West Coast Route Modernisation
Strategy for Phase 2

RAILTRACK

Prepared By
The Nichols Group

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EXECUTIVE SUMMARY

Railtrack's original strategy for West Coast Route Modernisation (WCRM) was the basis for contractual commitments with Virgin and Undertakings to the Rail Regulator in 1998. Following a review and restructuring of WCRM early last year, the Railtrack Board approved proposals for Phase 1 (for May 2002), involving conventional upgrades of infrastructure. However concern remained regarding the risks in meeting the Phase 2 outputs (for May 2005) through the development of a new, moving block signalling system (TCS-M), as previously planned. The Board therefore commissioned an immediate review of the implementation strategy for Phase 2.

Railtrack engaged the Nichols Group to lead and facilitate this task. Nichols formed a strong, integrated team including specialists from Nichols, Railtrack, control systems contractors (Alstom Signalling and US&SI) and other consultants (including Parsons Brinckerhoff and HF&A2). A Review Group, chaired by Simon Murray, Director Major Projects and Investment, met weekly to consider interim findings and ensure the team had access to all necessary resources and support.

Key findings from the review are:

1. The planned infrastructure would not provide the necessary capacity, and the strategy for the introduction of the proposed moving block signalling (TCS-M) was not viable within an acceptable timescale. As a result a revised strategy is needed for Phase 2.

2. The revised implementation strategy for Phase 2:
   - retains fixed block conventional signalling
   - implements a radio-based cab signalling overlay Train Control System, to enable:
     - increased line speeds
     - Automatic Train Protection (ATP)
     - compliance with European inter-operability legislation
   - requires further civil and signalling infrastructure works some of which will be the subject of new TWA approvals.

3. The additional train paths, reduced journey times and enhanced punctuality contracted to Virgin for 2005 could be achieved with the revised strategy, but this is equally dependent on:
   - timely completion of the Network Change process
   - Virgin achieving their operational performance targets
   - adequate HMRI resources to support the significant volume of safety approvals
   - successful TWA approval.

4. The Undertakings are not clear and specific in all respects. Railtrack should discuss the interpretation of a number of issues further with the Rail Regulator.

5. The review identified a small number of relatively minor issues in relation to the Undertakings that are not covered by the revised strategy. It is considered that providing further
Strategy for Phase 2

Infrastructure is not the appropriate solution in these cases. Railtrack is recommended to discuss with the sSRA, Rail Regulator and customers opportunities to modify these requirements. Subject to such agreement, Railtrack could meet its Undertakings, and Railtrack is reviewing its plans to enable earliest practicable completion.

6. Retaining the conventional signalling:
   - allows trains without TCS equipment fitted to continue to operate on the route, enabling the programme of train fitment and driver training to be progressive
   - requires replacement of life-expired conventional signalling. The condition of existing signalling has been assessed and will need substantial replacement on all routes between Euston, Birmingham and Manchester prior to completion of Phase 2. This is a new risk which the programme management team will need to assess carefully with both its supply and customer partners

7. The 53 VATT trains will require fitting with cab signalling equipment by 2005 to meet PUG2 contractual commitments.

8. The scope requirement to fit other WCML trains, the timescales and the responsibilities for undertaking this work will be influenced by:
   - the findings of the Sir David Davies Inquiry and subsequent response by the Government
   - the operational requirements of TOCs, FOCs, ROSCOs and other industry stakeholders

9. The revised strategy will provide ATP functionality on the infrastructure over all route sections covered by the WCRL programme.

10. The revised strategy increases confidence in meeting Railtrack's objectives for the WCRL programme, although there is a substantial increase in the volume of work to be undertaken.

11. The overall capital cost, at 80% confidence, is now £5,849m (£099 prices). This has increased by £1,101m compared to the Baseline 1 estimate of £4,748m. This includes the cost of the additional work scope and the effect of a higher estimating confidence level.

The Railtrack Board endorsed these findings, subject to funding, on 9 December 1999.

A much higher level of confidence now exists that the revised strategy can be successfully implemented within the timescales quoted. However, it is not without risk in terms of schedule and cost. To undertake such a major upgrade on a busy, operational, mixed traffic trunk route like the West Coast Main Line is a huge and unprecedented challenge. Railtrack can only succeed if each and every one of the key stakeholders contributes fully and in a timely manner throughout the programme's life cycle. The stakeholders include the Shadow Strategic Rail Authority (sSRA), the Rail Regulator, the Health & Safety Executive, the train and freight operators, the ROSCOs and Railtrack's suppliers, as well as the passengers.

During this review the tragic accident at Ladbroke Grove occurred. The subsequent review of train protection systems by Sir David Davies has not been published and therefore is not reflected in this report.
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PART I - INTRODUCTION AND BACKGROUND

1. Scope of Report

This report describes the results of a review of the previous strategy for implementing Phase 2 of the West Coast Route Modernisation (WCRM) programme. The report outlines:

- significant events over the last year which have led to the review
- the approach adopted for the review
- why it is necessary to revise the Phase 2 strategy
- the strategy now recommended
- the impact of the revised strategy on capacity and performance, timing, cost, other financial implications and risk.

It should be noted that parts of this review, and some of the associated supporting documentation, are commercially sensitive and should not be disclosed to third parties without Railtrack’s prior knowledge and written consent.

2. Main Conclusions

The principal results can be summarised as:

- a new strategy is needed for Phase 2
- this could enable commitments to Virgin, and substantially all of the Undertakings to be met by May 2005, subject to:
  - timing of Network Change process
  - operational performance of Virgin Trains
  - adequacy of HMRI resources
  - TWA approvals
- the interpretation of, and response to, some of the outstanding issues with commitments and Undertakings needs discussion with the SSRRA, the Rail Regulator and customers
- the revised strategy entails:
  - retention of conventional signalling
  - overlay with radio-based cab signalling
  - further infrastructure works
- the recommended approach provides:
  - progressive implementation of signalling, including ATP
  - incremental fitment of rolling stock beginning with the 53 Virgin Active Tilting Trains
  - adherence to EU standards for interoperability
Strategy for Phase 2

- the revised strategy significantly increases confidence in meeting Railtrack's objectives for Phase-2, but at a considerable increase in cost

3. Re-assessment of WCRM

Over the last year, the WCRM programme has undergone a re-assessment resulting in a fundamental restructuring, strengthening of organisation and revision of strategy. This has been carried out in four partly overlapping stages, as outlined below.

3.1 Programme review (December 1998 – March 1999)

In December 1998, Railtrack appointed the Nichols Group to conduct a review of management arrangements for the WCRM. Nichols recommended adopting a 'programme management' approach, compiling a baseline for the programme and strengthening WCRM management by:

- creating a small, powerful programme Board to establish and maintain a consistent strategy for the programme
- separating the roles of sponsor and delivery, under the Director Commercial and Director Major Projects & Investment respectively
- appointing a new General Manager WCRM to provide strong drive and direction to the massive task of implementing the programme on a busy operating railway
- setting up a programme management office within the Delivery team to oversee implementation of the delivery strategy and to direct system integration, logistics, safety and compliance and overall planning, control and reporting
- procuring necessary external support, by appointing a world-class programme management contractor.

3.2 Baselining (March – May 1999)

The Railtrack Board endorsed Nichols' recommendations and immediate steps were taken to implement them through an intensive 11 week Action Plan carried out by a joint Railtrack/Nichols team, led by Railtrack. An immediate action was the appointment of Tony Fletcher as General Manager WCRM on 1st March 1999. The plan comprised three work streams:

- baselining, to establish clear programme objectives and high level definition of scope, programme, capital cost, business plan and risks. The results were set out in what is referred to later in this report as Baseline 13
- strengthening organisation, setting up the separate Sponsor and Delivery teams and creating a programme management office
- setting up framework agreements with leading programme management organisations, selected through international tendering, to support Railtrack's long term capital investment programme. Parsons Brinckerhoff were later appointed as programme management contractor for WCRM.

Key findings from the baselining exercise were:

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3 Baseline May 1999, dated June 1999 (WCRM-033)
Strategy for Phase 2

- Phase 1 contractual commitments could be met by adopting conventional infrastructure solutions by 2002.
- Phase 2 had a very low probability of being delivered by 2005 and there were major risks associated with the TCS-M system and associated fitment of equipment to the West Coast Main Line (WCML) train fleet.

On 26th May 1999, the Railtrack Board endorsed the Phase 1 execution plan and target cost, but directed a further review of Phase 2 with three specific objectives:

i. Evaluate feasibility of TCS-M for WCML.
ii. Model performance likely from the proposed infrastructure and benchmarked performance of the Virgin Active Tilting Trains (VATT).
iii. Devise alternative fallback solutions that could satisfy Railtrack's contractual commitments and Undertakings.

The Board paper which proposed this review illustrated the way forward with the diagram, reproduced as Figure 1, in which the completion date (9 December 1999) was depicted as a black diamond and has subsequently become widely known as "Black Diamond" day.

![Diagram](image)

Figure 1: Way ahead from May 1999

3.3 Phase 2 strategy review (July - December 1999)

Railtrack engaged the Nichols Group in June 1999 to undertake the review so as to enable the WCRM General Manager to recommend a revised strategy to the Railtrack Board on 9 December.

The remit for the review was given in a Board paper* presented in July 1999.

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*Phase 2 Action Plan, dated 15th July 1999 (WCRM-034)
3.4 Phase 2 cost validation and regulatory treatment (October - December 1999)

In parallel with the strategy review, Railtrack commissioned two related activities:

- an independent validation of WCRM programme costs, led by Parsons Brinckerhoff and supported by HF&A, which resulted in the Baseline 2 Cost Plan for the programme
- an assessment of regulatory treatment for remuneration of WCRM costs - led by Ernst & Young

The outputs of the Phase 2 Review were fed into both of the above activities.

4. Organisation and Resourcing

The organisation set up for the review is shown in Figure 2.

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Figure 2: Organisation of Phase 2 Review

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5 Submission to the Rail Regulator, date 13th January 2000 (in WCRM Sponsor’s files)
Review team

Mike Nichols, Chief Executive of Nichols, led the review. He formed a strong, integrated team with Railtrack, using Nichols consultants, Railtrack personnel and other consultants with relevant experience and expertise. Specialists in both the WCRM Sponsor and Delivery teams, and from elsewhere in the organisation, have also been consulted and involved throughout.

Contractor support

In addition, Railtrack's signalling supplier, Alstom Signalling, has acted as technical advisor on train control systems and worked in a Joint Project Team (JPT) with Railtrack to define potential solutions and assess their impact on schedule, cost and risk.

Union Switch & Signal has also advised and participated in a JPT to help establish a revised strategy for the Network Management Centre (NMC).

Review Group

A Review Group, chaired by Simon Murray (Director Major Projects & Investment), met weekly to consider interim findings, ensure deployment of appropriate resources, provide advice and policy decisions associated with the recommended revised strategy and to direct the further work of the team. The Review Group comprised Directors and senior managers responsible for sponsoring and delivering the programme.

Use of external experts

External experts were engaged to:

- provide an independent assessment of the status and viability of the TCS-M signalling system
- assess availability and potential use of alternative control systems available elsewhere in the world
- draw on first-hand experience in adopting a moving block system on the Docklands Light Railway (DLR) and the attempted development and implementation of such a system on the Jubilee Line Extension (JLE) of the London Underground
- assess the likely response of the Railway Inspectorate to the proposed signalling options and risks involved in gaining safety approval.

Programme managers

Following their appointment as programme managers for the WCRM, Parsons Brinckerhoff were involved in the review and immediately joined the Review Group in late September 1999. They have provided advice on performance modelling as well as systems integration, development and application, based on their extensive experience of heavy rail enhancement programmes throughout the world, especially in the USA.

WCRM Delivery and Sponsor teams

The review team directed analysis that in some cases was managed through the WCRM Delivery and Sponsor teams. The emerging findings and conclusions were checked with both teams as appropriate.
Strategy for Phase 2

Cost estimating
To assess the financial implications of various options, and of the proposed WCRM Contacts & Supply strategy for Phase 2, the review team, supported by HF&A, managed a number of costing and related risk analysis exercises carried out by other experts, including:

- costs of additional infrastructure schemes undertaken by Railtrack's multi-functional consultants
- estimates for conventional signalling prepared by HF&A
- costs of options for new train control systems compiled by Alstom Signalling.

Cost validation
The cost validation exercise was managed by Parsons Brinckerhoff, supported by Ernst and Young, with input and support from the review team on costs relating to the revised Phase 2 strategy.

5. Process for Review

5.1 Main activities
The three primary work streams of the review - evaluating TCS-M application on the WCML, performance modelling and devising a fallback strategy - were undertaken in parallel in order to complete the review by 9 December 1999. The work streams were interrelated, and the process was necessarily iterative, as shown in Figure 3 below.

![Figure 3: Phase 2 Review process](Image)
Strategy for Phase 2

Infrastructure, train performance and control systems

The infrastructure, train performance and control systems, as summarised in Baseline 1, were defined in greater detail to provide the basis for the review.

The commitments and Undertakings

The WC RTC Sponsor team had summarised the contractual commitments to operators and Undertakings made to the Rail Regulator, and the dates by which they were to be achieved, in the May 1999 baselining exercise. The review team used this as input to confirm the objectives to be met by the Phase 2 strategy.

Timetable

The development of a timetable is a recognised method for demonstrating that the necessary train paths can be accommodated. The WC RTC Sponsor team had begun preparation of the first specimen 2005 timetable at the start of the Phase 2 Review and identified a number of outstanding issues during that process. The approach to resolution of these issues was a crucial assumption of the revised strategy.

Performance modelling

The timetabled services were modelled to demonstrate that they were workable and to assess how infrastructure, train performance and control systems contribute to overall route performance.

Further modelling was commissioned to simulate the effects of changes to infrastructure and control systems.

The modelling was managed by the review team and undertaken by WCRTC Systems Engineering Group with specialist consultancy support from AEA Technology Rail and Jardine Associates.

Evaluate TCS-M

The previous assumptions regarding the development and implementation of TCS-M on the WCML were challenged in workshops involving Railtrack's TCS supplier, Alstom Signalling, and Railtrack's technical and operational experts. External experts reviewed the proposals, using their experience of implementing novel signalling systems on other railways.

Infrastructure options

Changes to the Baseline 1 Infrastructure were considered and their ability to resolve the outstanding timetable issues was assessed using expert analysis, local timetable amendments and modelling. Pre-feasibility studies were used to validate the resulting designs, costs, schedules and risks.

Other control system options

Research was commissioned into the availability and status of control system options around the world and those available were assessed for compliance with ERTMS/ETCS Specifications.

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4 Specimen Timetable Phase 2 Undertakings, July 1999 (WCRM-025)

5 Functional Specification, dated 16th April 1999 (WCRM-012) and Supplement to the Functional Specification, dated 14th May 1999 (WCRM-12)
Strategy for Phase 2

The allocation of the suitable alternatives to sections of the route was proposed in outline and the likely migration path from the existing signalling through to the completion of Phase 2 was defined. This enabled equipment quantities to be estimated.

Possible solutions

Combinations of the infrastructure schemes and alternative control systems were considered in a series of scenarios. The team determined the revised strategy by comparing performance, schedule and costs of those scenarios.

Time, financial and risk implications

The team confirmed that Phase 2 would have been completed significantly late under the previous strategy, especially implementation of the TCS-M. The schedule for the revised strategy combines input from Alstom Signalling and the technical consultants, and takes resource constraints into account.

The cost of each control system option was estimated by Alstom Signalling and validated by the review team. This information, plus Railtrack's historical cost data for conventional signalling, formed the basis for costing each of the scenarios being considered. Both WCRM Delivery and HF&A challenged and endorsed the infrastructure costs.

The review team led the identification and assessment of risks, supported by Alstom Signalling, technical consultants and HF&A, and proposed how the key risks should be mitigated.

Revised strategy

The revised strategy was accepted in principle by the Review Group on 28 October, was developed in detail and then endorsed at the Railtrack Board meeting on 9 December 1999, subject to funding. This report supports the presentation made to that Board meeting.

5.2 Underlying assumptions

In order to contain the scope of the review and to complete it in the limited time available, the following assumptions were made as the review progressed, with guidance from the Review Group:

- Phase 1 of the WCRM programme will deliver its outputs on time
- the existing targets set by the Rail Regulator for annual reductions in train delay will be met
- the infrastructure as set out in the WCRM Functional Specification for execution in Phase 2 can be implemented on time
- the specimen timetables produced by the WCRM Sponsor team, and the associated list of 'outstanding issues', represent the deliverable capacity and journey time commitments for Phase 2
- commitments to implement ATP 'within a reasonable time' can be met by Phase 2 works and will not be required for Phase 1
- the Virgin Active Tilting Trains will perform in accordance with the Benchmark Data
- electrical power will be available to support operation of the timetabled services, including recovery from service perturbations.
5.3 Scope of the review

The paper recommending the Phase 2 Review, which was submitted to the Railtrack Board in July 1999, posed seven key issues to be addressed in the review. These are listed in Table 1 below, which indicates how they are covered in this report.

<table>
<thead>
<tr>
<th>Issue raised</th>
<th>Report Section</th>
<th>How the issue is addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Demonstrate that the solution meets the business requirements</td>
<td>Section 8</td>
<td>Performance assessed</td>
</tr>
<tr>
<td></td>
<td>Section 11</td>
<td>Infrastructure assessed against business requirements</td>
</tr>
<tr>
<td></td>
<td>Section 12</td>
<td>Alternative control systems assessed against criteria</td>
</tr>
<tr>
<td>2. Develop a practical strategy for TCS implementation and stakeholder participation</td>
<td>Section 12</td>
<td>Appropriate control systems selected</td>
</tr>
<tr>
<td></td>
<td>Section 16</td>
<td>Strategy recommended</td>
</tr>
<tr>
<td>3. Assess the key risks and propose mitigation</td>
<td>Section 8</td>
<td>Performance of Baseline 1 systems and infrastructure would not satisfy the requirements</td>
</tr>
<tr>
<td></td>
<td>Section 9</td>
<td>TCS-M risks evaluated</td>
</tr>
<tr>
<td></td>
<td>Section 10</td>
<td>Risks invoke a revised strategy</td>
</tr>
<tr>
<td></td>
<td>Section 16</td>
<td>Revised strategy has lower risk</td>
</tr>
<tr>
<td></td>
<td>Section 16.4</td>
<td>Measures recommended to mitigate residual risk</td>
</tr>
<tr>
<td>4. Evaluate alternative infrastructure and system solutions to meet business requirements</td>
<td>Section 11</td>
<td>Infrastructure needs assessed against business requirements</td>
</tr>
<tr>
<td></td>
<td>Section 12</td>
<td>Alternative control systems assessed against business requirements</td>
</tr>
<tr>
<td>5. Assess the cost of the programme</td>
<td>Section 15</td>
<td>Financial implications summarised</td>
</tr>
<tr>
<td>6. Evaluate the wider benefits to the network of TCS-M</td>
<td>Section 9</td>
<td>Feasibility of TCS-M evaluated</td>
</tr>
<tr>
<td></td>
<td>Section 16.4</td>
<td>Separate research and development recommended</td>
</tr>
<tr>
<td>7. Propose strategic relationships with suppliers</td>
<td>Section 16.4</td>
<td>Contracting strategy outlined</td>
</tr>
</tbody>
</table>

Table 1: Scope of review
6. Commitments and Undertakings

6.1 Introduction

The WCRM programme is being undertaken to meet a number of objectives that arise mainly from:

- statutory requirements
- contractual agreements
- regulatory licence requirements and Undertakings.

These are described in more detail below as background for the analysis that follows. This does not constitute a definitive statement of Railtrack's legal commitments and Undertakings.

At the start of the Phase 2 Review, an exercise was undertaken by the WCRM Sponsor to ensure that all relevant contractual commitments and Undertakings had been identified and to clarify the objectives for each phase of the WCRM programme.

6.2 Statutory requirements

Railtrack's licence

Railtrack is a regulated utility, bound by the Railways Act 1993, to undertake its business in accordance with the provisions set out in its Licence. The Licence obliges Railtrack to maintain, renew and develop the network so as to satisfy the reasonable requirements of persons providing services for the carriage of passengers or goods by railways. Renewals of life expired equipment do not have to be exact like-for-like replacements, but must be of modern equivalent form.

European Interoperability

The objective of the European Union Directive 96/48 "Directive on High Speed Rail Interoperability" is to remove the barriers to interoperability imposed by the different systems currently in use on each national rail network. The Directive requires Railtrack to implement systems compliant with mandated European Technical Specifications for Interoperability (TSIs) whenever it is undertaking a major upgrade of a high speed Trans-European Network (TENs) route, one of which is the WCML.

The Technical Specification for Interoperability covering 'Command and Control' systems, requires the use of systems which are compatible with the European Rail Traffic Management System/European Train Control System (ERTMS/ETCS) for signalling and the Global System for Mobile Communications - Railway (GSM-R) for train radio purposes. Systems compliant with these specifications must therefore be applied on those sections of the WCML subject to major upgrade.

Safety

In addition to the general provisions of the Health and Safety at Work Act and Railtrack's Licence obligations to provide railway infrastructure capable of safe operation, there are also specific requirements concerning railway safety called for by other regulations.

Minimum requirements for train protection are mandated by the Railway Safety Regulations 1999.

Automatic Train Protection (ATP), which protects against driver error on a continuous basis, further enhances the safety of train operation. HMRI have indicated that ATP is a requirement for
the operation of trains at speeds in excess of 125mph. Railtrack has made various statements to Government, the Health and Safety Executive, the Office of the Rail Regulator and the public regarding the introduction of systems to protect automatically against driver error, particularly Signals Passed At Danger (SPADs).

6.3 Contractual Commitments

Virgin

On 8 June 1998 Railtrack and Virgin Trains, through West Coast Trains Ltd, entered into the 10th Supplemental Agreement for the enhancement of passenger services on the WCML. This contract, known as 'PUG 2' (Passenger Upgrade 2), superseded the previous upgrade agreement made between Railtrack and ORPRAW 1997. PUG 2 specifies the services that Virgin Trains are entitled to operate and the required journey times, punctuality and capacity to be supported by WCML in each of three phases, as summarised in Table 2:

<table>
<thead>
<tr>
<th>'Phase 0' (August 2001)</th>
<th>Phase 1 (May 2002)</th>
<th>Phase 2 (May 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing journey times and linespeeds (operation of new trains at 110mph)</td>
<td>Specified maximum journey times (implying 125 mph running)</td>
<td>Specified maximum journey times (implying 140 mph running)</td>
</tr>
<tr>
<td>Existing services (per hour in each direction):</td>
<td>Additional services (per hour in each direction):</td>
<td>Additional services (per hour in each direction):</td>
</tr>
<tr>
<td>1 Manchester</td>
<td>2nd Manchester</td>
<td>3rd Manchester</td>
</tr>
<tr>
<td>1 Preston/Glasgow</td>
<td>2nd Preston/Glasgow</td>
<td>4th Birmingham</td>
</tr>
<tr>
<td>2 Birmingham</td>
<td>3rd Birmingham</td>
<td>Additional North Wales/Chester services</td>
</tr>
<tr>
<td>3 Holyhead per day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punctuality of 90% within 10 minutes</td>
<td>Punctuality of 90% within 10 minutes</td>
<td>Punctuality of 85% within 5 minutes</td>
</tr>
<tr>
<td>VATT (Virgin Active Tilting Train) train performance characteristics (non-tilting)</td>
<td>VATT (Virgin Active Tilting Train) train performance characteristics</td>
<td>VATT (Virgin Active Tilting Train) train performance characteristics</td>
</tr>
</tbody>
</table>

Table 2: PUG 2 contractual commitments to Virgin

'Phase 0' of the WCRM represents the introduction of the new Virgin Active Tilting Trains (VATTs) on the WCML at existing linespeeds in existing train paths and without tilt. Activities required to achieve this objective comprise mainly route clearance and signalling immunisation works.

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* 10th Supplemental Agreement to the Track Access Agreement of 30th April 1995, dated 8th June 1998 (MISC017)
* Passenger Upgrade Agreement (1997) ("PUG 1") (MISC-019)
**Strategy for Phase 2**

**Journey times and train performance**

The maximum scheduled journey times for Phases 1 and 2 are contractually defined, for specific stopping patterns under PUG 2, in terms of Rolling Stock Parameters (RSPs) and Infrastructure Parameters (IPs) that form the Benchmark Data\(^\text{10}\). These parameters include train performance characteristics committed to by Virgin at the commencement of PUG 2 and commonly known as those of the Virgin Active Tilting Train (VATT).

**6.4 Undertakings to the Rail Regulator**

Railtrack gave a number of Undertakings to the Office of the Rail Regulator in connection with PUG 2. Under the conditions of its Licence, Railtrack must comply with these Undertakings.

The principal Undertakings are to provide, 'on completion of the PUG 2 project', and in addition to the access rights granted to West Coast Trains Ltd under the PUG 2 contract, standards of train performance which meet the reasonable requirements of operators and funders and sufficient capacity for:

- existing rights held by passenger operators as at 6th March 1998
- existing levels of freight services as at 6th March 1998
- two additional 140mph train paths per hour between Euston and Crewe
- one additional 125mph train path every other hour between Euston and Crewe
- forty-two additional slow line train paths per day between Willesden and Crewe.

**6.5 Objectives for Phase 2 of the WCRM**

The Phase 2 Review was concerned only with delivery of the outputs required for Phase 2 of the WCRM. In undertaking the review, it was assumed that:

- Phase 1 would be completed as planned on time
- Automatic Train Protection (ATP) was not a pre-requisite for the introduction of 125mph operation. If this were to become a requirement, then the provision of ATP would have to be incorporated in Phase 1 of the WCRM.

Therefore, the objectives to be delivered by Phase 2 of the WCRM can be summarised as:

- renew life expired assets and replace with modern equivalent form
- achieve European interoperability by adopting an ERTMS/ETCS compliant signalling system
- enhance safety by implementing ATP on all route sections covered by the WCRM
- increase capacity by 8 additional high speed passenger paths per hour and 42 slow line paths per day
- reduce 'inter-city' journey times by introducing 140mph maximum speed running on selected sections of the route
- improve punctuality.

\(^{10}\) 10th Supplemental Agreement - Benchmark Data (WCRM-021)
PART II - ASSESSMENT OF PREVIOUS STRATEGY

7. Previous Strategy and Assumptions

7.1 Introduction

The strategy for modernising the WCML was already in place in 1998 and underpinned the contractual and regulatory commitments made in that year. The strategic review that reported in March 1999, raised some concerns about the scale and complexity of the Phase 2 programme and the risks associated with the strategy for delivery. These were reinforced at the conclusion of the baselining exercise in May 1999, which drew attention to the unacceptable level of risk associated particularly with the planned, moving block train control system (TCS-M). That gave rise to the proposed review of strategy for Phase 2. Nevertheless, pending the outcome of this, the previous strategy for Phases 1 and 2 was adopted as the basis for Baseline 1.

The strategy for Phase 2 comprised:
- renewals and upgrades of infrastructure
- new control systems.

These are outlined and reviewed below.

7.2 Infrastructure

The infrastructure works for Phase 2 were planned to include:
- renewal of existing life-expired permanent way and Overhead Line Electrification (OHLE) assets and enhancements to improve reliability and allow trains to run at 140 mph
- re-modelling of junctions and provision of additional sections of track to remove conflicts and increase capacity.

Qualitative analysis was used to identify the set of junction remodelling schemes that were thought to be sufficient to enable the contractual commitments and Undertakings to be delivered. These were defined in the Functional Specification. But the qualitative analysis was not confirmed at that time by production of a specimen Phase 2 timetable or by computer modelling of performance.

The infrastructure improvements, combined with an assumed contribution from the new moving block train control systems, was thought to be sufficient to provide the required increase in the number of train paths.

7.3 Control systems

It was planned that the TCS-M system would replace existing conventional signalling on that portion of the route where it was beyond economic maintenance and deteriorating in performance (i.e. time expired). The TCS-M system, as described in Appendix D, was to be compliant with ERTMS/ETCS Specifications.

---

Functional Specification, dated 16th April 1999 (WCRM-012) and Supplement to the Functional Specification, dated 14th May 1999 (WCRM-013)
Strategy for Phase 2

Lineside colour light signals and track circuits would be removed in areas controlled by TCS-M (except in dual signalled islands). Trains passing through a TCS-M area would be fitted with trainborne TCS equipment, through which the driver would receive movement authorities via a display in the cab.

The proposed geographic scope of implementation would require TCS equipment to be fitted to approximately 1300 trains (approximately one third of all trains operating on the Railtrack network), of 34 different types operated by 13 different passenger and freight train companies. The estimated number of trains involved was later revised to 1500.

Fitting the TCS trainborne equipment would entail a major re-fit, specific to each class of train, requiring each train to be taken out of service for about two weeks. For new trains, provision can be made for installation during vehicle build - a much simpler task. Fitment rates were critically dependent on an excess of rolling stock to enable trains to be taken out of service for timely fitment. It is believed that there is no such excess of rolling stock.

The trackside component of TCS was to interface with a route management system operated from a Network Management Centre (NMC), which would control a wide area of the route. The NMC would request route settings by the TCS to control the pathing of trains. It would be responsible for managing services to the timetable and 'short term' work around and recovery plans to deal with interruptions. Thus the NMC would be focused on managing services to meet operational targets.

Geographic scope of TCS-M

The geographic scope of TCS-M was determined on the basis of:

- condition assessment of existing signalling
- desire to minimise the complexity of TCS design and to avoid coverage of major junctions and S&C (Switches and Crossings) by starting north of Euston, at the 7 mile post, and finishing south of Proof House Junction on the London side of Birmingham New Street
- minimising train fitment costs for TCS by avoiding the need to fit large numbers of trains having limited interaction with the WCML.

Using these criteria, it was decided that the new TCS-M control system would be implemented on the sections of the route shown in Figure 4.

Figure 4: Geographic application of control systems (as at May 1999)
Strategy for Phase 2

The remainder of the route would be signalled using conventional multi-aspect signalling which would be:

- renewed as part of a major construction project (e.g. London Euston to Mile Post 7)
- renewed where time expired (e.g. Birmingham to Stafford)
- not changed where the signalling was not time expired (e.g. areas North of Crewe)

It was necessary to create a "dual signalled island" at Crewe, where both conventional and TCS signalling were to be provided to allow non-TCS fitted trains to continue to operate under the control of the conventional system.

The proposed introduction of the TCS-M system involved a number of conceptual changes to signalling practices and offered a number of benefits. These are described in Appendix D.

TCS-M implementation strategy

The switch over of control in the TCS-M designated area was planned to occur in a series of six, almost consecutive, 96 hour possessions, effectively constituting a 'big bang' changeover. All trains and drivers would have to be prepared in advance, ready for the new control systems to take control at the end of the 'switchover' possession. The timing and logistics associated with managing such a 'big-bang' were assumed to be achievable.

A migration stage was planned because the introduction of the TCS-M system would involve such a significant level of change from current practices. It was therefore proposed that an intermediate system, known as TCS-F (fixed block) should be implemented on part of the route prior to the application of TCS-M. The TCS-F system is described in Appendix D. This intermediate step would provide important design, implementation and performance feedback for the main TCS-M implementation.

It was planned that TCS-F would be implemented on the fast lines only between a point 7 miles north of Euston and Basford Hall (just south of Crewe), thereby supporting potentially higher speeds than 125mph. The only trains that would be fitted with TCS-F trainborne equipment would be the 53 VATTs.

It was not proposed that the TCS-F system would be compliant with ERTMS/ETCS standards because of the short timescales available for its development, approval and implementation.

Operational implications

The conceptual changes to signalling introduced by TCS-M would lead to significant working practice changes for the staff running the operational railway environment, particularly train drivers. This would require changes to rules, procedures and safety cases before the new technology could be utilised safely. These would need to cover both operating under the new system and transitions between conventional signalling and TCS-M.

The most significant conceptual changes, in this respect, were:

- cab signalling

All drivers using TCS fitted trains would require to be trained in the new rules and standards before an area could be switched over to control by TCS-M. Approximately 4,000 drivers would need training.
Strategy for Phase 2

- removal of lineside signalling control indicators, e.g. colour lights and speed restriction markers
  
  The control of the railway was to be dependent on information known by the TCS-M system, with less obvious physical 'control indicators'. These indicators inform other operational staff, besides drivers, of what is going on e.g. platform staff.

- use of bi-directional working during perturbation recovery

  It was assumed that the capabilities of TCS-M to support bi-directional working would form part of the recovery strategies for managing the effects of perturbations. However, no operational recovery strategies had been agreed.

In the event of failure of TCS-M, all trains controlled within the affected area would have to stop as a failsafe mode. No other means of passing movement authorities exists, beyond manual means e.g. via voice radio. The colour light lineside signals would not exist as a fallback means of signalling. The principle of TCS-M is that it would be a highly reliable system with a very high level of availability.

The TCS trainborne equipment requires accurate data about the train on which it is located. For example, the length of the train is crucial to the calculation of track occupancy that would be passed to the TCS trackside system to maintain safe separation of trains. The precise method of ensuring that TCS trainborne equipment has accurate data was not yet defined. However, it was assumed that the driver would be involved in either maintaining the data or confirming that the data is correct.

Maintenance Implications

The TCS-M signalling system was assumed to provide several key advantages for maintenance over conventional signalling, notably:

- significant reduction in trackside signalling equipment with the removal of track circuits - and eventually integrated block joints (IBJs) - and very little lineside cabling, reduced whole life costs

- centralisation of control equipment into trackside processing centres and radio block centres improved access for maintenance

- TCS-M could take account of the location of staff on or near the line and reduce the speed of trains passing the area, thus improving their safety protection

- management of possessions could be improved, leading to shorter 'take up' and 'give up' times

- bi-directional working facilitated by TCS-M could improve the availability of diversionary routes during engineering works or during service disruptions.

7.4 Assumptions

Therefore, the key assumptions supporting the previous strategy were that the TCS-M system:

i. could be developed, approved and implemented on a significant proportion of the WCML by May 2005

ii. could deliver significant increases in available train paths, thereby allowing the capacity commitments to be delivered with the infrastructure enhancements specified in the Functional Specification

iii. was essential to enable the revised maintenance regime, necessitated by the train service enhancements, to be delivered
iv. could operate immediately at maximum reliability.

8. Performance Assessment

8.1 Introduction

The output performance of the WCML route must be improved to:
- reduce journey times
- provide more train paths (capacity)
- reduce train delay (punctuality and ability to recovery from perturbation).

A primary aim for the review team, based on guidance from the Review Group, has been to recommend a strategy which will enable all the required improvement in route outputs for Phase 2 to be delivered.

This section presents:
- the issues associated with achieving this aim
- the analysis undertaken to provide clarity on 'how performance is improved'
- the findings of the analysis
- conclusions as to how the revised strategy should achieve the aim.

8.2 Background

The following questions, related to achieving this aim, were identified at the start of the Phase 2 Review:
- was there a clear definition of the improvement in outputs required?
- if, as seemed likely, changes to the strategy were required, how could the outputs still be delivered?
  - did the previous strategy deliver the outputs required?
  - what were the contributing factors to increased outputs?
  - if the strategy changed the control system, what else was required to maintain the outputs required?

The performance assessment work was undertaken in parallel with the other threads of Phase 2 Review. Because of the existing concerns over TCS-M, the scope of the performance assessment work included looking at the performance of alternative signalling systems. The output of this analysis subsequently influenced the revised strategy.

Definition of outputs required

The Phase 2 Review built on the work that had already been undertaken by the WCRM Sponsor team to produce specimen Phase 2 timetables. The initial modelling work used the July 1999\textsuperscript{12}

\textsuperscript{12} Specimen Timetable Phase 2 Undertakings Issue 1\textsuperscript{st} July 1999 (WCRM-015)
Strategy for Phase 2

timetable and the later work was re-based against the September 1999 version. The specimen timetables were used as a definition of the capacity and journey times to be delivered by Phase 2. The 'shortfall in capacity' identified in the timetables was not significant to the modelling, as the analysis was seeking to clarify relative performance comparisons, not absolute performance. The punctuality commitments outlined in Section 6 were taken as being the train delay outputs required.

Factors contributing to railway outputs

This sub-section introduces terminology and concepts as an aid to understanding the later description of the performance modelling. It also presents a qualitative response to the question ‘What are the contributing factors to increased outputs?’

![Figure 5: Railway system outputs](image)

The factors affecting railway outputs are common, or generic, across all railways, and are illustrated in Figure 5. The specific characteristics of a railway determine how much each factor contributes to

---

1 Specimen Timetables Phase 2 Undertakings September 1999 (Version 3.1) (WCRM-012)
Strategy for Phase 2

Each output. To illustrate this point, Table 3 compares the contribution of each generic factor to capacity outputs for both WCML and a 'metro' type railway.

<table>
<thead>
<tr>
<th>Characteristic &amp; Influence</th>
<th>Metro</th>
<th>West Coast Main Line (WCML)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Train Performance</strong></td>
<td>Homogeneous - all trains will typically have the same acceleration and braking characteristics</td>
<td>Varied - rolling stock has a wide performance variation. This reduces capacity</td>
</tr>
<tr>
<td><strong>Infrastructure</strong></td>
<td>Straightforward - routes are typically simple with relatively few junctions and crossovers</td>
<td>Complex - there are a number of areas where:</td>
</tr>
<tr>
<td></td>
<td>Difficult to change - due to siting in densely populated areas and/or underground</td>
<td>- fast and slow lines are transposed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- the number of tracks reduces from four to two/three</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- other services cross the WCML, e.g. cross country services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- services cross WCML to access freight depots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capacity is affected by 'conflicting movements'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Some scope for change</td>
</tr>
<tr>
<td><strong>Control System</strong></td>
<td>Signalling Headway is dominant - for capacity improvements, as other factors are less constraining. 'Moving block' therefore can lead to significant improvement</td>
<td>Signalling Headway is important - but is not the dominant factor. The constraint to capacity is mainly infrastructure. 'Moving block' optimises capacity, within the constraints set by infrastructure. Most benefit can be obtained in a localised situation</td>
</tr>
<tr>
<td><strong>Timetable</strong></td>
<td>Straightforward - there is typically little variation in stopping patterns and few infrastructure related constraints. The distances are shorter</td>
<td>Complex - due to:</td>
</tr>
<tr>
<td></td>
<td>Station Dwell Times - significant influence on capacity</td>
<td>- wide variety of stopping patterns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- wide variation in train performance and types</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- constraints imposed by conflicting moves due to crossing moves, line ordering transposition, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This reduces capacity</td>
</tr>
</tbody>
</table>

Table 3: Comparison of contributions to metro and WCML outputs
Strategy for Phase 2

The following points are made in relation to the above:

- Table 3 indicates that the influence of 'moving block' signalling on capacity is less significant on WCML than for a metro. This suggests that an alternative signalling system could be used, without too much compromise on capacity.

- The options available to Railtrack to produce increased outputs are restricted because Railtrack does not control many of the timetable and train performance factors. Infrastructure and control systems are the main factors affecting outputs that are more directly under Railtrack control.

The Phase 2 Review team also used performance modelling to provide a quantitative analysis for all three output types, not just capacity\(^*\).

**How did the previous strategy deliver the outputs?**

At the time the contractual commitments were made and the Undertakings were given, it was assumed that the increased outputs could be delivered by a combination of the proposed infrastructure enhancements and Implementation of moving block signalling (TCS-M), as set out in the previous strategy. This was a qualitative assumption and had not been validated in detail by timetabling or performance modelling.

The qualitative assumption was probably based on an expectation that increased outputs likely to be gained by implementing moving block signalling on metros could also be realised on the WCML. The following assumptions under-pinned the previous strategy:

- increased outputs could be delivered by a combination of the proposed infrastructure enhancements and Implementation of moving block signalling (TCS-M)
- a 'moving block' signalling system was a pre-requisite to achieving the outputs
- train operation at 140 mph on the enhanced infrastructure was required to meet the journey time outputs
- the change that occurred in train performance, from RATT to VATT rolling stock parameters, only impacted journey time outputs.

In summary, the previous strategy needed more quantitative analysis to confirm the outputs. The work done by the WCRM Sponsor and the operational planners in the Zones to create specimen timetables has now enabled that analysis to take place.

**8.3 Process**

The Phase 2 Review assessed the WCRM outputs using:

- Phase 2 specimen timetables
- various computer simulations to check that the timetable is workable.

The specimen timetable assumed only infrastructure enhancements specified in the previous strategy. Sectional running times were based on VATT characteristics for the new 140mph trains.

\(^*\) Performance Modelling (Team-035)
Modelling tools

Two computer-based modelling tools were used to understand performance by recreating and simulating parts of the operational railway, as shown in Table 4 below. Both tools require a timetable to model.

<table>
<thead>
<tr>
<th>Modelling Tool</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>VISION(^5)</td>
<td>• assess timetable under unperturbed circumstances</td>
</tr>
<tr>
<td>(AEA Technology)</td>
<td>• assess the delay recovery characteristics of different railway configurations.</td>
</tr>
<tr>
<td>TRAIL(^6)</td>
<td>• assess expected punctuality on the basis of current asset reliability</td>
</tr>
<tr>
<td>(Jardine Associates)</td>
<td>• understand the change in asset reliability necessary to support delivery of a given performance target.</td>
</tr>
</tbody>
</table>

Table 4: Modelling tools used

Capacity assessment

Assessment of increased capacity outputs, defined as providing extra train paths, was assessed in two phases:

- analysis of the July specimen timetable to establish that all the required train paths had been provided
- modelling of the September timetable to assess whether it was workable and robust.

The first phase of the assessment was undertaken by the WCRM Sponsor team and identified that there was a 'shortfall' in capacity with the Baseline 1 solution. The 'shortfall' was recorded as outstanding issues in the introduction to the specimen timetable. In summary, the shortfall was in the Undertakings given to the Rail Regulator:

- not all of the high speed open access paths were included
- not all the open access freight paths could be included in a way that was considered suitable for use by the FOCs.

Other issues listed in the specimen timetable were not included in the later capacity shortfall assessment. These issues were assumed to be resolvable by the WCRM Sponsor team in due course and would not require additional train paths.

The second phase of the capacity assessment was undertaken within the scope of the Phase 2 Review modelling work. Even though the specimen timetable did not contain all the train paths, it was judged to be sufficient to assess the relative effects of changing the control system.

\(^5\) Performance Modelling (Team-035)

\(^6\) Performance Modelling (Team-035)
8.4 Delivering Phase 2 WCML outputs

Previous strategy - perceived contributions

The contributions to outputs by each component of the railway system, as perceived as the basis for the previous strategy, are summarised in Table 5 below:

<table>
<thead>
<tr>
<th>Contribution to WCML outputs</th>
<th>Journey Time</th>
<th>Capacity</th>
<th>Train Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Train Performance</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Signalling (TCS-M)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Key

✓ Minimum  ✓ Moderate  ✓ Major

Table 5: Contributions - perceived in previous strategy

The table reflects the previous expectation that TCS-M could be relied on to provide the required improvement in outputs.

Modelling

The review team directed a series of modelling runs against the specimen timetable, varying infrastructure, train performance and control system parameters one by one to identify their individual contribution to outputs. As stated earlier, the work was organised through the WCRM systems integration modelling team and its specialist consultants.

Conclusions were drawn where the effect of varying certain parameters provided consistent results across separate modelling runs using different configurations of input factors. For example, increasing maximum linespeed from 125mph to 140mph was observed to provide consistently better recovery from perturbation regardless of the input configuration of the model.

The effect of changing the signalling system was also assessed for impact on journey time and capacity outputs.

The infrastructure, train performance and control system options assessed by the modelling are shown in Table 6.
**Strategy for Phase 2**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Options Modelled</th>
<th>Previous Assumption Tested</th>
</tr>
</thead>
</table>
| Signalling      | • "Perfect" signalling
• ERTMS/ETCS Level 3
• ERTMS/ETCS Level 2
• ERTMS/ETCS Level 1
• Conventional Signalling | A Moving block signalling system required to achieve the Phase 2 outputs |
| System          |                                                                                   |                                                                                           |
| Train Performance | • VATT
• RATT                                                                 | Change from RATT to VATT rolling stock parameters impacted only journey time outputs |
| Infrastructure  | • "Perfect" infrastructure at 140 mph
• "Perfect" infrastructure at 125 mph
• Baseline 1 Infrastructure at 140 mph
• Baseline 1 Infrastructure at 125 mph
• Specific infrastructure schemes | 140 mph running required to meet the journey time outputs |

† "Perfect" signalling represents a control system that is able to maintain a safe headway with no delay from processing overheads.

★ "Perfect" infrastructure represents Baseline 1 infrastructure where the linespeed profile is constant for the given speed and practical elements such as cant and track geometry do not need to be considered.

**Table 6: Factors varied - output modelling**

Results of modelling

As illustrated in Table 7 below, the perceptions on which the previous strategy was based were shown to be inappropriate as a result of the modelling work.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Previously Perceived</th>
<th>Results from Modelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journey Time</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Capacity</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Train Delay</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Infrastructure Layout</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Train Performance</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Signalling System</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
</tbody>
</table>

**Table 7: Contributions - revised after modelling**

The implications of this were:
Strategy for Phase 2

- shortfalls in capacity are likely to require further enhancement of infrastructure
- impact of train performance on reduced train delay is more significant than was realised
- the importance of the signalling system in achieving enhanced performance and capacity is much less significant than originally thought.

Specific detailed results

The main results from the modelling are described below:

Infrastructure

i. Enhanced infrastructure has a major impact on journey time. The effect of varying infrastructure performance in terms of linespeed profile restrictions was observed to make a significant impact on journey time. Upgrading the infrastructure to remove linespeed restrictions provides journey time improvements of up to 8 minutes for Birmingham and up to 14½ minutes for Manchester.

ii. Enhanced infrastructure, targeted to resolve specific train delay issues, has a moderate effect in reducing overall train delay. For example, the addition of dual fast line platforms at Watford and four-tracking Tamworth to Lichfield result in 7-11% less delay for a given scenario than the same scenario without that additional infrastructure.

iii. Enhanced infrastructure, targeted to remove timetable constraints can provide additional train paths. The capacity analysis and timeabling undertaken by the WCRM Sponsor team provides evidence for this. Removing a localised timetable constraint, however, does not guarantee additional paths. A wider view of constraints has to be taken to provide additional train paths because a new constraint can appear elsewhere after solving the previous one.

Train performance

i. Train performance has a major impact on journey time. The effect of varying train performance in terms of maximum speed, acceleration and braking was observed to make a significant impact on journey time. Increasing maximum speed from 125mph to 140mph over the Baseline infrastructure reduces journey times to Manchester by between 3½ and 6 minutes depending on route. The acceleration and braking characteristics of the VATT result in journey times to Birmingham that are 30-60 seconds slower than those for the RATT.

ii. Train performance has a moderate impact on train delay. A VATT consistently recovers from perturbation more slowly than a RATT. The difference in performance results in 6-10% more overall train delay for a VATT than a RATT. Modelling the Virgin West Coast trains to run at a maximum speed of 140mph instead of 125mph results in 22-25% less train delay measured across all train services.

iii. The traffic mix on WCML means there is a wide variety of train performance and types that has a major impact on capacity. This is confirmed by the capacity analysis and timeabling undertaken by the WCRM Sponsor team. Additionally VATT train performance and station dwell times have been assumed in the specimen timetables and hence the modelling. These factors are outside Railtrack control. However, qualitative assessment shows that changes in either parameter would impact capacity, depending on location and stopping patterns.
Strategy for Phase 2

Signalling system

i. Between control systems that support 140 mph running - i.e. excluding conventional signalling and TPWS - there is minimal impact on journey time. Given that no control system consistently performs better than the others, the observed journey time differences are judged to be due to pathing conflicts caused by changes in timing characteristics between the control systems and, in many cases, could be resolved by further refinement of the timetable.

ii. The control system has only minimal impact on capacity. Against the capacity benchmark set by the specimen timetable, ERTMS/ETCS Level 2 and ERTMS/ETCS Level 1 signalling both supported the capacity output. This conclusion was drawn because the timetable was shown to be workable when modelled using the alternative signalling.

iii. There is a significant difference in the way that the alternative signalling systems recover from perturbation. The application of ERTMS/ETCS Levels 3, 2 and 1, which allow operations at 140mph, result in respective delay reductions of 51%, 28% and 24% when compared with conventional signalling with TPWS operating at 125mph. It should be noted, however, that a possible constraint imposed by the electrification system was expected to reduce the benefits available from ERTMS/ETCS Level 3 (moving block signalling) during perturbation recovery.

8.5 Conclusions

The previous performance assumptions were either revised or confirmed as a result of this work:

- all the improved outputs could not be delivered by a combination of the proposed infrastructure enhancements and implementation of moving block signalling (TCS-M)
- a 'moving block' signalling system was not a pre-requisite to achieving the outputs
- trains running at 140 mph on the enhanced infrastructure were required to meet the journey time outputs
- the change that occurred in train performance, from RATT to VATT rolling stock parameters, impacted outputs other than journey time. It is likely that overall train delay will deteriorate.

Other findings and associated conclusions from this analysis:

- there was a 'shortfall' in capacity with the previous strategy and further infrastructure enhancement would be the most likely solution
- if a change from TCS-M signalling was required, then the alternative systems modelled which supported 140 mph running could be viable. This would be dependant on making up any 'shortfall' in train delay that is estimated to occur.

These conclusions were used as input to the analysis of alternative signalling systems (see Section 12).
9. Feasibility of TCS-M

9.1 Background

At the time of Baseline 1, different assessments of the delay risks of TCS-M implementation, and hence its feasibility, existed between the WCRM programme management team and the supplier, Alstom Signalling.

As an example, one view on the probability of delay risk from safety approvals was given at 5% and the other view was that it was significantly higher, largely because of the novelty of the technology.

Given this uncertainty over the feasibility of the TCS-M proposals, it was decided to obtain an independent assessment of TCS-M feasibility, and this was included in the scope of the Phase 2 Review.

9.2 Process

The TCS-M assessment was undertaken by the Phase 2 Review team working closely with Alstom Signalling. In addition, a Phase 2 expert panel was established to provide judgement on the likelihood and consequence of risks. Expert advice was sought on:

- safety approvals
- control system development and implementation.

The assessment processes involved:

- establishing clarity on the current TCS-M development and implementation issues, risks and challenges in ‘value management’ style workshops. Knowledge of TCS-M was input to the workshop by the TCS Joint Project Team (JPT), the other attendees were drawn from WCRM Delivery and Sponsor teams and the Phase 2 Review team
- reviews of specific risks involving members of the Phase 2 expert panel and the TCS JPT
- revising the quantified risk assessment (QRA) with input from the Phase 2 expert panel. QRA is a systematic and analytical method of predicting likely timings and confidence levels. However, it relies on subjective judgements of likely delays and consequences of identified risks.
- evaluation of maintenance assumptions with Railtrack experts.

9.3 Lessons from other projects

Lessons learnt from other projects were also taken into account in the TCS-M assessment.

The introduction of moving block signalling on Docklands Light Railway (DLR) was subject to considerable delay and caused significant service disruption. Complex software requires a ‘bedding-in’ period after initial implementation, to reach the required performance and reliability targets. The ‘bedding-in’ period can be lengthy depending on how much change is required and the logistics of re-commissioning. ‘Right first time’ does not apply to complex software systems, as full simulation of the ‘real’ operational environment is very rarely possible.
Strategy for Phase 2

Plans for a proposed moving block system for the Jubilee Line Extension (JLE) were postponed. The design and development had been underway for several years and it was not clear that it could be completed on time. This showed that the true progress of complex software systems is very difficult to assess, unless there are intermediate implementation stages. Developing and implementing large control systems progressively is the only way to be confident that progress is being made and that issues are identified as early as possible.

JLE was a new extension of an existing railway and therefore did not have to maintain an operational service in the extended section whilst introducing the new control systems. In comparison WCML is even more complex.

The WCRM programme for implementing TCS-M would have made WCML the first main-line route in Europe to implement a moving block signalling system (to ERTMS/ETCS Level 3). Being first with new technology carries a high risk.

9.4 Assessment findings

TCS-M development and delivery

The following main risks to TCS-M development and delivery were identified:

- the size of software development was such that management, communication and co-ordination would be critical to timely delivery and the capability to respond to change. The Phase 2 Review team judged this to be a major challenge for the supplier to coordinate software development in several sites across Europe and around the world.

- requirements were not stable. Some of the more complex aspects of moving block design were not resolved. For example, a satisfactory solution to monitoring train integrity had not been identified.

- the TCS trackside system was planned to be developed using a new underlying safety processor platform. The trackside system was also the component with the most complex functions and performance requirements. Safety processor platforms also require 'bedding-in' periods before they provide a stable environment for software.

- an Inter-dependence on development of the Network Management Centre (NMC). The control of TCS-M was planned to be from the new NMC software being delivered by another supplier, US&S. This interface was extremely complex and was judged to be a major integration risk.

Safety Acceptance and Approval

The main risks to safety acceptance of TCS-M are set out below:

- the complexity of achieving cross-acceptance for safety integrity had been under-estimated. It was planned to build on acceptance gained through European implementation as a basis for gaining acceptance for use in the UK. Cross-acceptance would only be valid in the situations where the context for use could be proven to be the same.

- volume of work required to change and gain approval for all the operators' safety cases.

- proof of safety for bi-directional working. The methods and procedures for introducing bi-directional working for either maintenance or perturbation recovery were judged as being a level of complexity beyond all the other procedures required.
Strategy for Phase 2

- a major issue for the safety cases was the lack of degraded mode of operation. As a fail-safe measure, trains would stop when the system failed but the procedures to re-establish safe operation and recover the route after failure would take a long time
- comparing the assumed timescales for acceptance with recent experiences of gaining safety acceptance of TPWS, and new interlocking technologies, indicated that the assumptions about the timing of safety approvals were optimistic
- the use of a GSM-R bearer network for signalling and voice communications provides a common point of failure for both the main control system and its operational back-up. This may complicate the proof of safety.

Implementation on an operational WCML

The main risks are set out below:
- creating a realistic performance trial, with sufficient trains, working over a sufficiently long section of the route and interfacing to NMC, before final implementation, would have been almost impossible. This meant that a substantial performance risk would be carried over into live operation
- the 'bedding-in' period required after implementation for achieving performance and reliability would not be acceptable for WCML. The risk to degrading route operation was too great
- the risks involved in the planned 'big-bang' switch-over. The scale of change on such a large part of the route was judged to be impractical, specific issues include:
  - training all the drivers, estimated to be 4,000, in the use of cab signalling and new rules, and maintaining training readiness without in-service use
  - similarly training all the other railway staff affected
  - completion of the TCS train fitment programme ready for switch-over, see later
- no improvement in WCML outputs would have been achieved from the control system until the switch-overs had been completed.

Train fitment

The main risks to the TCS train fitment programme were identified as:
- time allowed to fit the 1,500 trains was based on a work estimate and made an allowance for train availability. This allowance was not thought to be realistic.
- train fitment needed to commence before completion of development, in order to meet the timescales. This would have meant fitting equipment which may require re-work subsequently
- time allowed did not account for inefficiencies introduced by train operators needing to manage mixed fleets of fitted and unfitted trains, which would have introduced constraints on train availability
- control of the pace and management of fitment was outside Railtrack control. No commitment to the required timings existed from train operators or ROSCOs.
Revised timing assessment

Using the analysis of risks discussed above, the Phase 2 Review team undertook a QRA of the likely timing of implementation on the operational WCML. This assessment included phases for TCS-M development, safety approval and tracks side implementation.

The revised assessment, at an 80% confidence level, estimated that TCS-M could be operational in March 2009. This would then have been followed by the 'bedding-in' period, could have been 3-4 years. The improved outputs of journey time and train delay would only be available reliably at the end of the 'bedding-in'.

Because of the timing, further renewals or life extensions of signalling would also have been required.

Maintenance

The maintenance assumptions for TCS-M were tested qualitatively during the Phase 2 Review.

The reduction in lineside equipment resulting from implementation of TCS-M was assumed to provide for a significant reduction in annual maintenance costs (estimated at approximately 50%). Although some reduction would result, consideration of the emerging system architecture indicates these initial estimates may be optimistic. For instance, although track circuits would no longer be required in plain line sections, it is envisaged that in certain locations they would still be required for the accurate positioning of trains (or proof that trains were not present) for safety reasons e.g. through junctions.

The reduction in Insulated Block Joints (IBJs) associated with the removal of track circuits would only be achievable by positive intervention. (They need physically removing either at rail renewal or as a special case.) IBJs would continue to require maintenance until replaced, irrespective of their functional requirements within the signalling system.

Point operating devices or 'point machines' would also continue to be required under any operational or signalling scenario. These require power supplies, communications and the provision of a telephone. Inevitably this equipment requires cabling, which in turn imposes an additional maintenance burden.

Labour and overheads account for a large proportion of maintenance costs. Although some savings in labour would result from the reduced volume of maintenance work, there is unlikely to be a pro-rata reduction in labour cost. It is likely that highly competent staff would be retained, under-utilised and on standby in case of system failures.

The TCS-M/NMC strategy did not make cost provision for renewal of major components of the signalling system through the life of the scheme, instead relying on the maintenance of the newly installed equipment for the whole period, notionally 30 years. With modern computer based equipment this is likely to be highly impractical, with lower equipment lifecycle times (typically 10 to 15 years) leading to higher whole life costs.

The shift in technology from predominantly electromechanical to electronic processor based equipment would result in a change in the set of skills, ability and competence required of the maintenance technician. The widespread use of processors leads to an increased requirement for software management skills and a lower requirement for failure finding techniques at component level.

The use of bespoke software and hardware platforms also increases the reliance on single suppliers for support, reducing competition.
Finally, the proposals to deliver the staff safety facilities envisaged with TCS-M were not yet specified or developed.

At the time the original strategy for TCS-M was declared, not enough was known about the resulting architecture, operation and performance to build an accurate schedule of maintenance activities and costs. The financial benefits associated with maintenance appear therefore to have either been assumed, or derived from data relating to conventional solid state Interlocking (SSI).

Was 'big bang' switch-over feasible?

It was the judgement of the Phase 2 Review team that the scale and size of change to the operational railway was too great to make a big-bang switch-over viable. It would represent an unacceptable risk to WCML service performance.

Progressive introduction of change over a longer period would be needed to achieve the required scale of change. With no fallback mode of operation, the opportunities to achieve a gradual switch-over were limited.

9.5 Conclusions

The above findings led to the following conclusions which then influenced the identification of an alternative signalling system:

- renewing the WCML signalling in one step with moving block signalling is not practical. This implies that fixed block signalling must be maintained whilst any new signalling systems are introduced, probably as an overlay
- a more progressive approach to the introduction of the new signalling system must be adopted which allows:
  - progressive fitment of trains, allowing unfit trains to continue to operate
  - parallel operation of the old and new signalling systems to allow a transition period, during which:
    - training and live practice of new procedures can take place at a practical pace
    - an operable service during the 'bedding-in' period can be maintained
    - an operable degraded mode to limit the effect of reliability problems can be provided
- the estimated implementation timing for the TCS-M system means that it is not a viable system to consider, either for replacing the existing signalling or delivering the improved outputs for Phase 2
- the maintenance benefits of TCS-M system had been over-estimated.

As the TCS-M feasibility analysis progressed, Alstom Signalling presented a revised proposal for a Train Control System based on ERTMS/ETCS Level 2 standards. This system would operate as an overlay on conventional signalling and could be introduced progressively. This revised proposal was used as an input to the analysis of alternative control systems.
10. Need For Change

10.1 Inadequacies of previous strategy

From the assessments in Sections 8 and 9, it was concluded that the strategy being followed would not enable Railtrack to fulfil its Phase 2 objectives for the following main reasons:

i. There are a number of severe bottlenecks, even after the planned infrastructure upgrades, which would prevent Railtrack from meeting its capacity commitments, whatever control system is adopted.

ii. The scope of application of the TCS-M system would not have provided ATP over all route sections covered by the WCRM.

iii. The TCS-M system could not be developed and implemented within the required timescale, could not be introduced in a 'big bang' implementation as envisaged, and provided no satisfactory, operational fallback.

It therefore became essential to devise a new strategy that would permit achievement of Railtrack's objectives.

10.2 Criteria for new strategy

Clearly, a suitable new strategy would need to overcome the above shortcomings by including:

- additional infrastructure to clear the identified bottlenecks
- provision for ATP over all route sections covered by WCRM
- an alternative signalling solution.

The review team stipulated the following criteria to be met by the new strategy for control systems:

i. It must satisfy the specimen timetable outputs - covering journey time, capacity and punctuality.

ii. Be capable of progressive implementation throughout the WCML route (as opposed to previous 'big bang' approach).

iii. Allow unfit trains to operate over the route.

iv. Provide improvements to route outputs incrementally as installation progresses - not only when the whole implementation is completed, as before.

v. Provide ATP functionality over the route sections covered by WCRM.

vi. Meet EU interoperability requirements through compliance with ERTMS/ETCS specifications.

vii. Provide a shared technology development path with other railways.

viii. Strategy to have a substantially lower risk of not meeting objectives within the planned timescales.

ix. Systems must have satisfactory operational fallback in the event of failure.

The above criteria, which were fully endorsed by the Review Group, were used as the basis for evaluating options and selecting the recommended strategy for Phase 2.
PART III - NEW STRATEGY & IMPLICATIONS

11. Additional Infrastructure

11.1 Need for new infrastructure

It is established in Sections 8 and 9 that implementation of the infrastructure changes, as set out in Baseline 1, would not provide sufficient capacity for Railtrack to provide all of the required train paths, irrespective of the control system applied.

The findings of the performance modelling detailed in Section 8 also show that capacity is primarily limited by infrastructure, mix of traffic and stopping patterns. Railtrack is constrained by contractual commitments from altering traffic mix and stopping patterns. Therefore it was concluded that any capacity shortfall must be resolved through the provision of new infrastructure.

The remainder of this section sets out:

- the process for identifying the infrastructure necessary to be included in WCRM
- the capacity shortfalls and the infrastructure constraints that cause them
- additions to the scope of infrastructure from that included in Baseline 1
- outstanding issues to be resolved by the WCRM Sponsor
- remaining actions to confirm the scope of WCRM infrastructure
- cost and risk implications
11.2 Assessment process

The process in summary

![Diagram showing the process to determine necessary infrastructure and develop a timetable]

**Figure 7:** Process to determine necessary infrastructure and develop a timetable

The relationship between the commitments and Undertakings, the train timetable, train performance and infrastructure is complex and interactive, as indicated in Figure 7.

The process for defining the set of infrastructure necessary to provide sufficient capacity on a route is heavily dependent upon the skills and experience of operational planners. Their skill in incorporating the required paths into a timetable, identifying timetabling constraints and suggesting effective solutions is fundamental to the definition of the appropriate infrastructure. This is particularly the case for the WCML programme, given the complexity of the traffic mix, the complicated layout and intensive use of the WCML. Although Railtrack's operational planners have been relied upon, their work has been subject to constructive challenge by the Phase 2 Review team, including the use of performance modelling to confirm the robustness of the suggested solutions.

**Inputs**

The 'Rules of the Plan' define headways, junction margins and other parameters required to construct the timetables. The required train paths, stopping patterns and journey times are derived directly from the commitments and Undertakings, as described in Section 6. Similarly, the existing configuration and geometry of the track are fixed inputs to the timetabling process.

Throughout the Phase 2 Review, it was assumed that the Virgin Active Tilting Trains (VATTs) achieve the Benchmark performance and that other trains generally achieve current performance levels.

The functionality of the control system dictates the minimum operational headway between trains, junction margins and platform approach and clearance times. The infrastructure requirements were assessed on the basis of fixed block signalling, such as the recommended ERTMS/ETCS Level 1 and
Level 2 systems. Scenarios applying ERTMS/ETCS Level 3 moving block signalling were modelled, but the operational advantage was insufficient to change the requirement for additional infrastructure.

With these fixed inputs and assumptions in place, the remainder of the process is designed to optimise the infrastructure provided.

Specimen timetables

The Phase 2 timetable produced by WCRM sponsor were used in assessing the capability of proposed infrastructure, train performance and control systems to deliver the required train paths and service performance. The July 1999 issue of the specimen timetable covered the most congested sections of the route for the busiest hour of the day. In both cases the infrastructure defined in the WCRM Functional Specification\(^\text{19}\) was assumed.

The operational planners optimised the ordering and timing of trains to maximise the usage of the available capacity. Despite this expert work, a number of the required train paths could not be provided, as described in each specimen timetable document, without amendments to the infrastructure.

Performance modelling

As detailed in Section iv, the specimen timetables were used as the basis of performance modelling. The modelled services were able to recover when service perturbations were introduced and this demonstrated that the specimen timetables are workable.

Constraints on adding train paths

The principal constraints on adding train paths into the specimen timetables were identified by WCRM sponsor as they were developed, and by expert inspection of the resulting document. Desktop analysis was undertaken, jointly between the Phase 2 Review team and the WCRM Sponsor team, in an effort to add those extra paths. Analytical and graphical techniques were used to identify the precise cause of the timetabling constraints.

In some cases specific conflicting moves, implied by a commitment or Undertaking, constrain train pathing. In other cases infrastructure constraints, such as reductions in the number of tracks from four to three or two and congestion around stations and junctions, cause a general constraint on capacity. Infrastructure schemes were proposed to alleviate these constraints where appropriate.

Infrastructure options

Workshops were conducted with specialists from the WCRM Sponsor and Delivery teams to identify potential infrastructure schemes to alleviate the constraints. The WCRM Functional Specification and the schemes being considered in the WCRM Strategic Capacity Review were primary sources of potential schemes. The participants to the workshops had considerable knowledge of the route, timetabling expertise and experience of changes suggested historically. They were also able to generate several other potential schemes.

The options were prioritised using the following criteria:

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\(^{19}\) Functional Specification, dated 16th April 1999 (WCRM-012) and Supplement to the Functional Specification, dated 14th May 1999 (WCRM-012)
**Strategy for Phase 2**

- operational benefits
- risk of delay in gaining Transport and Works Act (TWA) approval
- achievement of schedule
- cost
- impact on other elements of the WCRM programme.

**Pre-feasibility studies**

For the selected schemes, Railtrack commissioned pre-feasibility studies from the following Multi-Function Consultants (MFCs):

- Scott Wilson
- CEDG (a subsidiary of Corus)
- Mott McDonald

The objectives of the studies were to:

- confirm overall scheme viability
- consider alternative infrastructure options to achieve the desired change in track layout
- produce scheme plans of sufficient detail to provide a robust basis for scheduling and costing.

The consultants were instructed to consider all relevant technical, environmental, statutory (such as TWA) and schedule issues. Costs were estimated using standard library rates and both costs and schedule were subject to a quantified risk assessment.

In order to ensure the consistency and credibility of the proposals, Railtrack compared the costs against historic information and estimates for other planned schemes. The risks identified were included in a quantified risk assessment undertaken by the Phase 2 Review team.

**Timetable amendment and modelling**

To validate the expected benefit of each scheme, the specimen timetable was adjusted locally to take account of the infrastructure change and confirm that the required paths could be incorporated. Services were then modelled, using the VISION modelling tool, to prove that the timetable would be workable.

### 11.3 Findings - capacity constraints

The above assessment established that significant constraints exist at two locations, at Watford Junction Stadion and in the Trent Valley, between Tamworth and Lichfield. These two locations, above all, prevent the timetabling of the full complement of paths for fast passenger trains and freight trains. It was only by alleviating both these constraints that all the required paths in each direction could be provided.

All of the Virgin trains stop at Watford Junction Station. This causes severe erosion of the headway on the fast lines in the area, as the minimum headways cannot then be operated.

Four tracks will be available through the Trent Valley between Nuneaton and Coleshill when the schemes included in the WCRM Functional Specification have been completed, except for a two

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*Study reports are available in Phase 2 Review library (WCRM-030, WCRM-031, WCRM-032 and WCRM-033)*
track section between Tamworth and Lichfield stations. The resulting bottleneck causes congestion where the tracks converge. In addition, the slow traffic operating on the fast lines prevents the fast trains utilising the minimum headway available. As a result, it is not possible to provide both the additional two open access paths per hour and all of the 42 freight open access paths.

Providing four tracks throughout the six mile section alleviates both aspects of the constraint and enables all of the required train paths to be provided. A variety of alternative schemes were studied in an attempt to reduce the physical length and complexity of the infrastructure works. In each case, certain of the required paths could still not be time-cabled and the schemes were therefore inappropriate.

In addition to these two major constraints, local timetabling conflicts were identified at Northampton and Nuneaton.

11.4 Additional infrastructure required

The four schemes are shown in Figure 8:

**Watford Station**
- Two new fast line platforms
- Reduces minimum headway to provide extra high speed capacity

**Nuneaton**
- Additional track on proposed flyover
- Meets Central Trains and Virgin contractual obligations

**Northampton**
- One crossover
- Meets Silverlink and "freight" obligations

**Tamworth-Lichfield**
- Four track six miles
- Provides balance of high speed and "freight" open access in Trent Valley

*Figure 8: Infrastructure schemes required to meet capacity constraints*

Infrastructure changes can provide a step change in the capacity available locally. The four infrastructure schemes recommended will provide capacity at their locations in excess of that required to remove capacity constraints.

**Watford dual fast line platforms**

This project entails the creation of two additional fast line platform loops. These are provided by building new slow line platforms on the slow line side of the station, enabling the existing slow line platforms to be converted to fast line use. The resulting layout can support 3 minute headways and provides some capacity for future growth.
Strategy for Phase 2

Tamworth-Lichfield quadrupling

Increase the existing two tracks to four tracks over the six miles between Tamworth and Lichfield stations. This is in addition to the schemes in the WCRM Functional Specification for quadrupling the tracks between Rugby and Brinklow and between Lichfield and Armitage.

Northampton station crossovers

A crossover linking the down main platform and the up main is proposed, with bi-directional signalling. This will enable exit moves from the down main platform to be made in parallel with train arrival into the down loop platform.

Nuneaton double tracking

An extra track is proposed in the grade separation scheme included in the WCRM Functional Specification. The 2 km of double tracking will be incorporated in the main scheme.

Implementing the schemes

Three of the above schemes will need TWA applications. These are being prepared for submission in 2000. An order is not expected to be required for the Northampton scheme, as this should be progressed under Railtrack’s permitted development rights.

All four schemes are being progressed for completion by May 2005, however the dates are dependent on:
- Transport and Works Act (TWA) approval
- Network change process completion

Whilst it may be possible also to complete the Watford and Tamworth-Lichfield schemes by 2005, this is very challenging on current assumptions. It is expected that these two schemes will be completed by 2007. Railtrack’s programme management team is evaluating the options for completing this work at the earliest practicable date.

11.5 Outstanding issues

This additional investment in infrastructure solves a number of issues, there are a number of other issues remain.

11.6 Next Steps

Work is in progress by the WCRM Sponsor team to define the Rules of the Plan for a revised Phase 2 specimen timetable based on the revised strategy.

The WCRM Sponsor can then test the validity of the proposed infrastructure by modelling service performance. If the timetable is workable and train delay performance is sufficient for Railtrack to meet its punctuality commitments, then the proposed infrastructure will be confirmed to be sufficient.

11.7 Cost and risk implications

There remains a risk that further infrastructure changes will be required, particularly on sections of the route not included in the specimen timetable.

A contingency provision has been made in the cost plan for infrastructure schemes that may be required as a result of the ongoing design development work.
The cost of the four additional infrastructure schemes described above, and the contingency sum for further schemes, is included in the Baseline 2 cost summary.

12. Alternative Control Systems

12.1 Introduction

In parallel with assessing the feasibility of TCS-M, the review team sought to identify alternative signalling systems. The list of alternatives was compiled from a survey undertaken of world-wide signalling. The alternative systems identified were allocated into the following categories:

- conventional lineside signalling plus TPWS
- current generation ATP systems e.g. TVM430 used in the Channel Tunnel
- ERTMS/ETCS compliant systems

Appendix D provides a technical overview of the above types of signalling system.

As the findings and conclusions of the performance assessment and the TCS-M feasibility emerged, the number of alternative feasible signalling systems was reduced.

At this time also, the criteria for a new TCS strategy were applied to the Network Management Centre (NMC), specifically to identify a means of progressive implementation.

12.2 Signalling system criteria

The lessons learnt from the TCS-M and performance assessments (Sections 8 and 9), were rationalised and combined with the criteria for a new strategy in Section 10.2 to form a consolidated set of criteria for an alternative signalling system, which must:

- either replace or renew the life-expired assets that had been planned to be replaced by TCS-M
- allow trains to operate at 140 mph, this was assumed to imply cab signalling
- have lower development and implementation risk than TCS-M, to support achieving improved route outputs by 2005
- provide an ATP environment on the infrastructure
- allow un-fitted trains to operate over the route. This was assumed to imply that conventional lineside signals needed to be retained, with the new system operating as an overlay
- be compliant with ERTMS/ETCS standards
- allow progressive trackside implementation
- have a viable operational fallback mode
- provide incremental improvement to route outputs
- deliver the improved outputs required for 2005 in combination with the infrastructure enhancements.

Survey of Alternative Signalling Technologies for Phase 2 (Team-016)
Strategy for Phase 2

In addition, with the requirement to comply with ERTMS/ETCS, the review team judged that Railtrack would benefit in the longer term from supporting the move toward standardisation of signalling. The benefit would arise from shared development risk with European railways, choice of products and suppliers and access to a larger pool of signalling resources.

Assessment against the consolidated criteria identified that only a few options for alternative signalling were suitable:

- renewal of signalling:
  - replace with modern equivalent assets and currently approved electronic interlockings
  - replace with modern equivalent assets and latest generation electronic interlockings, known as computer based interlockings (CBI)
- cab signalling overlay for 140 mph running
  - ERTMS/ETCS Level 1
  - ERTMS/ETCS Level 2
- ATP environment tracksid
  - ERTMS/ETCS Level 1
  - ERTMS/ETCS Level 2.

Each of the above options supported progressive implementation and allowed unotted trains to operate. The choice between ERTMS/ETCS Level 1 and Level 2 signalling was not exclusive, as ERTMS/ETCS is designed such that the trainborne part of TCS is compatible with both systems on the trackside. This allows the route to be fitted with a combination of ERTMS Level 1 and Level 2 systems.

To reduce potential timing risk, it was decided to plan for renewal of signalling by current generation electronic interlockings i.e. Solid State Interlocking (SSI). Should the position on approvals for CBI interlockings change, then a re-appraisal of the use of CBI instead of SSI would be needed.

The rest of this section covers how the revised signalling strategy for Phase 2 was derived on the basis of suitable signalling options.

12.3 Revised signalling strategy

Conventional signalling renewal

Establishing a reasonable view of the condition of the current signalling was therefore essential in developing the signalling strategy.

The current signalling on the route was implemented in two phases:

- south of Crewe (including southern approaches to Manchester) during the 1960s
- north of Crewe during the 1970s.

Figure 9, overleaf, summarises the current condition of signalling assets across WCML.
Strategy for Phase 2

For the types of equipment concerned, the signalling asset base in the area south of Crewe has reached what would normally be termed the nominal economic life. At the end of the economic life, the cost of the intensive maintenance and the cost of failures coupled with the safety risks arising from equipment failures potentially represent a higher cost than renewal of the asset.

Railtrack assessment of the route assets has identified that the vast bulk of the signalling asset base between London and Manchester cannot be economically life extended and requires renewal over the next five years. A programme of independent assessments undertaken by Scott Wilson is currently underway to validate the assessments made by Railtrack engineers. Results to date confirm the findings of the Railtrack assessments.

On this basis, by the end of Phase 2, all of the signalling between Euston and Manchester (via both Crewe and Stoke) and between Rugby and Proof House junction will be upgraded to modern electronic interlockings.

Some signalling between Birmingham and Stafford will also be upgraded as part of the West Midlands re-signalling scheme. The exact scope in this area is still to be subjected to detailed definition and refinement. It will be determined following the completion of the independent condition assessment of the signalling assets on the section.

Level 1 or Level 2 selection

Qualitative technical analysis, supported by computer modelling, indicates that an ERTMS/ETCS Level 2 system should deliver better performance than an ERTMS/ETCS Level 1 system.

The ERTMS/ETCS Level 2 system, when applied to electronic interlockings, requires significant trackside signalling equipment than the ERTMS/ETCS Level 1 system. This, coupled with the ability to implement data change centrally, should result in lower capital and operating costs for a Level 2 system.
Strategy for Phase 2

Applying an ERTMS/ETCS Level 2 system on a relay interlocking requires considerably more equipment tracksidethan a Level 1 system. It is therefore assumed that this will have higher capital and operating costs. It is not therefore proposed to apply ERTMS/ETCS Level 2 on relay interlockings.

Consideration of the route on a section-by-section basis is required in order to avoid frequent transitions between ERTMS/ETCS Level 1 and Level 2. When a train passes from an area fitted with Level 2 to an area fitted with Level 1 the driver of the train will be required to acknowledge the transition (the requirement for acknowledgements arises whenever the train moves into an area controlled by a system with a lower level of protection). There will be subtle differences in the operational rules and methods in areas fitted with the two systems.

In order to avoid the introduction of human reliability risks, it was considered important that transitions are kept to a minimum, and occur at clear boundary locations. For this reason, major route sections will be fitted with either ERTMS/ETCS Level 1 or Level 2, but not a mixture of the two.

As a result of the above considerations, the process for determining whether ERTMS/ETCS Level 1 or Level 2 should be used includes consideration of the route on a section-by-section basis and applying the following two criteria:

- is the performance difference between Level 1 and Level 2 significant?
- will the route section be controlled (within the Phase 2 timescales) mostly by electronic interlocking?

If the answer to both of the questions was yes, then ERTMS/ETCS Level 2 was selected. If the answer to both of the questions was no, then ERTMS/ETCS Level 1 was selected. Where the assessment did not produce the same answer to both questions, then a specific analysis of the section must be undertaken. This was not possible within the timeframe of the Phase 2 Review and all route sections falling into this 'undecided' category have been designated as ERTMS/ETCS Level 1 in the revised strategy.

Using the above process, the following scope of application of ERTMS/ETCS Levels 1 and 2 is determined:

- ERTMS/ETCS Level 2: Euston to Manchester via all routes, and from Rugby to Birmingham New Street
- ERTMS/ETCS Level 1: Weaver Junction to Edinburgh
- ERTMS/ETCS Level 1: Birmingham New Street to Stafford, Crewe to Liverpool and Carstairs to Glasgow

Assumed (subject to further analysis)

The sections from Birmingham New Street to Stafford, Crewe to Liverpool and Carstairs to Glasgow are subject to further analysis.

Train fitment

ERTMS/ETCS equipment fitted to trains is designed to operate in areas controlled by either ERTMS/ETCS Level 1 or Level 2.
Strategy for Phase 2

The 53 VATT trains will require fitting by Railtrack with cab signalling equipment by 2005 to meet PUG2 contractual commitments.

The scope of the requirement to fit other trains, the timescales and responsibilities for undertaking this work will be influenced by:

- the findings of the Sir David Davies Inquiry and subsequent response by the Government
- the operational requirements of TOCs, FOCs, ROSCOs and other industry stakeholders

Retaining the conventional signalling allows trains without a Train Control System fitted to continue to operate on the route, enabling the programme of train fitment to be progressive.

Schedule risk

Qualitatively, the revised strategy significantly reduces schedule risk. A comparison of schedule risks between ERTMS/ETCS Level 1, 2 and TCS-M is shown below:

Technical development and delivery

- ERTMS/ETCS Level 1 represents the lowest schedule risk of the ERTMS/ETCS applications as the technical development is relatively well progressed
- the risks are higher for ERTMS/ETCS Level 2 than for Level 1 due to its greater sophistication and its dependence on the development of the Radio Block Centres (RBCs) and related communications systems. The scale of the software development is significantly less than a Level 3 system because most of the key safety functionality is retained within existing interlockings rather than within the RBC. The interaction between the signalling system and the GSM-R radio bearer network is less than for a Level 3 system in terms of both quantity of communication, and performance criticality of the communications systems
- the plan for development and application of the Level 1 and Level 2 systems is de-coupled from that of the NMC, significantly reducing the schedule risk
- more extensive possessions are now required, representing an increased schedule risk.

Safety approval

- The degree of operational and technical change is significantly less with ERTMS/ETCS Level 1 and Level 2 systems and safety approvals are likely to present lower risk.

Implementation

- the volume of training per driver, and therefore its duration, increases with the degree of change from the driver's previous experience. For ERTMS/ETCS Level 1 and Level 2 systems the driver training is less complex, affects fewer drivers and can be planned against progressive application. It is therefore considered to be practicable.
- ERTMS/ETCS Level 1 and Level 2 systems can be applied incrementally both trackside and on trains. ERTMS/ETCS Level 1 represents a relatively minor change from current ATP systems offered by a number of suppliers. Hence operating procedures already in use on Great Western and Chiltern lines may be applied with little change.
- Each ERTMS/ETCS system provides an upgrade path (particularly for the train equipment) to higher levels of ERTMS/ETCS system, offering additional functionality with limited rework and disruption.
Strategy for Phase 2

Operational fallback

Conventional signalling is available to provide an operational fallback if the ERTMS/ETCS Level 1 or Level 2 system, or the associated telecommunications systems, should fail.

Incremental benefits

Renewal of conventional signalling will allow progressive improvements in reliability and reduction in disruption.

The progressive application of ERTMS/ETCS Level 1 and Level 2 to appropriate sections of the route will provide an ATP environment incrementally. Unfitted trains will still be able to use the route. This allows for progressive train fitment, increasing the size of the fleet able to use the ATP environment.

12.4 Network Management Centre

The review of the Network Management Centre (NMC) strategy for Phase 2 of the WCRM was undertaken with the remit:

"Devise a credible operational control strategy which enables an incremental low risk approach. The strategy should be aligned to deliver benefits for Phase 2 and enable fully integrated network management control to be achieved at an optimal point in the future." 22

As a result, a revised strategy for NMC has been developed which features:

- progressive implementation of facilities
- achievement of early reduction in train delay
- reduction in risk of systems integration, development and acceptance.

The revised strategy comprises the following steps:

i. Deployment of route planning advisory tools.

ii. Implementation of basic signalling control, interfacing to conventional interlockings.

iii. Integration of route planning and signalling (which enables automatic execution of optimal train plans).

iv. Implementation of further functionality enhancements (e.g. electrical control).

v. Development of interface to ERTMS/ETCS Level 3 system when required.

On current plans, both route planning and signalling control could be implemented on the Euston to Crewe section of the WCML to support delivery of the Phase 2 outputs.

22 NMC Phase 2 Group Review Close Out Report (WCRM-335)
13. Impact on Performance and Capacity

13.1 Implications for maintenance

Implications of the revised strategy on maintenance and renewals

Many of the issues associated with TCS-M apply to some extent when considering the ERTMS/ETCS Level 2 element of the revised strategy. However, the operation and performance of the conventional system on which it is overlaid is reasonably well understood and provides a starting point from which to develop initiatives to improve dependability.

The revised strategy for the implementation of the ERTMS/ETCS Level 1 and Level 2 compliant systems will result in a significantly higher volume of trackside signalling infrastructure than was originally envisaged and the loss of some of the functionality assumed for TCS-M. The introduction of tighter track quality specifications, necessary for higher speed operation, will tend to increase the need for maintenance access.

The Maintenance and Renewal Strategy, endorsed by the Maintenance & Reliability Group within WCRM, includes a further review of the implications for maintenance of applying ERTMS/ETCS Levels 1 and 2.

The introduction of new assets relating to ERTMS/ETCS Level 2, and their ongoing maintenance and renewal, impacts considerably on the Maintenance and Renewal Strategy. Simplistically, the introduction of ‘new assets’ is driven by the need to enhance or increase the capacity and performance of the route, whereas ‘maintenance and renewals’ must be appropriate to stabilise and sustain this performance.

Implications of Upgrade Works

Phase 1 signalling and track renewal is planned on the basis of weekend and evening blockades. For Phase 2, possessions within Rules of the Route are assumed. The use of ‘high output’ plant and techniques is assumed in both cases. The renewal plans have not assumed the introduction of bi-directional signalling. A change of project scope to include bi-directional functionality in certain areas may be advantageous and will be evaluated for viability.

To allow faster implementation times for engineering possessions, the introduction of common ‘isolation points’ for the signalling and electrification systems should be determined and agreed, with consideration given to the introduction of additional ‘isolation point signals’.

Ongoing Maintenance and renewals

The step-changes required in route performance and reliability will require the provision of new equipment and assets with excellent performance immediately they are brought into use. This performance must be continuously sustained and will require a change of asset maintenance approach towards a more proactive regime.

A high volume of ‘conventional’ signalling maintenance and renewals work will result from the replacement of the existing signalling infrastructure in modern equivalent form. The opportunities to carry out this work will be particularly affected by the move from ‘daytime’ to ‘overnight’ working when the Phase 2 timetable is introduced. The overnight maintenance ‘white period’ runs from approximately 01:30 to 06:00 and is interrupted only by freight and mail trains.

North of Crewe (where the linespeeds are less than 125mph) the location of access points, walkways and cess paths must allow safe working throughout the day. Faulting activity is assumed
to be an exception to this in all cases and will require the imposition of temporary 'green/red zone' working.

Maintainability is therefore a key design requirement for the new assets.

13.2 Maintenance Management

If the WCRM maintenance and renewal regime is to be successfully implemented then it requires the support of new asset management systems.

For example, it is appears that the new MIMS computerised maintenance management system will be adequate for the purposes of steady state infrastructure maintenance on WCRM. The management of such asset data and information will be vital during the transition phase and the existing Railtrack asset databases are judged not be adequate. The planning and implementation of these maintenance management systems represents a major challenge to WCRM, irrespective of the choice of signalling technology.

13.3 Implications for operational working

Scale of change

The scale of change to operational working under the revised strategy is significantly less than for TCS-M. This has been achieved by retaining the lineside colour light signals and other conventional techniques.

The conceptual change to introduce cab signalling, by both ERTMS/ETCS Level 2 and Level 1 will lead to changes in operational working for WCML staff. Although these changes will be new to WCML, there are several examples of cab signalling in the railway industry to draw on. The ATP projects at GWML and Chilterns provide a basis for any required changes to rules, procedures and safety cases for the ERTMS/ETCS Level 1 and Level 2 systems.

The ERTMS/ETCS standard addresses issues related to transition between areas of different levels of ERTMS/ETCS and specifies functions to cater for these situations. The rules and procedures associated with driving in a ERTMS/ETCS Level 2 area need further consideration to identify:

- whether there will be any differences from operation in a ERTMS/ETCS Level 1 area
- the difference for the driver as the train makes the transition between a ERTMS/ETCS Level 2 and Level 1 area.

In common with the TCS-M strategy, the introduction of centralised route management, through the Network Management Centre (NMC), will introduce changes for those staff involved in route management. The effect of the revised strategy, with reduced interdependencies between the implementation plans for the two systems, is that those changes can be introduced more gradually.

Operational fallbacks

In the event of failure of ERTMS/ETCS Level 2 or Level 1, the colour light lineside signals will still exist as a fallback means of signalling. Operation in fallback mode will be at lower line speeds, according to the underlying signalled speed. The method of recovery from a TCS mode into fallback mode needs careful definition and consideration during the design of the TCS system.

Driver’s perspective

After completion of the implementation of TCS trackside, a WCML driver of a TCS fitted train would be using cab signalling between London Euston and their WCML destination. Rules for
operating in ERTMS/ETCS Level 1 and Level 2 areas will be largely identical. The number and complexity of transitions has been reduced compared with the TCS-M strategy and transitions between Level 1 and Level 2 areas are defined in the ERTMS/ETCS specifications.

13.4 Implications for performance

To assess the implications of the revised strategy on performance, the review team estimated the likely overall train delay and whether that would meet punctuality requirements for Phase 2.

The current overall train delay on WCML, comprising delay attributable to Railtrack, TOCs/FOCs and planned/excluded delay, is estimated to be 2.89m minutes per year. Using this figure as a basis, the review team estimated:

- the likely increase in overall train delay due to additional services. The team calculated that the likely overall train delay would increase to 3.3m minutes per year
- the reduced level of overall train delay that would need to be achieved in order to meet Phase 2 punctuality targets. The team calculated that the target for overall train delay per year would be approximately 1.65m minutes per year

![Graph showing estimated overall train delay target for Phase 2](image)

Figure 10: Estimated overall train delay target for Phase 2

The review team estimated the likely overall delay arising after implementing the revised strategy to be less than the estimated target of 1.65m minutes per year. Achieving this overall train delay target is dependant on:

- Railtrack achieving existing annual train delay reduction targets
- train operators achieving corresponding levels of train delay reductions
- realising additional train delay benefits from the revised strategy, in line with the results of performance modelling and expert estimates.

As outlined in Section 8.5, the performance modelling indicates that overall train delay performance of an ERTMS/ETCS Level 3 system would be better than a Level 2 system. In the revised strategy,
the ERTMS/ETCS Level 2 system extends over a wider area of the route than the previous strategy. This application over a wider area was estimated by the Phase 2 Review team to provide overall train delay performance, broadly equivalent to that which would have been provided by the planned application of TCS-M.

14. Timing Achievable

In Baseline 1, there was very little confidence that the control systems thought necessary could be developed and implemented and made to operate reliably, by May 2005. The revised strategy now recommended substantially increases confidence in achieving the objectives for Phase 2 of the WCRM.

14.1 Works required

As explained in Section 11, it has now been established that Railtrack must carry out the following works to fulfil its Phase 2 objectives:

i. To meet contractual commitments to Virgin by May 2005:
   - carry out infrastructure upgrades to remove capacity constraints and permit trains to run at 140 mph in designated sections of the route
   - develop and implement new signalling systems to enable Virgin's high speed tilting trains to operate safely at 140 mph
   - support fitment of train-borne signalling equipment for Virgin's high speed trains

ii. To satisfy Undertakings to the Rail Regulator:
   - complete the CIP renewals programme for Phase 2 (as defined in Baseline 1)
   - upgrade additional infrastructure (as explained in Section 11 above)
   - undertake a major replacement of time expired, conventional signalling equipment

iii. To provide ATP throughout the route:
   - install trackside ATP signalling equipment: first, in sections designated for 140 mph train operation; then extend ATP installation elsewhere
   - work with railway industry partners to facilitate the fitment of train-borne ATP signalling equipment, provide new operating rules for drivers and support driver training.

The timescales now estimated for implementing the above activities, in line with the revised strategy for Phase 2, are shown in the indicative schedule in Figure 11. The schedule is backed by a more detailed outline programme and a quantified risk assessment\(^\text{24}\).

The outline programme is derived from more detailed programmes which were compiled by:

- Alstom Signalling\(^\text{25}\), for new signalling and train fitment
- WCRM Delivery team for:
  - the Network Management Centre (NMC)\(^\text{26}\)

\(^{24}\) Revised Strategy Schedule Assessment (Team-046)
\(^{25}\) Scenario 4A Summary Programme (IPF-030)
Strategy for Phase 2

- existing baseline programme\textsuperscript{27} for infrastructure renewals
- Multi functional consultants and Phase 2 Review team, for additional infrastructure\textsuperscript{28}

<table>
<thead>
<tr>
<th>Train Fitment</th>
<th>First</th>
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<tbody>
<tr>
<td>For 63 VATTs</td>
<td></td>
<td></td>
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<tr>
<td>For other WCML trains (approximately 2,000 trains)</td>
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<tr>
<th>Trackside Signalling</th>
<th>Level 2 re-signalling and ATP - 140 mph running areas</th>
<th>Level 2 re-signalling and ATP - other areas</th>
<th>Level 1 re-signalling and ATP - elsewhere</th>
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<th>Route Management</th>
<th>Network management systems and NMC</th>
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<th>Civil renewals for Phase 2</th>
<th>Additional schemes for capacity</th>
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<th>PLQ 2: Phase 2</th>
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**Figure 11: Indicative schedule for revised strategy (at 50% confidence level)**

### 14.2 Revised timescales

The indicative schedule in Figure 11 shows that, based on a number of suggested mitigation measures, with a 50% confidence level:

- contractual commitments to Virgin could be met by May 2005
- Undertakings can be satisfied, but unlikely all by 2005
- ATP trackside equipment can be installed:
  - in 140 mph operating sections, by 2005
  - in other route sections, by 2007
- fitment of train-borne signalling equipment and driver training, though prioritised to cover the 53 VATTs by 2005. It is likely to be more protracted for the remaining trains in the 2,000 plus WCML fleet, possibly extending to 2010.

However, it should be noted that the timescales shown in Figure 11 for train fitment and additional infrastructure schemes are indicative only. Train fitment is largely dependent on train operating companies and ROSCOS and therefore outside the control of Railtrack. The timing indicated is

\textsuperscript{27} NMC Phase 2 Group Review Close Out Report (WCRL-005)

\textsuperscript{28} WCML Programme Level 1 Schedule (WCRL-003)

\textsuperscript{29} Infrastructure Assessment (Team-041)
Strategy for Phase 2

estimated simply by applying an assumed rate of fitment to the number of trains involved. Furthermore, the actual scope of train fitment and responsibilities within the industry for the work will need to take cognisance of the Government's response to the Sir David Davies Inquiry into Train Protection. The completion of additional infrastructure schemes depends mainly on the time required to obtain necessary planning consents.

The indicative schedule is drawn up on the assumptions that:

- programme for Phase 1 works will be met. Any delay could cause conflicts for resources and possessions between Phases 1 and 2
- Phase 2 additional or changes in scope of works can be integrated with existing Phase 2 works.

14.3  Risk assessment

The revised strategy has increased confidence in the schedule. This has been accomplished mainly by:

- enabling incremental installation of signalling and other control systems
- prioritising Phase 2 objectives
- greatly reducing the number of trains to be fitted and therefore also the drivers to be trained, prior to May 2005
- decreasing the scale and uncertainty of new signalling systems development, testing and safety approvals
- de-coupling control centre and signalling implementation.

However, the revised strategy has substantially increased the scale of conventional re-signalling, with the resulting increased risks of:

- shortage of available signalling resources
- increased time needed for trackside installation.

In developing the indicative schedule in Figure 11, a practical assessment was made of how these risks could be mitigated by adopting early measures to increase signalling resources and by prioritising signalling works - first to sections designated for 140 mph running, then to areas needing re-signalling with other performance requirements and lastly to areas not needing renewal and without specific performance requirements.

Further work is needed to evaluate other mitigation measures that could result in some reduction to the indicative timescales.

15.  Financial Implications for Control Systems

The cost validation report for Baseline 2 provides a full statement of costs. This new baseline fully integrates the direct impacts of the Phase 2 strategy with a cost review, conducted in parallel, of the full WCRM scope, including Phase 1. In summary, the financial implications of adopting the revised control system strategy are:

- capital costs have increased

WCRM Baseline 2 Cost Assessment (in WCRM Delivery files)
 Strategy for Phase 2

- risk provision has been reduced.

The Phase 2 Review team identified the impact on these parameters – as well as operating and maintenance costs and revenue - as input to a separate review of the business case being undertaken by the WCRM Sponsor team, with support from Ernst & Young.

The treatment of costs for regulatory purposes of the revised strategy were dealt with separately.30

Capital cost and risk provision

Through a detailed review of the cost and risk impact of the revised strategy, a new Baseline 2 Cost Plan has been established.

The overall capital cost, including risk provision, of the WCRM programme at 80% confidence levels (P80) is now estimated to be £5.849m (2Q99 prices). Contingencies at P80 now stand at 29%.

To enable direct comparison with the previous Cost Plan for Baseline 1 which incorporated risk provision at a 50% confidence level (P50). Table 8 below summarises the principal impacts of the Phase 2 strategy on a common cost base of 2Q99.

<table>
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<tr>
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<th>£bn</th>
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<tr>
<td>Baseline 1 @ P50</td>
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<td>Additional conventional signalling</td>
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<td>Net price underestimation and change in scope of works</td>
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<td>Inclusion of additional infrastructure works</td>
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<tr>
<td>Change from P50 to P80 confidence levels</td>
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<tr>
<td>Reduction in net Global Risk</td>
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<tr>
<td>Baseline 2 @ P80</td>
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</table>

Table 8: Cost comparison of Baseline 1 and Baseline 2

Control systems

The total cost of Control Systems is now assessed as £2.029m at P80. The changes are attributed to:

- ATP is now costed for all route sections covered by the WCRM, and fitment of all trains operating on the WCML, at £986m at P80
- net increase in the TCS costs is £235M at P80
- additional conventional signalling renewal south of Crewe adds £550M at P80.

30 Submission to Rail Regulator, date 13th January 2000 (in WCRM Sponsor file)
Strategy for Phase 2

Infrastructure

Additional infrastructure requirements have been costed at £434M at P80. This includes the estimated costs for the four specific schemes at Watford, Trent Valley, Nuneaton and Northampton, and a risk provision.
PART IV - RECOMMENDATIONS & CONCLUSION

16. Summary of Findings and Revised Strategy

16.1 Findings

The main findings from the Phase 2 Review are:

- TCS-M is not a viable option for meeting the Phase 2 objectives for WCRM - in terms of development, implementation, safety acceptance, schedule or acceptable operational risk.
- Additional infrastructure changes are required beyond those identified in the previous strategy.
- 'Time expired' conventional signalling will be replaced by 'modern equivalent form', electronically based, conventional 4 aspect signalling.
- A Train Control System (TCS) based on European Rail Traffic Management System/European Train Control System (ERTMS/ETCS) Level 2 is a feasible development and implementation strategy to support meeting the WCRM outputs.
- A TCS based on ERTMS/ETCS Level 1 is a compatible and feasible implementation strategy to complete an Automatic Train Protection (ATP) environment for the WCRM.

The rest of this section summarises the revised strategy.

16.2 Recommended strategy

The proposed new strategy can be summarised as follows:

**Infrastructure**

1. Adopt the following additional infrastructure schemes:
   - Watford dual fast line platforms
   - Tamworth-Lichfield quadrupling
   - Northampton station crossovers
   - Nuneaton double tracking.

2. Resolve a small number of remaining issues by agreement with train/freight operators and the Rail Regulator.

**Control Systems**

3. Develop and implement progressively ERTMS/ETCS Level 2 and Level 1 systems, with:
   - ERTMS/ETCS Level 2 on all sections intended for 140 mph operation (Euston to Crewe) and all sections with modern electronic interlockings.
   - ERTMS/ETCS Level 1 on all other sections (subject to further analysis).

Figure 12 shows the proposed geographic application of each system.


4. Replace time or condition expired conventional signalling with modern equivalent signalling and interlockings.

5. Adopt a progressive strategy for operational route management. Instead of proceeding straight to a single integrated management control centre (as previously proposed with the NMC):
   - start by using stand-alone route management systems
   - gradually extend their scope
   - finally, implement a full Network Management Centre (NMC)

16.3 Benefits of new strategy

The recommended strategy has a number of advantages over the previous strategy, including:

- gives full ATP over all route sections covered by the WCRM (via ERTMS/ETCS Level 2 or Level 1)
- TCS will now extend into Euston, Birmingham and Manchester (unlike the planned TCS-M coverage)
- TCS and NMC developments can now be progressed largely independently
- operational fallback is provided by conventional signalling, albeit with reduced line speeds
- the technology involved in these train control systems is simpler and less risky to develop
- both ERTMS/ETCS Level 2 or Level 1 are fully compliant with European requirements for interoperability
- train fitment and driver training can be progressive, because unfitted trains can continue to operate on the route controlled by conventional signalling
- improvements in route outputs are delivered incrementally, rather than in a single, 'big bang' step, as shown by Figure 13.
16.4 Other recommendations

To support effective implementation of the revised strategy, the following further measures are suggested:

**Validation**
1. Complete the timetabling for Phase 2 over the revised infrastructure and model performance of the services to validate the conclusions of this review.

**Management**
2. Appoint a senior manager and small support team to focus on planning and driving delivery of Phase 2.
3. Involve senior operations managers immediately to ensure operability, ownership and fitness for use of all aspects of Phase 2.

**Planning**
5. Agree a pragmatic integrated plan for route upgrade, train fitment and driver training with SRA, ORR, ROSCOs, TOCs and FOCs.
6. Research ways of increasing efficiency of undertaking conventional re-signalling works, including new interlocking options (e.g. CBI).

**Contracting**
7. Develop a contracting strategy for control systems which shares the risks and will deliver the necessary functionality and performance over the long term.
Strategy for Phase 2

8. Establish control systems contracts and create an alliance between the contractors concerned to facilitate systems integration.

9. Secure top level management commitment from contractors, and help them achieve a strong focus on delivery.

10. Incentivise contractors to increase signalling resource levels and prioritise their allocation to WCRM.

Further analysis

11. Undertake the further work suggested in Appendix C to refine the definition of the scope of the works for implementing the revised strategy.

17. Concluding Remarks

The Phase 2 Review team has recommended a revised implementation strategy to Railtrack. In making this recommendation, the following observations are made:

- the scale and complexity of the work to deliver Phase 2 is unprecedented. It is believed that the WCRM is the largest upgrade project to an operational railway anywhere in the world. Although the revised strategy has increased the confidence in achieving implementation timescales, the challenge of managing the volume of work that is to take place should not be under-estimated.

- WCRM needs to maintain its high profile to ensure that the railway industry devotes its best resources to achieving the construction, development and implementation timescales. A collaborative approach is essential to enlist the full support and resources of other parties such as HMRI, sSRA, ORR and the TOCs, FOCs and ROSCOs. Railtrack must take a lead in orchestrating the combined industry effort.

- the ‘economies of scale’ of the WCRM works provides an opportunity to use WCRM to re-write ‘best practice’ for Railtrack and its suppliers. The scale of the signalling work presents ‘best practice’ opportunities for design, development, installation and commissioning.

- the benefits offered by TCS-M were compelling and undoubtedly would still be the long-term aim for signalling systems. The review has assessed that relying on TCS-M to achieve PUG 2 outputs is not a reliable strategy for WCRM. The review team believes that WCRM should focus entirely on the revised strategy. Any long-term view, including TCS-M, defined at this stage should be adjusted in light of experiences from WCRM implementation of TCS.
Strategy for Phase 2

Appendices

Appendix A  Abbreviations
Appendix B  Guide to the Review
Appendix C  Further Technical Analysis
Appendix D  Technical Overview of Control Systems
Strategy for Phase 2

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### Appendix A Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>ATP</td>
<td>Automatic Train Protection</td>
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<tr>
<td>DLR</td>
<td>Docklands Light Railway</td>
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<td>EMU</td>
<td>Electric Multiple Unit train</td>
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<tr>
<td>ERTMS/ETCS</td>
<td>European Rail Traffic Management System</td>
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<td>ETCS</td>
<td>European Train Control System</td>
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<td>EU</td>
<td>European Union</td>
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<td>FOC</td>
<td>Freight Operating Company</td>
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<td>GSM-R</td>
<td>Global System for Mobile communications – Railway</td>
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<td>HF&amp;A</td>
<td>Harris Franklin &amp; Andrews</td>
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<td>HMRI</td>
<td>HM Railway Inspectorate</td>
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<td>Infrastructure Parameter</td>
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<td>Multi-Function Consultant</td>
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<td>Network Management Centre</td>
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<td>Office of Passenger Rail Franchising</td>
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<td>Railtrack Active Tilting Train</td>
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<td>System Requirements Specification</td>
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<td>Shadow Strategic Rail Authority</td>
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<td>TCS</td>
<td>Train Control System</td>
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<td>Train Protection Warning System</td>
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<td>TSIs</td>
<td>Technical Specifications for Interoperability</td>
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<td>TWA</td>
<td>Transport &amp; Works Act</td>
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<td>WCRM</td>
<td>West Coast Route Modernisation</td>
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Appendix B  Guide to the Review

B.1 Background

The Phase 2 strategy review process was undertaken between July 1999 and December 1999, concluding with Railtrack Group Board approval to the revised strategy on 9 December.

The team undertaking the review included a broad range of expertise drawn from the Railway Industry.

The definition of a revised strategy evolved through a thorough process with defined checkpoints. The evolution of the strategy is recorded through working papers and reference documents. The supporting papers to the review are contained in a referenced filing system.

B.2 The team

The Phase 2 Review team was formed in July 1999. The leadership for the team throughout the review came from Mike Nichols, the Chairman and Chief Executive of the Nichols Group.

The Nichols Group is an international consultancy specialising in programme and project management. It has managed many large-scale railway developments including the Jubilee Line Extension (JLE), all phases of the Docklands light Railway, Channel Tunnel and Hong Kong Mass Transit Railway. Its recent experience has included managing integration and delivery of control systems for the JLE. Mike Nichols led a similar review during 1998 of the strategy for delivery of the JLE for London Underground.

The review process needed access to a broad range of experience, skills and knowledge to complete the work thoroughly in the demanding timescales. The review was organised around a core review team comprising Railtrack expertise, Nichols Group consultants and other independent consultants. The core review team worked full-time, with support from others on a part-time basis, including:

- an external panel, comprising experts to provide advice on specific issues
- members of the WCRM Delivery and Sponsor teams to manage specific analysis tasks and to provide on-going review of the evolving strategy
- Railtrack’s suppliers e.g. Alstom Signalling, Union Switch & Signalling, AEA Technology.

Core review team

The following is an outline of the experience of the core review team members:

- a Senior Project Manager with experience of technical development projects and safety approvals from his leadership of previous Railtrack projects, specifically TPWS and DART. Other experience includes the role of Railtrack National Project Manager for ERTMS, secondment to the European Rail Research Institute to review ERTMS proposals for the European Commission, project management of feasibility studies leading to the establishment of the Network Management Centre project and bid management of a Railtrack led submission to develop the GSM-R system. The role in the team was to facilitate
and manage a number of the technical analyses. He led the definition and evaluation of signalling system alternatives, working closely with the WCRM Delivery team and Alstom Signalling.

also provided a technical management review of the schedule risk, qualitative performance assessment and other analysis activities.

• formerly Head of WCRM Train Systems and Head of Project Engineering. is experienced in the preparation, planning, design and implementation of major infrastructure projects. role in the team was to facilitate the feasibility analysis of additional infrastructure identified during the review process. worked closely with the WCRM Sponsor team to develop a system that matched contractual commitments and Undertakings and operating service requirements with infrastructure schemes and ensured that these schemes were robustly planned and costed.

• , is Strategy Manager for the NMC project. She has 13 years experience in rail operations and business development, both on a zonal and large area scale. worked closely with the WCRM Delivery team to assess the operational implications of all strategy recommendations on the NMC concept and to ensure that NMC strategy aligned with Black Diamond review work.

• Senior Consultant, Nichols Group has extensive experience of managing complex systems project. Recently, was responsible for the strategy and management of commissioning and acceptance of complex station control systems on the Jubilee Line Extension. role in the review team was to project manage the completion and quality of the Phase 2 Review process.

• Senior Consultant, Nichols Group is an expert advisor on the organisation of major projects and programmes. He has managed train procurement and commissioning, railway infrastructure and major signalling works. His experience includes the introduction of moving block signalling at Docklands Light Railway. role in the review team was to prepare presentations and the final report.

• Senior Consultant, Nichols Group is a Chartered Mechanical Engineer, experienced in project management and consulting for development projects in the UK and overseas. oversaw the cost and risk planning activities within the team and their interface to parallel activities within Alstom Signalling.

• Consultant, Nichols Group, is experienced in programme scheduling and risk analysis. Previous experience includes: Docklands Light Railway Re-signalling to Moving Block, Jubilee Line Extension, programme management for BR sale of BRIS and other railway projects. managed the integrated schedule and risk analysis for the Phase 2 Review.

• Consultant, Nichols Group, is experienced in computer based modelling, simulation and analytical techniques. role was to manage and evaluate results from the railway system performance modelling, in conjunction with the WCRM Systems Engineering Group, AEA Technology Rail and Jardine Associates.

• Senior Consultant, Nichols Group is a Fellow of the Institute of Civil Engineers with extensive experience of the design and construction of railway systems, including Hong Kong Mass Transit, Kowloon Canton Railway, Docklands Light Railway, London Underground and others. role in the team was the analysis of the interface between operational aspects and the infrastructure to be provided.
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(Asset Management Consulting Limited (AMCL)) is an experienced Chartered Engineer with a wide knowledge of the Rail Industry, particularly within the Signalling and Telecommunications disciplines. is a founder member of the International Institute of Asset Management (IAM) and has previously worked as a senior manager in infrastructure maintenance with responsibility for the safety and performance of the railway. He is currently a Director of AMCL, a company involved with many of Railtrack's strategic asset management projects. has been associated with WCRM since 1997. His role within the Phase 2 Review was to assess signalling asset condition and the implications on maintenance of revising the strategy. He also played a major role in the formation of the revised signalling migration

is a Railway Development Consultant employed by PB Kennedy & Donkin. is a Signal Engineer with particular experience of the West Coast Mainline in both Operation and Maintenance. He has been associated with the WCRM project since the Railtrack Feasibility Study. His role in the team was to provide background history of the project development, to support the definition of infrastructure solutions and provide expertise on the issues related to perturbation. He also assisted in reviews of the Safety and Operational aspects of the proposed solutions.

Strong support on cost planning and risk management was provided by Harris Franklin & Andrews - a joint venture of Franklin & Andrews and E C Harris - both leading cost consultants in the UK rail industry. Their involvement included:

Senior Partner Franklin & Andrews, is experienced in leading cost and risk validation on Thameslink 2000, the Channel Tunnel Rail Link and other Railtrack projects.

was responsible for authorising the cost estimates for the Phase 2 Review and undertook a similar role for the earlier WCRM baselining exercises in 1999

Head of Risk Management for Franklin & Andrews and a Director of OPML (an F&A company), is experienced in conducting Risk Analysis for several previous Railtrack projects.

role was to facilitate workshops and meetings to complete qualitative and quantitative analysis for control systems and infrastructure implementation and Global Risk

Principal Quantity Surveyor for Franklin & Andrews, is experienced in cost estimating from London-Tilbury-Southend re-signalling and Thameslink 2800 projects.

undertook cost estimating for additional conventional signalling works identified as part of the revised strategy

External panel

The following is an outline of the external panel and their involvement:

Executive Director, Nichols Group, has extensive railway industry experience of delivering large railway projects based on complex signalling and control systems. Most recently was Commissioning Manager for the Jubilee Line Extension project for London Underground. expert input and judgement was crucial to the assessment of the feasibility of the control systems delivery programmes

Associate Director, Nichols Group, and an Independent Transport Safety Consultant. He had formerly 20 years experience with HMRI on safety assessment for all new main line signalling including light railways & developing tramways. He has direct experience of approving ATP systems. expert judgement was used to assess the scale of the safety approvals risk of both the previous and revised strategy
Strategy for Phase 2

Appendix B

(Railtrack) is Movements Manager for the LNE Zone. He is widely recognised as being highly experienced in all aspects of rail operations. role was to act as a source of independent advice on aspects of the NMC strategy.

, Senior Professional Associate, Parsons Brinckerhoff is an experienced railway operations analyst. He has managed the development of strategic plans for several railways in the United States – including the U.S. national passenger rail network, the Amtrak Northeast Corridor between New York and Washington DC, the Long Island Rail Road and the Maryland Rail Commuter system. experience has been used to review the railway simulation modelling undertaken as part of the Phase 2 Review.

, Parsons Brinckerhoff, was formerly the head of Research and Development for Burlington Northern/Santa Fe railroad in the U.S. and brought to the team his considerable knowledge about the past and current efforts regarding signal systems in the U.S.. He became heavily involved in the development of a migration strategy for the interlockings on the WCML, as part of the review process.

WCRM Delivery and Sponsor teams

(Railtrack) Head of Delivery (Control Systems) in WCRM and formerly Head of Projects (East Anglia Zone) and Client Team Leader (Thameslink 2000). was a member of the Review Group and led parallel and supporting activity across the signalling and control groups, keeping in close liaison with the senior executives of Alstom and US&S.

(Railtrack) is the Route Strategy Manager for WCML. He has over 21 years experience in the industry, the majority of which has been gained in current operations management. He also spent 2 years as Head of Operations Planning for the Great Western zone. As part of the WCRM Sponsor team, was a member of the Review Group and provided the link to timetabling work and Railtrack customer issues.

(Parsons Brinckerhoff) Head of programme management office. was formerly Chief Engineer for the New York City subway system during the largest reconstruction in its history and is experienced in the integration requirements of major rail infrastructure programmes. As Manager programme Integration for WCRM, role on the team was to review the overall Black Diamond strategy from the aspect of integration and interface issues.

(Railtrack) is the Systems Integration Manager for WCML. He has a large number of years experience in systems engineering evaluating safety critical software design and designing system architecture, mainly in the defence industry. As a key member of the WCRM programme management office, was a member of the Review Group and provided the link to the performance modelling team.

(Railtrack) is a Senior Signalling Engineer with 25 years experience in the industry ranging from maintenance to scheme and product development, including ATP. Before joining WCRM Control Systems Delivery he was responsible for developing Railtrack’s signalling strategy and for the introduction of new signalling technology. role as a part time team member was to facilitate the matching up of a practical and deliverable train control solution to identified requirements.

(Amey Vectra Ltd), a systems engineer with nearly twenty years experience of computer technology, including Technical Architect for the Jubilee Line Extension. role in
the team was to develop a representation of the emergent WCML system architecture through review with the WCRM Delivery teams

- a signal engineer with 24 years experience in railway signalling design and design management. role was to support the review team to develop a signalling migration strategy and feasibility input to conventional signalling works schedules.

- is the Route Development Manager for WCRM. He has 22 years experience in the engineering sector, the last 7 of which have been spent in the rail industry. He had both performance and commercial roles in British Rail before moving into his current development role with Railtrack. As part of the WCRM Sponsor team, has supported the review team on the assessment of capacity contractual commitments and Undertakings and the means to meet them.

B.3 Supporting Material

The outputs and reference material supporting the Phase 2 Review are organised in the hierarchy shown below:

![Figure 14: Output and reference material hierarchy](image)

All the above documents use a common Phase 2 filing system, coding for this is:

- TEAM all papers produced as a result of analysis by the Phase 2 Review team. This includes the 'Final Report – Supporting Papers' and working papers produced as the strategy evolved
- WCRM reference documents produced by the WCRM programme
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- JPT reference documents input to the Phase 2 Review team analysis from the Alstom Signalling team
- MISC reference documents received from miscellaneous sources.

A full index of documents is provided below.

Final report - supporting papers

A series of 'Final Report - Supporting Papers' were written as part of the review process. The papers document the results of the assessments and analysis undertaken as the strategy evolved. The 'Phase 2 Final Report' presents an overall view of the Phase 2 Review and the supporting papers provide more detail on specific aspects of the review. The supporting papers were used to check specific aspects of the review with members of the WCRM Delivery and Sponsor teams.

Certain of these documents may be commercially sensitive.

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<th>Description</th>
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<tr>
<td>Team-033</td>
<td>Phase 2 Requirements</td>
<td>Provides background information on the Phase 2 contractual commitments and regulatory undertakings to others</td>
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<tr>
<td>Team-034</td>
<td>Commitments Not Delivered By Baseline</td>
<td>A definition of the Phase 2 requirements not met by the previous strategy. This document provides a baseline for the 'shortfall' that the Phase 2 Review sought to meet</td>
</tr>
<tr>
<td>Team-025</td>
<td>Performance Modelling</td>
<td>Summarise the key findings of all the performance modelling work undertaken in support of the Phase 2 Review. This work covers assessments of the May 99, alternatives and revised strategies.</td>
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<td>Team-036</td>
<td>TCS-M Assessment</td>
<td>Documents the conclusions of the technical, feasibility and risk assessments of previous strategy by the Phase 2 Review team</td>
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<tr>
<td>Team-037</td>
<td>Operational Assessment</td>
<td>Documents the conclusions of operational assessments of the TCS-M and revised signalling strategies</td>
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<tr>
<td>Team-038</td>
<td>TCS-M Schedule Assessment</td>
<td>Documents the results of a review of previously undertaken TCS-M schedule assessments and a rationalised view undertaken by the Phase 2 Review team</td>
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<td>Team-039</td>
<td>ERTMS Overview</td>
<td>Provides background information on the European Rail Traffic Management System.</td>
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<td>Team-040</td>
<td>Signalling Options Assessment</td>
<td>Documents the evaluation of alternative signalling system options</td>
</tr>
<tr>
<td>Reference</td>
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<td>Documents the assessment of existing Baseline 1 and additional infrastructure schemes required to provide additional capacity</td>
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<td>Team-042</td>
<td>Timetable - Rules of The Plan</td>
<td>Documents an assessment of the change in signalling strategy on the Rules of the Plan used for the Phase 2 timetable</td>
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<td>Team-043</td>
<td>Revised Signalling Strategy</td>
<td>Summarises the scope of signalling works to support the revised strategy</td>
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<td>Team-044</td>
<td>Signalling Condition Assessment</td>
<td>Documents an analysis of the current signalling condition assessments and their applicability to prioritising Phase 2 signalling works</td>
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<td>Maintenance Strategy Assessment</td>
<td>Documents the results of considering the implications of the revised strategy on maintenance of the WCML</td>
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<td>Team-046</td>
<td>Revised Strategy Schedule Assessment</td>
<td>Documents the results of a schedule assessment of the revised strategy and its likely implementation</td>
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<td>Team-049</td>
<td>Cost Plan Report</td>
<td>Documents the audit trail of the cost and risk analysis work undertaken by the Phase 2 Review team</td>
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<td>Team-051</td>
<td>Derivation of Operational Expenditure (OPEX) For The Recommended Solution</td>
<td>Documents the Opex assumptions used to assess the effect of the revised strategy on the WCRM business case</td>
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<tr>
<td>Team-052</td>
<td>ERTMS Level 3 Cost Estimate</td>
<td>Documents an analysis of the costs attributable to development and testing of Level 3 TCS product from Alstom. This cost is being separated from the other estimates as an R&amp;D item</td>
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<tr>
<td>Team-053</td>
<td>Remuneration For TCS and ATP.</td>
<td>Documents the arguments and rationale in relation to specific categories of control system costs related to the revised strategy</td>
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**WCMM documents**

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<td>JPT-024</td>
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<td>JPT-025</td>
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<td>JPT-029</td>
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<td>JPT-032</td>
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<td>JPT-034</td>
<td>Scenario Analysis - Tamworth/Lichfield - Transition from 4 to 2 Track</td>
</tr>
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<td>JPT-035</td>
<td>Scenario Analysis - Tamworth/Lichfield - Transition from 2 to 4 Track</td>
</tr>
<tr>
<td>JPT-036</td>
<td>TCS Phase 2 Scenario 4A Scope Definition</td>
</tr>
<tr>
<td>JPT-037</td>
<td>TCS Phase 2 Scenario 4A Summary Risk Report</td>
</tr>
<tr>
<td>JPT-038</td>
<td>Scenario 4A - Summary programme</td>
</tr>
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<td>JPT-039</td>
<td>Scenarios 4 &amp; 5 for the Installation of TCS on the West Coast Main Line</td>
</tr>
<tr>
<td>JPT-040</td>
<td>Summary Commercial Report on Scenario 4A for the Installation of TCS on the West Coast Main Line</td>
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<tr>
<td>JPT-041</td>
<td>TCS Timescale Risk Assessment</td>
</tr>
<tr>
<td>JPT-041</td>
<td>Timescale Risk Analysis Based Upon PB5c (£600m) Project programme.</td>
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</table>
### Reference | Title
--- | ---
JPT-041 | Timescale Risk Assessment - Option 5B programme PB5c - P50 & P80 Dates
JPT-041 | Timescale Risk Assessment - Option 5B programme PB5d Timescale Risk for TCS-F
JPT-041 | TCSTimescale Risk Assessment based on PB5d (£532m)
JPT-041 | Timescale Risk Analysis Based on PB5d (£532m)Project programme
JPT-042 | TCS Phase 2 Scenario 4A Summary Risk Report
JPT-043 | WCML TCS Phase 2 - Scenario 4 - Summary programme
JPT-044 | Letter from M Southwell to P Kent regarding Train Control Systems - ERTMS/ETCS programme
JPT-045 | TCS JOINT PROJECT TEAM WCML
JPT-046 | TCS Joint Project Team System Design Plan
JPT-047 | Agenda of Meeting 23rd September 99 OMEGAT Conference Room
JPT-048 | Presentation by TCS JOINT PROJECT TEAM WCML
JPT-049 | TCS JOINT PROJECT TEAM WCML
JPT-050 | TCS JOINT PROJECT TEAM WCML
JPT-051 | Detailed System Description
JPT-052 | Phase 2 High-Level Scenario Definition
JPT-053 | Monte Carlo Files -
JPT-054 | Further Headway Performance Analysis
JPT-055 | Essential Scope and Cost Analysis — Task Scopes

#### Miscellaneous documents

| Reference | Title |
--- | ---|
MISC-001 | Advice on the present cost (October 1999) of national fitment of Automatic Train Protection |
MISC-002 | TCS Tender Evaluation May 1998 |
MISC-003 | Research report 009 Railtrack Performance Strategy Analysis |
MISC-004 | Extended Capacity Scenarios (Fax/E-mail) From Nigel Lee (AEA Technology Rail) to Elaine Davis |
### Strategy for Phase 2

#### Appendix B

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
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<tr>
<td>MISC-005</td>
<td>Extended Capacity Scenarios (Fax/E-mail) From Nigel Lee (AEA Technology Rail) to Elaine Davis</td>
</tr>
<tr>
<td>MISC-006</td>
<td>Extended Capacity Scenarios (Fax/E-mail) From Catherine Green (AEA Technology Rail) to Elaine Davis</td>
</tr>
<tr>
<td>MISC-007</td>
<td>Extended Capacity Scenarios (Fax/E-mail) From Catherine Green (AEA Technology Rail) to Elaine Davis</td>
</tr>
<tr>
<td>MISC-008</td>
<td>Train Control System Phase 2</td>
</tr>
<tr>
<td>MISC-009</td>
<td>Benefits of TBTCs on the WCML</td>
</tr>
<tr>
<td>MISC-010</td>
<td>Consultation on the Draft Conventional Interoperability Directive Memo to Sue Turner from J Legay</td>
</tr>
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</tr>
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<td>Integrated Business Plan for the WCML (McKinsey Report - TCS)</td>
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</tr>
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</tr>
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</tr>
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</tr>
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<td>Vehicle and Route Acceptance Agreement with West Coast Trains</td>
</tr>
<tr>
<td>MISC-019</td>
<td>Passenger Upgrade Agreement (1997) (&quot;PUG&quot;)</td>
</tr>
<tr>
<td>MISC-020</td>
<td>Scott Wilson Interim Signalling Review</td>
</tr>
</tbody>
</table>
Appendix C Further Technical Analysis

Within the timeframe for the Phase 2 Review, it was not possible to determine in detail all of the issues pertinent to the technical strategy. Further analysis required to close out these issues is detailed below.

C.1 Maintenance Strategy

A number of additional studies are required to resolve outstanding issues on the maintenance arrangements required to support the revised strategy. Specific studies are required to resolve the following issues:

- the operational and maintenance analysis confirmed that route-wide bi-directional signalling was not required to support the maintenance or perturbation management strategies. However, an issue remained open as to whether there was a justifiable case for bi-directionally signalling the middle track in the three track section between Brinklow and Attleborough in the Trent Valley.

- the revised requirements for access points and safe ccess walking routes arising from the increases in proposed lineside equipment need to be resolved.

- define common 'isolation points' for the signalling and electrification systems and identify whether additional 'isolation point signals' should be provided in order to improve times for the implementation of engineering possessions.

- determine requirements for condition monitoring systems to support pro-active maintenance and faulting regimes.

- determine requirements for asset registers and configuration control arrangements during the modernisation works.

C.2 TCS development

Although Railtrack has chosen not to apply ERTMS/ETCS Level 3 as part of Phase 2 of the West Coast Route Modernisation, the benefits of applying a system of this kind instead of conventional signalling have not changed. The eventual application of an ERTMS/ETCS Level 3 system on Railtrack therefore remains a valid strategic objective.
However, the system design and development can be progressed on either an immediate or delayed basis:

<table>
<thead>
<tr>
<th></th>
<th>Immediate</th>
<th>Delayed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td>• Level 2 system is designed with progression to Level 3 in mind, maximising opportunities for common development</td>
<td>• Level 2 development can progress with simple and clear scope of work</td>
</tr>
<tr>
<td></td>
<td>• Momentum for development of Level 3 is maintained, avoiding loss of key skills</td>
<td>• Costs of Level 2 development will be more transparent and manageable</td>
</tr>
<tr>
<td></td>
<td>• Support of supplier for strategy is maximised</td>
<td>• Level 2 development will not be delayed by Level 3 issue resolution</td>
</tr>
<tr>
<td></td>
<td>• Earlier availability of Level 3 system for application elsewhere on Railtrack's network</td>
<td>• Potential resource conflicts between demands for Level 2 and Level 3 design activities are removed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Level 3 system can be designed incorporating lessons learnt from the design of the Level 2 system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Many of the current uncertainties with the Level 3 design (e.g. train integrity) will either be resolved by other European railways, thereby reducing costs to Railtrack, or will become easier to resolve with the benefit of experience of operating Level 2</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>• Risk of delay to development of Level 2 system (and hence to Phase 2 of the WCRM) whilst Level 3 issues resolved</td>
<td>• Future implementation of Level 3 on Railtrack's network potentially delayed</td>
</tr>
<tr>
<td></td>
<td>• Lack of clarity as to development costs for Level 2 system</td>
<td>• Design of Level 3 system may require more rework of Level 2 designs</td>
</tr>
<tr>
<td></td>
<td>• Management of system design and development made more complex</td>
<td>• Loss of credibility by Railtrack</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Potential loss of key resource</td>
</tr>
</tbody>
</table>

Table 9: Comparison of development strategies for ERTMS/ETCS Level 3
Strategy for Phase 2

Appendix C

It is recommended that a specific study is undertaken to analyse this issue in greater detail and recommend the development strategy to be adopted.

C.3 Network Management Centre

Two issues are recommended for further analysis:
- centralised or distributed route management
- migration strategy for signalling control.

The arguments for centralised (i.e. the whole route within the Midlands Zone), as was originally driven by the desire to control the whole of the TCS-M area from the same location, or distributed (e.g. by Infrastructure Maintenance Contract area) are presented in Table 10:

<table>
<thead>
<tr>
<th>Centralised</th>
<th>Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>* Single building required for major area</td>
<td>* Requires more buildings</td>
</tr>
<tr>
<td>* Operational benefits from co-location of signalling control with Zone Control</td>
<td>* Operational benefits from co-location of signalling control with Zone Control reduced</td>
</tr>
<tr>
<td>* Maintenance benefits from co-location of signalling control with electrical control</td>
<td>* Maintenance benefits from co-location of signalling control with electrical control reduced</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>* Lack of alignment with Infrastructure Maintenance Contract areas prevents turnkey responsibility for route sections from being given to contractors</td>
<td>* Requires more buildings</td>
</tr>
<tr>
<td>* Increased centralisation is contrary to current corporate strategies of maximising local accountability and responsibility through Area Delivery Groups</td>
<td>* Requires more buildings</td>
</tr>
</tbody>
</table>

**Table 10: Comparisons of operational management strategies**

The migration issue to address for signalling control is the functionality to be provided by interim systems prior to the introduction of Network Management Centre systems and the extent to
Strategy for Phase 2

Appendix C

which the interim systems are replaced, or enhanced, by the subsequent application of NMC systems.

It is recommended that specific studies are undertaken to resolve these two issues.

C.4 ERTMS/ETCS geographic scope

Although the criteria for the application of ERTMS/ETCS Level 1 or ERTMS/ETCS Level 2 gave clear decisions for the vast major of route sections, further analysis is required for the following sections:

- Birmingham to Stafford
- Crewe to Liverpool
- Carstairs to Glasgow

Although ERTMS/ETCS Level 1 has been assumed within Baseline 2 for these route sections, signalling renewal works already planned, coupled with the potential importance of these route sections in influencing performance may justify the deployment of ERTMS/ETCS Level 2.

It is recommended that studies are undertaken for each of these route sections to determine the optimal choice of system for each.

C.5 GSM-R scope

The GSM-R estimates for Baseline 2 of the West Coast Route Modernisation assume that:

- the scope of application of GSM-R is identical to the scope of application of ERTMS/ETCS Level 2 (i.e. Euston to Birmingham and Manchester, ignoring the issues described above)
- GSM-R is always applied as a fully duplicated network (i.e. 200% coverage), as was specified for ERTMS/ETCS Level 3
- new voice radios are fitted to the trains at the same time as the ERTMS/ETCS train equipment.

However, these assumptions ignore:

- there may be justification to provide GSM-R for voice radio purposes only, outside the scope of application of ERTMS/ETCS Level 2 (e.g. to allow existing voice radio systems to be decommissioned)
- the 200% coverage requirement arose from the reliability requirement placed on the GSM-R network by TCS-M. With this system, any failure of the radio system would prevent trains from receiving movement authorities (i.e. they would be brought to a halt). Under the revised strategy, the effect of a radio failure on a 140mph route section is to reduce the line speed to 125mph, whilst there is no service effect on an area with 125mph line speed or less, although ATP protection is lost in the area of failure
- new train radios can be fitted during normal rolling stock maintenance cycles, rather than needing extended outages as required for fitment of ERTMS/ETCS ATP equipment. Therefore, the safety and performance benefits of improved train radio facilities could be available much earlier than ATP timescales would indicate.

It is therefore recommended that a specific study is undertaken to determine:

- the geographic scope of application of GSM-R, considering:
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- geographic scope of application of ERTMS/ETCS Level 2
- opportunities for de-commissioning existing train radio equipment

- the level of coverage of GSM-R to be provided on:
  - route sections with line speeds in excess of 125mph
  - performance critical route sections with line speeds of 125mph or less
  - other route sections with line speeds of 125mph or less

- the scope and programme of train radio fitment to maximise opportunities for:
  - de-commissioning existing train radio equipment
  - performance benefits
  - safety benefits

- reduction in fixed lineside telephony.
Appendix D  Technical Overview of Control Systems

D.1 Introduction

This appendix provides a brief technical description and overview of the control systems considered within the review of Phase 2 of the West Coast Route Modernisation. More comprehensive descriptions of these control systems are available in the supporting working papers and referenced documents.

D.2 Conventional signalling

The conventional signalling system in use on the West Coast Main Line and on most of Railtrack's major routes is multi-aspect colour light signalling with Automatic Warning System (AWS). The key features of conventional signalling are:

**Indication to drivers**

The primary means of communicating instructions to train drivers is through colour light signals. On the West Coast Main Line, these are mainly four-aspect signals. Normally, the signal indications have the following meaning:

- **Red** the track in the signal section ahead is occupied or set for another train
- **Single Yellow** the next signal is currently indicating red
- **Double Yellow** the next signal is currently indicating single yellow
- **Green** there are at least three clear signal sections ahead.

On the approach to diverging junctions there are also junction indicators on signals to inform the driver which route ahead has been set.

Speed limit boards are also sometimes provided to supplement the driver's route knowledge.

Within the train cab there is also a display for the Automatic Warning System. This indicates whether the last signal sighted was indicating a Green or a cautionary aspect. This is updated from magnets located on the approach to signals, with an audible indication given on the update.

**Speed control**

The control of the train's speed to safe limits is undertaken entirely by the driver. The driver determines this based on route knowledge coupled with the sighting of indications provided at the lineside.
Route proving and setting

The safe control of the setting of routes of trains is provided by the interlocking. This can be mechanical (i.e. lever frames), electrical (relays), or electronic (computer processor based).

Train detection

The signalling system detects the location of trains using either track circuits or axle counters.

Protection against driver error

The Automatic Warning System provides a basic level of protection against driver error. If the driver does not acknowledge the audible indication within a given time, then the train brakes are applied automatically to bring the train to a halt.

D.3 Train Protection and Warning System

The Train Protection and Warning System (TPWS) provides an enhanced level of protection against driver error on conventional signalling. It can be applied selectively to both signals and trains. The standard configuration consists of two pairs of loops:

- a 'Speed Trap' located in advance of the signal
- a 'Train Stop' located at the foot of the signal

This is shown below:

![TPWS Schematic](image)

**Figure 15: TPWS schematic**

The loops are energised when the signal is displaying a red aspect. When the train passes over the arming loop, a counter is started on the TPWS trainborne equipment which measures the time for the train to reach the trigger loop. Should this be less than a pre-set time (normally 1 second) then the train is going 'too fast' and the TPWS trainborne equipment will automatically apply the train brakes. The speed at which trains are judged to be 'too fast' can be set by varying the distance between the arming and trigger loops.

The TPWS system is currently being deployed throughout Railtrack, with the West Coast Main Line targeted for completion by May 2002. The system is also being applied to all trains operating over Railtrack's infrastructure for completion by the end of December 2003.
D.4 Current Automatic Train Protection systems

Automatic Train Protection (ATP) systems to protect against driver error and provide signalling indications in the train cab are deployed on high speed lines throughout continental Europe and have been trialed on the Great Western and Chiltern lines on Railtrack. ATP provides protection against driver error on a continuous basis (as opposed to TPWS which only provides protection at the location of loops). Examples of the many ATP systems currently available are TVM430 (made by CS Transport), TBL (Alstom) and LZB (Siemens).

The current systems available from different manufacturers are incompatible with each other and use a variety of means of communicating information to trains, e.g. coded track circuits, loops and transponders (balises).

However, the core features of these different systems are largely identical, consisting of:

- the communication of 'distance to go' and speed limits to the train, called the movement authority
- the display of information to the driver
- the continuous monitoring of the train speed and position to ensure these are within the 'safe envelope' calculated from the movement authority
- the intervention of the system to apply train brakes if the driver tries to operate outside the 'safe envelope'.

D.5 ERTMS/ETCS overview

All European manufacturers of ATP equipment are now working together to develop common systems that comply with equipment standards. These systems are known as European Rail Traffic Management System / European Train Control System (ERTMS/ETCS). The use of ERTMS/ETCS specifications on Trans-European Network (TENs) routes subject to major upgrade is mandated by the European Union Directive 96/48 (and supporting Technical Specification for Interoperability for Command Control systems).

The ERTMS/ETCS standards define three levels of application of these systems:

<table>
<thead>
<tr>
<th>European standard</th>
<th>WCRM Equivalent (Previous Strategy)</th>
<th>WCRM Equivalent (Revised Strategy)</th>
</tr>
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<tbody>
<tr>
<td>ERTMS/ETCS Level 1</td>
<td>-</td>
<td>TCS-L1</td>
</tr>
<tr>
<td>ERTMS/ETCS Level 2</td>
<td>TCS-F</td>
<td>TCS-L2</td>
</tr>
<tr>
<td>ERTMS/ETCS Level 3</td>
<td>TCS-M</td>
<td>TCS-L3</td>
</tr>
</tbody>
</table>

Table 11: Mapping of WCRM strategy to ERTMS/ETCS standards

The principle technical differences between the three levels of application are:

- the means of transmitting information to the train
- the means of detecting the location of trains
- the means of setting routes and providing safe separation of trains.
Strategy for Phase 1

These are:

<table>
<thead>
<tr>
<th>Transmissions to train</th>
<th>Transmissions from trains</th>
<th>Train location</th>
<th>Train completeness</th>
<th>Train separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switchable balises</td>
<td>None</td>
<td>Track circuits or axle counters</td>
<td>Track circuits or axle counters</td>
<td>Conventional fixed block interlocking</td>
</tr>
<tr>
<td>GSM-R radio</td>
<td>GSM-R radio</td>
<td>On-board odometry</td>
<td>Train integrity system</td>
<td>Conventional fixed block interlocking</td>
</tr>
<tr>
<td>GSM-R radio</td>
<td>GSM-R radio</td>
<td></td>
<td></td>
<td>Moving block Radio Block Centre</td>
</tr>
</tbody>
</table>

Table 12: Technical comparison of ERTMS/ETCS Levels

In functional terms the technical differences translate into the following differences:

<table>
<thead>
<tr>
<th>ERTMS/ETCS Level</th>
<th>Safety Protection</th>
<th>Ability To Revoke Movement Authority</th>
<th>Ability To Extend Movement Authority</th>
<th>Ability To Update Train Location For Train Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPWS</td>
<td>Discrete</td>
<td>Discrete</td>
<td>Discrete</td>
<td>Discrete</td>
</tr>
<tr>
<td>1</td>
<td>Continuous</td>
<td>Discrete</td>
<td>Discrete</td>
<td>Discrete</td>
</tr>
<tr>
<td>2</td>
<td>Continuous</td>
<td>Continuous</td>
<td>Continuous</td>
<td>Discrete</td>
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<tr>
<td>3</td>
<td>Continuous</td>
<td>Continuous</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
</tbody>
</table>

Table 13: Functional comparison of ERTMS/ETCS Levels

Continuous means that a change of state is possible at any location along the track; whereas discrete means that a change of state is only possible at specific locations along the track.

Technical descriptions of the three ERTMS/ETCS application levels and the ERTMS/ETCS trainborne equipment are provided in the following sections.

D.6 ERTMS/ETCS Level I

The simplest form of ERTMS/ETCS, Application Level I, is based on the use of discrete track transponders (balises) to transmit signal aspect data to ERTMS/ETCS fitted locomotives and rolling stock. The ERTMS/ETCS Application Level I system architecture is similar to many proprietary cab-signalling and ATP systems in use around the world, e.g. TBL.
Strategy for Phase 2

Appendix D

Trackside sub-system and application to UK main lines

The ERTMS/ETCS Level 1 system can be applied as an overlay to multiple aspect signalling used in the UK in a similar manner to that installed on the Great Western Main Line (GWML) and Chiltern Lines ATP pilot schemes. A simplified block diagram of the trackside infrastructure is shown in Figure 16.

![Figure 16: ERTMS/ETCS application level 1 trackside sub-system](image)

For the sake of clarity, Figure 16 does not give any details of the existing signalling system and its associated interlocking. The EUROBALISE transponder system may be easily added to any existing signalling installation regardless of the underlying technology employed since the only interface required is a simple electrical connection to the signal lamp outputs. Virtually any signalling technology can be upgraded in this way including SSI, geographic or free wired relay interlockings.

The trackside sub-system consists of Lineside Electronic Units (LEU) and track transponders or baiises. The LEU connects directly to the aspect lamp drive circuits at each lineside signal and passes the necessary aspect status data to the EUROBALISE transponder. An embedded processor within the transponder is pre-programmed with fixed infrastructure-related parameters such as gradient, line speed and balise linking data. The balise linking data acts as a pointer to the location of the next balise group to enable the trainborne sub-system to detect a missing or defective balise.

Semi-continuous transmission or in-fill may be required at certain geographic locations to prevent trains being forced to brake unnecessarily should a signal clear before the next transponder is reached. In-fill would typically be provided on the approach to controlled signals at junctions or in station areas. In-fill can be implemented using the EUROLOOP leaky feeder based on the use of spread-spectrum transmission. This feature can also be implemented using GSM-R based radio transmission.

Increased line speed with ERTMS/ETCS application level 1

No improvement in line speed or capacity is obtained if the ERTMS/ETCS Application Level 1 trackside sub-system is simply overlaid on an existing signalling system without modification. It is expected that a simple ERTMS/ETCS overlay would be appropriate for the majority of UK main lines requiring basic cab-signalling and ATP.

Higher line speeds are possible if the existing signalling system is upgraded to provide an additional aspect at each lineside signal, e.g. fifth aspect in four-aspect territory. This alternative configuration is shown below:
**Strategy for Phase 2**

Existing signal structures can be retained at their current locations. The additional aspect is not displayed by the lineside signal but is instead forwarded directly to the LEU. This approach allows an ERTMS/ETCS fitted train to receive the additional aspect data for display on the driver's MMI. The existing installation will need to be modified to generate the additional aspect taking due account of any corresponding interlocking requirements, e.g. extension of approach locking zones. New computer based interlockings such as SSI would be needed to accommodate the additional signalling functions.

**Operation without lineside signals**

The explanation given so far assumes that ERTMS/ETCS cab-signalling indications supplement lineside signals. The cab-signal is never in conflict with lineside aspects though the cab-signal may clear to a less restrictive aspect some time later than the lineside signal due to internal ERTMS/ETCS system processing delays. An additional delay will also be experienced on approach to signals if no in-fill transmission is provided.

The ERTMS/ETCS SRS states that lineside signals are a mandatory requirement for Application level 1, with the exception of lines equipped with infill where lineside signals may optionally be removed. Complete removal of lineside signals does of course carry the serious disadvantage of denying access to non-fitted stock. Furthermore, the simple but effective mechanism of fall-back to lineside signals is not available if all signals are removed. Nevertheless, it is possible to envisage a scheme based on a combination of lineside signals and block marker boards to optimise line speed and capacity for high speed trains without serious impact on interoperability with non-fitted stock and fall-back provision.

**Key features of ERTMS/ETCS application level 1 system architecture**

**Level 1:**
- provides cab-signalling and full ATP
- can be overlaid on any existing signalling installation
- similar architecture and performance capability to current generation ATP solutions such as TBL used on GWML.

**but:**
- does not increase line speed or capacity without modification to existing interlocking.
The architectural differences between ERTMS/ETCS Application Level 1 and 2 are mainly related to the way in which signalling commands are transmitted to trains. In Application Level 1, signalling data is transmitted by track transponders or ballises. In Application Level 2, the same data is transmitted via a GSM-R mobile telecommunications network.

There are two variants of ERTMS/ETCS Level 2 system, depending on whether it is overlaid onto relay based signalling (as per the TCS-F proposal within the previous strategy) or signalling with electronic interlockings (the TCS-L2 proposal within the revised strategy). These are described in turn.

**ERTMS/ETCS Level 2 in areas with electronic interlockings**

The ERTMS/ETCS Level 2 system can be applied on any type of electronic interlocking in use on Railtrack. For simplicity, only the most common of these interlockings, SSI (Solid State Interlocking) is referred to. The trackside system architecture for ERTMS/ETCS Level 2 is shown in Figure 18.

![Figure 18: ERTMS/ETCS Level 2 (SSI area)](image)

The interface to the existing signalling system is very straightforward in SSI areas. All that is required is a simple connection to the existing SSI Data Link network. Configuration data within the Radio Block Centre (RBC) enables the contents of the SSI telegrams to be decoded and the aspect status for the entire SSI area to be obtained at a single location. For fitted trains, the RBC interprets the sequence of aspect data ahead of the train's location. A new Movement Authority is generated with an End of Authority (EOA) corresponding to the location of the next red aspect or
other obstruction ahead of the train's position. Infrastructure related data such as gradients and speed restrictions is transmitted with the Movement Authority.

Balises are provided in a passive mode with no connection to other trackside equipment at regular intervals. Use of balises in ERTMS/ETCS Application Level 2 is largely restricted to odometry initialisation and re-calibration requirements.

**ERTMS/ETCS Level 2 in areas with relay interlockings**

In the case of electrical relay interlocked areas, alternative arrangements need to be made to gather lineside signal aspect data. Two solutions exist:

- replace existing interlockings with new electronic interlocking equipment
- install SSI Data Link Network and Aspect Interrogator Modules.

The first option is clearly preferable in the case of existing interlocking installations which are approaching the end of their operational life. A simple connection to the SSI Data Link then allows the aspect data to be collected in the manner described above.

An alternative approach is available in situations where it is not economic to replace existing interlockings with SSI. This alternative approach is based on the provision of Aspect Interrogator Modules. These modules are installed at each signal location to obtain the required aspect data by a direct electrical connection to each lamp. This arrangement is shown in Figure 19.

![Diagram](image)

**Figure 19: ERTMS/ETCS application level 2 trackside sub-system (non-SSI areas)**

The Aspect Interrogator Module process passively monitors the status of each lineside signal aspect. This interface requirement can be implemented using a simple relay interface to a standard
SSI Signal Module. The aspect status data gathered in this way is transmitted to the RBC via a newly installed SSI Data Link transmission network using either copper or fibre-optic cables.

**Increased line speed with ERTMS/ETCS application level 2**

A significant benefit of the ERTMS/ETCS Application Level 2 solution is its ability to allow ERTMS/ETCS equipped trains to run at higher line speeds. This is possible since centralisation of the aspect encoding process allows the increased braking distances necessary for higher line speeds to be taken into account in the preparation of the Movement Authority. The principles employed in this process are illustrated graphically in Figure 20.

![Figure 20: ERTMS/ETCS Level 2 concept of operation](image)

For WCML, it is intended that 100% GSM-R coverage be provided to eliminate performance problems caused by interruption to the continuous transmission medium. In the case of low capacity lines such as rural lines with low traffic demands, it may be appropriate to restrict coverage to stations and passing loops. The areas with radio coverage can be identified in the RBC Route Map to ensure that Movement Authorities are sufficiently long to allow the train to reach the next GSM-R radio cell.

**Operation without lineside signals**

As in the case of ERTMS/ETCS Level 1, operation without lineside signals is possible using this architecture. The same issues of interoperability with non-fitted stock and fall-back in the event of ERTMS/ETCS equipment failure apply equally.

**Key features of ERTMS/ETCS application level 2 upgrade**

ERTMS/ETCS Level 2 offers the advantage over ERTMS/ETCS Level 1 of provision of continuous infill as an intrinsic feature of the GSM-R data transmission medium. The ERTMS/ETCS Level 2 solution also has the advantage of requiring significantly less trackside equipment and cabling than
ERTMS/ETCS Level 1 since the interface to the interlocking system can be made at a single point at a central location.

The key features are:

- facilitates increased line speed without changing signal spacing
- allows mixed operation with fitted and non-fitted trains
- provides continuous in-fill (and associated headway improvement through earlier signal sighting)
- minimal operational disruption during upgrade process
- can be used with intermittent GSM-R coverage for low capacity rural lines.

D.8 ERTMS/ETCS Level 3 and TCS-M

ERTMS/ETCS Level 3 (known as 'TCS-M in the previous strategy) represents a fundamentally different system concept to that of ERTMS/ETCS Levels 1 and ERTMS/ETCS Level 2. Instead of providing additional protection functions to existing signalling, it completely replaces the conventional signalling functionality.

- **Indication to drivers** The sole means of communicating instructions to train drivers is through the in-cab display.
- **Speed control** A target speed is calculated by the ERTMS/ETCS train equipment and displayed to the driver. The protection system intervenes if the driver exceeds the safe speed.
- **Route proving and setting** The safe control of the setting of routes of trains is provided by the Radio Block Centre using moving block algorithms for determining train separation.
- **Train detection** The ERTMS/ETCS trainborne equipment determines its position using odometry and transmits the information to the Radio Block Centre.
- **Protection against driver error** Full Automatic Train Protection is an inherent feature of the system. The train speed is monitored continuously and the ERTMS/ETCS trainborne equipment intervenes immediately if a safe speed is exceeded.

In ERTMS/ETCS Level 3, track occupancy is derived from location reports received from the trainborne equipment. Information on train length is used to determine the maximum possible extent of the occupied portion of track taking account of worst-case odometry errors. This information is used as an alternative to traditional means of train detection based on track circuits.

The trackside sub-system uses this dynamic track occupancy data to control the route locking and releasing functions and to calculate the maximum extent of the Movement Authority that can be issued to each train. This changed mode of operation demands a very different functional architecture to the Level 1 and 2 overlay systems already described.

Because the only means by which the signalling system knows the position of a train is by the train reports it, if a train splits, then the signalling infrastructure will not be aware of the carriages/wagons left behind. This is an inherent feature of track circuits and axle counters. The
ERTMS/ETCS Level 3 system therefore includes the requirement for a train integrity monitoring system on every train to confirm to the ERTMS/ETCS equipment that the train has not split.

**ERTMS/ETCS Level 3 trackside system**

The ERTMS/ETCS trackside system is shown in Figure 21.

The key features of upgrading conventional signalling to ERTMS/ETCS Level 3 are:

- conventional trackside signalling equipment, i.e. track circuits and lineside signals, is decommissioned
- new centralised interlocking and moving block Radio Block Centre systems are provided
- a trackside SSI Data Link network is provided for the purpose of controlling points and any residual signals required for fallback and degraded mode operations
- passive balises are provided for odometry referencing purposes.

**Key features of ERTMS/ETCS Level 3**

An ERTMS/ETCS Level 3 system involves significant change from current practices and signalling concepts:
Strategy for Phase 2

Appendix D

Table 14: Comparison of current practices and signalling concepts with ERTMS/ETCS Level 3

<table>
<thead>
<tr>
<th>Current Practices</th>
<th>ERTMS/ETCS Level 3 (TCS-M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route signalling</td>
<td>Speed signalling</td>
</tr>
<tr>
<td>Current convention provides authority to progress along a route, from which the driver evaluates the appropriate speed to travel based on knowledge of the route.</td>
<td>ERTMS/ETCS Level 3 trainborne equipment displays the authorised speed to the driver.</td>
</tr>
<tr>
<td>Lineside colour light signals</td>
<td>In-cab signalling</td>
</tr>
<tr>
<td>Fixed block train separation</td>
<td>Moving block train separation</td>
</tr>
<tr>
<td>Movement authority updated at discrete locations, by colour light signals</td>
<td>Movement authority updated continuously, over a GSM-R radio network</td>
</tr>
<tr>
<td>Protection against driver error at discrete locations, via TPWS attached to lineside signals</td>
<td>Continuous protection against driver error</td>
</tr>
<tr>
<td>Track based detection of train location, via track circuits</td>
<td>Train reported location using reference balises and odometry equipment</td>
</tr>
<tr>
<td>Track based detection of train integrity, via track circuits</td>
<td>Train based detection of train integrity</td>
</tr>
</tbody>
</table>

An ERTMS/ETCS Level 3 system is envisaged to offer a significant number of benefits compared with conventional signalling, including:

- enhanced safety through the provision of Automatic Train Protection (ATP), reduced exposure of maintenance staff to trackside risk and staff protection facilities
- full bi-directional functionality where required
- lower implementation and whole life costs
- improved possession management
- increased capacity and linespeeds
- lower rail maintenance costs (due to no requirement for track circuit insulated block joints)
- lower electrification immunisation bonding costs
- improved train delay performance.

D.9 ERTMS/ETCS trainborne equipment

The ERTMS/ETCS Level 1 trainborne sub-system is shown in Figure 22. The trainborne architecture is similar in many respects to current generation ATP systems in use on Railtrack, e.g. TBL on the GWML.
The trainborne sub-system receives aspect data coded in the form of an ERTMS/ETCS Movement Authority from the EUROBALISE transmission sub-system. A second EUROBALISE antenna may be provided for increased availability. The ERTMS/ETCS trainborne computer interprets the received data and generates the necessary cab-signalling commands for display on the driver's Man Machine Interface (MMI). Trainborne odometry sensors enable the speed and distance travelled by the train to be continuously monitored and compared with the speed profiles defined within the Movement Authority.

The only material difference to the trainborne sub-system for Application Level 2 is the addition of necessary GSM-R radio transceivers. The intrinsic functionality of the trainborne sub-system does not change. The cab signalling display (MMI) informs the driver of the distance to target and applicable line speed in the same manner as the ERTMS/ETCS Level 1 overlay system.

The only significant difference from the driver's perspective is the provision of in-fill throughout the entire GSM-R coverage area. Some additional changes will of course be evident if the system is used to facilitate higher line speeds over existing signalling, however the information displayed to the driver will never be in direct conflict with lineside signal aspects. The upgraded trainborne sub-system architecture is shown below.
Strategy for Phase 2

Appendix D

GSM-R Mobile Stations

Figure 23: ERTMS/ETCS application level 2 trainborne sub-system

The trainborne sub-system ERTMS/ETCS Application Level 3 is identical to that required for Application Level 2 except for the addition of a Train Integrity System. This function is necessary to prevent the reported location of the tail end of the train being updated should a loss of integrity occur. Train integrity detection is required not just to protect against the risk of collision involving a train separating on the move but also to ensure that train length data following a joining or splitting operation is fully reconciled before declaring the line is clear for a following train.

D.10 Network Management Centre

The NMC is designed to provide centralised route management functions from a single building which provides integrated management control of the route. The NMC is responsible for managing services to the timetable and ‘short-term plans’, with the timetables revised to account for and recover from interruptions. The focus for the NMC is on managing an operational service to punctuality targets.

Key features are:
- the NMC software environment is based on standard business environment processors
- the route planning component provides short-term re-planning of the timetable to define approaches for recovery from timetable perturbation. The route managers are supported in their decision making, as they seek to minimise the overall effect of the perturbation on resulting delays to trains
- route control component providing an automatic route setting request function based on either the timetable or the short-term plans. It interfaces to the signalling interlocking, from
where it receives feedback on train positions etc. and to which it passed the route setting requests

- other systems interface, including TRUST, TOPS and other railway industry systems which share common information
- power control, management of the isolation of sections of the route.