. In practice, a change in rail capacity will not lead to an equal proportionate change in rail travel, and all the displaced rail travellers will not switch to car. Our own estimates suggest that the EPTFR overestimated the increase in road fatalities, for their assumed lost of rail capacity, by a factor of four or five.

However, there would be important additional costs of inter-modal transfer if Option 1 were to be implemented, in the form of increased traffic congestion, air pollution, noise and greenhouse gas emissions.

We understand that this is an area where EPT is undertaking substantial new work.

Business Risk

The major difference between the risks involved in Options 1 and 4R is in the additional risks involved in the very tight timescale of Option 1. On the other hand later implementation has considerable technical development risk.

One risk not yet considered by the EPTFR is that of a major ERTMS-induced multi-fatality accident.

Presentation of risk by the EPT is dominated by Monte Carlo analysis of costs. This uses well-established methodology, and has a useful role, but often hides the judgements that underlie the overall risk estimates. It also focuses on the single dimension of costs, to the exclusion of time and performance.

Our main concern about the handling of business risk with respect to ERTMS is what we see as the absence of a strategic overview. The risk analysis which has been and continues to be done is of a high professional standard, but it needs to be complemented by higher level analysis, to provide those responsible for strategic decision making with the most constructive insights into the key uncertainties, into the judgements which they as decision makers need to make, and into the data on which these judgements need to be based.

The Role of Cost-Benefit Analysis

The more technical aspects of cost benefit analysis (CBA), such as valuation of non-marketed impacts, and identification of national as distinct from commercial costs and benefits, have a contribution to make to the appraisal of train protection options. However we see the most important role for CBA (and other appraisal techniques such as multi-criteria analysis), at this stage in ERTMS development, to be in the setting of frameworks. These frameworks include, in particular, the identification of objectives and of alternative options. On neither count is the appraisal of ERTMS yet developed. We recommend a review of the numerous and sometimes conflicting objectives of the industry's ERTMS activities, followed by the identification of alternative options, given that the UK already has an unqualified commitment to follow the ERTMS route.

Conclusions and Recommendations

We believe it is likely to be a year, or longer, before sufficient information is available to support firm policy decisions about ERTMS installation timescales for the British railway network as a whole. Our Review therefore supports the EPT conclusion that endorsing the Joint Inquiry recommendations on timing would be premature, and not now justifiable against the government's policy appraisal criteria.

At the same time we cannot endorse the economic analysis of the EPT Final Report. It contains many weaknesses and seriously over or understates important quantitative arguments.

More authority was claimed for the EPTFR than was merited by the quality of the work undertaken at the time, and this does not enhance the trust which the industry needs to develop with its stakeholders.

Many of the boundaries in the industry, between disciplines and between activities, are significant obstacles to efficient progress.

A wider range of strategic train protection options for the British railway needs to be developed and examined by the SRA and government, including options of speed restriction until ERTMS is reliably available.

Funding options for ERTMS need to be developed and modelled.

We assume that some regulation is needed to implement the EC directives. Any further regulation, if needed, should be designed to adapt to changing circumstances.

PART I: INTRODUCTION

1. BACKGROUND

1.1. OUR TERMS OF REFERENCE

We have been commissioned to undertake an Economic Review of the economic aspects of the work of the ERTMS Project Team, in particular their "Final Report" of April 2002. The Terms of Reference for this Review are recorded in Appendix A, as a set of Economic Questions. Also recorded are the Technical Questions specified for a parallel Technical Review managed by NEL.[1]

1.2. PROJECT ADMINISTRATION

This Economic Review has been led by NERA, drawing on major contributions from Professor Andrew Evans of University College London, on transport safety, from Adam Sedgwick, of Sedgwick Wharf, on railway safety and the railway industry, and from a team from Corus Rail Consultancy, on unit costs.

One aspect which we originally believed might merit some input is legal interpretation of the EC directives and possibly other aspects of the study. In the event we conclude that the Economic Review does not require this input, although at a later stage it might be relevant. In other fields the scope of the study has widened. While the terms of reference for the project were focused on the ERTMS Team Final Report, the work undertaken by the EPT after that report is more wide ranging than was originally foreseen. Also more complex than expected is the institutional environment, which has a material impact on the ground rules for the EPT's economic analysis.

One potential constraint has been the confidentiality of much of the documentation and other information in the industry, dictated mainly by the complex contractual structures binding together many commercially independent parties. However in practice, after all team members had signed a strong confidentiality agreement, this does not appear to have significantly prevented access to any information available to the EPT.[2]

We are grateful for prompt and constructive help in the early weeks from NEL. EQE, who carried out much of the work of the Technical Review, have also been most helpful in providing documentation. We met members of the EQE team on 19 and 27 September and 11 November, for open and useful discussions of the issues.

We have been in close touch with the HSE throughout. We met with HSE on 9 September, to launch the project and for a presentation by the EPT. We subsequently met on 7 November, to discuss our draft Interim Report; on 11 November, to meet the full Technical Team; and on 6 December to discuss our Draft Final Report. This Final Report is for presentation with the other review reports at a seminar at the HSE on 17 December.

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[1] *A third parallel review has been commissioned by the HSE on public attitudes, but work on that Review has been conducted independently of the Economic and Technical Reviews.*

[2] *Although the make up of the unit costs of ERTMS equipment remains less than clear. To protect commercial confidentiality, the EPT's cost data has been obtained by agreement through a third party on a consolidated basis.*

We have had five substantial meetings with EPT. The first was an overview meeting. Subsequent meetings were respectively on capacity, safety, and costs, and to get the EPT's reactions to our Draft Final Report. All five meetings included expert members or advisers to EPT in relevant areas.

We have also had three meetings with staff of Railtrack, and single meetings with the SRA, with a representative of the ROSCOs, with an RIA representative of the suppliers, and (on a non-attributable basis) with policy officials in *DfT*. We have also met and had several discussions with D*f*T technical staff. We have offered to meet Railway Safety, but this has not been taken up.

We would like to record the helpfulness of all those whom we have consulted, notably Stephen Jones and Nigel Williams of the EPT.

1.3. OUR APPROACH

We have approached this study as a constructive review and not as an "audit". An audit would in some respects be too demanding, as it would be unrealistic to examine all of the very extensive work of the EPT Final Report, let alone subsequent work, for economic rigour. However it would also be too narrow, in that we have inquired not only into what has been done, but also into broader issues of policy analysis, such as the rationale underlying the assumptions, and the choice of options.

We have not set out to "find holes" in the EPT's analysis or recommendations. We have seen our role as that of teasing out the key issues and helping in the process of understanding, revealing and justifying whatever best serves the national interest. Our objectives have been to support the EPT's recommendations to the extent that the evidence supports them, while identifying anything we see as possibly open to improvement, and suggesting how it might be remedied.

The HSE remit specifies "the EPT's Final and Interim reports [and] associated data sources". We have interpreted this, with the HSE's agreement, as including subsequent work.

Chapter 2 of this Report summarises, mainly for readers not already closely familiar with EPT work, the EPT Reports and ongoing work. Part II of the report, consisting of Chapters 3 – 10, contains our economic analysis of ERTMS, incorporating both a review of the EPT work and our own interpretations. In Chapter 11 we discuss the key economic issues. In Chapter 12 we present our conclusions and recommendations.

This Final Report subsumes our Inception and Interim Reports of 30 September and 8 November.

2. SUMMARY OF THE EPT REPORTS AND ONGOING WORK

2.1. BACKGROUND TO THE EPT REPORTS

The Joint Inquiry into Train Protection Systems chaired by Professor Uff and Lord Cullen, following the Southall and Ladbroke Grove accidents, reported in March 2001. It recommended that the European Train Control System (ETCS) – a key, safety-critical element of the European Rail Traffic Management System (ERTMS) - should be installed on the GB main line network. It recommended that regulations should be made requiring that ETCS should be installed to a certain timetable. It acknowledged that "the precise drafting of the regulations" would "require lengthy and detailed consultation", but made firm recommendations about dates, one being that all lines that carry trains above 100mph should be fitted with ETCS no later than 2008.

Railway Safety and the SRA have subsequently set up and co-chair an ERTMS Programme Board (EPB), with wider industry representation, and with the HSE, ORR and *DfT* as observers. The EPB appointed a cross-industry ERTMS Programme Team (EPT) to produce an industry plan for ERTMS implementation, to be submitted to the Health and Safety Commission (HSC). The EPT work "has been done on the basis that ERTMS will be implemented in accordance with EC Directives".[3]

Box 2.1 What is ERTMS?

The following is a summary version of the description of ERTMS in the EPT Final Report of April 2002.

ERTMS is a complex, modern train control system comprising the following:

1) The **E**uropean **T**rain **C**ontrol **S**ystem (**ETCS**) is a new system comprising complex computer equipment on trains and trackside. It is available at several levels, and the higher the level the better the effect on performance. It is supplied by six signalling companies, represented in Europe as UNISIG, and in the UK as RIASIG.

2) **G**lobal **S**ystem for **M**obile communications – **R**ailways (**GSM-R**), comprising fixed and mobile telecommunications, provides 'voice' radio. Higher levels of ERTMS require GSM-R to provide data transmission from the track to the train.

3) Rules and Procedures for Operations, starting with **H**armonisation of **E**uropean rail **R**ules for **O**peration of **E**RTMS (**HEROE**). Core rules for ERTMS are currently being prepared, but require significant national rule changes, particularly in the UK, where historically, "route" signalling has been used, as opposed to the continental practice of "speed" signalling.

4) Interfaces to traffic management, trains and signalling, which must be integrated with ETCS and GSM-R. The **E**uropean **T**raffic **M**anagement **L**ayer (**ETML**) is not yet fully specified or developed. The UK signalling principles will require rewriting for ERTMS at the higher levels of performance.

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[3] *EPTFR, p.5.*

2.2. THE EPT REPORTS

The EPT Final Report (EPTFR) was published in April 2002. This report, and a summary version of it, are the only published work of the EPT.[4] There were two earlier internal reports: a Preliminary Report in August 2001, and an Interim Report in January 2002. The Interim Report considered five options for ERTMS implementation, as shown in Box 2.2

Box 2.2 EPT implementation options

Option 1, Uff/Cullen network implementation scenario as set out in annex 10 of the Joint Inquiry report, which defined the timescales, sequence and priority of trackside fitment.

Option 2, the same scope, sequence and priority of trackside implementation as Option 1, but with the timescales varied according to resource criteria and other constraints.

Option 3, compliance with EC Directives on interoperability, where the timescales for ERTMS implementation are determined by the forecast asset renewal/replacement dates.

Option 4, a hybrid of Option 2 and 3, whereby the trains are fitted with ERTMS to a programme determined by Option 2 and the trackside is fitted with ERTMS when the signalling is replaced or renewed.

Option 5, another hybrid of Option 2 and 3, whereby the trackside is fitted with ERTMS to a programme and the trains are fitted with ERTMS when they are replaced or renewed.

Following the Interim Report, the EPB asked the EPT to focus on Option 1 and a refined version of Option 4 (Option 4R). The EPTFR compares each of these two options against a common baseline with no ERTMS. They were modelled and appraised over a 40 year time period.

The EPTFR (page 7) explains as follows that there are three main reasons for implementing ERTMS:

- ***Capacity and performance*** **-** to increase capacity at bottlenecks, facilitate enhanced train performance and help support the traffic growth envisaged in the SRA Strategic Plan. ERTMS can deliver a part of this, alongside other infrastructure investments, whilst reducing the complexity of trackside systems and decreasing maintenance costs.

- ***Interoperability*** **-** the main reason for EC legislation and support. This will enable trains to operate safely and effectively with control systems supplied in part or whole by different companies. This should result in greater mobility for trains across Europe and more open, competitive procurement. Multi-vendor application is a key requirement to be demonstrated.

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[4] *The report and the summary may be found in the Publications page of the website of the Strategic Rail Authority.*

- ***Safety*** **-** a means of providing Automatic Train Protection (ATP) to further reduce the incidence and consequences of signals passed at danger (SPADs), which is why Uff/Cullen recommended the adoption of ERTMS. As TPWS (which is due to be fully implemented in 2003 and has a design life of 15 years) significantly mitigates ATP-preventable risks, the relatively small additional risk reduction achieved by ERTMS (once TPWS is installed) appears not to be justified purely as a safety investment. However, providing a signal in the train cab through the use of ERTMS will be a major step forward for drivers, particularly at high speeds, in complex layouts, and under adverse weather conditions. ERTMS is effectively a requirement for trains to travel at over 125 mph; this is a safety requirement, but it means that ERTMS also has commercial benefits in this area. The higher levels of ERTMS will also facilitate improved management of "possessions" for track work, and require less trackside infrastructure, thus reducing risks to trackside workers.

Box 2.3 ERTMS levels and systems

ERTMS exists conceptually (although not yet in practice) at three levels, specified by the European Commission, as follows.

Level 1 is the simplest and most readily available. However it requires more trackside equipment than any variant of Level 2. The EPT consider two variants of Level 1, described as System A and System B. System B differs from System A in that for some signals it may have more than one trackside "balise" or beacon to communicate with the train, so that more up to date information is provided and less signalling capacity is lost.

Level 2 requires the development and commissioning of centralised computers, known as Radio Block Centres (RBCs), and GSM-R, and as a consequence has less trackside equipment than Level 1. It generally requires electronic interlockings, and most of the network does not yet have these installed. The EPT consider two main variants of Level 2, described as System C and System D. System C retains trackside signals. In System D they are removed. A subsidiary variant, System E, is designed for regional lines with low frequency services, and includes some, though much reduced, trackside infrastructure.

Level 3 requires more complex software than Level 2. It is not currently being offered by the suppliers. Level 3 is not considered in the work of the EPT, nor in this Review.

2.2.1. Safety modelling

Key findings of the safety modelling presented in the EPTFR were:

- The fitment of ERTMS is likely to save around 1 equivalent life[5] per annum initially, over and above TPWS, based on present traffic levels. This rises to 2.8 equivalent lives per annum by 2042 (EPTFR, p.38).[6]

- However, because Option 1 reduces rail capacity, there is expected to be a shift of traffic from rail to road, and a consequent increase in overall transport fatalities. The EPTFR estimates an increase of about 700 road fatalities over the 40 year period considered.

- High speed routes (17 per cent of the network) contribute 49 per cent of the ATP-preventable safety benefit; high density passenger routes with line speeds of between 60 mph and 100 mph (22 per cent of the network) contribute 33 per cent of the ATP-preventable safety benefit.

- The EPTFR considers the impact of installing and maintaining ERTMS trackside equipment on trackworker accidents. It also notes but does not quantify improvements in trackworker safety from the reduced need to install trackside equipment with more sophisticated ERTMS systems, and safer possessions. The EPTFR suggest that, while installation and maintenance of trackside equipment would cause a relatively small increase in trackworker fatalities, this would be counteracted by the effects of the other two factors.

2.2.2. Capacity modelling

The ERTMS Interim Report considered impacts on capacity of ERTMS systems A, B, C and D, concluding that maximising application of ERTMS without trackside signals (System D) would have the best capacity impact. Following this, the EPB asked EPT to focus on the impact of System D on specific bottlenecks such as Welwyn Viaduct, and to refine assessment of capacity impacts of system types, including results of Railtrack capacity modelling and input from ERTMS suppliers.

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5 *"Equivalent lives saved" are a weighted sum of fatalities, serious injuries and slight injuries.*

6 *These figures, which apply to ATP-preventable accidents only, depend upon the baseline assumption of what the level of train protection would be in the absence of ERTMS. The EPT analysis assumes that this would be provided by TPWS. The EPT Interim and Final Reports assumed TPWS effectiveness to be 81 per cent. (Although a supporting Work Package quotes a figure of 86 per cent in its executive summary and implies a value of 72 per cent in some of analysis.) Since the EPTFR the EPT have assumed a value of 75 per cent. As discussed below, this is likely to be increased by the installation of TPWS+ which is estimated by various parties to add a further benefit of 3 to 8 per cent.*

The EPTFR acknowledges that uncertainties remain about impacts on capacity, including network-wide effects, driver response times once a signal clears, impact of actual signalling layouts, and potential impacts of improved traffic management systems. Overall, the Joint Inquiry implementation strategy (Option 1) is estimated to reduce the capacity of the rail network by 12.5 per cent, leading to a loss of 1 in 8 train paths, while the EPT's preferred implementation programme (Option 4R) is estimated to increase capacity by up to 10 per cent (with complementary investment).[7]

The EPTFR suggests (page 60) that "because of the predominance of Level 1 and/or basic Level 2, Options 1, 2, 3 and 5 appear commercially unattractive and their degradation of network capacity seems unacceptable".

2.2.3. Costs

Capital costs are estimated as £6.0 billion for Option 1 and £3.6 billion for Option 4R. These costs are made up of two components. "Unrisked capital" (otherwise referred to as "base capital costs"), and "risk on Capex up to P80" (or "P80 capital addition"). The first of these is the basic estimate of capital costs. The second is the estimate of an additional level of capital cost, allowing for risk, which is not expected to be exceeded with an 80 per cent probability.[8] For Option 1, base capital costs are £3.4 billion and the risk element £2.6 billion. For Option 4R, base capital costs are £2.7 billion and the risk element £0.9 billion. The EPTFR notes (page 58) that the much higher risk element for Option 1 reflects the fact that implementation would start before sufficient completion of the development phase.

Train fitment labour costs are the same for both options, although retrofitting, which is more applicable to Option 1, is broadly twice as expensive as factory fitting in labour costs; and Level 2 trainborne equipment will be more costly that that for Level 1, because of GSM-R (although we understand that Level 1 has never been modelled). ERTMS Level 1 trackside fitment is broadly twice or three times as expensive as that of Level 2.

Whole life costs are described as being only at a pre-feasibility analysis stage. Over 40 years they are estimated at £3,036 million for Option 1, and £2,266 million for Option 4R.[9] Both trackside and on-train equipment are estimated to have a life of 20 years.

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[7] *Railway Safety and SRA, 2002, ERTMS: Towards a Better, Safer Railway System (Summary of EPTFR), page 9.*

[8] *This is a common procedure in engineering contexts. The Treasury Green Book conventions focus, in contrast, on the mean or "expected" outturn (although the recent consultation draft proposes that estimation of this mean should be improved by adding specific premia to the estimated costs, in the absence of clear evidence that risks have been adequately considered). The P80 convention is used in industry partly because private financiers are often much more concerned with cost of an overspend than with the benefits of an equal underspend below the expected value. However the main contrast between this Monte Carlo based approach and the information needed for policy decisions about major investment programmes is that of transparency. The 'expert opinion' judgements about probabilities built into these figures are appropriate for some purposes, but for policy analysis many key risks need to be presented in ways in which policy decision makers can apply their own judgement.*

[9] *EPTFR, p. 59.*

2.2.4. Commercial and economic modelling

The EPTFR includes a brief section on **commercial and economic modelling results**. The factors considered were:

- Safety;
- Capacity/performance;
- Capital expenditure;
- Maintenance;
- Whole-life costs;
- Signalling renewal cost savings; and
- "Macroeconomic/societal" – these were not considered in the commercial analysis, but some estimates were made of costs of journey delays.

Commercial factors were considered at an aggregate network level, rather than at an individual route level.

The main conclusion on commercial considerations in the EPTFR is that "Option 4 (refined – EPB Preferred Strategy) potentially offers both commercial and safety benefits through expected improvements in network performance and capacity".[10]

The Report concludes that the whole programme of ERTMS implementation would take over 30 years.[11]

2.3. IMPLEMENTATION

The EPTFR includes two chapters on implementation programmes, covering institutional, project management, contracting and legislative issues, which we have not examined as a part of this Economic Review, except in the context of identifying and considering business risks. They have limited economic content, and these issues, while vitally important, do not appear yet to be high priority, relative to the policy analysis of the broad implementation timescale.

2.4. THE EPT FINAL REPORT RECOMMENDATIONS

The EPTFR concluded that ERTMS should be implemented over a significantly longer timescale than recommended by the Uff/Cullen Joint Inquiry. This was because the industry's preferred strategy (Option 4R) would be:

- much cheaper (capital: £3.6 billion as opposed to £6.0 billion; and present value: minus £0.5 billion as opposed to minus £8.7 billion);
- better for transport safety, because the loss of capacity caused by early versions of ERTMS would drive people onto the roads, where many more would be killed, and because of a greater amount of track work.

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[10] *EPTFR, p.63.*

[11] *EPTFR, p.101.*

In the public mind the EPTFR may overlap another report on railway safety that was published three days before the EPTFR. This was a report by the Commission for Integrated Transport (CfIT), published under the title *Fact Sheet 10: The implementation of rail safety measures: implications for overall safety on the UK transport system*, on 22nd April 2002.

That report noted that the Government and the SRA were apparently signing up to the delivery of the Uff/Cullen proposals (ERTMS Level 1) within the Ten Year Plan period. Allowing for the impact of TPWS, CfIT estimated that this would reduce rail fatalities by 0.74 a year, but that rail capacity would be reduced by between 10 and 15 per cent. They reported the EPT estimates that, as a result of this capacity reduction, 7 to 10 per cent of current rail traffic would transfer to road, with a consequent additional 820 to 1230 road accidents per year, of which 14 to 22 would be fatal accidents.

On this basis CfIT concluded: "With these kind of fatality statistics, spending £3.5 billion on ERTMS does not seem to be the right way forward in improving overall transport safety". Instead CfIT recommended that implementation of ERTMS be delayed until an ERTMS system that did not reduce rail capacity could be implemented.

The EPTFR itself was published on April 25th. The Press Release issued by Railway Safety listed the key findings of the report as including the following:

- Level 1 ERTMS, which is available for earlier installation, reduces rail capacity by over 10 per cent, forcing more travellers to use the road network, and also requires additional trackside equipment with additional risks for track workers. "Rapid implementation of Level 1 would reduce transport safety overall."

- Planning should be based on the higher performance Level 2 system currently under development, but which is not ready yet. This could increase capacity by up to 10 per cent. "Preparatory work has started for the introduction of this ERTMS system through an SRA-funded Early Deployment Scheme initiative, to support national implementation from 2008."

The Press Release included comments from the SRA and from Railway Safety. According to Richard Bowker, Chairman of the SRA:

> *Today's report is a major step towards the development of the right ERTMS system for Britain which will provide the benefits of European compatibility, an even safer journey for passengers and greater network capability. Safety is paramount. ERTMS will be introduced.* ***But the basic systems ready for use now are simply not good enough and would actually reduce capacity and force people onto our already crowded roads.*** *(NERA's emphasis)*
>
> *This will be the biggest technical and operational change on the network for 100 years. It is essential that the system we choose is robust and reliable.*
>
> *The Health and Safety Commission has the programme team's very comprehensive and helpful report to validate. They will now consult on the report, and consider its implications. Meanwhile, the Project Team will continue with its development work to enable early deployment of the system as set out in the Strategic Plan.*

Rod Muttram, Chief Executive Officer of Railway Safety, noted that the EPTFR should be seen as the first step in implementing the right system.

2.5. WORK SINCE THE REPORT

The EPT "Final Report" was, despite its title, a very preliminary exercise. It has been described to us by the EPT as the end of a pre-feasibility phase. The EPT, and the industry more generally, are thus still in the early stages of investigating the way forward for what is, or should be, what the SRA describe as the biggest technical and operational change on the network for 100 years, with considerable cost and management implications.

It became clear during 2001 that the state of development of ERTMS was markedly less advanced than had been believed by the Joint Inquiry, and the work required within the industry to carry forward its development and implementation was considerable and wide ranging. As a consequence the work of the EPT continues strongly. On many issues the EPT's views and analysis have evolved since the EPTFR, and they continue to do so. As far as is practicable, we have taken account of this in our Review, through discussion with the EPT and review of some ongoing documentation.

PART II
THE ECONOMIC ANALYSIS OF ERTMS

3. THE SCOPE OF THIS REVIEW

3.1. THE SCOPE OF ECONOMIC ANALYSIS

The technical expertise needed to design, supply and operate the railway, and ERTMS, is overwhelmingly that of the engineer, systems planner, contract negotiator and project manager. Economics as a technical specialism can sometimes contribute useful numbers, such as valuations of quantities such as leisure time that are not marketed, and contribute ideas on incentive frameworks, such as empirically based advice on regulatory regimes. The scope for such contributions to the current, preliminary stage of appraising ERTMS policy options is fairly limited but in some areas important. We apply these to some extent in this Review.

However we turn also to the general principles of welfare economics, which ask simply what would best reflect people's preferences, albeit recognising that there are no definitive answers to ethical choices, such as the relative importance of different people's interests. Getting anywhere useful on such a question in a practical application depends heavily on data and expertise far beyond the competence of economics, but economics can help to provide a reasonably holistic framework.

Economics in both these senses is markedly different from commercial analysis. Indeed in public policy analysis, a contrast is often drawn between commercial analysis, where benefits are measured in terms of the commercial revenues and, possibly, institutional reputation, and economic analysis, which seeks to identify all interests.

Economics is also quite different from costing. Costs are essential to most practical economic as to commercial analysis, and economics has much to say about how costs should be measured for particular purposes. However it is not by chance that the analysis of unit costs in this Review has been handled by colleagues from engineering and contract specialisms rather than economics.

Economics as a discipline also places considerable weight on formal logic and on quantification. Thus its contribution to the understanding of safety risks is to look for methods of defining and quantifying peoples' preferences and then valuing then in monetary terms. Economics has no ethical stance on fairness, but it seeks, again, to identify how such concepts can be defined and how quantitative information can be constructed to help guide opinion formers and decision makers.

We make these explanations in part because, in the context of railways as elsewhere, the word "economic" is widely used in different and often ambiguous senses. A topical example is the current HSC consultation on automatic train protection, issued by the HSE on 7 November.[12] This asks, as one of five questions, "given the information on the safety benefits of ERTMS, should any decision to fit ERTMS be determined purely by economic factors?". Any sensible respondent will answer no, because public decisions should be determined with regard to all factors, and not purely by any subset. But the intended meaning of economic here is wholly obscure. Perhaps many readers would take it to mean "financial", having regarded especially to the government's or regulators' views on what can or should be afforded. Others might take it to mean "commercial", reflecting the interests of the industry. A few might wonder if it means what it means to economists, as the valuation of risk to reflect the considered preferences of those affected, but generally excluding the media driven consequences of some kinds of accident.

3.2. THE SCOPE OF OUR INVESTIGATION

The foundation of this Review is the set of Economic Questions prescribed by the HSE, as recorded in Appendix A. With regard to some of these questions, and some of the Technical Questions also in Appendix A, we were asked to consult the Technical Review Team and we have done so. However we have also addressed what we see as economic aspects of some of the other Technical Questions, relating to risk, capacity and safety.

Following discussion with HSE we have structured this final report into subject areas rather than the original questions. We have addressed some questions more comprehensively than others, reflecting their relative importance as this emerged during the study. We have also tried where possible to carry our various findings through to practical implications for ERTMS policy and for the future work of the EPT. We hope this will be of value to the industry as well as to HSE.

We hardly need say that, given the helpfulness of all those consulted, the dominant constraint on this Review has been time. As the work has progressed the potential avenues for exploration and clarification have continued to expand. However we believe that we have identified and assessed the key economic issues.

[12] *HSE Press Release C049:02.*

4. BASELINES AND OPTION CHOICES

4.1. GENERAL PRINCIPLES OF BASELINES

The baseline is the alternative, or "counterfactual", against which a proposal is compared. Baselines are often defined as "do nothing" or "do minimum" options, against which a selection of more proactive options is compared. This is essentially the convention adopted by the EPT, in a baseline formally agreed by the EPB. This is a baseline of implementation of TPWS (without TPWS+).

Economic Question 1 (see Appendix A), questioned the potential as a baseline of the EPTFR Option 3, defined as "compliance with EC Directives on interoperability, where the timescales for ERTMS implementation are determined by the forecast asset renewal/replacement dates". This would not however be a stable baseline. "ERTMS implementation" can describe any of a wide range of possibilities. "Forecast renewal/ replacement dates" are to a significant degree determined by management rather than externally imposed.

It has emerged that there are several aspects of the baseline for the ERTMS analysis, as we discuss in Sections 4.2, 4.3 and 4.4.

4.2. THE TRAIN PROTECTION BASELINE

The economic questions emphasise the train protection system baseline. For most purposes this is taken by the EPT as TPWS only. However this means that the quantification of the effectiveness of TPWS (and, as we discuss later, of TPWS+) directly affects estimates of the extent to which ERTMS reduces ATP-preventable accidents and expected fatalities. In practice estimates of TPWS (and TPWS+) have varied markedly over time and between documents, although they appear now to be more stable.

The EPTFR reported a figure for the reduction in ATP-preventable accidents achieved by TPWS of 81 per cent. The EPT are now using a figure of 75 per cent, which is not inconsistent with the HSE's assessment that the figure is in the range of 65–80 per cent. The installation of TPWS (and probably also TPWS+[13]) will thus considerably reduce the risk of ATP-preventable accidents. ERTMS will eliminate perhaps 80 to 90 per cent of the remaining ATP-preventable risk.

We understand that the EPT are not carrying out further work on TPWS. And any further work on TPWS+ (which entails fitting more trackside equipment, but no additional trainborne equipment) is seen by EPT as a matter for Railtrack.

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[13] *At present the EPT analysis excludes any consideration of this effect of TPWS+ because it is outside its formal remit. TPWS+ is variously estimated to add a further benefit in the range of 3 to 8 per cent. The recent West Coast Main Line Consultation published by the SRA recorded that "Trials recently have also demonstrated that the risk for higher speed trains with modern braking systems can be controlled further by implementation of enhanced TPWS, called TPWS+, with extra lineside track loops. This additional benefit is still to be quantified firmly, but an initial assessment is that the additional control will be in the order of 6-8 per cent, dependent on route section and traffics." (SRA, West Coast Strategy Consultation, Appendix, section B15)*

Besides data on TPWS and TPWS+, issues such as sensitivities to assumptions on, for example, driver behaviour, and on the trend over time in the effectiveness of TPWS, for example with increasing train speeds, also appear to us to merit more attention in the EPT work, even though this will entail drawing on data from elsewhere in the industry.

We also note below the relevance of TPWS to the capacity baseline.

4.3. THE TRAFFIC AND CAPACITY BASELINES

Baselines for traffic and capacity over time were not developed in EPTFR. The commercial analysis assumed a growth or contraction of traffic which exactly corresponded to the presumed capacity impact of the ERTMS systems installed. The consequent revenue effects emphasised the benefits of the more advanced systems. The safety analysis assumed 10 Year Plan traffic growth to 2010, and slower growth thereafter to give a doubling of traffic in 2043 relative to 2000.

EPT's continuing safety analysis takes account of known infrastructure changes in estimating the safety impact of alternative options. However for broader commercial analysis, or for cost benefit analysis, there is a need in due course for an integrated analysis of ERTMS and other infrastructure developments, at a disaggregated level, with alternative traffic levels. The EPT are planning analysis on these lines in 2003, probably using the PLANET model. However the communication barriers within the industry are a significant constraint. It is not clear that such work can be satisfactorily led by the EPT, as opposed to the SRA/Network Rail.

A problem faced by the industry is the political aspiration to much higher levels of traffic. There are obvious dangers in political aspirations being taken as a constraint on objective analysis. However we understand that analytically based forecasts are being developed in the SRA and by the EPT.

There is some indication that even the increases forecast for 2010 will require more "major investment", which we take to mean substantial investments beyond the existing plans for WCRM and Thameslink. The industry's difficulties in delivering these investments may suggest that the capacity increases promised by the higher levels of ERTMS could be very important. They also suggest that the industry would have major difficulties in delivering ERTMS before it has been fully developed and proven.

We understand that there is a view among train operators that TPWS has had a material adverse capacity effect. It is for example designed to oblige drivers always to drive "defensively", specifically by keeping within a 6%g braking curve when approaching a TPWS fitted signal at red, while the full service braking of modern multiple units is 9%g. Recommendation 34 of the Joint Inquiry encouraged HMRI to conduct research into the possibility of conflict between defensive driving and punctuality, which is essentially the same issue. Drivers can be deprived of the option of using the full capability of the train when running behind schedule.

We have been told that the capacity impact of TPWS will be taken into consideration in the forthcoming review and rationalisation of "the Rules of the Plan", the parameter values on which the timetable is built. However it does not appear to be considered significant by network planners at the strategic level. Nor has any such effect yet been considered in the EPT analysis. There is not yet enough hard data to formally model such an effect, and this appears to be seen as a reason to exclude it. This seems to us an example of over reliance on modelling distorting the bigger picture.

4.4. OPTION CHOICES

The selection of option choices in the EPTFR was designed to compare the Joint Inquiry timescale with a later timescale. For that function the choice made has served its purpose well, even if, as we explain later, the reasons as presented for preferring a later programme are in our view substantially flawed.

The EPT Interim Report considered a wider range of options. However these were essentially building blocks, from which Option 4 was constructed, and then further refined to construct Option 4R.

If the case is accepted that Option 4R is a better choice than the Joint Inquiry timescale, this does not mean that Option 4R as defined in the EPTFR, or even any closely similar option, is the *best* choice. Exactly what the crucial variables are is far from clear.

It has been put to us, and we accept as far as it goes, that Option 4R is an indication of the broad direction proposed by the industry, from which a series of more detailed options and variables are being developed and appraised. However the range of options and variables, even within the EPT remit is indefinitely large and we have seen no strategic analysis of the key choices which this detailed analysis needs to be designed to steer. Much industry is going into examining the trees; much less, so far as we have seen, into mapping the wood.

It may be that this structuring of the issues, for the options within its own remit, is within the scope of the EPT. Perhaps it is a role for the SRA. The EPT institutional structure certainly constrains the development of policy options. We note in Section 6.7 below how it constrains the baseline option. As for ERTMS related strategic options there is a raft of possibilities, some of which are clearly outside the EPT remit. However we suspect that the existence of the EPT weakens the incentive in the industry to develop wider options.

Perhaps the simplest and quickest train protection option is that of speed restriction. This would impose costs in terms of passenger time to offset against lower accident risk. However it is not clear how these time costs compare with the cost of installing ERTMS before it can provide substantial operational benefits to the railway, and minimal risks of serious cost overruns or performance shortfalls. The choice between time savings and the once in 10 years risk of an ATP-preventable accident remaining with TPWS/TPWS+ could then lie with passengers. We are not aware of any consideration of this option in the industry.

An intuitively less promising option, which should nonetheless be more clearly on the table, since it is being canvassed widely within the industry, is that of building new “greenfield site” “TGV” lines. This would:

- by-pass difficulties of major work on existing lines; and
- segregate high speed Intercity traffic from slower speed, stopping traffic.

This might mean, for example, that TPWS/TPWS+ would suffice for all but the new high speed lines.

Closer to the EPT remit, but probably still beyond their role to consider, are options such as:

- A strategy of concentrating development on increasing capacity for commuting into London. This might imply a heavy premium on technology that increased capacity without major track and structures work, possibly associated with investing in trains with uniform speed and acceleration. Speed above 100 mph might not be at a premium.

Other potential options overlap with consideration of business risk, which we consider later, but are nonetheless distinct options in response to certain risks – whereas the EPT analysis of risk is focused solely on risks associated with a given option. Examples might be options designed to respond to:

- Funding restrictions on the railway, which prevent a policy of installing ERTMS Level 2 on effectively all traction during a short time window;

- Railway redevelopment not being able to wait for ERTMS Level 2 becoming available;

- Non-viability of combining line side signals and radio-based updating of ERTMS-equipped trains, and with some trains ERTMS-equipped and some not (a possibility perhaps hinted in the apparent difficulties in reconciling "head-up" and "head-down" modes evidenced by the WCRM paper underlying the EPT capacity analysis).

5. RAILWAY CAPACITY AND RAILWAY OPERATION

5.1. EFFECTS ON SIGNALLING CAPACITY

ERTMS systems can lead to increases and decreases in signalling capacity.

All currently proposed ERTMS systems suffer transmission delays in the communications systems. (We understand that this is because the systems search for new information on a short but not insignificant time cycle.) The Level 1 systems, especially System A, suffer from the further problem that, on approaching a signal which changes from, say, red to green, the driver cannot respond until the cab reaches the trackside balise which gives this information to the train. There are choices to be made about the detailed operating rules, particularly with cab-signalling co-existing with line side signals, that can involve considerable restrictions.[14]

Offsetting gains in capacity should be provided by the flexibility opened up by ERTMS, in which signal and other information, such as speed restrictions, can be made more specific to the train and provided more quickly. This applies especially to System D, with the removal of fixed trackside signalling. For example the effective signal location can be optimised to changes in circumstances and to the type of train.

The current EPT position is that, relative to the no-ERTMS baseline,[15] ERTMS Level 1 will reduce signalling capacity by say 5 to 15 per cent, that ERTMS Level 2 as an overlay to trackside signalling (System C) might be marginally good or bad for capacity, and that Level 2 with no line side signalling (System D) would bring some signalling capacity benefit of say 10 per cent.

This is materially different from the message given to the Joint Inquiry. The Inquiry Report assumed that Level 3, which has now receded into the remote and uncertain future, would bring capacity benefits because of the use of moving block (although Railtrack's evidence was more that it would facilitate recovery from perturbations), and that ERTMS Levels 1 and 2 would have no capacity impact. The Inquiry heard from a supplier that Level 1 would bring capacity *gains*. Railtrack mentioned that single balise Level 1 (System A) would have a significant adverse effect on signalling capacity, and that the extra balises or loops to avoid this would make Level 1 extremely costly relative to the benefit – but this was in effect dismissed by a question implying that costs were not an issue for the Inquiry.

These impacts need in due course to be more seriously assessed. One issue is that of signalling rules and procedures, as discussed below. System A would not be installed system wide - as extra balises or loops would be installed in some locations. Some gains, such as the possibility at some signals that the train would know of a change to a favourable aspect before the trackside signal can be seen, are omitted. The technical assumptions generally are acknowledged to be conservative.

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[14] *These are illustrated by a WCRM paper "ERTMS/ETCS Overrun Intervention Thresholds" (RM/CSD/REP/10XXX, of 23 May 2001) that we understand formed the basis for the EPT analysis of the capacity effects of ERTMS.*

[15] *These are relative to a TPWS baseline in which it is assumed that the TPWS itself has no significant effect on capacity. It practice it now seems likely that TPWS does reduce capacity. It this leads to a change of baseline the negative impact of ERTMS Level 1 will fall, relative to the previous baseline, and the positive impact of Level 2 will increase.*

We note elsewhere that no account appears to have been taken of the baseline capacity impacts of TPWS and TPWS+.

5.2. EFFECTS ON SYSTEM CAPACITY AND TRAFFIC

A loss of signalling capacity will have little effect on traffic where the system is already constrained by other factors, nor where the system is not used to capacity. These effects are outside the scope of signal engineering and have not been analysed in depth by the EPT. The EPT work so far, while employing very complex modelling, has been based on extreme simplifications, partly because of limited data, but largely because of the need to use immediately available model structures, which are designed to handle marginal changes to the existing system, and in some cases are designed specifically to address commercial issues arising from the current performance regime.

One aspect of these system interactions is pinch points – as noted in Technical Question 10 (see Appendix A). Detailed analysis would be very complex. However our understanding is that the operation of the network has mostly been built around the pinch points and that the benefit from using ERTMS selectively to ease them would be limited. Using ERTMS only at pinch points would in any case probably require fitting all the trains using the pinch points, and most of the cost of ERTMS is in fitting the trains (EPTFR, Table 7, page 59 suggests 54 per cent in Option 1; 68 per cent in Option 4R). It also seems likely that much of the signalling to be fitted would be around pinch points (which typically would be complex junctions and stations). In this case fitting pinch points only would save relatively little installation cost or time. (Installation costs, access restrictions and delay costs are all at a premium at pinch points.) It would save no development cost. It would lose some direct safety benefit. It would introduce the risks of large numbers of drivers having frequently to switch between the ERTMS regime and the conventional regime. It does not appear to be a promising implementation philosophy.

We conclude that the negative capacity impact of ERTMS Level 1 is overstated. The effects of non-signalling constraints, of intelligent placing of extra balises, and of substituting for TPWS all reduce the net impact.

5.3. SIGNALLING RULES AND PROCEDURES

Technical Question 13 asks about WCML TCS, but the issue of rules and procedures is much wider – indeed fundamental to ERTMS implementation at Level 2.

All of the capacity modelling has used existing modelling tools, which are designed to model the use of trains on a given network. They are not particularly well suited to modelling the effects of a change in the signalling system, but they were the only models available to EPT. Furthermore many conservative assumptions have been used, implying a more restrictive regime in some respects than at present. Yet further, it has been assumed that no adaptation of signalling rules and procedures will be feasible until trackside signalling is removed. It seems to be generally assumed that nothing can change until system D is installed. This appears to be partly because the Rules of the Plan upon which timetabling is based are seen as extremely hard to change, and partly because, for some other changes to make operational use of the benefits of better train protection, HSE agreement would be needed. Some early reoptimisation might greatly reduce the negative impacts of System B. It has been put to us, and we accept, that the industry is undergoing a complex evolution even without ERTMS. What we have not found is evidence that ERTMS is satisfactorily integrated into the wider scene. Again this is largely outside the scope of the EPT. It is a further key issue which needs to be lifted from the mass of complexity.

A supplier giving evidence to the Joint Inquiry said that elsewhere in Europe it is generally assumed that any improvement in train protection will allow some operational gain. We have been told that this does not apply to the British railway because of its different methods of working, in particular the use of route based rather than speed signalling. The differences in methods of working are no doubt important. However we have not found a clear explanation why the usual principle does not apply that, if one constraint in a system is eased, the benefit can be increased by further adaptation. This is perhaps another example of key points being buried in the detail. These several conventions and constraints appear to be a major contributor to the claimed capacity impact of ERTMS Level 1 and possibly Level 2 System C. They appear to be accepted because they are seen as institutionally too difficult to change. However if the improvements in train protection offered by TPWS and ERTMS Level 1 do not justify any adaptation, this gives reason to doubt that ERTMS Level 2 will bring about more far-reaching adaptation.

There seems to be too little communication between the railway and HSE in this area. HSE should clarify its general position on adapting safety measures when new controls are introduced. The railway should identify adaptations that appear justifiable on the basis of TPWS, both to identify possible capacity benefits to the railway that might offset the capacity detriment that TPWS has probably brought, and to develop a practical understanding with the HSE of how improved train protection can be adapted to changes in signalling principles.

We understand that a major exercise is in hand to unify and update the Rules of the Plan – the very large set of mainly mandatory conventions needed to define how railway infrastructure and rolling stock can be timetabled for service delivery. It would be premature for ERTMS to figure prominently in this exercise, but it is surprising that it appears not to figure at all.

6. RAILWAY SAFETY

6.1. THE ECONOMICS OF RAILWAY SAFETY

The main contribution of economics to safety regulation in general is to the setting of safety standards, where (often in conjunction with psychology) it can sometimes provide monetary valuations of very small changes in risk of death or injury. The HSE is a leader in promoting and publishing high quality research in this field.

The basis for this valuation is people's willingness to pay. In European work this is usually derived by carefully designed and expertly managed surveys. The work has many pitfalls, especially because the changes being measured are so small, but methods have been developed which appear to yield consistent results. For convenience the results of such studies are expressed in terms of values per prevented fatality. Thus if it were found that people were willing to pay £0.90 for a 1 in 1,000,000 reduction in the risk of death, this would be expressed as a value per prevented fatality of £0.9 million. To such a figure is added other costs, such as ambulance and police costs. Values have also been derived for willingness to pay values, and other costs, for serious and for minor injuries.

Willingness to pay valuation is ethically contentious. In some countries it is politically unacceptable. However every country, like every individual, continually makes decisions in which small changes in safety are traded against other considerations, such as time or direct expenditure. The choice is not between valuing and not valuing. It is between valuing explicitly and valuing implicitly. In the UK the principle of explicit valuation has been accepted for more than 40 years in the context of road transport, and the transport ministry, at present D*f*T, has long been the lead UK government authority in deriving values for this purpose.

Even in the road context the principle is treated with great political caution. However for roads it has not, to the best of our knowledge, ever been a source of significant British controversy.[16]

The ethical objections, and the political concerns, appear to arise mainly from the contrast between public attitudes before the event, when taking some risk is widely accepted as a normal and unavoidable part of life, and attitudes after the event. In the case of road accidents and most railway accidents there is no public outcry. When someone is killed on a level crossing there is not generally a widespread demand there should have been a bridge. However train collisions which could be prevented by train protection have been seen by victims, and more especially by the media, in a very different way.[17]

This characteristic of train protection is certainly politically important. Whether it is also an ethical issue is less clear. In either event economics has little to contribute, beyond the observation that giving much more weight to people's safety in some transport contexts than in others cannot make the best use of given resources to reduce the suffering caused by transport accidents.

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[16] *In practice road safety investment falls far short of that which would appear to be justified by the DfT's published valuations.*

[17] *Even though this does not appear to be reflected in people's views before the event, where the usual attitude appears to be that "a life is life", and equally worth protecting almost regardless of the particular context.*

We understand that the SRA convention is to regard special political concerns such as those posed by train protection as a factor which cannot usefully be valued explicitly, and to value railway safety in the same way as road safety. The political dimension can then be considered alongside all other factors. This is in our view a sensible convention.

The term "societal concern" is often used by the HSE to describe the special public reaction to certain kinds of accident. It is sometimes proposed that a premium should be added to the value of an expected fatality on this account. This seems to us an inappropriate practice. While public furore is relevant to the political weight which will be given to reducing specific risks, it is a poor measure of the informed public preferences on which explicit valuations are in principle based. These effects are in any case much more a function of particular (fatal) accidents than they are of numbers of fatalities.

We note that the EPTFR uses the term "societal" in the HSE sense (in the terms "societal response" and "societal pressure" following certain types of accident), but also uses it in the very different sense of describing any impact other than the industry's financial costs and revenues (as for example in the EPTFR section 4.8.2). This second usage is confusing, and we understand it is has been dropped in the EPT's subsequent work. Also potentially confusing is the presumption in the EPTFR that all the non-commercial impacts are benefits, and that they are simply a figure to add to the commercial impacts. Neither presumption is correct.[18]

Estimates of the impact of safety expenditure are often expressed in terms not of prevented fatalities but of prevented "equivalent fatalities". Equivalent fatalities are the weighted sum of fatalities and non fatal injuries. Accident injuries are nearly always classified as either major or minor. The exact classification and exact weightings vary between contexts, but on the railways in Britain, as in the work of the EPT, one fatality is taken as equivalent to ten major injuries or two hundred minor injuries.

6.2. THE EPT ESTIMATES

The safety differences between the options now being considered are extremely small. Using any plausible value of risk to reflect the wishes of taxpayers or railway passengers, they are swamped by the other cost and benefit differences between options. However the absolute impacts, although exposing individuals to minute risks, have an exceptional political profile relative to other safety risks, on the railway or elsewhere.

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[18] *The balance of non-commercial impacts, or external; costs and benefits of ERTMS will almost certainly be a significant net benefit. But there will be some costs. One such cost might be the negative impact on the economy of any extra public spending required by the programme, although this effect is not explicitly valued in current Treasury guidance. The interaction of external costs and commercial costs is complex. For example insurance premia are commercial, but if the damage which they are insuring against is included in a CBA they are not social costs. There is also obvious scope for confusion at the many commercial boundaries within the industry, in distinguishing whose commercial interest is being measured and how any particular measure of cost or revenue interfaces with a national CBA.*

The EPT's estimates of risk are in terms of equivalent fatalities. In train accidents the ratio of equivalent fatalities to actual fatalities is about 1.5. The EPT's estimate of ATP-preventable risk before TPWS is 9.2 equivalent fatalities per year in 2001.[19] This is expected to rise in future broadly in proportion to passenger numbers. If TPWS were fully operational in 2001 and prevented 75 per cent of the ATP-preventable risk, the remaining risk, with EPT risk estimates, would be 2.3 equivalent fatalities per year. These would also rise broadly in proportion to passenger numbers. Once installed, ERTMS would prevent most of these, so the APT safety benefit of ERTMS depends on the timing of its installation. ERTMS is installed faster under Option 1 than Option 4R, so its calculated safety benefits are somewhat higher: the EPTFR estimated these as 83 and 74 equivalent fatalities respectively over 40 years. Both these figures would presumably now be re-estimated by the EPT to be somewhat higher, as a consequence of the agreed reduction in the estimated effectiveness of TPWS. However, as explained in the following section, we believe that for another reason they should be significantly lower.

Many technical aspects of the EPT work on passenger safety are questionable, but we do not believe these doubts are material to the policy conclusions.

6.3. THE PROJECTION OF ATP-PREVENTABLE FATALITIES

We have considered carefully the EPT's consultant's explanations of why the EPT estimates of future railway accident risks are based on Railway Safety's Safety Risk Model (SRM). However we are persuaded that, although there is a important role for the SRM in some contexts, it is not appropriate for estimating absolute risk differences in this study. The arguments are set out in Appendix B. The estimates should be based on data on accidents over the past few decades in Great Britain and the rest of Europe.[20] The use of the SRM overestimates the differences in absolute railway risks by a factor of about 2.5.

In terms of fatal accidents and fatalities, we estimate a frequency of about 0.5 ATP-preventable accidents per year before TPWS at 2001 traffic levels, and an average of about 2 fatalities per year (actual rather than equivalent). If TPWS and TPWS+ removes 80 per cent of these, the remaining risk to be prevented by ERTMS is about 1 fatal accident in 10 years, or an average 0.4 fatalities per year at 2001 traffic levels. It follows that for each 10 years for which ERTMS is delayed, we could expect the occurrence of one fatal ATP-preventable accident (with an average fatality rate of four). If rail traffic increases as planned, this frequency would rise accordingly.

6.4. THE IDENTIFICATION OF RAIL JOURNEY RISKS

The EPT has defined journeys (whether road or rail) as beginning and ending at railway stations. This leads, probably, to a proportionately large underestimation of the railway risk avoided if passengers are driven off by lack of capacity, because the risk of death or injury in the journey to and from the stations may be many times greater that the risk on the train. Railway risks other than the small proportion which are ATP-preventable also appear to have been ignored. This issues are discussed in their intermodal context later, in Chapter 8.

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[19] *Interim Report document WP A4.2 (electronic filing) or Work Package A4.3 (hard copy numbering), December 2001, Table 5, page 20.*

[20] *The leading analysis of British and European a railway accident data and its application in Great Britain has been carried out in recent years by Professor Andrew Evans, who is a member of our Economic Review Team. We must stress that the rest of the team has therefore considered the technical issues especially critically, so as to avoid favouring one estimation over another for any reason other than the merits of the arguments.*

6.4.1. Railway access risk

Data from the National Travel Survey[21] show that 73 per cent of passenger journeys on the national rail system involve at least one 'walk stage', that is an access journey on foot, and some might involve more than one. There are no direct data on the average distance walked in such stages, but an estimate of 1 km walked per rail passenger journey seems reasonable. In 2001 there were 963 million railway passenger journeys.[22] If ERTMS led to a rise or fall in rail passenger traffic of 3 per cent, it would add or subtract 29 million journeys per year, and thus about 29 million kilometres of walking in access. Walking is one of the riskier modes of transport: in 2000, the fatality risk was estimated by the Department for Transport to be 0.048 fatalities per million kilometres walked (unpublished but publicly available). Thus the extra rail journeys would lead in an additional 1.4 expected fatalities per year in access. This is a small number, but it is of the same order of magnitude as the other railway journey risk changes being considered.

6.4.2. Other railway risks

Even before the installation of TPWS, ATP-preventable accidents represented a fairly small minority of all railway risks. In the six years from April 1995 to March 2001, there were 209 fatalities on the main line railway, excluding trespassers, of which 39 occurred in three ATP-preventable accidents (at Watford Junction in 1996, Southall in 1997 and Ladbroke Grove in 1999), and 170 in other fatal accidents (HMRI annual reports). Therefore there are about 28 non-ATP-preventable railway fatalities per year at 2001 traffic levels. If railway traffic were to change for any reason (such as extra capacity), it is reasonable to presume that non-ATP-preventable fatalities would change in proportion. Thus, for example, if railway activity increased by 3 per cent, one might expect about 0.9 extra non-ATP-fatalities per year. Even this small change is larger than the safety benefits of ERTMS.

6.5. DISCOUNTING OVER TIME

The discounting of safety benefits is tricky and is not an issue addressed in the EPTFR, in which it was decided not to value, nor therefore to discount, expected fatalities or equivalent fatalities prevented. Discounting would have a noticeable effect on the present values of the figures over 40 years, especially as they increase over time. We are sceptical of the value at this stage of aggregated, long term calculations of safety impacts (with or without discounting). More useful at this stage are single year estimates, supplemented by projections of how quantities change over time. However we record in Box 6.1 a note on the discounting of safety benefits, where the conceptual basis now adopted by the EPT, as it has been explained to us, could be slightly developed.

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[21] *Focus on Personal Travel, 2001, Table 3.8, p.23.*

[22] *SRA National Rail Trends, September 2002, Table 1.2b.*

Box 6.1 Time discounting of safety benefits

The UK government discount rate has since 1990 been explicitly based on “social time preference”. This rate is defined for discounting future real expenditure - that is expenditure (or expenditure savings) in “real terms” (i.e. at a constant general price level, as opposed to increasing with general inflation), normally as public expenditure. This social time preference rate conventionally has two main components.

One component, generally the larger, reflects the fact that the welfare or utility enjoyed from an extra £1 will be less for a richer than for a poorer population, because people will generally spend money on what is most important to them, so that extra spending will be on less important goods and services. The size of this effect depends upon the ‘elasticity of marginal utility of money’. The Treasury has decided, in its current revision of the discount rate, that the value of this elasticity should be taken as 1. This means that this component of the discount rate is equal to the rate of forecast annual per capita income growth, which is taken by the Treasury to be 2 per cent. This component is generally seen as an empirical issue, with no significant ethical component.

The other component is often described as pure time preference. This may in part reflect a non-ethical consideration that some general man made or natural catastrophe may prevent the future cost or benefit materialising, and in part people’s individual time preference about their own benefits from public actions. However it also reflects, more contentiously, the fact that most people, while caring a great deal about future populations, do not care quite as much as for the present population – rather as people evidently care more for populations culturally close to them than to those more distant. In the discount rate now being introduced, the Treasury has set this component at 1.5 per cent.

In public debate about environmental and, less often, safety policy there is often confusion about the discounting of quantities which change in value through time. It is sometimes presumed that in CBA environmental or safety impacts are given a constant value through time, and discounted at the same rate as conventional costs and benefits. However in practice the real value of such impacts increases through time with income, so that the effective discount rate applied to, say, expected fatalities prevented is less than the rate applied to pounds of expenditure.

This can be handled in two arithmetically different ways. One way is to be assume that the suffering caused by death or injury is independent of income. The impacts can then be left with a constant value and discounted at the pure time preference component of the discount rate. Alternatively the values of these special impacts can be increased through time, and then discounted at the standard rate. The first approach is more direct and avoids the errors which can arise from increasing the impacts at an inappropriate rate. (For example it is a convention in transport to update the value of prevented fatalities, between major reviews, by the rate of increase of GDP. However if this rate is applied over a period of years to impacts which are then discounted at the previous discount rate of 6 percent, this seriously over-discounts them.) However is simpler to explain the use of a single rate that separate rates. We understand that the EPT prefer this second approach, compounding the values at 2 per cent and discounting at 3.5 per cent.

Whichever arithmetic process is adopted the rationale needs be clear. Mistakes are otherwise likely.

We note that the Treasury specified in its recent Consultation Document that the discount rate should be reduced from 6 per cent to 3.5 per cent and that the new discount rate should be applied with immediate effect to policy analysis, although not yet to projects seeking approval. It seems to us that, from the government perspective, the work of the EPT falls into the category of policy analysis.

6.6. OTHER TECHNICAL ASSUMPTIONS

Some other technical assumptions are open to question, such as an assumption of a quadratic increase in risk with increasing traffic density. However the quantitative effects of these other assumptions appear to be small. The concern which they raise is rather the pervasive "wood for the trees" problem of the EPT work. Over-concern with detail and "black box" modelling conceals the bigger picture that is needed for policy advice and decisions.

6.7. TPWS AND TPWS+

We note that the EPT assume that the percentage change in the number of expected accidents with TPWS is the same as the percentage change in the number of expected fatalities, implying that the distribution of fatalities across ATP-preventable accidents is the same with and without TPWS. We do not challenge this, but it should be made explicit.

It has been explained to us that the figure of 2 per cent quoted in EPTFR for the effectiveness of TPWS+ should be ignored, and that the EPT analysis is now closer to the figure of 6 to 8 per cent estimated by the SRA for WCRM. However the TPWS/TPWS+ base case has not been as carefully examined as it needs to be to provide a reliable comparator for the ERTMS options. We understand that this omission follows from the institutional structure of the EPT, which we discuss further in Section 11.

TPWS+ appears to have considerable potential for reducing ATP-preventable risk in the period before general installation of ERTMS. This is obscured in the EPT reports, and, as noted above, EPT do not plan further work in this area. The EPTFR reported that TPWS+ could reduce the post-TPWS risk from 19 per cent of previous ATP-preventable risk to 17 per cent. As noted above, later work is interpreted by EPT as meaning that TPWS+ could reduce the post-TPWS risk from about 25 per cent of total ATP-preventable risk to about 20 per cent.

Assessing the effectiveness of TPWS+ is subject to major uncertainties, especially in terms of the implication of new rolling stock, with higher speeds tending to reduce the effectiveness of TPWS and increase that of TPWS+, counterbalanced by improved crashworthiness. It would seem likely that taking account of these trends elsewhere in the system would lead to a higher estimate of TPWS+ effectiveness than not doing so.[23]

TPWS+ is not only an interesting safety measure in its own right, but may offer some "hedge" against errors in estimating the effectiveness of TPWS. It involves no technical development, no cost in fitting trains, and only about 700 signals. The timetable for fitting TPWS+ appears to us to be an important element in the development of train protection. The EPT analyses envisaged TPWS+ installation in 2007. It seems to us there is a case for installation with more urgency (subject to the comment below), perhaps by the end of 2003, the deadline under the Regulations for completing TPWS installation on trains. If this meant that other expenditures of lower safety benefit were delayed it would provide more safety for the given budget, (although we accept that, if this gave cause to question the timing of any spending required by regulation, this should not be revised slightly).[24]

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[23] *The work to improve crashworthiness has been focused on reducing driver vulnerability in relatively slow speed (up to 40 mph) collisions. This will have limited value in high speed collisions. We are not aware of work to improve emergency braking beyond the 12%g that has been standard on new multiple units for many years. This suggests that the higher speeds that new rolling stock can deliver will be the dominant safety effect.*

[24] *Railtrack/Network Rail propose to fit 700 signals with TPWS+. If this captures 7 per cent of ATP-preventable risk, each TPWS+ signal captures about twice as much risk as the average TPWS signal (about 14,000 signals capturing about 70% of the risk). The cost per signal should be less than average, because the*

TPWS+ must be presumed to have some adverse effect on capacity (unless mitigated by adaptation of capacity-reducing control measures). It seems that the railway has not evaluated this (just as it is only now coming to evaluate the adverse capacity effect of TPWS). The railway should check that this is not a major effect, and ensure it fits only those signals where there is net benefit.

6.8. TRACKWORKER RISK

The impacts on trackworker accidents of ERTMS Level 1 installation are so small that they begin to merge into the effectively infinite noise of consequential impacts of any economic activity. For example the construction and transportation of the materials will undoubtedly contribute to deaths. More importantly, the trackworkers, if not installing ERTMS, would be carrying out some other activity which would not necessarily be much less risky, especially given a trend to reducing the risk of track work. We have therefore not examined these figures closely. We understand that the EPT share this view of the materiality of the incremental trackworker risks.

Given the very small differences in passenger safety between ERTMS options, the estimated trackworker risk is significant relative to the safety comparison of some options – which may be a material ethical and political issue, although it would not be significant in a conventional CBA.

Total trackworker risk would of course increase if the loss of capacity from ERTMS Level 1 required more track work to restore capacity by conventional means.

6.9. SUMMARY OF CHANGES IN SAFETY RISKS

It is useful to summarise the absolute risks and risk changes discussed above in a single table. We include also the changes in road risk brought about by inter-modal shifts considered in Chapter 8 below.

The first column of figures in Table 6.1

Table 6.1 gives the absolute numbers of fatalities per year at 2001 traffic levels, if TPWS (but not TPWS+) were fully installed. The third column of figures shows the effect of ERTMS alone, with no associated impact on passenger traffic. The second and fourth columns show the effect of ERTMS, if it were with associated a change in passenger traffic either downwards, as might follow from system-wide ERTMS Level 1, or upwards, as might follow from system-wide ERTMS level 2. (The changes of passenger numbers in the Table of 3 per cent might be the consequence of a 10 per cent reduction in rail capacity, as discussed in Chapter 8).

The road fatality impact of 5.4 in the second and fourth columns of figures in Table 6.1 is derived as follows.

(huge) development/project control overheads are sunk. TPWS+ is not economic in CBA terms against willingness-to-pay values per expected fatality prevented, but it is prima facie the best buy going in terms of train protection. The case for installing it now rather than later, and for installing it instead of applications of TPWS with safety benefit a fraction of that of TPWS+, needs to be recognised.

In 2001 there were 473.7 billion motor-vehicle-km and 3,450 road fatalities, including non-vehicle occupants, giving an overall fatality rate of 7.28 fatalities per billion vehicle-km (*Road Accidents Great Britain 2001*, or Table 8.2 below of this Report). In 2001 there were 38.6 billion rail passenger-km (*National Rail Trends*). If ERTMS-induced capacity reductions or enhancements of 10 per cent caused 3 per cent of these passenger-km to transfer to or from roads, there would be 1.16 billion more or less road passenger-km.[25] If these are converted into vehicle-km at an average car occupancy rate of 1.56, there would be 0.74 billion more or less road vehicle-km. If the fatality rate for these vehicle-km, including fatalities to non-vehicle occupants, were the same as the average above of 7.28 fatalities per billion vehicle-km, they would cause 5.4 more or less road fatalities than would otherwise be expected to occur.

Some observations on the results are the following.

- The changes in fatality risk brought about by ERTMS are small compared with the absolute risks, even for railways alone.

- Changes in capacity caused by ERTMS appear to lead to changes in *non*-ATP-preventable railway accident risks, and in railway access risks, which are larger than the extra ATP safety benefit. This is not however apparent in the EPT analysis.

- The qualitative conclusion in the EPT report that changes in road risk brought about by intermodal shifts in one direction or the other are greater than changes in rail journey risk is correct. However, the magnitude of the changes in road risk is much smaller than is indicated by the EPT report. This is further developed in Chapter 8.

Table 6.1 Expected fatalities and changes in expected fatalities per year, at 2001 traffic levels

	Total fatalities with TPWS, but *no ERTMS*	**Change in fatalities *with ERTMS*, and rail activity**		
		***reduced* by 3%**	**unchanged**	***increased* by 3%**
ATP-preventable fatalities	0.5	-0.5	-0.5	-0.5
Other rail fatalities	28.3	-0.9	0	+0.9
Rail access fatalities	Included below	-1.4	0	+1.4
Road fatalities	3,450	+5.4	0	-5.4
Total expected fatalities per year	**3,479**	**+2.6**	**-0.5**	**-3.7**

If the no-ERTMS baseline were taken to include TPWS+ the first row figure of 0.5 would fall to about 0.4.

If changes in trespasser fatalities were included on the same basis as other fatalities, they would materially change the numbers of “other rail fatalities”.

[25] *The “frequency elasticity” of 0.3 is as advised by DfT, as noted in Table 8.3 below.*

7. UNIT COSTS

7.1. INTRODUCTION

This Chapter is concerned with the assessment of the unit costs underlying the ERTMS report, in accordance with Economic Question 3. While we have had access to detailed spreadsheets showing the calculations on which base capital costs were made, the main difficulty is in assessing whether the actual costs quoted for trackside equipment and for on-train equipment are realistic, given that they are based on manufacturers' estimates of costs of equipment that are not yet being commercially produced.

One of the European Commission's prime motives in seeking interoperability of equipment, which is the dominant objective of the ERTMS legislation, is to bring effective competition into the railway supply market place. Success in developing interoperable ERTMS should bring major economies in its wake, compared to the previous model. Arguably, the cost reductions seen in the supply of new trains, where costs have fallen considerably in the last five or ten years, indicates the potential. One important criterion for choosing an ERTMS development strategy would seem to be that it gives assurance of genuine common standards for suppliers.

We have constructed Table 7.1 to illustrate how train protection costs appear to have grown to a surprising degree over time. The 1993/94 and 1997 figures have been updated to 2002 prices by reference to the retail price index (RPI).

Table 7.1 ATP installation costs (supply and fit), £2002 prices

		1993/94 BR-ATP Report[26]	**1997 review[27]**		**April 2002 (supplied by EPT)**	
		£'000	**£'000**	**Rise from 1993/94**	**£'000**	**Rise from 1997**
GW: Retrofit - 1 cab per vehicle	Train/cab*	50	80	68%	352	340%
	Track/signal	10	15	41%	72	380%
Chiltern: New – 2 cabs per vehicle	Train/cab*	30	56	83%	272	386%
	Track/signal	6	17	169%	72	324%

**The cost of a complete new multiple unit vehicle is about £750k (Modern Railways, September 2002, page 18).*

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26 *Report from British Railways Board to Secretary of State for Transport, March 1994, paragraph 73*

27 *Review of economics of BR-ATP pilots by Sedgwick Wharf for Railtrack, Spring 1997. Cost data from TCI Consultants, formerly BR Projects, subsequently taken over by AEA Technology, checked by train operators and Railtrack Zones for BR-ATP pilots. Communicated to HMRI 3 July 1997.*

Hourly labour costs will have increased faster than the RPI, but we would expect that this would normally be offset, to a greater or lesser extent, by productivity increases. The cost of electronic equipment would be expected (again, in normal circumstances) to have fallen. We are told that discussions are in hand to bring these costs down, although there is no expectation that they will return to close to the levels of 1997. The EPT advise that current generic average for train/cab fitting is in the region of £275,000 (which compares with a corresponding figure in April 2002 of £325,000).

Recent increases in railway costs are a phenomenon that is not confined just to safety equipment. There has been widespread concern within the industry about the way that costs of capital expenditure have been rising. This was commented on by Professor Chris Nash, Professor of Transport Economics at the University of Leeds, in his recent Beesley Lecture on Regulation.[28] Quoting the "Ford Factor", named after the railway journalist Roger Ford who has coined the term, Professor Nash noted that a major problem at the present time is increases in the cost of maintaining, renewing and enhancing the infrastructure (compared with costs under British Rail). Nash suggests there appear to be at least four distinct reasons for the increase:

- transactions costs, both because there are now more parties involved and also because of other possible factors such as a different approach to contracts;

- compensation for possessions doing engineering work, which are now explicit payments between companies in the privatised regime;

- safety spending, although this also impacts on the cost of *installing* ERTMS when additional safety spending is required in installing the equipment; and

- different attitudes to risk, though Nash notes here that his views are based on "hearsay rather than hard evidence". Nash says: "it is not surprising that private sector contractors require a risk premium to undertake rail investments; it has long been recognised that the private sector will take a more cautious approach to risk than should the public sector. But in the light of escalating costs of projects and safety problems as with Hatfield, it seems clear that the private sector is now adding substantial risk premium to all projects involving rail infrastructure."[29]

These observations are consistent with what the industry tell us, although they can only be part of the story. The magnitude of the ERTMS cost increases has been so large as to require further explanation. And despite the factors identified by Nash the cost of trains has declined. Further reasons for increases in infrastructure capital costs suggested to us by the EPT are:

- "Bow waves" of renewals (e.g. signalling) created by the peak in activity in the seventies;

- Growth on the network, contributing to a persistence in the asset condition backlog and an increase in the renewal rates for assets (although it is not clear why this should materially increase unit costs);

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[28] *C A Nash "What to do about the railways" Lectures on Regulation (the Beesley Lectures) Series XII London, October 29th 2002, written text.*

[29] *Op. cit., p.7.*

- Higher engineering standards introduced by Railtrack (we have not had time to explore what higher standards are being required for ERTMS);
- Inefficient and poorly planned renewals (as well as maintenance) following Hatfield.

7.2. CAPITAL COST ESTIMATES IN THE EPT REPORT

Table 7.2 shows capital cost estimates for the two programmes of work, defined as Option 1 (re-run) and Option 4 (refined), in the EPTFR. Costs are shown under two components: base capital costs, and "P80 risk addition". The "P80 risk addition" is defined as the level of additional capital expenditure above the base capital costs that is not expected to be exceeded 80 per cent of the time. Summing these two components gives the "total estimated risked capital costs" of £6.0 billion for Option 1 and £3.6 billion for Option 4R.

Table 7.2 EPTFR capital cost estimates

	Option 1 - (re-run) ***£ million***	***Option 4 – (refined)*** ***£ million***
Estimate of base capital costs	3,415	2,698
P80 risk addition	2,625	910
Total estimated risked capital costs	**6,040**	**3,608**

The EPTFR notes that the higher risks for Option 1 reflects the fact that implementation would start before sufficient completion of the Development Phase.[30]

Table 7.3 shows how base capital costs are split between different components.

[30] *EPTFR, p.58.*

Table 7.3 Components of base capital costs

Cost Head	*Option 1 - (re-run) £ million*	*Option 4 - (refined) £ million*
Train labour	507	485
Train materials	696	696
Track labour	587	394
Track materials	306	131
Training not included above	19	19
New trains/roads	30	30
Train cancellations	268	134
Possession over-runs	91	9
Planned disruptive possessions	108	51
Project management	329	337
GSM-R data upgrade	143	143
Trials/test tracks	131	131
EPT to end March 02	5	5
System authority (development)	9	9
Project management (development)	186	124
Total estimated base capital costs	**3,415**	**2,698**

Our review of the unit rates used in modelling the cost estimates included in the EPTFR has been carried out by Corus Rail Consultancy. This has included a review of the risks and uncertainties applied to the quantities and unit rates used to derive the capital costs. Corus Rail Consultancy's full report[31] is attached as Appendix 2.

Because of its detailed and document-based nature this part of our Review has generally been confined to examination and discussion of the EPTFR and its supporting documentation. We record in Chapter 9 a more general discussion of business risk, having regard also to subsequent work.

7.3. ASSESSMENT OF UNIT COSTS

7.3.1. Train and track labour

Train labour and track labour elements collectively represent approximately one-third of the total base capital costs of the ERTMS options.

Day rates have been derived by the EPT from a number of sources and applied to the resource models for train and track installations to produce yearly labour costs aggregated to arrive at total costs. The calculated day rates for track labour reflect the fact that a major element of this work will need to be carried out during night/weekend possessions.

[31] *Corus Rail Consultancy Review of the Economic Aspects of the ERTMS Programme Team Report Dated April 2002 19/11/02.*

In deriving day rates multipliers have been applied to salary costs to allow for employers' contributions, overheads and profit. Checking with published estimating books appears to support the logic that has been applied in deriving these rates. Straight mathematical averages have been applied across the range of rates supplied by each firm and the overall range of rates to calculate the average day rates used in the calculations. The use of un-weighted averages from small samples of rates does raise some questions. Since the rates supplied by each firm are given equal significance within the calculations this might not reflect the likelihood that some firms will be in a better position than others to actually provide significant labour resources for the project. It should seem logical that the rates supplied by firms in this position should have a greater weighting within the calculations. It might also be desirable to consider the geographical spread of the project and reflect in the average labour rates the fact that a major part of the work will take place within the South East and thus be subject to labour rates at the higher end of the ranges shown.

We otherwise conclude that the day rates used in the report can be generally validated by comparison with the charge out rates in a sample of current Railtrack/Network Rail Framework Agreements.

The EPT advise us that not all the rates used are "day rates". Others are build-up rates that are subsequently converted to a rate per day. **However the question does arise as to whether the use of day rates is appropriate in the context of this project.** Day rates are a suitable way of charging for contracted labour in a call-off contract situation or for the short-term hire of personnel and, to an extent, the use of these rates within these cost calculations simply reflects current contractual relations within the railway industry. However it is to be hoped that the scale and length of the ERTMS programme would enable significant savings to be made in the labour element. This might be achieved by means of a greater level of direct employment by the infrastructure controller; a longer term strategy made possible by the scale and length of the projected workload, and requiring development and training programmes to provide the necessary labour resources. Alternatively, given the scale of the projected workload, contractors' charge out rates might with justification be negotiated below the day rates quoted.

Further work would be needed on the project procurement strategies before the effect of these alternative scenarios on the labour rates used in the EPTFR could be properly assessed.[32]

7.3.2. Train and track materials

Train materials and track materials collectively represent approximately a further one-third of the total base capital costs of the projects. We note that, because of the ongoing development of the technology required for the various ERTMS systems, no other sources of cost data are available to validate the equipment costs other than those provided by the manufacturers themselves. Consequently we were not able to validate these costs within the constraints of this Review. Despite speculation that there is an element of 'front end loading' in these costs it has not been possible to draw any firm conclusions from the information currently available.

Two major assumptions appear to have been made by EPT in calculating the quantities of train and track equipment that will be required for the two options. Firstly it had been assumed in the EPTFR that the number and type of trains requiring fitment will remain static. The calculations do not make any allowance for future changes in rolling stock currently planned to meet TOC aspirations for additional services. We understand however that the

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[32] *Although this is in any case an area of continuing work. The EPT advise us that the unweighted average of day date in the EPTFR was £466, and that following a subsequent review this has been reduced to £423.*

EPT are now modelling a non-static fleet. Secondly the classification of high, medium and low density routes, which feed into the calculations of the quantity of track materials and track labour required, does not appear to take into account planned and current improvements which may reclassify these routes and affect these quantities. It might be expected that these two factors would have a potentially greater effect on the costs of Option 4R, given the greater time period involved. Further study should enable judgements to be made in due course about the effect of these factors on the scope of work required.

The number of signals is obviously critical to the calculation of the costs of track materials and track labour. For the EPTFR, the number of signals was estimated from data supplied by the Railtrack Headquarters Signalling Asset Management Group. Since the EPTFR, Railtrack have produced a better database which, for signals, gives each one a unique reference number and hence no uncertainty as to the quantities. This new database has been used for the recent EPT work on the High Speed Lines.

We believe that the rates used for costing the Level 1 cable and cable troughing requirements are reasonable. However an optimistic scenario appears to have been adopted in assessing the likely extent of this work. It has been assumed that 90 per cent of the cables can be accommodated within existing troughing. This presupposes (i) that existing cable troughing routes are present, (ii) that they are in a suitable condition and (iii) that they have the capacity to accommodate the new cables. Further investigation into the current state of cable routes would provide more confidence in these assumptions.

7.3.3. Other cost elements

Our full review of unit costs at Appendix C also covers a number of other cost elements:

- plant required for track installation;
- training;
- new trains/maintenance roads;
- train cancellations, possessions over-runs and planned disruptive possessions; and
- trials and test tracks.[33]

7.3.4. Project management costs

Project management costs in the EPTFR are extremely high and, while since reduced, remain high. Project management costs relating to the development and implementation of the project are set out in the EPTFR documentation. Other elements of project management costs are included within the assessments of the cost of track labour, train labour, GSM-R data upgrading and trials/test tracks.

Table 7.4 below sets out summaries of the EPTFR project management costs. In brackets are current EPT figures (which have yet to validated by the EPB), which for Option 4R are markedly lower.

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33 *See Appendix C for details of all of these.*

Table 7.4 Project management costs

Cost Head		*Option 1 (re-run)* *£ million*	*Option 4 (refined)* *£ million*
Specific PM costs	Development	185.59 (124.05)	124.05 (69)
	Implementation	328.71 (336.78)	336.78 (222)
		514.30 (460.83)	**460.83 (291)**
Individual section PM costs	Test Tracks	5.64 (19.95)	19.95 (26)
	GSM-R	11.01 (13.24)	13.24 (8)
	Track labour	140.72 (90.49)	90.49 (76)
	Train labour	174.43 (167.73)	167.73 (33)
		331.80 (291.41)	**291.41 (143)**
Total project management costs		**846.10 (752.24)**	**752.24 (434)**

Project management costs in the EPTFR represent additions of 32 per cent to the physical works costs in Option 1 and 39 per cent to the physical works costs in Option 4R. **These percentages appear to be very high and not in line with the budgetary allowances applied to normal Railtrack infrastructure projects, which are more likely to be in the range of 8 per cent to 10 per cent.** It is recognised that the ERTMS project has a number of special features, not least in the new technology that needs to be developed and the major logistical and organisational challenges that need to be met. However it is obviously necessary to examine these costs rigorously.

In terms of resources it needs to be asked whether there is any element of double counting involved within the separate analyses of project management costs applied to train and track labour and the project management (implementation) costs.

The resources required for the system authority project team, the development project team and the implementation project team have been calculated based on the experience of the EPT. Weighted day rates have been derived from the known rates of the personnel involved in the team and applied to the estimated resources to derive yearly costs for project management at different stages of the project. The day rate used for the project management resource that is directly related to track and train labour has been averaged from the sources of information that have been discussed earlier in this report.

7.4. TREATMENT OF RISK

A detailed appendix relating to cost and strategic risks, extracted from the EPTFR, was made available to us for review. This includes a register of the risks used in the analysis, together with the modelling notes, but not the actual risk model. We have not been able to establish details of any correlations used in the model, and since the P80 results are used in the scheme costs, this is relevant because relationships between risks do have an effect on results at this percentile. In addition, we have not within the time available been able to access the minutes from the risk workshops nor the one-to-one interviews with the risk owners.

We have reservations about the use of matrices to determine ranges of costs and probabilities, but note that it is common practice at this level of the study, and that time constraints in producing the data precluded independent verification of this data. We were assured that wherever information existed which more accurately described the risk, this had been substituted for the matrix values.

The individual risk owners and other interested parties have produced the estimates of the cost of risks. We have some reservations about this method of assessing costs in that it may be preferable to have an estimator as part of the Risk Team to provide a consistent basis for evaluation across the whole of the model. This is because it is possible that individual owners will tend to over or under estimate the impact of their risks compared with other risk owners.[34] It is also essential with such wide bands in the matrix for the analyst to be able to account for a 'most likely' area within the wider bands to enable the distribution to be weighted accordingly. Again this might be assisted by having specialist estimating skills within the team to standardise the quantification of risks.

We also have comments on particular risks and uncertainties included within the risk analysis. These are set out in full in Appendix 2. Here we draw attention to two:

- the need to refine contract costs downwards due to a more advantageous procurement strategy

- in regard to the important cost component of labour rates, the need for a more detailed analysis of the rates most likely to apply to specific tasks in order to produce a more robust cost estimate.

Overall in regard to risk assessment we conclude that the methodology used for the risk assessment of unit costs has been thorough and that the range of risks considered demonstrates a considerable depth of understanding of the uncertainties. The quality of the assessment at this level is of a high standard.

It has not been possible however to review the correlations between the risks without having had access to the Risk Model.

One suggestion to achieve an even greater level of quality in future risk assessments would be to include an estimating specialist as part of the team in order to refine the cost estimates used in the model.

7.5. ASSOCIATED INFRASTRUCTURE COSTS

Economic Question 5 (see Appendix A) notes that the EPTFR does not cost any infrastructure work that would be necessary to realise the full capacity gain with fitting the more sophisticated versions of ERTMS (although it makes reference to these costs). We were asked whether the inclusion (or explicit exclusion) of such factors would alter the EPT results. We have not attempted any quantitative analysis of this issue, partly because the information is not readily available even for broad brush estimates, but also because, having reflected on the issue, we do not feel it would be helpful to quantify such expenditure at quite this time. It would we believe contribute further to hiding the key issues which need to be addressed in the structuring of further work on ERTMS. We confine ourselves to some qualitative observations as follows.

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[34] *The EPT advise us that, while this point may be valid, they have made efforts to ensure that such effects are minimised. They also suggest that in any event, at this stage of the work, it is inevitable that risk assessments will be to some extent judgmental. We very much support this sentiment. It is premature to go into detail where this can be avoided.*

- These costs should clearly be included in the comparison of options. However this applies not only to infrastructure costs. It applies to the likely costs of new trains, to make use of any extra capacity. It also applies to the extra infrastructure spending which would be needed to mitigate, in part, any capacity reductions imposed by the less sophisticated versions of ERTMS.

- It would in any case seem misleading to perceive other railway costs as an element of the appraisal specifically of ERTMS. ERTMS should rather be seen as one element contributing to general planning of railway development.

8. CROSS-MODAL IMPACTS

8.1. EPTFR TREATMENT OF CROSS-MODAL IMPACTS

It seems reasonable to accept that if would-be passengers are dissuaded from using the railways because of capacity constraints there will be some additional car travel, which is likely to exceed the reduction in car journeys to and from stations. The EPTFR suggests that relatively rapid implementation of ERTMS through Option 1 could potentially reduce safety overall, since it would reduce rail capacity, and therefore lead to some transfer of traffic from rail to road. The report estimates the consequent increase in overall transport deaths, because of the increase in road accidents, as between 680 and 720 additional road fatalities **over 40 years**.

Later in this section of our report we review the assumptions on which this EPTFR estimate is based, and present sensitivity analysis both of numbers of road deaths, and of wider cross-modal impacts, under a range of different assumptions.

Under "main findings" in both the Executive Summary and Conclusions and Recommendations of the EPTFR it was reported:

> *The analysis work carried out by the EPT has demonstrated, against previous expectations, that attempting to achieve the relatively rapid implementation suggested in Annex 10 of the Joint Inquiry Report would potentially reduce safety overall. That is because it has now become clear that the types of ERTMS likely to be available within that time-frame would:*
>
> - *reduce capacity, thus potentially causing a shift of passengers to the roads, where mortality rates are far higher*
> - *require additional trackside equipment and hence increase risk exposure to trackside workers.*[35]

Section 4.3.6 of the EPTFR explains that:

> *The modal shift due to the changes in capacity was estimated using similar methods to the analysis of ATP-preventable benefits. It was then assumed that all rail capacity variation would be taken up by a modal shift and that no journeys would be lost or gained. The relevant alternative road routes were then identified and the accident risk calculated for the different road types.*
>
> *The conclusion from this work is that Option 1 (Joint Inquiry Report), which reduces capacity, could result in a net societal loss of between 680 and 720*[36] *additional road fatalities, over 40 years, as passengers transfer from the rail network.*[37]

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[35] *EPTFR, pages 5 and 126.*

[36] *A footnote in the EPTFR notes that these figures are provisional, based on several assumptions, and are subject to further validation.*

[37] *EPTFR, p.43.*

The EPTFR records that, in contrast, ERTMS options expected to *increase* rail capacity could result in benefits in the range of 150 to 400 road fatalities avoided over 40 years, again on the assumption that changes in rail capacity are mirrored by the change in road journeys.[38] It also notes that the calculations assume that the rate of road accidents per vehicle km remains constant.[39] It also notes that an increase in rail capacity could lead to a move of freight from road to rail, with associated safety benefits, but that this has not yet been included in the analysis.

The EPTFR does not include explicit valuations for either rail or road safety benefits. It does however comment on public views of risk: "Public perception of risk varies considerably between road and rail travel. Small numbers of railway passenger fatalities, caused by the type of accident mitigated by ERTMS (for example, SPAD related collisions), attract more public and media attention than larger numbers of road fatalities. Similarly, track worker fatalities attract lower levels of attention than rail passenger fatalities." (EPTFR, p 44)

8.2. THE EFFECT OF RAIL CAPACITY CHANGES ON RAIL AND ROAD TRAFFIC FLOWS

A change in rail capacity is likely to affect rail traffic volumes, which in turn are likely to affect road traffic.

The relationship between rail capacity and volume is not generally one-to-one (though the EPTFR appears to assume that it is). If the number of trains that can be handled on a section of route within an hour falls from 6 to 5, and initially there are 6, then passenger traffic will also fall, but probably not in the same proportion.[40] If the existing trains are not full, or if train length/capacity can be increased, then more passengers still travel on some or all of the remaining trains. We have discussed this with *DfT* officials concerned with modelling, who explained the current development of the National Traffic Model.[41] Following this, they ran the model for us with a 10 per cent and 20 per cent reduction in rail frequency across the network to simulate the effect of a capacity reduction following introduction of ERTMS Level 1.[42] The 10 per cent frequency cut reduced the overall number of rail trips by 3.2 per cent, while the 20 per cent cut caused a 7 per cent reduction, implying frequency elasticities of +0.32 and +0.35. Rail passengers displaced by a fall in peak rail capacity may still travel by rail, but at different times of the day when capacity is not restricted. The EPTFR assumption that a change in rail capacity would result in an equal proportionate change in numbers of passengers is extreme.

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[38] *This means too that the reduction in rail capacity is translated directly into a change in rail demand, since the percentage changes in capacity under options 1 and 4 are translated into equal percentage changes in revenue.*

[39] *There are two different ways in which this statement might be interpreted: one is that the accident rate does not change when traffic levels increase as a result of transfer of traffic from rail to road, the other is that rates do not change over time (see Section 8.3 below).*

[40] *The proportionate change in the demand for rail travel divided by the proportionate change in service frequency (the average number of trains in each direction per hour) defines the "frequency elasticity" of passenger demand. This elasticity is generally less than 1.*

[41] *The version of the model under development includes models of road traffic and a network model of rail traffic, with the two linked by a mode split model.*

[42] *DfT note that their work "must be presented as preliminary evidence on the relationship between train frequency and transport demand, and not as NTM modelling of ERTMS introduction".*

Passengers who are displaced may travel instead by bus or coach. They may accept lifts from existing car drivers. They can make journeys by car, either as a driver or as a passenger, that would not otherwise be made, between origins and/or destinations which may be the same as or different from those of the rail journey. Distance travelled by car, even in those case where the origin and destination are the same as for the rail trip, may be different from the rail distance. They may travel by other modes, such as bus/coach, air, cycling, or walking, or they may not travel at all.

The proportional change in car travel[43] divided by the proportional change in rail service quality defines a "cross-service elasticity". Alternatively a "diversion factor" can be defined as the absolute change in car travel divided by the absolute change in rail travel that results from the change in rail service quality. That is to say, it is the proportion of those additional rail travellers who divert from car (in the case of an increase in rail service quality), or the proportion of those lost rail travellers who switch to car (in the case of a fall in the rail service quality).

A paper by Acutt and Dodgson estimated diversion factors for rail fare changes in the early 1990s.[44] These diversion factors were 0.25 for InterCity services, 0.24 for Network South East services and 0.21 for Regional Railways services. In addition, the paper identified the relevant car occupancy rates as 1.62 for InterCity services, 1.54 for Network South East services and 1.60 for Regional Railways services. These numbers would imply the impacts on car trips following any loss of rail passenger traffic as a result of an increase in rail fares shown in Table 8.1.

Table 8.1 Proportion of lost rail passengers translating into extra car trips as a result of a rail fare change

	Translation of lost rail passengers into extra car trips
InterCity	15.4%
Network South East	15.6%
Regional Railways	13.1%

Source: Acutt and Dodgson, 1996.

These figures of about 15 per cent are low in relation to other estimates. We understand that a figure of 50 per cent has been used in recent years for planning purposes in the rail industry, and has been used by the EPT since the EPTFR. As noted above, the *DfT* has run the National Transport Model for NERA's present study: the conclusion was that, of the rail trips no longer made, 76 per cent would be transferred to car trips, 21 per cent to bus and coach trips, 2 per cent to cycle trips, and 2 per cent to walk trips. These proportions relate to the 10 per cent rail frequency cut (but exclude very short distance rail journeys), but *DfT* report that the distribution is similar for the larger frequency cut. The NTM used assumes that the total

[43] *Most of this Chapter is concerned for simplicity with diversion to car travel rather than to bus/coach, cycling, or walking. For impacts on congestion this sufficient. For impacts on safety the picture is more complex. For example an increase in the numbers of buses would increase the number of pedestrians struck by these vehicles.*

[44] *M Z Acutt and J S Dodgson "Cross-elasticities of demand for travel" Transport Policy 1996, pp 271-277.*

number of trips made is fixed, although trip origin/destination and length may change, so changes in trips do not translate directly into changes in passenger-km.[45]

In our sensitivity analysis we use the following proportions of rail trip passenger-km that translate into road trip passenger-km: 1.00 (to reproduce the EPTFR assumption); 0.75; and 0.50. These are then further adjusted to car vehicle-km using an average car occupancy rate of 1.56 from the 1998/00 National Travel Survey. We understand that the EPT is now using a similar rate.

8.3. THE EFFECT OF CHANGES IN ROAD TRAFFIC FLOWS ON ROAD CASUALTIES

To assess the effect of changes in road traffic flows on road casualties we have to consider:

- Road accident and casualty rates per vehicle km;
- Trends in road accident and casualty rates over time; and
- The relationship between accident rates and traffic density.

8.3.1. Road accident and casualty rates per vehicle km

Road accident and road accident casualty rates are published each year in *Road Accidents Great Britain*. The latest edition is *Road Accidents Great Britain 2001*, published in September 2002 and containing results up to and including the year 2001. This gives casualty and accident rates for different types of road user, for different types of road, and for different types of accident/casualty.

Table 8.2 shows road fatalities (including pedestrians and cyclists) and fatality rates in Great Britain for each year from 1970 to 2001. While traffic levels have more than doubled, the number of fatalities has more than halved, and the fatality rate per vehicle-km in 2001 was only 20 per cent of its rate in 1970.

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[45] *The EPT advise us that they also have met with the DfT to discuss the NTM. The DfT has suggested that, as part of the ongoing testing and validation of the NTM, some further runs of the model for ERTMS could be done early in 2003.*

Table 8.2 Road fatalities and fatality rates in great Britain, 1970-2001

Year	*Vehicle-km (billion)*	*Fatalities*	*Fatality rate per billion vehicle-km*	*Year*	*Vehicle-km (billion)*	*Fatalities*	*Fatality rate per billion vehicle-km*
1970	200.5	7499	37.40	**1986**	325.3	5382	16.54
1971	212	7699	36.32	**1987**	350.5	5125	14.62
1972	222.5	7763	34.89	**1988**	375.7	5052	13.45
1973	234	7406	31.65	**1989**	406.9	5373	13.20
1974	229.8	6883	29.95	**1990**	410.8	5217	12.70
1975	231.7	6366	27.48	**1991**	411.6	4568	11.10
1976	243.5	6570	26.98	**1992**	412.1	4229	10.26
1977	246.9	6614	26.79	**1993**	412.2	3814	9.25
1978	256.5	6831	26.63	**1994**	422.6	3650	8.64
1979	255.9	6352	24.82	**1995**	430.9	3621	8.40
1980	271.9	6010	22.10	**1996**	442.5	3598	8.13
1981	276.9	5846	21.11	**1997**	452.5	3599	7.95
1982	284.5	5934	20.86	**1998**	459.2	3421	7.45
1983	288.1	5445	18.90	**1999**	466.0	3423	7.35
1984	303.1	5599	18.47	**2000**	467.7	3409	7.29
1985	309.7	5165	16.68	**2001**	473.7	3450	7.28

Source: Road Accidents Great Britain

The trend in fatality rates is as shown in Figure 8.1.

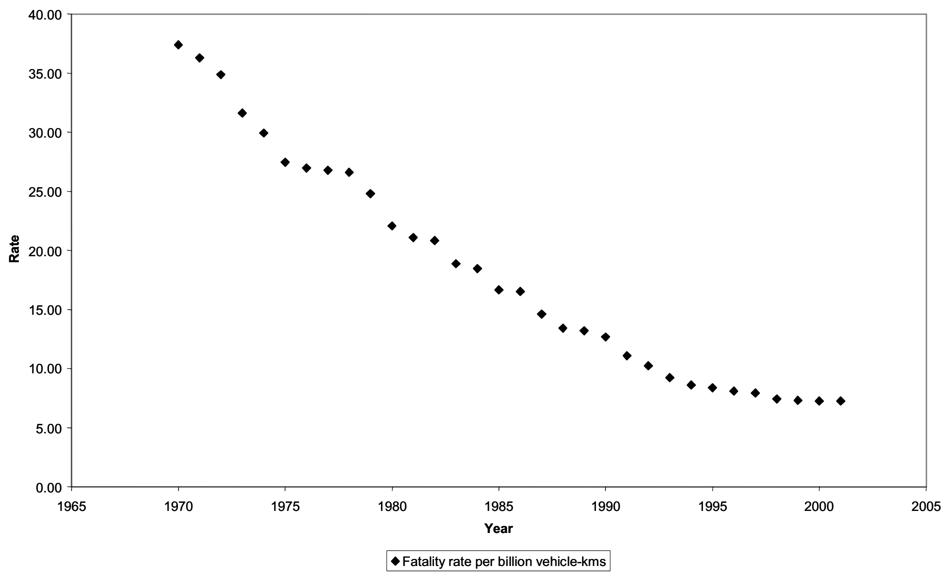

Figure 8.1 Fatality rate per billion vehicle-km

Although the most recent fatality rates have been fairly constant, we believe it is reasonable to assume that the rates will resume their fall. Indeed this is an explicit, quantified objective of the Government's transport policy. The safety strategy in *Tomorrow's Roads: Safer for Everyone*, published in 2000, aimed to achieve the following road accident targets by 2010 compared with the average for 1994-98:

- a 40 per cent absolute reduction in people killed or seriously injured – this is an annual rate of fall of about 3.5 per cent a year;
- a 50 per cent absolute reduction in children killed or seriously injured; and
- a 10 per cent reduction in people slightly injured per 100 million vehicle kilometres – this is an annual rate of fall of about three quarters of one per cent a year.

The *DfT* have published a recent progress report.[46] In 2001 the number of people killed or seriously injured in road accidents was 15 per cent below the 1994-98 average, the number of children killed or seriously injured was 27 per cent below the 1994-98 average, and the slight casualty rate per vehicle km was 6 per cent below the 1994-98 average.

Any estimates of the impact of ERTMS on road accident rates should take account of the fact that rates have been falling and include a considered view of the extent to which they are likely to continue to fall. The EPT advise us that they are now using the accident rate reduction factors in the D*f*T COBA Manual (which are derived from TRL Report 382 and later, more disaggregate work undertaken for DETR).

8.3.2. The relationship between road accident and casualty rates and traffic density

There does not appear to be evidence that accident rates increase with road traffic density. This implies that, where traffic is assumed to switch from rail to road, it is satisfactory to model the impact by assuming that the average accident rates per vehicle-km on that type of road **in that year** do not change. We understand this assumption is implicit in the EPT reports. Our conclusion that increased traffic density does not increase accident rates per vehicle-km is based on a written submission by Professor Andrew Evans to the Southall and Ladbroke Grove Joint Inquiry into Train Protection Systems on "Frequency of accidents at junctions and traffic density". This submission in turn drew on *DfT* advice on assessments of the impacts of increased traffic at junctions on accident levels at those junctions.

8.4. CONSEQUENCES FOR RAIL PASSENGER ACCIDENTS

While changes in rail capacity following introduction of ERTMS will result in changes in road accidents, there will also be impacts on rail casualties. These were discussed in Chapter 6 above on Railway Safety. Table 6.1 showed our estimate that introduction of ERTMS in addition to TPWS would reduce expected annual ATP-preventable rail fatalities by 0.5, and that reduction of capacity by 10 per cent would reduce other rail fatalities by 0.8, while the reduced number of trips by rail would reduce annual fatalities in pedestrian access to rail stations by 1.4. The overall reduction in annual rail fatalities of 2.8 would be less than the annual increase in road fatalities, which we estimated at 5.4. We pointed out that the overall differences were not large.

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[46] *S Oxley and H Lambert "Review of progress towards the 2010 casualty reduction targets" in Road Accidents Great Britain 2002 DfT.*

8.5. OTHER COSTS IMPOSED BY TRANSFERS OF TRAFFIC FROM RAIL TO ROAD

Transfers of traffic from rail to road impose other social costs besides an increase in accidents. These consist of:

- Increased road congestion;
- Localised air pollution;
- Noise; and
- Climate change.

Estimates of these costs, on both a fully allocated cost and on a marginal cost basis, have been made in a study conducted by the Institute for Transport Studies (ITS) at the University of Leeds for DETR, and published in 2001.[47] Costs are provided for five different types of vehicle: car; LDV (light diesel vehicle); rigid HGV; artic HGV; and PSV (public service vehicle); and for three different types of road (motorway, trunk & principal, and other), for two time periods (weekday peak, and off-peak), and for various different area types (such as Central London, inner conurbations, rural, etc).

While the ITS report includes estimates of marginal road congestion costs, more disaggregated estimates of congestion costs are included in the NERA road congestion cost model used to estimate optimal road congestion charges for the Commission for Integrated Transport. The published CfIT Technical Report on *Paying for Road Use*[48] includes estimated congestion charges, which are equal to marginal congestion costs per extra vehicle at optimal traffic flows, rather than actual present-day flows. However, the NERA model has been modified to generate marginal congestion levels at existing levels of traffic flow across the road network.

8.6. TIMING OF ERTMS INTRODUCTION

No ERTMS system could bring its full effects network-wide immediately, so sensitivity analysis has to take account of implementation timescales. For the purposes of sensitivity testing we adopt the timings shown in the EPTFR, without necessarily signifying our agreement that these are practicable. As to impacts on capacity, we take the EPTFR assumptions that Option 1 would reduce rail capacity by 12½ per cent, while Option 4R would increase it by 10 per cent.

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47 *Institute for Transport Studies, University of Leeds, with AEA Technology Environment Surface Transport Costs and Charges, Great Britain 1998 DETR 2001.*

48 *Oscar Faber/NERA Paying for Road Use: Technical Report A Report to the Commission for Integrated Transport, February 2002.*

The EPTFR contains details of a programme for implementing Option 4R, in five phases between 2006 and 2030.[49] It notes that, to ensure consistency when comparing Options 1 and 4R, the train fit programme for Option 1 was altered to the same logic, but two years earlier than that for Option 4R.[50] For Option 4R, Phase 1 in the implementation programme would consist of predominantly 100+ mph routes, the first high density routes and three other routes, and would be completed by 2012. Phase 2 would consist of the remaining 100+ mph, high density and intercity routes, and would be completed by 2015. Phases 3 to 5 would cover all other routes and would be completed by 2030.

For purposes of assessing cross-modal effects, NERA has assumed that 50 per cent of the capacity impact of Option 4 on transfers of traffic is achieved by the end of Phase 1 (2012), 83 per cent by the end of Phase 2 (2015) and 100 per cent by the end of Phase 5 (2030). We assume that capacity impacts of Option 1 are felt two years earlier.

8.7. SENSITIVITY ANALYSIS OF CROSS-MODAL EFFECTS

8.7.1. Sensitivity model

To analyse the impact on road safety and other cross-modal effects of rail capacity increases or reductions as a result of various ERTMS options, we have constructed a spreadsheet model which calculates the impact under a number of assumptions.

The assumptions can be manipulated and include the following:

- the impact of a change in capacity on the number of trains run;
- the impact of the number of trains run on the number of passenger kilometres (the frequency elasticity) for long-distance, London & South East and regional services;
- the proportion of lost/won rail passengers transferring to and from roads;
- the average car occupancy rate;
- the predicted (exogenous) growth in rail traffic between 2000 and 2010; and between 2010 and 2043; and
- the average annual change in casualty rates per vehicle kilometre.

On the basis of these assumptions, the model calculates the number of additional car kilometres on the roads. It then calculates the number of expected casualties and associated costs on the assumption that these additional car kilometres will transfer to motorways, built-up and non built-up roads in the same proportion as the current aggregate proportions of traffic on these types of road.

The sensitivity model therefore calculates not only the number of fatalities, but also (separately) the numbers of serious injuries and slight injuries on the roads. These are also valued using standard *DfT* valuations for the three different types of road accident casualty.

Both options use casualty rates per car kilometre that are assumed not to vary with traffic growth.

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[49] *EPTFR, section 4.5.3 ERTMS System Fitment Assumptions, and Chapter 6 Industry Plan.*

[50] *EPTFR, p.49.*

However, as noted above, it is possible to specify an average change in accident rates per car kilometre across the various road types over time. In our main runs we assume that accident rates for fatal and serious casualties fall by 3 per cent a year, while those for slight injuries fall by one half of one per cent a year.

Both casualty rates and casualty costs are based on 2001 values. All costs are discounted at a real discount rate of 2 per cent, following current HSE convention (although recent Treasury guidance – see Box 6.1 - is proposing a pure time preference rate of 1.5 per cent).

In addition, the model also includes other cross-modal impacts of changes in rail traffic on road traffic. These are:

- congestion costs as a result of an increase or reduction in car traffic. These are estimated using the NERA model and are based on the additional time and operating costs imposed by an extra car km between 07:00 and 19:00 on weekdays, on motorways and on all other roads combined.

- localised air pollution costs imposed by extra cars. These estimates are those for marginal air pollution costs derived from the Leeds ITS model, and are the averages of the Leeds high and low estimates, converted from 1998 prices to year 2001 prices.

- noise costs imposed by extra cars. These estimates are those for marginal noise costs derived from the Leeds ITS model, and are the averages of the Leeds high and low estimates, converted from 1998 prices to year 2001 prices.

- greenhouse gases emitted by extra cars. Estimates of the costs of these are derived from the Leeds ITS model, and are the averages of the Leeds high and low estimates, converted from 1998 prices to year 2001 prices.

8.7.2. Sensitivity results

We have calculated the results using permutations of the scenarios shown in Table 8.3.

Table 8.3 Sensitivity analyses

Variable	*Value 1*	*Value 2*	*Value 3*
Frequency elasticity	0.3 (value advised by D*f*T)	0.6	1.0 (EPTFR assumption)
Percentage of lost/won rail passengers transferring to/from car	50%	75% (value advised by *DfT*)	100% (EPTFR assumption)
Average car occupancy	1.56 (current value)		
Average annual reduction in fatality rates per vehicle kilometre	3%		
Average annual reduction in serious injury rates per vehicle kilometre	1%		

Table 8.4 Increases in road fatalities from option 1

Frequency elasticity	*Assumptions* Proportion switching to car	Car occupancy	Increase in road fatalities over 40 years
0.3	0.5	1.56	77
0.3	0.75	1.56	115
0.3	1	1.56	154
0.6	0.5	1.56	154
0.6	0.75	1.56	231
0.6	1	1.56	308
1	0.5	1.56	257
1	0.75	1.56	385
1	1	1.56	513

Table 8.5 Increases in road external costs from option 1

Frequency elasticity	*Assumptions* Proportion switching to car	Car occupancy	Increase in external costs, discounted to 2002 (£m)
0.3	0.5	1.56	1376
0.3	0.75	1.56	2064
0.3	1	1.56	2751
0.6	0.5	1.56	2751
0.6	0.75	1.56	4127
0.6	1	1.56	5502
1	0.5	1.56	4586
1	0.75	1.56	6878
1	1	1.56	9171

Note: external costs consist of road casualty costs, air pollution, noise, climate change and congestion

Table 8.4 and Table 8.5 show the impact of Option 1 under different assumptions about the impact of rail frequency changes on rail demand (the frequency elasticity) and the proportion of losses in rail passenger miles that convert to car passenger miles. In all cases we hold the car occupancy rate fixed at 1.56.

We understand the EPTFR analysis of cross-modal effects to be based on an assumption of a frequency elasticity of 1, and an assumption that all lost rail passenger-km convert to rail passenger-km.

Analysis carried out for us by the *DfT* suggests a rail frequency elasticity of 0.3, and a proportion of lost rail passenger km switching to car of 0.75. These seem to us plausible values and we used the former in constructing Table 6.1 above.

Table 8.4 shows sensitivity of fatalities as a result of adopting ERTMS Option 1 over the next 40 years to these assumptions. Our model shows that the total increase in fatalities would be 115 under our own preferred assumptions, but 513 under the assumptions adopted by the EPTFR.

Table 8.5 shows the Net Present Values of external impacts of cross-modal effects under different assumptions. The external costs measured include road accident casualty costs of fatal, serious and slight injuries (though not damage costs), air pollution costs, noise, greenhouse gases and congestion. Under "NERA" assumptions the discounted present value over 40m years would be £2.1 billion. Under the EPTFR assumptions the NPV would be £9.2 billion.

Table 8.6 Reductions in road accident fatalities from option 4R

Assumptions			*Reduction in fatalities over 40 years*
Frequency elasticity	***Proportion switching to car***	***Car occupancy***	
0.3	0.5	1.56	56
0.3	0.75	1.56	84
0.3	1	1.56	113
0.6	0.5	1.56	113
0.6	0.75	1.56	169
0.6	1	1.56	225
1	0.5	1.56	188
1	0.75	1.56	282
1	1	1.56	375

Table 8.7 Reductions in road external costs from option 4R

Assumptions			*Reduction in external costs, discounted to 2002 (£m)*
Frequency elasticity	***Proportion switching to car***	***Car occupancy***	
0.3	0.5	1.56	1014
0.3	0.75	1.56	1521
0.3	1	1.56	2028
0.6	0.5	1.56	2028
0.6	0.75	1.56	3042
0.6	1	1.56	4056
1	0.5	1.56	3380
1	0.75	1.56	5070
1	1	1.56	6760

Note: external costs consist of road casualty costs, air pollution, noise, climate change and congestion

Table 8.6 and Table 8.7 show the impact of Option 4R under different assumptions about the impact of rail frequency changes on rail demand (the frequency elasticity) and the proportion of losses in rail passenger miles that convert to car passenger miles. In all cases we hold the car occupancy rate fixed at 1.56.

Again, we understand the EPTFR analysis of cross-modal effects to be based on an assumption of a frequency elasticity of 1, and an assumption that all lost rail passenger-km convert to car passenger-km. As already explained, our own best view is that the rail frequency elasticity is about 0.3, and that the proportion of lost rail passenger km switching to car is about 0.75.

Table 8.6 shows sensitivity of road accident fatalities as a result of adopting ERTMS Option 4R over the next 40 years to these assumptions. Under NERA's preferred assumptions for some of the input variables we would expect the number of road accident fatalities to be reduced by 84. Under the EPT assumptions the corresponding estimated reduction is 375.

Table 8.7 shows the Net Present Values of external cross-modal effects of ERTMS Option 4R under different assumptions. Under "NERA" assumptions the reduction in the discounted external costs of car traffic would be £1.5 billion. Under EPT assumptions it would be £6.8 billion.

These figures are not offered as definitive answers, but they are produced to check and reinforce our impression that the figures in the EPTFR are too high.

We note however that since the EPTFR the EPT has considerably strengthened its expertise in these fields. We understand that in its current work it is estimating congestion costs on the basis of D*f*T benchmarks, with a view to possible further refinement; it has done some work on environmental impacts of additional/reduced cars and of additional/reduced trains - although monetary values have not been assigned; and the values used for the frequency elasticity of rail travel and for the diversion of displaced passengers to cars are now based on assessment of the empirical evidence. These are all to be welcomed, with the important proviso that, as in all the EPT work, the modelling should serve to follow and refine a clear prior understanding of the issues and the relevance of the empirical data.

9. BUSINESS RISK

Chapter 7 addressed unit costs, including the risks associated with specific items. In this chapter we address the wider economic aspects of Technical Question 8, about the linkage between early implementation of ERTMS and businesses risk.

9.1. THE SCOPE OF BUSINESS RISK

"Business risks" are factors that might lead to the outcome falling short of the plan, in time, performance and cost. Well-developed plans will include action to mitigate these risks, and estimate the effect of residual uncertainties after mitigation.

Our main concern about the handling of business risk with respect to ERTMS is what we see as the absence of a strategic overview. The risk analysis which has been and continues to be done is massive, and in its own terms of a high professional standard. But it needs in our view to be complemented by somewhat higher level analysis, to provide those responsible for strategic decision making with the most constructive insights into the key uncertainties, into the judgements which they as decision makers need to make, and into the data on which these judgements can be based. This overview role may be difficult for the EPT. Perhaps it is more appropriate for the SRA and D*f*T.

9.2. THE ASSESSMENT OF BUSINESS RISK

The EPT have put it to us, and we agree, that in evaluating the costs of undeveloped systems on an industry basis, some expert judgement is inevitable and essential until such time as there is actual experience or historic data. As this is a developing technology, this information is not available yet, and therefore assumption/supposition comes into play.

The EPT also make the point, with which we again agree, that the more high-level the descriptions of risks, the less easy it is to define unique responsibility and management approaches to them. Thus any descriptive summary of risks, such as that used in the EPTFR, will have such overlaps. They note that their detailed risk registers identify risk owners and management actions at a more disaggregated level.

The essence of our concerns about the EPT reports' analysis of business risks is that we believe EPT have opted for premature, or at least over reliance on formal, complex modelling techniques for the investigation and presentation of strategic and programme risks.

9.3. IDENTIFICATION AND CATEGORISATION OF BUSINESS RISKS

9.3.1. Business Risks in the EPTFR

The EPTFR and its Appendices record Strategic Risks and high level Programme Risks as shown in Table 9.1. The EPT have explained to us that the risks as presented here were examples of strategic and programme risk and should not be taken as an extensive or definitive list. They were a summary of some of the types of risk that exist within the risk registers. The listing in the EPTFR was also not indicative of how risks were modelled and captured within the commercial evaluation. However, while we accept this, these were the risks as presented by the industry in a major published document submitted to government as being for immediate policy use. They have to be taken as including all the strategic and programme risks considered to be important in that context.

Strategic risks are regarded in the EPTFR as "largely outside the control of the EPT or other programme teams". The EPT note that in some cases mitigation is available but to be effective this would require action from outside parties. Programme risks are regarded as being "within the management and control of the ERTMS programme team". However, given that the EPT derives all its resources from the railway industry, and much of its work is effectively a vehicle for negotiation with those outside the industry, a more useful prime distinction would be between risks largely outside the industry's control and those largely within it.

Table 9.1 EPTFR strategic and programme risks

Strategic risks (EPTFR page 91)	***Programme risks (EPTFR Appendix F1.6 Table 4)***
Reduction in WCRM scope, or substantial delays to delivery	Late availability or changes to technical specifications
Inability of GSM-R to provide the communications capacity for the operation of ERTMS, or substantial delays in the GSM-R delivery programme	Role and suitability of adopted System Authority
Lack of sufficient or timely funding	Possessions
Inability of industry to resource the programme of work	ERTMS Performance
Substantial delays in carrying out the signalling renewals	Early Deployment Schemes
On-going uncertainty about the industry structure	Stakeholder communication
Failure of ERTMS to deliver interoperability or significant capacity increases	
Failure to implement European Traffic Management Layer (ETML) needed to ensure capacity benefits.	

Most of the issues listed as strategic risks would in other industries fall largely within the industry's own control. They illustrate the special difficulties facing the railway.

The list of programme risks, defined as those largely within the industry's control (indeed, within the programme team's control), sits oddly against the list of strategic risks. For example the technical development risks (late availability or changes to technical specifications; ERTMS performance; results of early deployment schemes) overlap several strategic risks, and seem only partially under industry control. In particular, we have been given to understand that one of the current difficulties facing Europe's railways is instability of the EU-level specifications.

Risks related to availability of possessions and trains out of service, listed as programme risks, come down to cost, which is said to constitute a strategic risk. Otherwise, provision of track access and train access is not a risk of ERTMS, but a requirement, with a price tag like any other requirement.

Role and suitability of adopted System Authority has to be subject to issues of the industry's structure, which again is said to constitute a Strategic Risk.

9.3.2. Strategic risk analysis versus detailed Monte Carlo analysis

The handling of risk in the EPT work appears to be strictly bottom up. It was explained to us that the broad risk headings listed as strategic or project risks in the EPTFR were summaries, for the layman, of the detail assembled in the risk registers.

Our view is that at this early stage of development of a multi billion pound programme, funded at least in part by public subsidy, this approach needs to be complemented with top down risk analysis, in which the standard, computerised Monte Carlo techniques come into play at a late and subsidiary stage, if at all.

This is perhaps more of a framing issue than one of technical substance. The risk registers, after all, will have originated with some high level categorisation and thinking. However this thinking appears to have been captured at too early a stage by the Monte Carlo machine of intensive collection of largely technical, judgemental data, to feed into the black box for arithmetical manipulation, producing numerical outputs which are elegant, but whose validity it is all but impossible to assess.

Examples of high level risks which we are told are fully dealt with in the risk registers are:

- Failure of the development process to deliver workable ERTMS;
- Inability of the industry to deliver major investment to cost, time and performance;
- Intractability of a migration path to ERTMS Level 2 without trackside signalling.
- Unwillingness of the regulatory authorities to allow changes to signalling principles.

Whether or not sufficiently reliable information is available for such risks to be adequately covered in the risk registers might be debated. But even if it is, the approaches to these risks, within and beyond the EPT, will be strongly steered by the way in which they are framed. We do not believe the risk register machinery is sufficient for well informed development of the programme.

As one example, the industry does not have a good record in delivering major investment, especially investment involving technical innovation. The very large risk additions to cost are perhaps an implicit acknowledgement of this. However it would be better to admit the problem openly, and for the industry to argue that its present incapacity to deliver major investment is bound to affect a Joint Inquiry timescale, but that it might reasonably be expected not to affect an Option 4R timescale. In other words, this particular risk applies unequally to the different options.

This problem must be in the forefront of the minds of regulators and government

The present handling of risks also conceals question such as how far ERTMS depends on further work at EU level for workable systems to be delivered.

We note in passing one risk which has been missed, namely that of an ERTMS-induced multi-fatality accident in the early days of ERTMS. We presume that this will now be absorbed into the Monte Carlo process. However it is unlikely that such a politically important risk would have been overlooked within a framework based at more general level.

Another risk which we have noted above is that of development of a distinctive British version of ERTMS. We have been told that this could not happen because it would not then comply with the European specification. We do not share this confidence and suspect that the risk would be treated more effectively within a high level framework.

9.4. POSITIVE RISKS

The EPT lists are all of adverse factors. No mention is made of uncertainties that might have a material positive effect - opportunities.[51] There are "positive risks" - developments where a successful outcome is far from certain, and only partly under the GB rail industry's control, but with potential for improvement on the EPT scenarios and base case predictions. This is of course a baseline issue. If the baseline is sufficiently optimistic then all risks are downsides. This may be true of the EPT analysis. But if this is so it needs to be spelt out, and perhaps re-examined.

One example is that the "interoperability" aspect of ERTMS, which may reduce equipment supply costs substantially, as the European Commission intend. We find here some confusion of terminology, and perhaps in framing of the issues. Interoperability appears to be seen in much of the industry in terms of train operation – that the ERTMS standard ought to make it easier for a given train to operate over different parts of the network, or different networks. The industry also explains that "interchangeability" of equipment from different suppliers is a non-starter. Each supplier's package will be unique to that supplier, except at the standard train-track interface and possibly at the interface with the driver. However a major objective of the directives, and a major concern of the suppliers, is that the standards should indeed be international, and that development which suppliers put into provision for the British market should be almost equally applicable to the continental market.[52] If this is achieved, competition should increase and development and production costs should be more widely spread. This is not an issue which appears to have much priority in the EPT remit.

The SRA and Network Rail may master the "Ford Factor" of escalating infrastructure investment costs, and installation costs fall substantially.

Continental European Suppliers and railway operators may develop ERTMS more quickly than is now expected.

The first two of these potential positive risks could have a beneficial effect on cost, and the third on time and performance. But they will not happen (or will not bring benefits to Britain) unless the British industry sets out its stall to help bring them about and capture their benefits.

These positive risks are not relevant to early implementation of ERTMS. This is a drawback of the Joint Inquiry timescale: it forgoes these positive possibilities. But they are relevant to a later timescale. The uncertainties of a later timescale appear to be much more evenly distributed about the base case than those of any early implementation option.

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51 *The concept of uncertain opportunities - "positive risks" - is noted in the Cabinet Office Strategy Unit paper of November 2002: Risk: Improving Government's Capability to Handle Risk and Uncertainty.*

52 *One of perhaps hundreds of superficially minor issues which could lead to a markedly different British ERTMS is that of code numbers for individual trains. The continental standard is a unique six digit numeric code. The British standard is a non-unique four character alpha-numeric code. Changing the British system would incur a substantial initial cost because so much existing equipment is geared to the alpha numeric system. We understand that this issue is as yet unresolved.*

9.5. MIGRATION

It is recognised by EPT that "it is not uncommon on complex train control systems to find that these transition requirements are more demanding than the final steady state" (Interim Report, page 6).

The EPT aim is to maximise System D, in-cab signalling without trackside signals. The reports recognise (EPTFR, section 4.5.5) that this involves fitting all of the trains using a route before introducing System D. This is extremely costly. It also presents difficult operational and human factors issues, involving safety, because of the ensuing requirement for drivers to switch between control regimes during a journey. This switching may involve not just the difference between "head-up" and "head-down", but different operating principles. It may not be feasible to move straight to System D. Once a lower-level system is in place, it may be excessively costly to move to System D, especially given that the change will then have no safety implications.[53]

The difficulties associated with migration mean that the recent developments on WCRM TCS seem positive from the point of view of ERTMS system-wide. One risk not mentioned in the EPTFR was that WCRM TCS went ahead on a basis suitable for WCRM initially, but unsuitable system-wide, and that the line of least resistance then turned out to be general implementation of a second-best version. Given the importance of interoperability, it is much to be preferred that ERTMS is developed from a national, not just a WCRM viewpoint (and, indeed, a WCRM high speed viewpoint).

9.6. COMPARATIVE RISKS OF EARLY AND LATE IMPLEMENTATION

Most of the strategic and programme risks identified by EPTFR do not apply to early implementation. However it does not follow that the risks applicable to early implementation are low. All the following could hit early implementation.

- Industry inability to deliver major investment;
- Intractable problems with retrofitting existing trains and signalling;
- Failure of the development process to deliver workable ERTMS; and
- An ERTMS-induced multi-fatality accident.

The risks listed by EPTFR mostly impact on time and performance. But its quantification of the effects of risk is entirely in terms of cost. This leads to the paradox that Option 1 is represented as riskier than Option 4R, despite the fact that much more technical development is required for Option 4R. The higher risk in Option 1 is explained as "reflecting the commencement of implementation prior to sufficient completion of the Development Phase". But Option 2, which is Option 1 but implemented without the constraint of the Joint Inquiry timetable, shows the same proportion added for risk as Option 4R. The figures in Table 9.2 for Options 1 and 4R are from the EPTFR (section 4.7.2); those for Option 2 are from the Interim Report (Figure 3).

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[53] *The EPT explain that the migration issues of going from Level 1 to 2 are much more significant (operationally and in cost) than those of migrating between Systems C and D as long as the CBIs used for C are D-capable, but that nonetheless the whole basis of the piloting strategy is to ensure that a move straight to System D on a route (to avoid stranded Level 1 assets, and maximise the capacity benefits and cost savings relative to System C) will only be done with proven systems. Work in this crucial, and prima facia technically high risk area is ongoing.*

Table 9.2 EPT figures for risks of early and later implementation

	Capital Cost, £ billion		
	Option 1	***Option 4R***	***Option 2***
Unrisked capex	3.415	2.698	3.7
Risk on capex	2.625	0.910	1.3
(per cent of "unrisked")	(77%)	(34%)	(35%)
Total	**6.040**	**3.608**	**5.0**

The explanation of the contrasting cost of risk of Options 1 and 4R seems to lie in the quite different pattern of risk applicable to the two approaches. The Joint Inquiry timetable, Option 1, is low risk in technical terms (relative to options depending on ERTMS Level 2). It is also low risk in terms of time, because it is time-constrained: in effect, it has to be assumed that "money will be thrown at it" in order to deliver it on time. It is therefore very high risk in cost terms (to the point where risk approaches certainty).

By contrast, Option 4R involves considerably more technical risk. This should show up in terms of uncertainty of time to start installation, and performance. It also should show up in terms of uncertainty of development cost. However by following a timetable set by the redevelopment of the railway, rather than one with a fixed and early end date, the costs should be more controllable.

The very different characteristics of the risks (and opportunities) applicable to Option 4R do not emerge in the presentation chosen by EPT. Indeed it is probably premature to cost risk for such an option at this stage.

9.7. CONCLUSION ON BUSINESS RISK

- The EPT analysis of risks needs further work not only on risk analysis per se, but also on higher level framing and understanding of the risks. The scale of the risk additions is evidence that the project is not yet at a stage where reliable plans can be made. At this stage, risk analysis can only be broad-brush.
- The pattern of risks for the very early implementation of Option 1 is wholly different from the pattern for later implementation options such as Option 4R.
- Early implementation has less technical development risk and less time risk, but has the possibility of massive cost overruns because of the overriding needs of the timetable. The performance risk in terms of train protection is relatively low. The risks are all adverse, except possibly on capacity (where the estimated capacity reduction would probably not be allowed to occur, but be mitigated at a cost).

- Later implementation has considerable technical development risk. This has its effects on time, cost and performance risk. However the uncertainties are both positive and negative. With good management, and with good fortune with regard to the irreducible uncertainties, the benefits could be greater, and the costs less, than currently envisaged. This is quite different from the uncertainties of early implementation.

- It could usefully be made more explicit that no commitment should be made until firm evidence is available on ERTMS costs, availability and performance.

- The presentation of risks should explicitly address time and performance risks, as distinct from cost.

10. THE ROLE OF COST BENEFIT ANALYSIS

10.1. THE RELEVANCE OF COST BENEFIT ANALYSIS TO ERTMS

The more technical aspects of cost benefit analysis (CBA), such as valuation of non-marketed impacts, and identification of national as distinct from commercial costs and benefits, have a contribution to make to the appraisal of investment, as to any major, publicly subsidised expenditure. However the more important role for CBA, and other holistic techniques such as multi criteria analysis (MCA) at this stage in ERTMS development would seem to lie in the setting of frameworks, as set out for example in the Treasury guidance on appraisal and evaluation. We understand that, since the EPTFR, the EPT have taken substantial measures to equip themselves to do this, following Treasury conventions.

These frameworks include, in particular, the identification of objectives and of alternative options. On neither count is the appraisal of ERTMS yet developed. At the most general level the objectives no doubt include the adoption of EC directives and the development of as safe and efficient railway, but the primary objective of the EPTFR appears to have been to achieve acceptance that the Joint Inquiry timescale should not be imposed. We see a need for a review of the numerous and sometimes conflicting objectives of the industry's ERTMS activities, followed by the identification of alternative options, given that the UK already has an unqualified commitment to follow the ERTMS route. This is however probably a function which needs to be led by the SRA and D*f*T.

In parallel with this there maybe a need to establish clearly the policy ground rules, if there remains any doubt about this. The Joint Inquiry took the view that, given Ministerial statements and the EC directives, "w*e are not, therefore, called on to come to any judgment on whether these systems satisfy a cost benefit analysis*" (paragraph 4.30). Since that time, the estimated costs and the technical and managerial uncertainties of ERTMS installation have grown, the safety potential of TPWS/TPWS+ may have improved, the potentially negative and positive capacity impacts of ERTMS, with consequences including those on road accidents, has emerged, and the breadth of the implications of ERTMS has become a little clearer. Nor are we aware of any formal government statement underlying the Joint Inquiry's position. It seems to becoming clear that an analytical approach is now preferred, in which the special characteristics of ATP-preventable accidents relative to other accidents will continue to play a role, but will be made explicit and assessed on their merits. We note that the SRA appears to be firmly committed to an analytical approach.

10.2. IMPLEMENTATION OF CBA (AND MCA)

The EPT is now equipped to carry out both commercial appraisal and cost benefit analysis (CBA). Many of the costs are the same in both cases. However revenue in the commercial case, from customers and perhaps in compensation payments to operators, is replaced in CBA by the value of extra or lost time and risk of death or injury. The CBA would also include additional costs or benefits, such as impacts on road congestion, the environment and road accident risk.

We understand that figures for all of these CBA impacts have been estimated, except for environmental impacts, on which work is in hand. The EPT advise us that they also have plans to estimate the implications for rolling stock costs of extra capacity provided by ERTMS, and as noted in Chapter 7 is beginning to integrate work with the industry's general infrastructure planning. (The EPTFR included some valuations of time, but also some double counting. It also appeared to claim credit for the extra revenues from extra traffic without including the costs of the non-ERTMS infrastructure and rolling stock needed to achieve these in full.)

An aspect of the EPT analysis which is now being phased out in government is the use of the 6 per cent discount rate for analysis in central government. As noted above in section 6.5, the new rate of 3.5 per cent has already been implemented in government for policy analysis. The EPT advise us that they are now using both rates. It is not clear how much the lower rate will affect the estimated cost differences between the earlier and later options. All the present value net costs or benefits will increase, but the proportionate increase, and perhaps the absolute increase, will be larger for the later installation options.

The high priorities, such as identifying options, improving information on costs and financial risks, technical and managerial feasibility, and capacity impacts, are all equally relevant to CBA and commercial appraisal.

There may be scope in this application for formal decision analysis techniques, which we describe under the general heading of MCA, which do not require explicit valuations. However this would not fit into the current, highly formalised frameworks. Nor would they be of use until a higher level framing of the issues was developed, or there was a commitment to move in this direction.

PART III:
OUR OVERALL VIEWS

11. DISCUSSION

11.1. OVERVIEW

We believe it is likely to be a year, or longer, before sufficient information is available to support firm policy decisions about ERTMS installation timescales for the British railway network as a whole. Our Review therefore firmly supports the EPT conclusion that endorsing the Joint Inquiry recommendations on timing would be premature, and not now justifiable against the government's policy appraisal criteria[54], even having regard to the special, "media amplifying" characteristics of ATP-preventable accidents.

At the same time we cannot endorse the economic analysis of the EPT Final Report. It contained a number of weaknesses and, especially in its public presentation, seriously over or understated important quantitative arguments.

We face in this Review, as do all stakeholders, a major challenge in separating the wood from the trees. From an economic perspective, the key issues for ERTMS policy are too often hidden in the forest of engineering, modelling and systems detail, institutional complexity, and political sensitivities. In attempting an overview, these problems emerge within several themes.

One theme is the extreme technical and institutional complexity of the railway, combined with compartmentalisation. We are encouraged to learn that all strategic capacity work on the railway network is to be centralised. However development and implementation of ERTMS is not integrated into this work, even though signalling capacity impacts are seen in the ERTMS work as important. At the same time ERTMS work builds in assumptions which appear to imply significant delays with no safety benefit, without input from network planners or expertise in driving procedures. ERTMS work appears to have been rigidly compartmentalised into the EPT and separately in WCRM. We have been told that these programmes are now being coordinated, although the barriers appear still to be high.[55] We understand that the need for ERTMS to be considered in conjunction with signalling renewals and other SRA-sponsored enhancements is now well recognised, and that it has been agreed with Network Rail and SRA that this integration process will be a key piece of work for 2003. This is much to be welcomed, but suspect that the needs for integration, or at least communication, are wider, bridging far beyond signalling engineers. A related theme is the widespread, albeit we understand contested, presumption that, until trackside signalling is removed, ERTMS should be no more than a check that the driver is doing everything he should be doing without ATP. He should be driving head up rather than head down, and all the rules and procedures should remain unchanged. There are no doubt complex arguments

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[54] *We note in particular the Cabinet Office Strategy Unit paper of November 2002: Risk: Improving Government's Capability to Handle Risk and Uncertainty, which includes references to railway safety. The regulation of ERTMS might be regarded as a test case for the application of these Cabinet Office principles.*

[55] *It has been put to us by the EPT that the WCRM/ERTMS barrier arose directly from the regulatory and contractual structure put in place at privatisation. We are not persuaded that privatisation required two centres of ERTMS development. If it did, this has important implications for the regulatory structure.*

either way, but we have found no evidence of a strategic policy for making best use of these new developments in train control (and TPWS).

Another aspect of compartmentalisation has been the nature of the EPT inputs. The amount of engineering and costing and detailed modelling has been very considerable, but this has contrasted with the level of economic input, which was largely absent in the EPTFR. So far as we can tell however this imbalance has now been corrected.

Symptomatic of these divisions, and of the safety/ operational division noted below, is the sudden appearance of the capacity impact of ERTMS level 1 as a dominant issue, even though it made no significant appearance during the many weeks of the Joint Inquiry. There appears to have been no substantial new technical information to explain this.

ERTMS policy suffers further from the label of safety. Following the ATP-preventable collisions at Southall and Ladbroke Grove it was inevitable that the political focus should have been on the safety aspects. However improvement of procedures when ATP is defective will prevent a replication of Southall. TPWS installation, now well advanced, would have prevented Ladbroke Grove. ERTMS/ETCS will bring extra safety benefits, and will become essential as speeds rise above present levels However we estimate that TPWS and TPWS+ should reduce the frequency of ATP-preventable fatal accidents (with an average fatality rate of four) to about once every ten years. This is an example of the kind of information needed to guide policy, which does not emerge from the current objectives set for the EPT.

Thus, with the passage of time, the focus on safety has led to decisions, in particular about TPWS, which have taken *the safety differences between the option choices that are still available* to levels which are very small indeed, relative to the typically large differences in direct costs, in technical and managerial risks, and possibly in capacity impacts. Indeed, as the EPTFR usefully stressed, stepping beyond the artificial constraint of considering only ATP-preventable risks, to consider the much larger non-ATP-preventable risks of railway journeys, risks of journeys to and from stations, and risks caused by diversion of traffic to roads, not to mention the options for life saving expenditure in other transport modes or in the public services, the safety impacts prove to be more complex. The numbers in the EPTFR for the extra road deaths are much too high, but safety impacts alone, even setting aside costs and risks of many other kinds, such as cost and time overruns, unreliability and incompatibility (which may well eliminate or reverse the small safety benefit if ERTMS were implemented quickly and successfully) do not appear to favour rapid installation of ERTMS.[56]

However ERTMS is still placed in the safety box. It is there that it is placed in the SRA's Strategic Plan of January 2002. The report of the Joint Inquiry carried this so far that, apart from technical feasibility, all factors other than safety were set aside, although this extreme view, to the best of our understanding, has never been government policy.

A related and recurrent theme is that of trust in the railway industry, matched by industry impatience at its problems not being understood. We sympathise with both sides. However the presentation of the EPTFR did not contribute to building trust by claiming more authority for the analysis that was justified, presenting inflated numbers, and presenting it as a fait accompli, for the safety regulator to validate. This is not a comment on the EPT. Indeed we have been impressed with the competence, industry, commitment and integrity of all the EPT staff whom we have met. And the text of the EPTFR had many caveats. The issue is one of presentation, and the view of the world which the presentation appeared to imply.

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[56] *We note in passing that, by increasing traffic, ERTMS Level 2 is likely to increase the number of railway fatalities, because other railway hazards will kill more people than those saved by the small increase in train protection.*

This is relevant to the issue of explicit regulation of a timescale for train protection. We are persuaded by the industry's concern that, given the uncertainties, regulatory requirements about timescales for installation of ERTMS, if considered necessary, should be designed to be suitably flexible, or kept wholly in reserve at least until the technology to which they apply is available. Regulatory pressure can have a role in driving technological innovation, but it cannot produce technical solutions that do not exist. The whole European industry is struggling to develop workable systems. Their lack of success so far provides evidence of the intractability of the problems, at least for the existing rail industries and their established suppliers. ERTMS is also directly driven by European legislation. It is not clear that still further regulation would serve the interests of railway users.

11.2. WAYS FORWARD

The SRA Chairman, in the announcement of the EPT Final Report, said that "This [ERTMS} will be the biggest technical and operational change seen on the network for 100 years. It is essential that the system we choose is robust and reliable." We agree with both sentences. However the industry's approach appears at present to be dominated by the second sentence, and a perception that, apart from work led by the EPB and WCRM, ERTMS is tomorrow's problem. The "ERTMS debate", in which the HSC/HSE is one key player, needs to be broadened.

Uncertainties about the technology, and the still uncertain nature of the standards, argue persuasively against early implementation of ERTMS. The perceived operational feasibility, especially of early implementation, has become much more uncertain since the Joint Inquiry.

Delay does leave some risk of a fatal ATP-preventable accident and the political cost of this needs to be assessed. As we note above, with a delay of more than 10 years there would probably be such an accident. This has to be set against the other consequences of early installation, including a likely increase in road deaths, risks of serious cost and time overruns and performance shortfalls, the apparent consensus that installation of Level 1 cannot readily upgrade to Level 2, and the considerable diversion of railway management from other demanding tasks. In terms of safety, the likelihood of an ERTMS-induced accident would probably be higher with early implementation.[57] Other sources of train accident risk will continue collectively to be much greater than ATP-preventable sources.

A measured approach would allow the possibility of substantial direct installation of ERTMS Level 2 which offers:

- ATP;
- In-cab signalling;
- Freedom to place signal sections where most effective;
- No trackside signals;
- Elimination of controls required when dependent on human responses to signals and speed restrictions;
- Improved communications; and

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[57] *Although even with well established ERTMS the risk of an ATP-preventable fatal accident would not be zero. With 97 per cent reliability the frequency might be one such accident about every 60 years.*

- A more competitive supply market.

In terms of service delivery these can mean:

- Greater safety (which may have to remain in prime position for historical reasons);
- Speeds over 125 mph;
- More capacity;
- Better recovery from perturbations; and
- Lower cost.

To obtain these benefits in full requires major changes both to trains and to signalling, together with improvements to track and to stations (including those of LUL).

ERTMS needs to be perceived as part of the way the railway needs to develop to meet society's needs over the next generation. The railway needs to increase capacity; increase reliability; improve customer service, including shorter journey times; improve safety and reduce cost. To do all this, the railway needs to reconstruct itself physically and technically. ERTMS at Level 2 will play an important and pervasive role in this.

In that context, ERTMS ceases to be a cost to which people seek to ascribe safety and other benefits in order to justify it. It becomes part (and a cost-saving part) of the preferred way of attaining objectives set for external reasons (whether passenger demand or government policy).

ERTMS does have one important special feature in this process, with its investment in both trains and infrastructure. On the British main line system many trains are dedicated to a given route, but it is very rare for that route to have only that set of trains running on it. It follows that once a "critical mass" of trains and routes are fitted with ERTMS, the marginal cost of extending its use is much reduced.

On this view, the logic is:

- Develop, or contribute to the development of, ERTMS Level 2;
- When its availability can be relied on, plan the railway's development utilising it.

This implies some reframing of "the ERTMS project" to become a component of railway redevelopment, which drives the introduction of ERTMS - not as the plan for introducing ERTMS which drives the redevelopment of the railway. The EPT reports – inevitably – have tended to present their analysis as the latter, and so to understate the needed shift in perceptions.

The case for regulation to accelerate the introduction of ERTMS needs to be considered against that background.

Once ERTMS Level 2 has been developed, its installation is integral with the redevelopment of the main line railway overall. It is also governed by European legislation, which (when duly given effect by corresponding national legislation) appears to serve many of the purposes of national regulation of implementation timescales. The best role for national safety regulation would seem to be to reinforce a well structured and integrated programme. This will be most easily achieved if the railway can develop a climate of trust, built on a closer understanding by the industry of the needs of public sector procedures such as regulatory impact assessment, as well as commercial interests.

12. CONCLUSIONS AND RECOMMENDATIONS

12.1. CONCLUSIONS

12.1.1. General conclusions

The main conclusion of the EPT Final Report (EPTFR), that it would not be appropriate to implement ERTMS to the timetable proposed by the Joint Inquiry into Train Protection Systems, is robust.

The EPTFR concluded that implementation of the currently available ERTMS technology would reduce rail capacity, and as a consequence divert passenger traffic from road to rail, and increase expected transport fatalities. Such an effect is likely, but the EPTFR overestimated the numbers. In practice the numbers are unlikely to be more than two or three extra expected fatalities per year, at today's traffic levels.

More important reasons for reconsidering ERTMS implementation are those of operational feasibility, the risk of an ERTMS-induced accident, other business risk and the need for integration with wider railway development strategies.

Much of the EPTFR input was of very high technical quality. However there was an imbalance between a strong emphasis on detailed analysis and modelling, and a much weaker emphasis on higher level strategic analysis. Lack of higher level analysis limits the value of the work as a source of policy advice. Subsequent work of the EPT has started to address the higher level strategic issues. This needs to be encouraged by the SRA and by government.

The EPTFR compared the industry's own preferred option with one other option, which the industry concluded was infeasible. The EPT programme is now examining a range of sub-options within the broad framework of the earlier preferred option. However the institutional context of the EPT heavily restrains the range of train protection options considered.

An example of the basic information needed for policy analysis is the frequency of ATP-preventable fatal accident in the temporary absence of ERTMS (but with TPWS and TPWS+). We estimate this to be one in about every ten years (with an average number of fatalities per accident of four). With ERTMS this might fall to one in about every 60 years.

Many barriers within the industry reduce the effectiveness of the EPT programme. Widely acknowledged is that between the EPT programme and that of the West Coast Route Modernisation. Another lies between the programme and mainstream network planning. These divisions, in particular the development of two centres for ERTMS development, are not, in our view, barriers attributable to privatisation, as the EPT suggest. But if they are, this has implications for the regulatory structure.

12.1.2. Technical conclusions

The train protection baseline against which ERTMS options are compared by the EPT is somewhat unstable and, more seriously, institutionally constrained. Figures for the effectiveness of TPWS have moved around markedly. TPWS+ cannot be considered because it is not in the EPT's formal remit from the EPB. The likely capacity impact of TPWS appears not to be considered relevant until the data is available for it to be formally modelled.

The choice of two options in the EPTFR was satisfactory as a basis for rejecting the unqualified Joint Inquiry timescale. It does not provide a basis for identifying the key differences between, and comparing alternative more feasible options. Subsequent EPT work is examining sub-options within the industry's previous determined preferred strategic option, but the range of options within the EPT remit is very constrained.

One important train protection option apparently not being considered by the industry is that of speed restriction. The costs of time delays, while probably large relative to the safety benefits, might be smaller than the costs which might be expected from early implementation of ERTMS.

The performance impacts of ERTMS appear to be confined to those derived by signalling engineering. It is not clear how these impacts would work through to the service capacity of the network, given that signalling will often not be the binding constraint and that constraints in one field may be largely accommodated by changes in others.

The EPT railway safety analysis has in many respects been of high quality. However it also bases its projections of railway accidents on fault-tree analysis rather than on past accident frequencies. Both kinds of analysis have their uses, but the evidence suggests that past accident data is the appropriate basis for estimating absolute GB railway train accident risks. The fault-tree method overestimates these risks by a factor of about 2.5. The EPTFR also ignored some issues, such as the risks of journeys to and from stations, which are small but important relative to the very small safety differences now remaining between ERTMS and non-ERTMS options.

One unresolved aspect of the EPT costing of ERTMS development and implementation is the relevance of applying unit labour costs for "call out" work to programme of this kind. Another is the exceptionally high proportion of project management costs.

A more general concern issue is the extremely large increase in the estimated unit costs of ATP equipment and installation over the past ten years – by a factor of about five in real terms. Examination of these figures is achieving some reduction, but not by a large factor.

The intermodal analysis in the EPTFR was incomplete in its handling of the linkages between network capacity and passenger traffic, and between passenger traffic diversion and road travel, although we understand that this work is being further developed.

The EPT's Monte Carlo based analysis of risks of unit cost is of a high professional standard. However it needs to be complemented by higher level top down assessment analysis of risks. This needs to draw upon wider data, such as past project performance, address issues of project time delay and performance shortfall as seriously as costs, distinguish more clearly between problems and risks, and have regard to some upside as well as the many downside risks.

A policy of focusing ERTMS implementation on pinch points looks unpromising. Such a policy would offer little saving in capital costs, no saving in development costs, some loss of direct safety benefit, and extra operational difficulties and risks.

The relative emphasis on fault-tree analysis and past accident rates in projecting future railway accident rates on the British network should be based on careful empirical comparison of the two techniques. Current evidence suggests that the past accident approach is appropriate for estimating the underlying level of risk of ATP-preventable fatal accidents.

12.2. RECOMMENDATIONS

The industry should be congratulated on applying substantial high quality effort to this crucial aspect of railway development.

Future work should include analysis focused at the somewhat higher level needed to provide a basis for sound policy advice about ERTMS strategy. This would require, for example, substantial clarification of objectives, further definition of plausible options and clearer identification and presentation of the key numerical data and the key issues on which high level decisions are required. We note that the EPT work is moving in this direction, but some important aspects of need to be led by the SRA and D*f*T.

Stronger measures should be taken to integrate the work of the EPT and of WCRM with other railway developments, and with disciplines beyond signalling engineering.

- This includes the development, in the SRA or elsewhere, of a wider range of policy options, including for example the speed restriction options for the interval before ERTMS is reliably available.

- It also includes consideration of structural change. Consideration should be given to absorption by the SRA of the EPT, the train control/network management work of WCRM, and the three System Authorities for TPWS/AWS, ETCS/ERTMS and GSM-R. The consultative networks set up by EPT and the TPWS System Authority should in this case be retained and widened, but the leadership role should lie clearly with SRA. ERTMS development and application should become one element in the development of the railway.

The most useful immediate role for government would be to support this integration and to encourage the kind of analysis which is needed for policy advice. It would be premature to consider the regulation of an implementation timescale.

TPWS+ should be installed at those signals where it can bring material safety benefit without material adverse effect on capacity, as soon as practicable.

The British railway industry and government should consider enhancing its input to ERTMS at the European level, in order to reduce the dangers of a British ERTMS which is so different from continental design that many supply chain benefits are lost, and that application of ERTMS in Britain is not held back by limitations on national development capability. Britain should not hesitate to give financial and other support to continental development and trials where this could accelerate the availability of ERTMS Level 2 in Britain.

APPENDIX A TERMS OF REFERENCE

Our scope of work is defined in the form of a set of Economic Questions. A parallel contract with Technical Team was similarly tied to a set of Technical Questions. The two teams were required to liase with other on some of their questions. The Economic Team also included in their work some other issues covered by the Technical Questions which appeared to have an important economic dimension. The two sets of questions, as presented by the Health and Safety Executive, are recorded in Box A.1 and Box A.2 below.

Box A.1 Scope of work – economic review

On the basis of the evidence in the ERTMS Project Team's (EPT's) Final and Interim Reports, the associated data sources, and (if necessary) discussions with the EPT, the Consultant shall undertake a review and prepare a report addressing the following questions :

Economic Questions

1. To what extent has the modelling in the EPT report provided a reasonable baseline for the fitment of ERTMS? What should the baseline be – none; the minimum needed to meet Interoperability (option 3 in the report); or something else e.g. the lifetime of the signals? Work should include taking a view on what HM Treasury would regard as the baseline, taking into account its published guidance.

2. If you consider Option 3 to be the appropriate baseline, has this been properly defined in the EPT Report in terms of the mix of systems types used? [Note that the mix is different to that for Option 4].

3. Are the unit costs for inputs used in modelling to develop the reports' conclusions (e.g. equipment costs; labour costs for fitting track and trains) realistic, justifiable and representative of an efficient strategy for running a fitment programme on this scale?

4. Is the approach taken in the reports to the calculation of the net social value of ERTMS appropriate? There are possible benefits in terms of additional passengers, reduced over-crowding and timeliness. Is the estimation of benefits representative of the true net social value, given the inter-relationship of different effects? Does the EPT's work cover all the issues that need to be taken into account; if not, what is omitted?

5. The report does not cost any infrastructure work that would be necessary to realise the full capacity gain with fitting the more sophisticated versions of ERTMS (although it makes reference to these costs). Would the inclusion (or explicit exclusion) of such factors alter the results obtained?

6. Given any capacity effects of ERTMS, are the proposed cross-modal economic consequences properly justified [including the totality of risk faced by travellers] based on good economic data and consistent with the Department for Transport's National Transport Model and other economic research ?

Note:

The Contractor is asked to discuss emerging findings with the contractor undertaking the technical review of the EPT Reports on questions five and six. The contractor will also be expected to make contact with those modelling patterns of road and rail usage at the Department for Transport as part of this work.

Box A.2 Technical questions

On the basis of the evidence in the ERTMS Project Team's (EPT's) Final and Interim Reports, the associated data sources, and (if necessary) discussions with the EPT, the contractor will be required to address the following questions:

1. To what extent are the reports' conclusions about the effects on network capacity of installing different levels of ERTMS supported by good quality evidence cited in the reports or otherwise justifiable?

2. To what extent are the reports' conclusions about the effects of installing different levels of ERTMS on (a) passenger safety and (b) railway worker safety supported by good quality evidence cited in the reports or otherwise justifiable?

3. To what extent do the reports consider foreseeable risks to passengers and/or railway workers:

   - after ERTMS is fully installed on the network; and

   - during the time when ERTMS is being installed on the network?

4. Does good quality evidence cited in the reports support the reports' conclusions on these points, or are the conclusions otherwise justifiable?

5. To what extent are the reports' conclusions about the effects of changed railway network capacity on "modal shift" (i.e. passenger transfer to other modes of travel) supported by good quality evidence cited in the reports or otherwise justifiable? *(The Contractor is asked to discuss these issues, and questions 5 and 7, with the contractor undertaking the economic review of the EPT Reports and, if possible, to report in a similar format)*

6. To what extent are the reports' conclusions about the effects of modal shifts on totality of risks faced by travellers supported by good quality evidence cited in the reports or otherwise justifiable? *(see note after question 4)*

7. To what extent are the reports' conclusions about the development time needed for the different levels of ERTMS supported by good quality evidence cited in the reports or otherwise justifiable? Are the reports' conclusions on this issue supported by the experience of railway operators in other countries - for example Switzerland, Spain and Holland?

8. To what extent are the reports' conclusions on the business risks associated with early implementation of ERTMS, given its current level of technical development, supported by good quality evidence cited in the reports or otherwise justifiable? *(see note after question 4)*

9. To what extent have the reports identified the systems development issues that are on the critical path, and indicated whether there may be potential for acceleration?

10. To what extent have the reports considered the potential for early fitment of lower levels of ERTMS to "pinch points" in the network? Is this a feasible approach?

11. To what extent are the reports' conclusions about the current state of development of GSM(R), and about the possible need to develop GPRS [General Packet Radio Service] as an alternative, supported by good quality evidence cited in the reports or otherwise justifiable?

12. To what extent have the reports considered the scope for, and risk implications of, migration between levels of ERTMS?

13. ERTMS transfers some safety critical functions from trackside onto trains. Is there good quality evidence cited in the reports that shows that any risk implications resulting from this have been considered?

14. Is there good quality evidence cited in the reports to show that the EPT have fully considered the positive inputs, particularly in terms of identifying new operational rules, learning lessons from current technical specifications, and the application of GSM-R, that the West Coast Main Line Train Control System project could make into the UK ERTMS implementation?

APPENDIX B ESTIMATION OF ATP-PREVENTABLE TRAIN ACCIDENT RISK

This Appendix summarises the two principal methods of estimating ATP-preventable train accident risk on the main line railway system of Great Britain, and lists the key references.

B.1 THE TWO METHODS

The first method is based on the analysis of data on past fatal train accidents. The second is based on fault-tree and event-tree models of the precursors and consequences of train accidents, and, as developed for British railways, is entitled the Safety Risk Model (SRM). The first, past accidents method has been developed largely by Professor Evans, using official fatal accident data from 1967 to the present. The second, fault-tree method has been developed by Railtrack and subsequently Railway Safety. Both methods estimate the risks of ATP-preventable accidents as a component of train accidents more generally, including non-ATP-preventable accidents.

B.2 SOURCES

The principal formal account of Evans' analysis of data on past accidents is in the *Journal of the Royal Statistical Society* (Evans 2000), and the most up-to-date results are in a Centre for Transport Studies unpublished working paper (Evans 2002a), which incorporates changes in analysis and data up to the end of 2001. Evans has also applied similar methods to the analysis of major train accidents in the fifteen countries of the European Union (Evans 2002b).

The principal account of the Safety Risk Model is in the *Risk Profile Bulletin (RPB) Issue 2* (Railway safety 2001). A shorter account, with discussion, is provided by Muttram in the *Proceedings of the Institution of Mechanical Engineers* (2002). This article includes in the closing paragraphs the following view, with which we agree:

> *"This type of modelling [fault trees etc.] is good at producing relative results between different risks . . . It is less well suited to predicting absolute risk levels . . . even if the SRM answer is pessimistic this in no way detracts from its usefulness as a safety improvement tool."*

The estimate of overall train accident risk provided by the SRM is about 2½ times greater than the estimate provided in Evans' analysis of past accident data. The difference prompted Evans to explore the properties of estimates based on past accident data, resulting in a paper to be published in *Accident Analysis and Prevention* (Evans 2003, forthcoming).

B.3 HISTORY

The first serious quantitative estimate of ATP-preventable train accident risk on the main line railway appears to that in a British Railways Board report on BR-ATP (BRB, 1994). That estimate was based on the analysis of ATP-preventable accidents in the period 1968 to 1993. Since 1994, Evans has developed the analysis of past accidents in a series of papers, revising and extending incrementally both the data and the analysis.

This analysis of past accidents has informed the debates on measures to prevent or mitigate train accidents over the period, including the BR-ATP debate, the Mark 1 rolling stock and TPWS regulations, the Davies Report on ATP in 1999-2000, the Uff/Cullen Inquiries in 2000, and the recent CfIT work on inter-modal road/rail safety effects. Risk estimates based on past accidents are discussed in the Davies Report (2000, section 3.3) and in the Joint Inquiry Report (Uff and Cullen 2001, paragraphs 2.14-2.24). While both reports note the uncertainty in the estimates, neither suggests that such estimates are biased downwards.

The fault-tree based SRM was developed first by Railtrack and then by Railway Safety from the late 1990s, culminating in its first publication in Issue 1 of the RPB in January 2001. Issue 2 of the RPB was published in July 2001 (Railway Safety 2001). The first version of the SRM was thus too late to inform the Uff/Cullen Inquiries, but the SRM has now been adopted by the British railway industry as the standard method for estimating railway risks of all kinds. In keeping with that role, it is used as the basis for estimating the pre-TPWS ATP-preventable train accident risk in the work by A D Little for the ERTMS Programme Team (A D Little 2001).

The HSE do not formally approve or reject any single approach. However the SRM has been technically reviewed for the HSE by the Health and Safety Laboratory, and accepted, in its own terms, with only minor reservations. The past accidents approach is used by the HSE Economics and Statistics Analytical Unit for policy analysis.

The SRM was not available at the time of the Uff/Cullen Joint Inquiry. However the figures provided by Evans at that time, estimated by the past accidents approach, were accepted by all parties. There has been no subsequent suggestion that the Inquiry's deliberations should have been based on a markedly higher expected accident frequency.

B.4 WHAT IS ESTIMATED

Both methods estimate, among other outputs, the underlying, "expected"[58] number of casualties per year in train accidents. Both provide an underlying figure for a recent year, which can provide a basis for future projections, for which the past accidents approach has the advantage of measuring trends over time. Both methods permit the separate identification of those accidents that are preventable by automatic train protection, hypothetically presuming the absence of the Train Protection and Warning System (TPWS). These estimates of ATP-preventable risk form one key input into estimating the safety benefits of any form of ATP. In the present British situation, the approach to estimating the benefits of ATP after TPWS (or TPWS and TPWS+) is first to estimate the proportion of casualties expected to be saved by TPWS, and then to estimate those preventable by ATP as the residual. Estimating the benefits of TPWS is a separate exercise.

Evans' analysis of past accidents is confined to fatal train accidents, and only fatalities are analysed directly. The SRM considers non-fatal as well as fatal accidents, and the SRM measures casualties primarily in terms of 'equivalent fatalities'. Equivalent fatalities are a weighted combination of fatalities and injuries, in which, in this context, a major injury is weighted as 10 per cent of a fatality and a minor injury is weighted as 0.5 per cent of a fatality. Thus the 'headline' measures of risk of the two methods are not directly comparable. Nevertheless, it is possible make direct comparisons of the results of the two methods.

The SRM provides estimates of actual fatalities as well as equivalent fatalities. Evans has also estimated a conversion factor from actual to equivalent fatalities for train accidents, using

[58] *As note in the main text, the term "expected" is generally used in this report in its statistical sense of the mean or average of a distribution of possible outcomes.*

HMRI data on fatalities and injuries from 1978 to March 1996. (This is the entire period for which all major and minor injuries were reported by HMRI. They ceased to be reported in that form from April 1996 under the RIDDOR 1995 regulations.) In that 18¼ year period, there were 159 fatalities, 550 serious injuries, and 5,774 minor injuries to passengers and staff in train accidents. If the injuries are weighted as above, this is (159 + (0.1 x 550) + (0.005 x 5774)) = 242.87 equivalent fatalities. Thus the ratio of equivalent to actual fatalities is 242.87/159 = 1.527. A corresponding factor is implicit in the SRM; it is not very different.

B.5 COMPARISON OF RESULTS

The principal published comparison of the results of the two methods is of estimates of the mean number of fatalities per year in all train collisions, derailments and overruns. The mean frequency of such accidents estimated from past accident data is 1.07 per year in 2001, with 3.99 fatalities per accident, giving 4.27 fatalities per year (Evans 2002a, Table 2). The corresponding estimate of the number of fatalities per year from the SRM is 11.3 (Table A1 of the RPB[59]). The difference is a factor of 2.6.

It is now also possible to make a further comparison. The estimate based on past accident data of the frequency of all types of ATP-preventable accident in 2001 was 0.54 accidents per year, again with 3.99 fatalities per accident. This gives 2.16 ATP-preventable fatalities per year (Evans 2002a, Table 2). If we use the conversion factor of 1.527 above, this represents 3.30 equivalent fatalities per year. The estimate of the same quantity from the SRM given in A D Little's safety analysis for the EPT is 9.18 equivalent fatalities per year in 2001 (A D Little, 2001, Table 5, page 20). In this case, the difference is a factor of 2.8.

The coefficient of variation (the standard error divided by the mean) of Evans' estimate of mean fatalities per year in 2000 using accident data for 1967 to 2000 was 36 per cent (Evans 2003, section 5). This implies that a 95 per cent confidence interval for true mean is the observed value +/- about 70 per cent. That is a wide confidence interval, reflecting both the relatively small amount of data (77 accidents at the time) and the large variability in the numbers of fatalities in individual accidents: most fatal accidents have a small number of fatalities, but a few have large numbers. Nevertheless, the estimate from the SRM lies well outside this statistical confidence interval. Thus the two sets of estimates of expected fatalities per year are materially different.

What is the source of the difference? Is it the estimates of the frequencies or the average severities of fatal accidents or both? It is not possible to say. This is because the projections of past accident data are based on fatal accidents only, whereas the SRM covers all accidents of specified types, including those do not cause fatalities or injuries. There are no estimates of the frequencies or severities of non-fatal accidents in the past accident work, and no estimates of the frequencies or severities of fatal accidents in the SRM. Thus neither the frequency estimates nor the severity estimates from the two methods are directly comparable. Some further discussion is in Evans (2003, sections 2 and 6).

B.6 IS THE ESTIMATE BASED ON PAST ACCIDENTS TOO LOW?

Estimates of train accident risk from the projection of past accident data are materially less than the SRM's estimate. Are there reasons to expect the estimate based on past accidents to be biased downwards, which would therefore require an upward correction? Evans (2003,

[59] *The steps in the calculation are: (1) sum the number of fatalities per event across the three person types (passenger, staff, member of the public) for event types HET 1 to HET 9 inclusive, HET 12 and HET 13; (2) multiply fatalities per event by the number of events per year to give fatalities per year for each event type; (3) sum across the event types.*

section 6) considers two possible general arguments, though in the end he rejects both in the present context. The two arguments concern:

(a) The possibility of a recent increase in the average severity of fatal accidents; and

(b) The possibility of material under-representation in the past data of ‘low frequency/high consequence’ accidents.

On (a), if there had been a recent increase in the average number of fatalities per fatal train accident, it would reconcile (at least to some degree) the relatively low risk estimate based on past accidents with the higher estimate from the SRM. Furthermore, as discussed in Evans (2002c), all the British fatal train accidents since 1997 have indeed been severe, with fatalities at or above the historical average of about four. Therefore the data would be consistent with a recent increase in average severity. On the other hand, given the variability in the severity of individual accidents, the data are also consistent with the opposite hypothesis that the underlying mean severity has remained constant, and that the recent run of severe accidents is due to chance. Of these two competing hypotheses, Evans prefers at present to assume that the average severity remains constant, partly for simplicity and partly because the evidence is not yet strong enough to adopt the opposite view. The authors of the SRM do not argue the contrary. If the severity of train accidents were indeed rising, it would be a serious matter.

The ‘low frequency/high consequence’ argument envisages the possibility that a substantial proportion of train accident risk arises from serious accidents that are sufficiently infrequent for them to be not likely to occur in a long period of observed data (such as Evans’ 35 years), but sufficiently serious to have a major impact on the overall risk.

An example from outside railways is merchant shipping, in which it is clear from empirical data that a major proportion of the fatality risk arises from losses of ships, which occur infrequently but are serious when they do. (There were 193 fatalities on the *Herald of Free Enterprise* in 1987.) Therefore any period of observed accident data in which no merchant ships were fatally lost, such as the decade 1991-2000 in the UK, is likely to provide an underestimate of the true risk. More extreme examples are nuclear power, or offshore rigs, where incidents such as the disaster that Three Mile Island might have been, or Piper Alpha, are material risks but extremely infrequent.

At the opposite extreme are many activities, notably road accidents, where the past accident approach is accepted without question as the single appropriate basis for estimating the underlying level of risk. Railway accident frequencies are unusual in being amenable to both methodologies.

Does the 'low frequency/high consequence' argument apply to railways in Great Britain[60], in which a class of serious accident is missed in the 35-year observed data, but included in the SRM? Evans (2003, section 6) considers this possibility and concludes not, partly because the missing class of accident would need to be implausibly serious to close the gap between the two estimates (having an average of more than 200 fatalities per accident), and partly because there is nothing to suggest what that class of accident might be. The extension of the analysis to major European accidents (Evans 2002b) renders the low frequency/high consequence argument even more implausible. This is because the scope of the data for the EU is about 8 times larger than that for GB alone, but the observed average number of fatalities per accident in the major accidents (> 20 fatalities) is about the same. This is despite the fact that continental Europe has seen two railway accidents with just over 100 fatalities since 1967. Finally, the shape of the 'FN-curve' in the RPB (Railway Safety, 2001, page 29) indicates that the SRM does not in fact ascribe a high proportion of train accident risk to high-consequence accidents.

Railway Safety have commissioned further independent work on these issues, from Professor Tim Bedford at the University of Strathclyde, for completion in March 2003, which may bring some more insights.

B.7 CONCLUSION

The difference between the estimates of risk based on the SRM and on the analysis of past accidents thus remains unexplained. This is awkward for those who may need to choose between them.

Both estimates are obtained by methods that have passed peer review in their respective fields, and it is likely that either would be accepted in the absence of the other. Railways are one of the few fields in which both types of estimates are possible: they are sufficiently closely managed (unlike road transport, for example) for risk models to be feasible, and there are enough accidents for direct estimation from accident data also to be possible.

The strengths of the SRM's approach are that it represents the numerous paths by which accidents can happen and their consequences in much more detail than is possible with fatal accident data. In doing so, it deploys much more data. It provides much more detailed output than is possible with accident data. Its weakness is that the use of such models inevitably requires numerous assumptions and judgements, any of which, although plausible, might be wrong. It is possible that judgements may tend to be conservative more often than otherwise. The model is also something of a 'black box' to those not directly involved.

The strengths of the analysis of past accidents are that it is based directly on empirical data, and that it is transparent. Its weakness is the relatively small amount of available data, and the lack of detail and uncertainty this creates in the risk estimates. Nevertheless, from this report's perspective, the direct appeal to empirical experience is the decisive argument in its favour for the estimation of overall accident risk.

It would be desirable somehow to combine the empirical strengths of the analysis of accident data with the understanding of the structure of accident causation embodied in the SRM.

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[60] *It can certainly apply to railways for which the data set is very small. We were told during this EPT study that the Hong Kong metro has had no fatal accidents, whereas no one seriously suggests that zero is an unbiased estimate of the underlying level of risk. An engineering analysis concluded that the this underlying level was about 1 fatality per year.*

APPENDIX C REVIEW OF UNIT COSTS

CORUS RAIL CONSULTANCY

Review of the Economic Aspects of the ERTMS Programme Team
Report dated April 2002

Prepared by :	David Miller	Corus Rail Consultancy
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Corus Rail Consultancy
Review of the Economic Aspects of the ERTMS Programme Team Report dated April 2002
(Report for Inclusion in the Final Report to the HSE)

Introduction

We have been asked to review the unit rates used in modelling the cost estimates included in the EPT final report and to comment on the appropriateness and robustness of these rates. The purpose of this report is to describe the results of this review and to make recommendations as to the further steps which will need to be taken to refine the estimates included in the EPT final report.

Given the scale of the risks and uncertainties attached to the ERTMS project at this stage of its development the Capital Costs included in the Report must be considered to be high level. A considerable proportion of the total estimated capital costs is made up of the risk element. In order to be able to take a considered view of the reported costs it has therefore been necessary to consider both the quantities and rates used in deriving the capital costs and the risks and uncertainties which have been applied to them. The opportunity has been taken to examine the risk register and to draw some interim conclusions about the manner in which the risking exercise for each option has been carried out.

It has not generally been seen to be within the scope of this review to investigate in detail the quantities used in building up the estimated costs. However the opportunity has been taken to comment on some of the assumptions made concerning the scope of work required where it is considered that this will be of assistance.

In conversation with members of the EPT team it has become apparent that considerable further work has been carried out on costs and risks since the date of the Final Report. Consequently matters that are raised in this report may already have been considered by the team. However this review has been generally confined to the information made available from the Report dated April 2002.

General Approach to Reviewing the Capital Costs

The primary input and output spreadsheets have been examined and the build-ups to the estimates shown on the summary sheets traced back through the linked sheets; firstly to the point where quantities and rates are combined to derive the estimates and secondly to the derivation of the quantities and rates themselves. The flow of data has been clearly and logically organised and a very comprehensive costing exercise has been carried out.

In analysing the data provided particular attention has been paid to the sources of cost information that have been available to the ERTMS Project Team when arriving at the rates used in the Report. In view of the ongoing development of the technology required for the various ERTMS systems described in the report no other sources of cost data will be available to validate the costs of the equipment other than that provided by the manufacturers themselves. Where other sources of cost data have been available these have been used as sources of comparison with the rates used in the report.

The mathematical manipulation of the raw cost data (e.g. the use of averages) to derive the unit rates has also been reviewed to check the logic that has been applied in building up the rates used in the Report.

Capital Cost Summaries

The EPT report concludes that for the two programmes of work, defined as Option 1 (re-run) and Option 4 (refined), the estimates for the risked capital costs are as follows:

Table C.1 Capital costs

	Option 1 (re-run) £ million	*Option 4 (refined) £ million*
Estimate of base Capital Costs	3,415	2,698
P80 risk addition	2,625	910
Total estimated Risked Capital Costs	**6,040**	**3,608**

The estimates for the Base Capital Costs have been built up as follows:

Table C.2 Components of base capital costs

Cost Head	*Option 1 (re-run) £ million*	*Option 4 (refined) £ million*
Train labour	507	485
Train materials	696	696
Track labour	587	394
Track materials	306	131
Training not included above	19	19
New trains/roads	30	30
Train cancellations	268	134
Possession over-runs	91	9
Planned disruptive possessions	108	51
Project management	329	337
GSM-R data upgrade	143	143
Trials/test tracks	131	131
EPT to end March 02	5	5
System authority (development)	9	9
Project management (development)	186	124
Total estimated Base Capital Costs	**3,415**	**2,698**

Train and Track Labour

Train labour and track labour elements collectively represent approximately 1/3 of the total base capital costs of the projects. The labour rates used within the report are therefore an important area for review.

Day rates have been derived from a number of sources and applied to the resource models for train and track installations to produce yearly labour costs aggregated to arrive at total costs.

The calculated day rates for track labour reflect the fact that a major element of this work will need to be carried out during night/weekend possessions.

In deriving day rates uplifts have been applied to salary costs to include for employer's contributions, overheads and profit. A check with published estimating books appears to support the logic that has been applied in deriving these rates. Straight mathematical averages have been applied across the range of rates supplied by each firm and the overall range of rates to calculate the average day rates used in the calculations. The use of un-weighted averages from small samples of rates does raise some questions, which might be pursued further. Since the rates supplied by each firm are given equal significance within the calculations this might not reflect the likelihood that some firms will be in a better position than others to actually provide significant labour resources for the Project. It would seem logical that the rates supplied by firms in this position would have a greater weighting within the calculations. It might also be desirable to consider the geographical spread of the Project and reflect in the average labour rates the fact that a major part of the work will take place within the South East and thus be subject to labour rates at the higher end of the ranges shown.

Given these reservations the day rates used in the Report can be generally validated by comparison with the charge out rates in a sample of current Railtrack/Network Rail Framework Agreements. However the question does arise as to whether the use of day rates is appropriate in the context of this project.

Day rates are a suitable way of charging for contracted labour in a call-off contract situation or for the short-term hire of personnel and, to an extent, the use of these rates within these cost calculations is simply reflecting current contractual relations within the railway industry. However it is to be hoped that the scale and length of the ERTMS programme would enable significant savings to be made in the labour element. This might be achieved by means of a greater level of direct employment by the infrastructure controller; a longer term strategy made possible by the scale and length of the projected workload and requiring development and training programmes to provide the necessary labour resources. Alternatively, given the scale of the projected workload, contractors' charge out rates might with justification be negotiated below the day rates quoted. It is anticipated that further work will be needed on the project procurement strategies before the effect of these alternative scenarios on the labour rates used in the Report can be properly evaluated.

Train and Track Materials

Train materials and track materials collectively represent approximately a further 1/3 of the total base capital costs of the projects. However, as has been noted above, it is not considered that the materials rates provided by the manufacturers of the equipment can be validated in any meaningful way within the constraints of this Review. Despite speculation that there is an element of 'front end loading' in these costs it is not possible to draw any firm conclusions from the information currently available.

Two major assumptions appear to have been made in calculating the quantities of train and track equipment that will be required for the two options. Firstly it has been assumed that the number and type of trains requiring fitment will remain static since the calculations do not make any allowance for future changes in rolling stock currently planned to meet TOC aspirations for additional services. Secondly the classification of high, medium and low density routes, which feed into the calculations of the quantity of track materials and track labour required, does not appear to take into account planned and current improvements which may reclassify these routes and affect these quantities. It might be expected that these two factors would have a potentially greater effect on the costs of Option 4, given the greater time period involved. It is to be expected that further study will enable judgements to be made about the effect of these factors on the scope of work required.

The number of signals is obviously critical to the calculation of the costs of track materials and track labour. However since there is no central database which holds this information the EPT team will have had to make assumptions based on the Network Management Statement. The reliability of these quantities must therefore be in some doubt at present and it is expected that further work will be needed to validate the numbers.

The rates used for costing the Level 1 cable and cable troughing requirements are reasonable However an optimistic scenario appears to have been adopted in assessing the likely extent of this work. It has been assumed that 90 per cent of the cables can be accommodated within existing troughing. This presupposes (i) that existing cable troughing routes are present, (ii) that they are in a suitable condition and (iii) that they have the capacity to accommodate the new cables. Further investigation into the current state of cable routes would assist in ensuring a greater degree of confidence in these assumptions.

Plant required for Track Installation

Unlike labour and materials, plant has not been treated as a separate cost heading within the analysis. Enquiries have revealed that the labour rates are considered to be sufficiently 'all in' to cater for the small tools and plant that will be required for fitting the balises and LEUs. The rates used for cable troughing and cable fitting can also be considered to be inclusive of plant. In addition it has been stated that the materials rates obtained from RIASIG include for delivery to the point of installation. However it would appear likely that a considerable amount of road/rail transport will be required to transport materials to sites especially in remoter locations where access points are well spaced. It might be useful in further studies to treat road/rail transport as a separate item in order to allow a more detailed analysis of these costs to be carried out.

Training

The resources evaluated under this heading are those required to set up the training programme for the project and to train the trainers. The labour costs of the trainers and the personnel requiring training are included separately within the calculations of train and track labour. A detailed analysis of the anticipated resources has been made in arriving at the final figure. It is noted that 50 per cent of the cost of training is represented by the purchase of 8 driving simulators.

New Trains/Maintenance Roads

The costs calculated under this heading represent an assessment of the costs of substituting rolling stock during the periods when the existing rolling stock has to be taken out of service to be fitted with the onboard equipment. Costs have also been calculated for constructing additional maintenance roads to accommodate this stock but the analysis has concluded that no additional roads will be required.

An analysis has been carried out which has resulted in the identification of the need for 10 new trains and a further 20 trains which will require to be refurbished and kept running during the fitment programme.

It is noted that the rate used for the purchase of the new Class 170s and Class 375s is an average derived from the costs of a number of other trains. It would seem more logical to have based this rate on the cost of the actual trains that are specified in the analysis. An assumption has been made that spare rolling stock will be available for refurbishment.

However in the case, for example, of the recent withdrawal of the existing Virgin fleet as being surplus to requirements, much of the stock has not been placed into store but has already been acquired by new operators. If it were to be found that sufficient spare rolling stock would not be available then the requirement to purchase additional new trains would increase these costs substantially. It might be useful if further investigations into this question were carried out in order to de-risk this part of the capital cost of the project.

Train Cancellations, Possession Over-Runs and Planned Disruptive Possessions

Some necessarily broad assumptions have had to be made by the authors of the EPT Report in attempting to evaluate the likely costs of these eventualities. The headings cover (i) the cost impacts of ERTMS faults leading to cancelled services and requiring compensation to be paid to the affected TOCs, (ii) compensation to affected TOCs for over-running rules of the route possessions during the installation of the trackside equipment and (iii) Schedule 4 charges for utilising major possessions during the installation of trackside equipment outside the normal rules of the route.

Train Cancellations

Train cancellation costs have been based upon the impacts of faults recorded in 86 Class 43 ATP-fitted power cars over 29 periods. This has been applied to the total fleet to be fitted with ERTMS equipment over a period of 5 years and costed using a cost per delay minute rate representing an un-weighted average of Schedule 8 costs.

An overall factor of 100 per cent has been added to the Option 1 costs based on the assumption that faults will be greater during the period when the system is still being developed.

In calculating these costs it has been assumed by the EPT team that there would be a high level of faults for the first 5 years and steady state for the remaining years. It has also been assumed that the level of faults will be the same as for ATP installations and that, from a cost point of view, the number of faults that occur will be the same in all parts of the rail network.

In view of the significant costs recorded against this heading and the heavy reliance that has had to be placed on possibly unreliable historical cost information it is recommended that additional work be carried out in order to reduce the level of uncertainty associated with the train cancellation costs.

Possession Over-Runs

In calculating possession over-run compensation costs it has been assumed that 10 per cent of possessions required for the track fitment programme will overrun and that the likelihood of this occurring is the same on all parts of the network. Given the nature of the work involved it is considered that the 10 per cent allowance may be on the high side. The cost of these overruns is calculated using the same un-weighted average Schedule 8 costs as above and no account has been taken at this stage of regional variations and the location of routes most likely to be affected by such over-runs.

Planned Disruptive Possessions

Schedule 4 charges for the LNE Zone have been extrapolated to derive weighted average compensation costs to the TOCs for the different lengths of possessions required outside of the normal rules of the route. It would obviously be a worthwhile exercise to access Schedule 4 charges from all the Zones to enable a more representative nation-wide rate to be derived.

There does however appear to be some doubt as to whether Schedule 4 charges would be applicable at all in the case of the ERTMS project. Information received from Railtrack's Project Manager Schedule 4 (Implementation) points to the fact that work to meet new legislation does not incur Schedule 4 charges and that any such costs are left to the TOCs to absorb. It is understood that this is the case with the TPWS project and it seems likely that this would also apply to the ERTMS project. However a more definitive ruling would be required before this could be stated with certainty.

An allowance has also been included here for the costs of arranging the necessary third rail electrical isolations. The rate used for this calculation (£175.50) does not however tie up with the generally held view that £1500 per isolation would be a more realistic figure.

Project Management Costs

Project Management costs relating to the development and implementation of the Project are set out separately within the Report. Other elements of Project Management costs are included within the assessments of the cost of track labour, train labour, GSM-R data upgrading and trials/test tracks. The table below sets out summaries of the Project Management costs attributable to the Project.

Table C.3 Project management costs

	Cost Head	***Option 1 (re-run) £ million***	***Option 4 (refined) £ million***
Specific PM Costs	*Development*	*185.59*	*124.05*
	Implementation	*328.71*	*336.78*
		514.30	***460.83***
Individual Section PM Costs	*Test Tracks*	*5.64*	*19.95*
	GSM-R	*11.01*	*13.24*
	Track Labour	*140.72*	*90.49*
	Train Labour	*174.43*	*167.73*
		331.80	***291.41***
Total Project Management Costs		***846.10***	***752.24***

Project Management costs represent additions of 32 per cent to the physical works costs in Option 1 and 39 per cent to the physical works costs in Option 4. These percentages appear to be very high and not in line with the budgetary allowances applied to normal Railtrack infrastructure projects, which are more likely to be in the range of 8 per cent to 10 per cent. It is recognised that the ERTMS project has a number of special features, not least in the cutting edge technology that needs to be developed and the major logistical and organisational challenges that need to be met. However it is obviously necessary to examine these costs rigorously.

In terms of resources it needs to be asked whether there is any element of double counting involved within the separate analyses of project management costs applied to train and track labour and the project management (implementation) costs.

The resources required for the system authority project team, the development project team and the implementation project team have been calculated based on the experience of the ERTMS implementation programme team. Weighted day rates have been derived from the known rates of the personnel involved in the team and applied to the estimated resources to derive yearly costs for project management at different stages of the project. The day rate used for the project management resource that is directly related to track and train labour has been averaged from the sources of information that have been discussed earlier in this report.

It is understood that project management costs included in the Report are currently being reviewed by the ERTMS Programme Team.

GSM-R Data Upgrade

The GSM-R data upgrade costs have been obtained from Railtrack's GSM-R project and it is not considered that any further cost information is available than that included in the Report.

Trials and Test Tracks

The trials and test track costs have been calculated on the assumption that two trial projects and two test tracks will be required during the development phase. The estimate for the trial projects has been taken from a Railtrack business case document and the estimate for the cost of test tracks has been derived from some historical cost information relating to Old Dalby test track. A member of the Programme Team explained that these calculations had not been based on any very detailed analysis of the likely scope of this element of the work and it would be fair to say that the amount of £131 million included under this cost heading should be considered to be provisional.

Since the date of the Final Report a considerable amount of further study has been carried out by the Programme Team and it is to be expected that the high level of uncertainty that currently attaches to these costs can start to be reduced.

Review of Risked Capital Costs

Appendix F 1.6: Cost Risk and Strategic Risk, extracted from the EPT Final Report, has been made available for review. A meeting was held on 11/11/2002 with Nigel Williams and Tim Bartram, risk analyst for the Programme Team, to discuss the methodology used in the preparation of the Risk report. Queries that arose from the initial examination of the risk report have been answered in full by Tim Bartram.

The document that has been reviewed includes a register of the risks used in the analysis together with the modelling notes but precludes access to the actual risk model. However the modelling notes have been recorded in great detail and have provided most of the information needed to form a judgement. It has not been possible to establish details of any correlations used within the model and, since the P80 results are used in the scheme costs, relationships between risks do have an effect on results at this percentile.

It would have been useful to be able to review the correlations used between risks, but without access to the Risk Model this has not been possible. In addition it has not been possible within the timeframe of this report to access the minutes from the risk workshops that have been held and the one to one interviews with the risk owners.

We have reservations generally about the use of matrices to determine ranges of costs and probabilities, but it is common practice at this level of the study, and we note that time constraints in producing the data have precluded independent verification of this data. We have been assured that wherever information exists which more accurately describes the risk, this has been substituted for the matrix values.

The individual risk owners and other interested parties have produced the estimates of the cost of risks. There are some reservations about this method of assessing costs in that it may be preferable to have an estimator as part of the Risk Team to provide a consistent basis for evaluation across the whole of the model. It is possible that individual owners will tend to over or under estimate the impact of their risks compared with other risk owners. It is also essential with such wide bands in the matrix for the analyst to be able to account for a 'most likely' area within the wider bands to enable the distribution to be weighted accordingly. Again this might be assisted by having specialist estimating skills within the team to standardise the quantification of risks.

The following comments relate to particular risks and uncertainties included within the risk analysis.

Time/Resource Assumptions and Exclusions (4.1)

- Assumption 3 confirms that worst case scenarios have been used for the contracting strategy, although this is partly offset by Assumption 4 that there will be no restraints on simultaneous time scales for each segment. Future estimates should refine contract costs downwards due to a more advantageous procurement strategy.

Strategic and High Level Programme Risks (5.1)

- The actual renewal dates for signals have a big impact on the cost of the works, as others would bear some of the costs where renewal was scheduled within the ERTMS project implementation. This would appear to be a significant risk which could be relatively cheaply mitigated to firm up costs and project strategy. Although mitigation of strategic risks is generally outside the responsibility of the project team, the benefits of having accurate figures for this particular risk could far outweigh the cost of investigation. It is noted that this risk has been excluded from the model at this stage.

Appendix 4: Table of Uncertainties

- R761. Track Sections. Considering the future plans to upgrade many of the under utilised routes throughout the network, the parameters for uplifting current designations of densities appears low. However it may be that a pragmatic approach to the chances of these schemes being implemented has influenced the risk allowance.

- R770. Track Fitting Programme - Resources. There has obviously been a great deal of research into the spread of uncertainty surrounding individual elements of this risk, and, without having had sight of the actual Risk Model, it must be assumed that similar care has been taken in the correlations between the elements, which would make this a valuable contribution to the results.

- R771. Train Fitting Programme - Resources. Conversely to R770 all spreads are concentric and would rely on accurate correlations to avoid the overall effect becoming neutral.

- R788. Labour rates. These are a significant element of the estimated costs, and the treatment of uncertainty needs to be very carefully considered. It is suggested that a detailed analysis of rates most likely to apply to the specific tasks planned for this project would greatly assist in producing a more robust cost estimate. It follows then that, in future assessments, this item could be modelled in a much more detailed way around the uncertainties of these specific rates, rather than around an average of averages.

Appendix 5: Risk Register

- R372. Late Placement of Design Contracts. This risk immediately raises the question as to why there is no cost impact due to its occurrence as there must be some 'fall-out' other than just inflationary effects. Similar comments apply to R377 – Termination of Sub-Contracts.

- R387. RT unable to handle Acceptance of Designs. The figures used for Option 1 would suggest that direct mitigation measures would certainly be applied and the quantification of this risk should represent only that cost and not the cost of the potential damage.

- R441. Supplier Pricing. This is a particularly difficult risk to quantify. It is covered in the uncertainty on estimates but without sight of the Risk Model it has not been possible to check how the effects have been incorporated. It would be expected that that sufficient separate allowance has been made for this risk since its impact could have a major effect on installation costs.

- R493. Poor expectation management. Figures used for Option 1 in this version of the model suggest that this risk must be mitigated and subsequent versions will include only the cost of mitigation.

- R847. Double fitment of Great Western. Without access to the Risk Model it has mot been possible to check the treatment of this risk and its effect on the results.

The methodology used for the risk assessment has been thorough and the range of risks considered demonstrates that a considerable depth of understanding of the uncertainties surrounding the project has already been reached. The quality of the assessment at this level is of a high standard.

It has not been possible however to review the correlations between the risks without having had access to the Risk Model.

One suggestion to achieve an even greater level of quality in future risk assessments would be to include an estimating specialist as part of the team in order to refine the cost estimates used in the model.

It is understood that separate investment cases are now being put forward for early deployment schemes which should provide valuable information and assist in the progressive

Associated Infrastructure Costs

In order to consider fully the likely costs of associated infrastructure work which could realise the full capacity gains made possible by the installation of the Level 2 system, a programme of work would be required that has not been achievable within the timescales laid down in this review.

The implementation of ERTMS across the country would bring valuable safety benefits to the rail network. However, to attain the full capacity improvement potential of the system, additional infrastructure improvements would be needed. To define the improvements which would need implementation, it would be necessary to examine each route individually, calculating where conflicts would arise. This is likely to differ from the areas where current loops, sidings and stabling facilities exist. Using existing infrastructure knowledge, train planning and future route benefits, it would be possible to determine where improvements would be most cost effective. As well as analysing individual routes, the actions of other rail traffic joining, crossing or interacting with the main routes will have a major impact on projected capacity. The interactions of these services could result in a different set of infrastructure improvements being required. Once these calculations were completed, engineering decisions on the nature of the required infrastructure improvements could be made and estimates of likely costs prepared and included within the financial case for the installation of ERTMS. The benefits these infrastructure improvements would produce could be demonstrated in terms of optimising the capacity improving potential of ERTMS, and offsetting these benefits against the capital costs of the project.

Conclusion

The analysis that lies behind the calculation of the capital costs of the two options considered within the EPT final report has been comprehensive, thorough and, importantly for this review, logically organised and easy to follow. As has been indicated within the body of this report there are areas within the analysis where broad assumptions about the likely scope of the work involved and the rates used in the evaluation of costs have had to be made. This has obviously been recognised by the ERTMS team and is evidenced by the high level of risk that has been attributed to the base capital costs of the project.

It is understood that work has been ongoing since the publication of the Final Report in order to test the assumptions made in respect of the resources required and the rates used within the analysis of the project. It is obviously vital for the success of the ERTMS project that this process of refining the estimates should continue.

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GLOSSARY

Automatic Train Protection (ATP)
British Rail – ATP (BR-ATP)
Cost benefit analysis CBA
Computer Based Interlock(ing) (CBI)
Commission for Integrated Transport (CfIT)
Department for the Environment, Transport and the Regions (DETR)
Department for Transport (D*f*T)
European Commission (EC)
ERTMS Programme Board (EPB)
ERTMS Programme Team (EPT)
EPT Final Report (of April 2002) (EPTFR)
EQE International Limited (EQE)
European Rail Traffic Management System (ERTMS)
European Train Control System (ETCS)
European Traffic Management Layer (ETML)
Global System for Mobile communications – Railways (GSM-R)
Her Majesty's Railways Inspectorate (HMRI)
Health & Safety Commission (HSC)
Health & Safety Executive (HSE)
National Engineering Laboratory (a private sector company) (NEL)
Railway Industry Association (RIA)
Rolling Stock leasing Company (ROSCO)
Institute of Transport Studies (ITS)
Multi-Criteria Análisis (MCA)
National Transport Model (NTM)
Office of the Rail Regulator (ORR)
Railway Industry Association special interest group for the six ETCS suppliers in the European Market (Alstom, AnsaldoBreda, Bombardier, Alcatel, Siemens and Invensys) (RIASIG)
Radio Block Centre RBC)
Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 RIDDOR)
Signal Passed At Danger (SPAD)
Strategic Rail Authority (SRA)
Train Protection and Warning System (TPWS)
An enhancement to TPWS for higher speed trains (TPWS+)
Union of the European Railway Industries (UNIFE)
A UNIFE Working Group of companies providing equipment compatible with ERTMS (at present as under RIASIG above) (UNISIG)
West Coast Route Modernisation (WCRM)

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