Seeing Issues Clearly

West Coast Main Line – Timetable Performance Modelling Lessons Learnt

Report for Network Rail and Office of Rail Regulation

In Association With First Class Partnerships

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Summary

Introduction and objectives

When the Very High Frequency (VHF) service commenced on the West Coast Main Line (WCML) in December 2008, the performance (whether measured by Public Performance Measure (PPM) or other measure) was initially very poor, despite the expectation of managers / decision makers that it should perform acceptably, and that the initial timetable was an interim one intended to mitigate likely teething problems. Performance was better than expected by the end of September 2009 but has declined since.

The expectations of managers / decision makers were based partly on a number of modelling exercises undertaken using a combination of RailSys and TRAIL.

The **objectives** of this study were to understand the reasons behind the differences between modelled and actual performance. The overriding key issue was seen as being to establish whether:

- the modelling as such was flawed, for instance in terms of input data and assumptions, or
- the scenarios specified to be modelled did not actually reflect the circumstances of the timetables and realities of early experience with newly commissioned infrastructure.

We also saw it as crucial to establish first how closely the outputs from the modelling could be said to equate to either actual delay minutes or PPM, and the extent to which the equivalence between model outputs and PPM was understood within the client organisations.

It is important to note that the study was not intended to be a witch-hunt to identify who was at fault, but to learn lessons for future major projects such as Crossrail, Thameslink, and electrification.

Methodology

The study methodology was based on:

- an analysis of the facts behind the performance events actually experienced on the WCML before, during, and after the period of operation of the interim and final timetable, to clarify the outcomes expected to have been generated by modelling;
- a comprehensive consultation with relevant staff to establish the appropriateness of the specification to the issues of the interim and final timetables, other assumptions made, scenarios tested and sourcing of input data;

This was supplemented by our own experts, two of whom were specifically involved in senior roles in the West Coast Route Modernisation (WCRM) at some point during the project.

Findings

- **The reasons for the actual performance of the WCML in the period concerned:**
  Three major events made a significant contribution to the initial poor performance.
  Delays and cancellations changed as familiarity with the contingency plans improved, and they were implemented more rapidly.
  The subsequent improvement resulted from a reduction in both the significant incidents and the smaller events.

- **Modelling undertaken using RailSys and TRAIL:**
  Management did not fully understand the distinct roles of RailSys and TRAIL.
  Modellers did not communicate well the implications of the modelling, and the conclusions were to some extent misunderstood by decision makers; in particular, there seems to have been an expectation that model output would directly forecast PPM.

- **Reasons why the modelled and observed performance differed:**
  Reasons relate to different elements: significant and modest delays, which models were used, and non-robust input assumptions on asset failure.
  An important point is that the specification for the modelling was not clearly appreciated at all levels, especially by the managers / decision makers who used the model outputs.

- **ORR and Network Rail's questions in the Invitation to Tender were addressed:**
  These are answered in section 3.6.

The lessons learnt mainly related to modelling of performance, but we also draw out some conclusions that should directly improve the performance following implementation of major infrastructure schemes.

Summary of recommendations

- **Improved process to provide infrastructure assumptions into models:**
  Input assumptions into TRAIL should reflect expected failure rates in context of both the infrastructure and the level of train service, including the impact on unchanged assets; RailSys inputs should be consistent with these.

- **Plan and time modelling work so results have maximum benefit:**
  The preparation of robust inputs into the modelling work (TRAIL) can start before the timetable is finalised, requiring timely inputs from all stakeholders; once a reasonable development timetable is available, performance forecasts can be made; an earlier start will enable management to take action if predictions of delays are unacceptable.

- **Education of modelling audience:**
  Managers / decision makers need to understand what models can and cannot do so that they can both specify what they want from models and understand the outputs from them. This will result in fewer misunderstandings or optimistic assessments of likely performance.

- **Skills training for modelling team in presenting results:**
  Linked to previous point, modellers need to communicate clearly in terms that non-modellers can understand. Results should be presented in terms that give a comparison to standard industry metrics, but without misleading the audience. The implications should be drawn out.

- **Smooth transition to new timetable infrastructure:**
  Events such as infrastructure development, timetable introduction, rolling stock changes, and franchise changes should be staggered where possible, so that each can be managed and the impacts are not multiplied.

1 Introduction and Objectives

1.1 Introduction

1.1.1 The West Coast Route Modernisation was one of the UK's most significant strategic rail projects, aiming to renew infrastructure last modernised in the 1960s, and to provide enhancements with capacity to operate an increased frequency of service, the VHF (Very High Frequency) timetable. The works were undertaken in stages over a decade, with completion marked by remodelling of the Milton Keynes area over the Christmas and New Year period of 2008/9.

1.1.2 Specification and development of both the infrastructure works and the intended timetable was supported by a programme of performance modelling using the RailSys and TRAIL systems.

1.1.3 Pending completion of the final works, from 14 December 2008 until mid February 2009, the timetable operated was a slightly reduced version of the VHF timetable, termed the "commissioning" or "interim" timetable. This timetable was maintained until all concerned were confident that the infrastructure reliability and train utilisation would support operation of the full VHF timetable, which was in fact implemented on 16 February 2009.

1.1.4 However, the operation of the commissioning timetable from the beginning of 2009, and the first periods of operation of the VHF timetable were subject to actual PPM (Public Performance Measure) well below the target JPIP (Joint Performance Improvement Plan) level of 84.9%.

1.1.5 The study arises from this observation that poor performance (judged in terms of PPM) was experienced during the period of operation of the interim timetable and subsequently the first five months of the full VHF timetable, whereas the modelling had broadly indicated that the timetable was robust and decision makers believed that that target PPM was achievable.

1.2 Objectives of the study

1.2.1 ORR and Network Rail are jointly reviewing performance of the WCML services following implementation of the commissioning timetable and VHF timetable. Performance modelling had not indicated any major problems, yet actual performance was initially very poor. ORR and Network Rail are seeking to identify the reasons for the performance shortfalls (did they result from issues of the design, implementation or current operations), in order to understand the difference between actual operational performance and modelled performance.

1.2.2 This study sets out to support ORR and Network Rail in their review by focusing on the performance modelling and the value it added in decision-making. We consider the strengths and weaknesses of the processes and the tools used, outlining the validity and limitations of modelling practice, with the aim of informing about modelling legitimacy, and identifying lessons learnt for future projects.

1.2.3 The overriding key issue was seen as being to establish whether:

- the modelling as such was flawed, for instance in terms of input data and assumptions, or
- the scenarios specified to be modelled did not actually reflect the circumstances of the timetables and realities of early experience with newly commissioned infrastructure.

1.2.4 We also saw it as crucial to establish how closely the outputs from the modelling could be said to equate to either actual delay minutes or PPM, and the extent to which the equivalence between model outputs and PPM was understood within the client organisations.

2 Methodology

2.1 Overview

2.1.1 In this Section we record our methodology for the study, which was based on:

- an analysis of the facts behind the performance events actually experienced on the WCML before, during, and after the period of operation of the interim and final timetable, to clarify the outcomes expected to have been generated by modelling.
- a comprehensive consultation with participants and stakeholders to establish the appropriateness of the specification of the modelling to the issues of the interim and final timetables, other assumptions made, scenarios tested and sourcing of input data.

2.1.2 The study tasks were:

- Task 1 Involvement & Relationships Mapping: to reach a clear understanding of the responsibilities of and the relationships between the parties responsible for specifying and completing the modelling tasks, and of the timescales within which timetable development and modelling was undertaken;
- Task 2 Data Mining & Gathering: to understand the facts of performance on the WCML during the operation of the interim and VHF timetables, as these represent the reality that was expected to be forecast by the modelling;
- Task 3 Consultations: to bring as much honest information to the forefront of the process so as to gain a clear and true picture of the process involved in the modelling tasks;
- Task 4 Assumptions Validation: to validate the assumptions used in the modelling against the observed historic data to see how closely they match, and how wide the sensitivity of the modelling results was;
- Task 5 Evaluation: an objective evaluation of the appropriateness of modelling inputs, assumptions and scenarios to the issues raised by the operation of the interim and final timetables;
- Reporting: Our final output aims to enable ORR and Network Rail to allow the learning from the performance modelling completed for this project to be effectively embedded into other high profile projects which will mitigate future performance issues following completion of these projects.

2.1.3 Specific issues raised by ORR and Network Rail which we set out to resolve were:

- Was the modelling to build the high frequency timetable and to forecast performance of the WCML following project implementation robust?
- Did Network Rail combine both asset reliability and timetable modelling effectively?
- Was the modelling based on sound assumptions?
- How were re-designs handled? How close was the modelling to what was finally delivered?
- Was the poor performance from February to July 2009 aligned with the modelling forecasts? If not, why not?

- What happened to improve performance from July 2009 to September 2009 and how does this level of performance relate to the modelling?
- What were the assumptions about asset performance? How closely did they align with actual performance?
- Is the range/sensitivity around the outputs understood?
- Although PPM for Virgin Trains started off well *below* the predicted levels, it soon reached a level well *above*. Does this variation fall within the natural variation that should be expected, or is it systematic, for instance deriving from infrastructure interventions?
- What is the relative importance of the issues identified?

2.2 Involvement & relationships mapping

2.2.1 Details of the Interactions Map and Modelling Timeline are given in Appendix 1.

2.2.2 To compile this information we pulled together learning from the consultations and data sources to create a diagram of the teams & individuals involved, their roles and the interactions between them. We also produced a time based chart to show the sequence of events.

2.3 Data analysis

2.3.1 Details of the data analysis are set out in Appendix 2. The prime objective was to establish whether performance during the period of the interim and final timetable reflected:

- a high number of moderate incidents (under 1000 minutes delay)? or
- derived from a small number of significant incidents (over 1000 minutes delay)?

2.3.2 To reach a clear understanding of the facts of train service performance on the WCML, we analysed recorded data on incidents, minutes delay and PPM to establish fully:

- the nature of incidents affecting performance;
- their causes within categories,

so as to distinguish, for instance, infrastructure-related incidents from rolling stock failures, and identify externally-arising events that are beyond the control of the railway but whose impact can be controlled by some extent by the railway.

2.3.3 This understanding of the facts of performance provided a basis for evaluating the:

- modelling techniques;
- specifications;
- scenarios.

2.3.4 The data and information sources used were:

- Historic TRUST performance data;

- ORR data sets for WCML performance monitoring as provided by Network Rail;
- TRAIL and RailSys modelling reports and presentations;
- Network Rail Timetable operational planning production schedule;
- Selected Meeting minutes of Project working group & WC Infrastructure reliability group;
- Contingency planning documentation.

2.3.5 To understand the information from the data we looked for: trends in the data before and after the VHF timetable, the frequency and severity of significant incidents, the level of cancellations and how modelling inputs compared to subsequently observed events.

2.3.6 We also set out to identify the inputs to modelling, the data sources and the validity of any underlying assumptions.

2.3.7 Details on modelling theory, modelling tools are given in Appendix 3.

2.4 Consultations

2.4.1 Consultations were undertaken with the following :

- Network Rail, PCAT, Project manager, responsible for commissioning RailSys analysis from Robert Watson Associates (RWA);
- Network Rail, West Coast 2008, Route Team LNW, responsible for implementation of the train service post-upgrade and current operations on the WCML;
- Network Rail, Engineering Enhancements, undertaking TRAIL modelling;
- RWA, Project managers for the RailSys analysis commissioned by PCAT;
- Network Rail, Train Planning, undertaking timetable development up to the point at which it was handed to the Train Planning Centres for finalisation within normal access planning timescales;
- Network Rail, Operations & Customer Service, undertook development of contingency plans;
- Virgin Trains, Operations & Planning, contributed to development of contingency plans on behalf of the principal Train Operating Company (TOC) client.

2.4.2 We set out to undertake each consultation in a positive and open-ended atmosphere, taking care to avoid any perception of a witch-hunt. Whilst being ready to steer the discussion against a framework of pre-prepared questions, we aimed to allow full rein for wide-ranging discussion to capture the entire range of relevant issues.

2.4.3 Broadly the process covered the following areas:

- the consultee's role, position and relationships with other participants;
- the modelling specification and the locus of responsibility for developing it in relation to the development and modification of the infrastructure packages;
- the consultee's understanding of the capabilities of the modelling tools and the validity of their outputs;

- the basis for the assumptions of the modelling;
- the human response, investigating scope for improvement in control and service recovery actions.

2.5 MVA expert views and reviews

2.5.1 Our interim findings and emerging conclusions were tested against internal experts commissioned by MVA for their independent knowledge of the WCML Upgrade development and implementation.

2.6 Drawing conclusions

2.6.1 From the gathered information we were able to bring out the key messages that are the important lessons learnt for future modelling projects. This was done in partnership with Network Rail and the ORR.

3 Findings

3.1 Introduction

3.1.1 This has been a wide ranging study which has given insights across a number of areas, some of which were outside the core objectives, but nonetheless relevant and are worth reporting. This section of our report provides our findings under the following headings:

- involvement and relationships mapping;
- the actual performance of the WCML in the period concerned and what were the reasons for this performance (good and bad);
- a summary of the two modelling workstreams undertaken using RailSys and TRAIL. In terms of what they are inherently capable of forecasting (and what is outside their scope), and how they were used for the WCML;
- reasons why the modelled and observed performance differed – these may be because of unusual observed performance (i.e. could not realistically be predicted) or due to shortfalls in the modelling (for the purpose of predicting performance);
- questions asked by ORR and Network Rail in the Invitation to Tender; these are addressed individually.

3.1.2 Throughout the report on findings, we have sought to bring together the information from all the sources, notably:

- the analysis of data on actual delays;
- the interviews with those involved;
- the study team, the MVA expert panel and the Network Rail and ORR project team's knowledge and expertise in both performance modelling and the WCML more specifically.

3.2 Involvement & relationships mapping

3.2.1 The involvement and relationship mapping shows that the modelling teams for the WCML cross a number of different Network Rail functional areas such as Operations and Customer Services, Planning and Development, Engineering and Operations. In some cases it is only through the West Coast 2008 team that these different functional areas have a formal communication channel. The structure of the team is as a matrix with much cross team and cross industry working.

3.2.2 Specification of the modelling was typically driven from within the modelling team. The objective of the RailSys workstream was to understand the new timetable. The objective of the TRAIL workstream was to understand the overall reliability of infrastructure, timetable and operations.

3.2.3 Reporting of the modelling results was across a broad audience within Network Rail and the TOC community. Some of this audience have a modelling background and have a clear understanding of the modelling outputs. However it appears that there was some opportunity for misunderstanding of what the modelling outputs actually suggested.

3.2.4 The early TRAIL modelling workstream was concerned with determining the level of reliability of infrastructure required to meet a target PPM. This workstream was used for the specification of the equipment.

3.2.5 Strategic timetable development took place up to two years before the timetable priority date. This process produced the structure and service pattern to meet the DfT specification.

3.2.6 The Phase 1 RailSys modelling initially concentrated on timetable development and later performance analysis.

3.2.7 The contingency planning process used the initial RailSys model and the most recent timetable to develop scenario models that would inform the contingency planning process.

3.2.8 The Phase 2 RailSys modelling refined the timetable and completed performance analysis of both the interim and full VHF timetables.

3.2.9 The formal timetable planning process took place between TT priority date in February 2008 and CIF data release in T-14.

3.2.10 Between February 2008 and November 2008 all workstreams were working in parallel.

3.2.11 Final results from RailSys were not available until 10 November 2008 and final results from TRAIL not until 19 December 2008, the interim timetable was introduced on 14 December 2008.

3.3 Actual performance of the WCML

3.3.1 Figure 3.1 shows the 4 week moving average PPM of Virgin West Coast, London Midland (note this includes services not on the WCML) and as a comparison Intercity East Coast (ICEC). It can be seen that there is a period of very poor performance in January 2009 (especially for Virgin, but also London Midland). After this performance improved markedly, and for Virgin Trains continued on an upward trend (albeit with some short term dips) until November 2009 when very poor weather (floods followed by snow) caused a significant worsenment in PPM.

3.3.2 When compared to the TRAIL punctuality prediction of 82.4% moving annual average (MAA) we can see that between December and March the performance is lower, from March to June performance is comparable and from June to December performance is higher. The moving annual average is overall comparable. The TRAIL punctuality prediction is not exactly PPM but is the equivalent value as can be calculated within the limits and assumptions of the software, there are no upper and lower predictions quoted for this value.

3.3.3 The comparison between Virgin Train on the WCML and the ICEC show that in early 2009 the poor performance was localised to Virgin but at the end of 2009 both the East and West Coast routes have suffered due to poor weather conditions.

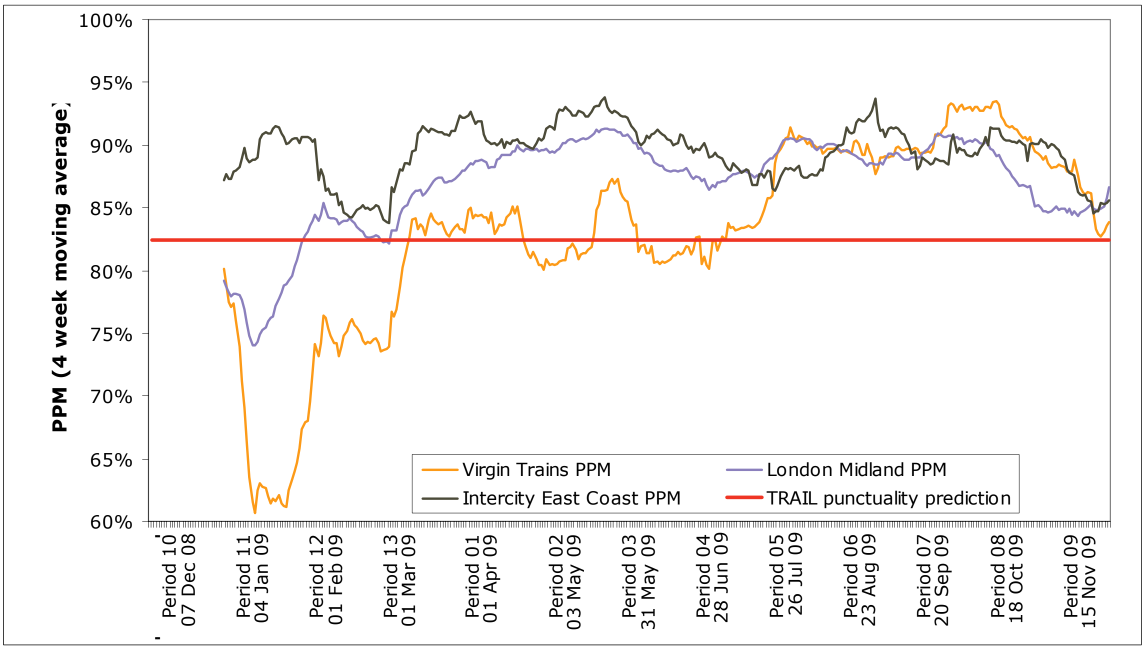


Figure 3.1 - PPM 4 week moving average

3.3.4 The explanation behind these figures is found in part by considering the occurrence of significant incidents (defined by Network Rail as those resulting in more than 1000 minutes delay). It is known in the industry (and we found this to be supported by the delay data) that such incidents can have a major impact on PPM.

3.3.5 January 2009 had three very large significant incidents (they covered railway periods 10 and 11, approximately Dec 2008 and Jan 2009):

- light aircraft crash causing 20,000mins delay;
- two different OLE failures causing 14,000 and 7,000mins each.

3.3.6 Without these three incidents, the minutes delay for the periods would have been close to the average, although we cannot actually be sure if this would have converted into comparable PPM figures.

3.3.7 A further finding is discovered by examining the numbers of cancellations. The major incidents in January 2009 coincided with the early period of a fundamentally new timetable. It is both likely, and was confirmed by our consultations, that control were still learning how best to implement contingency plans. As a result, contingency plans (which involved immediate cancellation of a number of trains) were not implemented as rapidly as in later periods with a further adverse impact on delays.

3.3.8 After this initial period, contingency plans were implemented by control in a very effective way. This resulted in further reductions in delays from both a large reduction in major incidents and to a lesser extent continuous improvement in the lesser delays.

3.3.9 Considering now the period from February 2009 (or Period 12), the subsequent improvement in Virgin's PPM does not appear to be due entirely to reductions in significant incidents; indeed, although the number and impact of significant delays appears to reduce slightly from period 12 onwards, the downward trend is only modest (see Figure 3.2). There is a greater downward trend in the delays due to modest incidents (i.e. those not defined as significant); this can be seen in Figure 3.3.

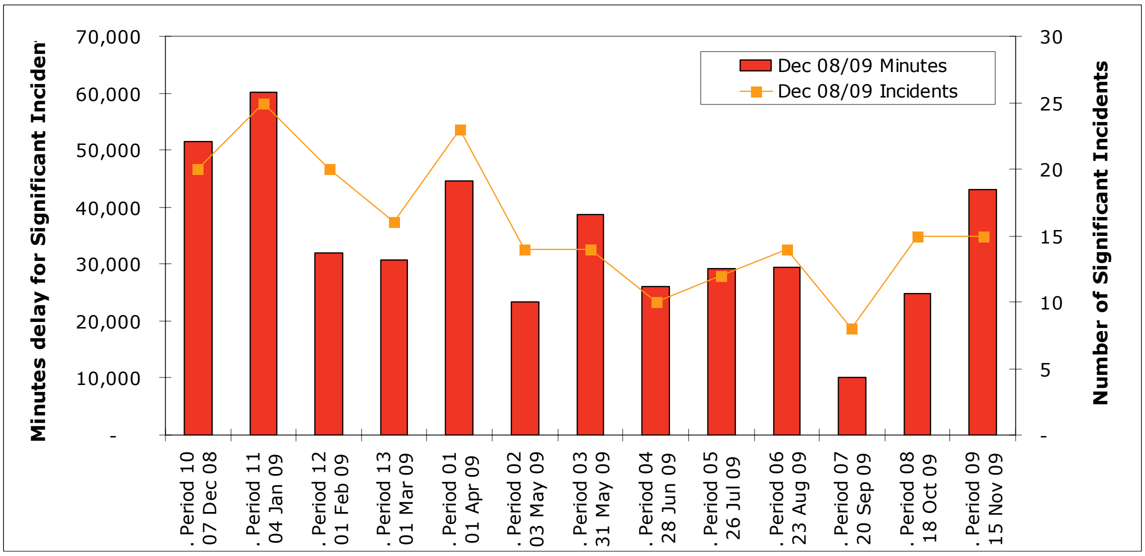


Figure 3.2 - Significant incidents and their associated delays

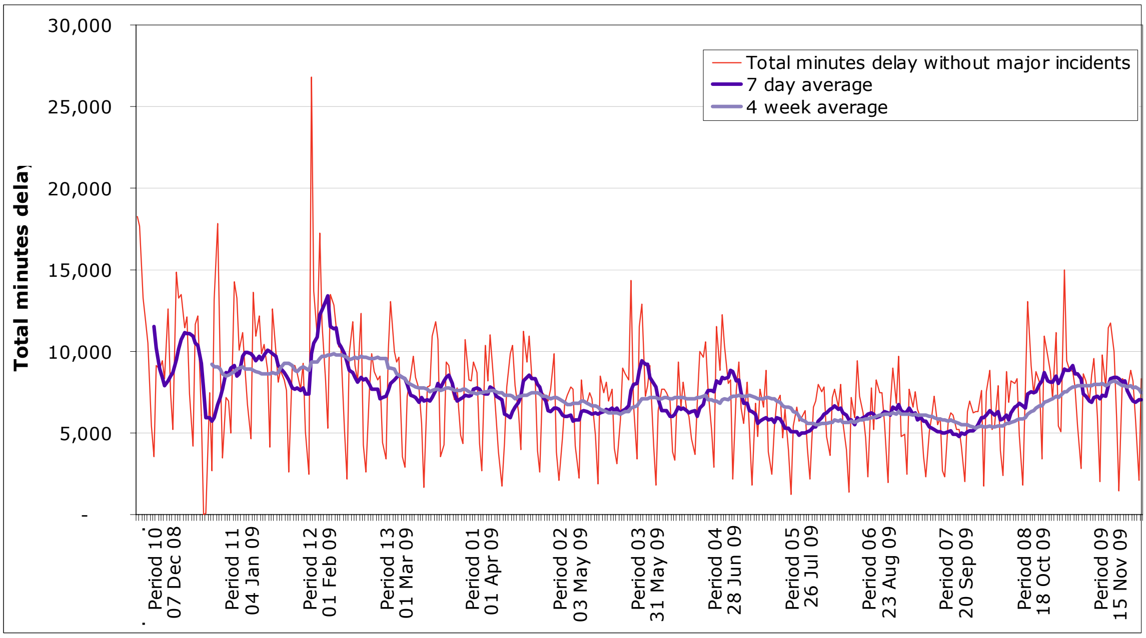


Figure 3.3 - Delays due to modest incidents

3.3.10 There is evidence that the enhanced maintenance regime that was implemented, the use of containment crews at key locations, (or possibly inherent improvements in asset reliability) resulted in a reduction in delays, particularly the modest delays.

3.4 Summary of modelling workstreams

3.4.1 Simulation modelling is an appropriate analytical method to support decisions on timetable robustness and infrastructure provision. It is now an established technique that tends to be used routinely: for instance, being a requirement at the intermediate stages of the NR GRIP process for project planning and development, including required outputs at each stage to gain authority to pass to the next stage. It can be conducted during a window in the project development process:

- after inputs have been defined in sufficient detail as to support modelling;
- while there is still the opportunity to reflect the findings in option selection, timetable development, scheme acceptance, and operational strategies after implementation.

3.4.2 The basis of RailSys and TRAIL modelling is Monte Carlo simulation (i.e. repeated random sampling), looking at how perturbation events, drawn from probability distributions for likelihood and magnitude, translate into overall train service performance. The simulation captures the secondary delay as trains delayed by incidents then interact further at locations remote from the original failure site.

3.4.3 The key traits of the two simulation packages used are:

- **RailSys** operates at a very detailed level down to individual track circuit operation. The range of perturbation events that can be imposed is quite limited. Its strength is in capturing the secondary delay given input data on primary delay. Its recommended application is in comparing scenarios such as a base and future timetable, rather than to attempt to make predictions of absolute values;
- **TRAIL** operates at a higher level, but focuses more closely on infrastructure issues, generating primary delay within the model from data on probabilities of infrastructure failures and durations, then capturing secondary delay. Its operation at a detailed level is more restricted, but this in part allows a wider geographical area to be modelled.

3.4.4 This simulation methodology is critically dependent on:

- the data used as the basis for input perturbation distributions;
- other assumptions made;
- the scenarios specified to be modelled.

3.4.5 The RailSys modelling was initiated in early 2008, less than a year before intended implementation of the VHF timetable. Although set-up time was reduced by availability of a VISION model that could be converted, creation of a RailSys model was a task falling between commissioning and availability of outputs. By contrast, the TRAIL modelling had been an ongoing exercise since about 2002, so that by 2008 the model infrastructure had already been set-up.

3.4.6 To allow effective modelling of the large geographic scope for the route and promote rapid set-up, the RailSys model was created and run in four sections, thus allowing set-up of each section to proceed in parallel without more than one person working on any one model simultaneously.

3.4.7 Both systems generate outputs relating to train delays and punctuality. In neither case, however, is it correct to say that they output forecasts of PPM, which is a compilation of pure punctuality as measured at the ultimate destination, with other issues such as cancellation of services (complete or partial, i.e. termination short of destination), and failures to stop. As outlined above, these are likely components of the service recovery response to significant incidents in practice.

3.4.8 In **RailSys**, the delay data is principally an input, with the model calculating 'added delay' consisting of secondary delays due to timetable interactions. It is thus good at showing the impact of the timetable on delays, but not the total amount of delays; furthermore, significant incidents are typically removed from the input data to RailSys. Thus a standard RailSys model run will result in much less delay than actually observed in practice on average; it effectively only models a 'good' day.

3.4.9 To remedy this, scenarios can be tested in RailSys such as a line blockage for a certain length of time; this was done for the WCML, but only to a limited extent due to lack of time. The results were not highlighted in the report (they were omitted from the Executive Summary).

3.4.10 In **TRAIL** modest delays are generated by failure rates and repair times of infrastructure and rolling stock; whereas significant incidents are input as specific events. Root causes of delays can be attributed and used in processing of results, but (at least in the outputs we have seen) this was not done in this case.

3.5 Reasons why modelling and observed performance differed

Significant incidents

3.5.1 Significant incidents cannot be modelled in RailSys.

3.5.2 TRAIL modelling was undertaken to address this amongst other factors. Our understanding is that this was done by extrapolating the significant incidents of 2006/7 forwards, and adding these to the normal level of root failures. This may have resulted in 'losing' those incidents which were not significant in this year, but would have become so had the more intensive service of 2008/9 been in place. By examining the proportion of incidents causing different levels of delay minutes, we estimated this as resulting in 20% more incidents and 16% more minutes delay. More details are provided in Appendix 2 (paras 2.4 and 4.2).

3.5.3 There were two other categories not picked up by the TRAIL modelling:

- two significant external incidents that clearly had nothing to do with the new timetable – the light aircraft crash (Period 10 Jan 2009) and the flooding (Period 9 Dec 2009)
- significant infrastructure failures that resulted in very substantial delays, notably the OLE problems (Period 11 Jan 2009) (one of which was the result of faulty installation), and possibly some signalling problems through Periods 1 to 4 2009, as these were not seen in the 2006/7 significant incident data.

3.5.4 Overall the TRAIL modelling forecast only 65% of the actual delay in 2008/9. We are not certain of the reason behind this, but believe it is due to a different definition of delay and geographic area. In the TRAIL report, most of the presentation of delay is in the form of PPM, although we do not believe that TRAIL really gives this, certainly for trains that run only partly on the WCML. However, this presentation in terms of PPM implies that it is delay at destination that is measured by TRAIL, whereas the actual figures (from TRUST) include delays en route which are subsequently recovered. This difference could explain the overall difference between TRAIL and actual quoted delays.

3.5.5 With the exception of these points, the TRAIL modelling seems to have been successful in modelling the likely delays, including those from significant incidents.

Modest delays

3.5.6 In principle the modest delays are modelled in both RailSys and TRAIL, but in different ways. The RailSys input on delay is taken from TRUST and applied at model boundary handover, station dwell and station departure to reflect in the model the delay that has already arisen from an incident. That is the delay (primary and some secondary) is an INPUT. What the system then generates is further secondary delay. The TRAIL input on delays is technical, e.g. distribution of probabilities for failure of different infrastructure elements and for time to fix. That is, it is the incident itself that is the input, and the model generates the primary delay as an OUTPUT, plus the secondary delay.

3.5.7 The figures presented by **RailSys** are for 'added delay'. These are the delays resulting from the imposed additional time at stations (used to simulate delays en route) and resulting secondary delays due to subsequent conflicts (including those resulting from late entry to the area being modelled). Thus most of the delay in RailSys is actually input, with only some of the secondary delay being generated by the model.

3.5.8 The station delays are all small, and hence the standard RailSys runs exclude those delays that (while not 'significant' – i.e. greater than 1000mins) are still substantial. Unsurprisingly, the added delay forecast by RailSys is only about half the observed delay, even when significant delays are excluded it seems close to the typical level of observed delays of less than 100mins for the period from June to October 2009.

3.5.9 In **TRAIL** modest delays are generated by failure rates and repair times of infrastructure and rolling stock; whereas significant incidents are input as specific events. However, the impacts of the different types of delay cannot be distinguished (at least in the outputs we have seen). We also believe that TRAIL allows trains to recover from the delay and hence will have lower delay (particularly in the case of modest delays) than actually observed in TRUST.

3.6 Questions from ITT

3.6.1 To support the joint ORR and Network Rail review of the performance modelling and the value it added, the Remit for the study poses a number of specific questions which we now address.

Was the modelling to build the high frequency timetable and to forecast performance of the WCML following project implementation robust?

3.6.2 In summary, the modelling was robust for what it was intended to do by the modellers; the question then becomes whether the audience within Network Rail fully understood what the modelling was telling them; we consider this later.

3.6.3 RailSys was robust for the tasks it was used for – i.e. to assist development of a conflict-free timetable capable of responding effectively to minor perturbations. TRAIL was robust for its intended purpose of specifying reliability of infrastructure components. Neither specifically set out to forecast PPM or delay minutes for the WCML train service, although TRAIL comes close to doing so and gives a good indication.

3.6.4 The RailSys workstream considered the interim timetable in terms of its static delays. The TRAIL workstream did not complete analysis on the interim timetable. The main focus for both workstreams was performance analysis on the VHF timetable and completed infrastructure works, primarily because the decision to run the interim timetable was made at quite a late stage within the project.

3.6.5 The sectioning of the RailSys model is one reason why it was not used or intended to be used to generate punctuality forecasts; for its intended purpose of timetable validation and checking, the sectioning did not jeopardise validity. Due to issues over train regulation at the boundaries, combining sections of model was considered during the work but rejected in favour of maintaining consistency and comparability with previous outputs. RailSys was aiming to assess whether the timetable worked, not the route.

3.6.6 The bathtub curve for infrastructure reliability turns out not to be a major issue, as by December 2008 the bulk of the infrastructure works had been in place for some time and should have reached steady state performance.

Did Network Rail combine both asset reliability and timetable modelling effectively?

3.6.7 No. RailSys takes no direct account of asset reliability, simply using historic data on the delays recorded from all causes including asset reliability as the basis for imposing perturbations on the modelled timetable. TRAIL uses input on actual and forecast asset reliability directly, but in this case there seems to have been little or no iteration with timetable planning to attempt to improve the response of the timetable to asset failures. We are not saying that there was in the event any benefit to be gained from doing so, simply that in this case doing so was not possible, as the timetable for modelling was delivered within normal access planning timescales and was not reported on until almost the date of implementation.

3.6.8 It would be possible to generate proxy-TRUST data from TRAIL to derive delay distributions representing future years. Historically this has not been done, and in this case would have been difficult within the available timescales. However, efforts to make this link are now being made in connection with projects currently undergoing analysis, for instance, Airtrack.

Was the modelling based on sound assumptions?

3.6.9 The RailSys modelling was based on the best possible assumption for its intended purpose, that is, taking historic TRUST data to derive probability distributions for entry delays, dwell delays and departure delays. This may give room for an element of double counting as observed delays will reflect secondary delay as well as primary delay, so taking observed delays as an input and then capturing secondary delay that arises from it, in effect models secondary delay twice. However, in this case we do not believe that validity would have been jeopardised.

3.6.10 TRAIL modelling has been based on extrapolating previous asset reliability into the future without taking account of the impact of new assets where relevant (either positive or negative). This seems to have been in some respects optimistic (at least in the short term) and did not capture significant incidents (those incidents that cause over 1000 minutes of delay). In the longer term (and certainly with the enhanced maintenance regime) this may have been pessimistic. The assumption for asset reliability was based on frequency of usage so the impact of higher frequency services will be reflected in the failure rates.

3.6.11 We note comments in the RWA reports on RailSys modelling that the 2007 TRUST data should be expected to improve after implementation of the upgrade. This may be plausible but there is no evidential basis for this, and the suggestion may tend to induce optimism. In fact, to assume the same level of handover delays within the intensified service is itself optimistic, as the tendency is for a given incident to cause disproportionately greater delay.

3.6.12 As outlined earlier, it would be wrong to regard RailSys output in any way as equating to PPM. TRAIL output is closer to PPM but should not be claimed to be an exact equivalent as human factors and service recovery strategies are not modelled. We note that some TRAIL reports did refer to output as PPM, but suggest that to avoid confusion the term should not be used except to refer to observed performance of the actual railway (at least until a process that can with validity claim to forecast PPM is developed).

How were re-designs handled? How close was the modelling to what was finally delivered?

3.6.13 As definitive modelling was not embarked upon until relatively late, redesigns were not a source of uncertainty. Although Milton Keynes was outstanding in December 2008, all modelling focused on the VHF timetable itself which was not implemented until after completion of work at Milton Keynes. As the RailSys model was converted from a pre-existing VISION model, a specific exercise was undertaken to check track layouts in that model against current designs.

Was the poor performance from February to July 2009 aligned with the modelling forecasts? If not, why?

3.6.14 RailSys output should not be regarded as forecasting PPM, so this question applies to TRAIL only, and the residual distinction between TRAIL punctuality outputs and PPM needs to be recognised. In fact the eventual PPM is not far outside the range of TRAIL outputs, and the gap we believe is explained by a greater frequency of significant incidents than assumed in the modelling. TRAIL significant incidents were based on those of 2005/6, without taking into account that the more intensive service would be likely to promote some non-significant incidents to significant (e.g. an incident that previously resulted in 900mins delay might in future, simply due to the more intensive service, result in more than a 1000mins delay).

3.6.15 We estimate (see para 3.5.2) that correcting for this would have resulted in 20% more significant incidents and 16% more minutes delay resulting from significant incidents (perhaps 13% more minutes delay in total). This adjustment would align the results of TRAIL with the observed minutes delay.

What happened to improve performance so significantly after July 2009 and how does this level of performance relate to the modelling?

3.6.16 We do not know the answer to this question definitively. There were generally fewer significant incidents, but a bigger factor seems to have been less delay due to modest incidents. This will in part be due to the enhanced maintenance regime (by which we mean having staff on stand-by at key locations); there may also be improved asset reliability, but we do not have data on this.

3.6.17 The indication we have both from the data and our consultations is that the contingency plans had been more effective from about Period 12 (Feb 2009) onwards.

What were the assumptions about asset performance? How closely did that align with actual performance?

3.6.18 Assumptions on asset performance in TRAIL were derived from the Railway Reliability Data Handbook (RRDH). This document was developed to aid the understanding of asset reliability by collating historic data for various asset types to determine failure probabilities. These can be applied in TRAIL as a function of time or as a function of the number of train movements.

3.6.19 We have not been able to obtain suitable data on actual asset performance, or on assumed asset performance, in a form that could be analysed for this project.

Is the range/sensitivity around the outputs understood?

3.6.20 We suspect that many members of the audience for the model reports were not really aware of what the central outputs meant, let alone the range and sensitivity. Key to this finding is that we believe that a false sense of security was gained from the RailSys report, yet this report only claimed to show that the timetable was robust when delays were small (additional TSRs, etc); subsequent performance has shown this conclusion to be correct.

3.6.21 The RailSys report could not comment on the impact of significant incidents (and we suspect also on incidents that were not classified as significant, but still had substantial impact – between 100 and 1000 minutes delay). As such it could never have been expected to predict the outturn delay minutes or PPM. Despite this, comfort seemed to have been gained as to potential PPM outcomes on the basis of the reports.

3.6.22 The TRAIL report was delivered too late to provide a real input into management decisions. From our consultation, there is only limited understanding of what TRAIL can do, despite its forecasts being much closer to actual PPM than RailSys ever could be. In addition, some of the audience do not understand the limitations of TRAIL.

3.6.23 We consider there is a strong learning lesson here in educating the audience for modelling reports into the capabilities of the two systems, particularly TRAIL which is little understood; this is not helped by loose wording in the TRAIL reports which present PPM when this cannot be said to be the case.

3.6.24 To balance this comment we will state that our examination of the two models has indicated that TRAIL is a powerful model whose potential is not fully appreciated.

Even though PPM for Virgin Trains started off well below where predicted, it soon reached a level well above. Is this part of the sensitivity range issue or is it wholly as a result of urgent action?

3.6.25 There has been a real improvement in the performance of Virgin Trains. We cannot in this study provide the reasons for this – a combination of the enhanced maintenance regime (staff on standby), and actual asset performance due to new axle counter software, further renewals, etc.

3.6.26 We do not believe the PPM measure reported in the TRAIL reports can be accurate in absolute terms, although differences in performance between scenarios may well be. The range of PPMs reported in the TRAIL report is much less than the observed daily range even since July 2009. It is not really possible to say whether the inputs to TRAIL represented the initial period excluding the three first major incidents, or the eventual state in the second half of 2009.

3.6.27 We are clear that TRAIL does not take into account the contingency plans that are now successfully implemented when major incidents occur, and for this reason is always likely to overestimate delays (and hence underestimate implied PPM).

What is the relative importance of the issues identified?

3.6.28 The most important issues are in our view:

- the models appeared to be robust in doing what they were asked to do;
- the need for education about what TRAIL can offer;
- the need for the audience for the reports to understand the limitations of both systems as to what circumstances they model, and hence assess the implications of the reports;
- the importance of significant incidents, particularly those very few but very serious incidents (greater than 5000mins delay) on overall delay minutes and PPM; and that these cannot really be modelled because of the high level of human intervention;
- there appear to be real benefits from having and activating contingency plans, but, whilst refinement of contingency plans can be assisted by modelling, preparing a contingency timetable remains a task to be undertaken outside the modelling tool; this can then be used as an input to modelling. Neither of the modelling tools in question can themselves generate a contingency plan or apply other service recovery actions that involve significant adjustments to the intended timetable.
- the bedding in period for both the infrastructure and the learning process of control staff could be modelled. This requires knowledge of how the asset reliability varies over time, how the human intervention impacts on cancellations, and sufficient time to model a range of scenarios.

4 Lessons Learnt

4.1 Lessons learnt to improve modelling of performance

4.1.1 Planning modelling work

- Plans should be put in place to forecast the performance of a new timetable or infrastructure as an integral part of planning for project development and implementation. A plan should include a methodology as to which tools should be used at which stages of the process to answer which questions. These can be developed from the WCML experience.
- A national methodology for capturing the impact of significant incidents should be developed. This will draw heavily on simulation but will probably call for analysis outside the actual simulation packages to combine forecasts for each element of PPM into a single forecast figure.
- There is an opportunity to link the TRAIL and RailSys models so that predicted asset reliability levels as an output from TRAIL becomes an input to RailSys.

4.1.2 Defining the modelling scope

- It is essential that the modelling specification is written down, especially the inputs and outputs, for example do they include the impact of significant incidents?
- The questions that are being asked to the modelling teams need to be clearly defined by those who will use the results, rather than, as for much of the WCML modelling, leaving the scope and methodology to be defined by the modellers.
- The modellers can then offer guidance to prospective modelling sponsors who ask the question "I have got to do some RailSys modelling". The modellers are best placed to help them define what the question is that can most suitable be answered within the limits of the modelling.
- The sponsor or senior team need to give guidance about what outputs they are looking for. On WCML the issue about what had been requested highlighted the need to define whether early phase modelling or steady state would be required, as well as whether significant incidents should be included and what asset reliability will be assumed?

4.1.3 Presenting modelling results

- Whoever the audience, it is recommended that the question asked of the modelling team, the caveats and assumptions are highlighted at the beginning of any presentation including results or conclusions from the modelling.
- It is recommended that great care is taken when presenting results to a non-modelling audience to avoid ambiguity. This may include having to give explanations of some of the modelling terminology.
- It is recommended that an explanation is given as to how results link (or not) to standard industry terms such as PPM, AML so the audience can see how conclusions can be drawn.

4.1.4 Timing of activities

- Given the dependence of simulation packages on the timetable as an input, there should be the earliest possible start to timetabling and delivering of a valid timetable for modelling, if necessary in advance of normal access planning timescales. The timetable drives the performance workstreams; the sooner it can be provided in a good state the greater the probability that the modelling can feedback into the timetabling and infrastructure planning processes.
- We suggest that the best time to do performance modelling to assess the timetable is between Timetable Priority Date (T-45) and Timetable Offer Date (T-22). During this period it can have a valid input into the timetable process (i.e. before T-14). However the WTT will not have been finalised, so in real terms there may be an assumed timetable, but it will not have been matched to operator aspirations for the next timetable commencement.
- This requires all stakeholders (including external project clients) to set their requirements in a timely manner.
- Modelling will almost certainly have to start with a timetable that is not finalised, but such a development timetable should be as close to comprehensive as possible, including taking account of associations between trains resulting from rolling stock and crew diagramming. Where the timetable or diagrams are not complete or subject to further development, the uncertainty that this introduces should be recognised and understood, including the direction of potential biases, rather than being regarded as a barrier to undertaking any analysis.
- TRAIL specification of infrastructure reliability data at a very early stage of the process is key to setting initial targets for performance and reliability.
- Scenario modelling to assist development of contingency plans is valuable and should be regarded as a step within the project development process. Ideally this modelling will reflect not only the timetable, but also "on the day" modifications to rolling stock and crew diagrams.

4.1.5 Aiding the process of timetable development

- RailSys is a very effective tool to asses the inherent conflicts / quality of a timetable and should be promoted in this role until the Integrated Train Planning System (ITPS) can take over the role.
- Recognise that two separate roles exist for RailSys, first in improving the quality of a timetable, then in the task of performance modelling itself.

4.1.6 Assessing the performance of a timetable

- RailSys is understood and the users and their immediate managers understand what it does and does not do. However, we suspect that expectations held at other levels are not realistic, especially as to its capability for forecasting (or not) PPM.
- TRAIL is not so fully or widely understood outside the immediate users – however it has real potential, and was probably the better tool to address many of the performance issues on the WCML.

- There needs to be a greater awareness between the TRAIL and RailSys teams so that transfer of data regarding failures can be fed from TRAIL to RailSys and the finalised timetable can be fed from RailSys to TRAIL.
- If a RailSys model has to be split into geographic areas, clearly define the model boundaries including all stakeholders in this process and explain the implications.
- Presentation of TRAIL results (and caveats) to non-expert groups needs to be improved so that managers / decision makers understand results and have confidence in them.
- Results from both RailSys and TRAIL need to give a broader view about the level of sensitivity to the modelling assumptions. These should include optimistic and pessimistic variants so that bands of certainty can be quoted alongside modelling results. There is a case for developing a level of optimism bias to apply to results.
- Rolling stock diagrams may be crucial to timetable performance because of tighter average turnrounds. They should be represented in the modelling.
- Crew diagrams and their impact on the ability to recover during significant incidents can affect timetable performance and should be represented in the modelling wherever practical.
- Predicting performance on a day with a significant incident, and predicting the proportion of days on which a significant incident is likely to occur should be considered to give an estimate of overall performance.
- The TRAIL model assumptions need to be linked more closely to inputs from the engineer on the ground who will be responsible for providing that level of mean time between failures and mean time to fix. If TRAIL then predicts poor performance the message is strong that an improvement must be made in equipment reliability and repair.

4.1.7 Modelling Contingency Plans

- The contingency plans were well defined and assessed by RailSys modelling. To be effective they need to be to be available well before the timetable is implemented so that operations staff can be briefed so that they are able to work to and activate the plans effectively.
- In future ITPS with inbuilt conflict detection, may be able to assist with the questions of assessing the expected delays in a contingency timetable. The simulation modelling tool will be better integrated with the ITPS, reducing the length of time taken to undertake simulation modelling against a developed timetable.

4.2 Lessons learnt to improve actual performance

4.2.1 Within the overall project team there needs to be a clear responsibility at the right level with the right authority for pulling together infrastructure reliability and the timetabling.

4.2.2 "Dry running" of newly completed infrastructure is accepted as advantageous but may only be truly possible where a critical element is potentially self-contained for operations, as may indeed be the case with the East London Line, Thameslink or Crossrail core routes. Where true dry running is not possible, for instance if the new infrastructure needs to be activated immediately on implementation to preserve coherent services, there may still be an advantage in basing initial operation of the public service on a reduced level of service, unless it means persisting longer than necessary with a very tight, un-robust and inconvenient blockade timetable. Staging of the resulting increases in service level, as was indeed eventually done in the case of the WCML Upgrade in the form of the commissioning timetable, should be considered as an intended feature of the overall plan for project delivery.

4.2.3 Responses to "events" need to be as close to optimal as can be reasonably expected. Briefing and planning on contingency timetables for WCML was carried out well. However it is acknowledged that there is room to improve in the early stages of operation of a new timetable where increased intensity of operation will increase the need to speedily activate contingency plans as a response to events.

4.2.4 The bathtub curve in terms of infrastructure failures (although on WCML most of infrastructure had been in place for months or years and so should have been well on the flat bit of the curve) will impact on performance.

4.2.5 The human factors response in the early stages of the timetable implementation was different (and possibly less optimal) despite comprehensive training than after a number of periods. This needs to be recorded as a risk and if possible mitigating action taken.

4.2.6 Knowing how the infrastructure will perform is a key input to TRAIL, and delivering the identified required levels of infrastructure performance are key to service performance.

5 Recommendations

5.1 Summary recommendations

5.1.1 The primary recommendations from this piece of work are as follows:

- improved process to provide infrastructure assumptions into models;
- plan and time modelling work so results have maximum benefit reflecting both availability of usable inputs and remaining window for acting on outcomes;
- education of modelling audience as to capabilities and limitations of modelling and models;
- skills training for modelling team in presenting results and sharing expertise more widely;
- smooth transition to new timetable infrastructure.

5.2 Model input assumptions

5.2.1 To obtain valuable model outputs the input assumptions need to be robust. The input assumptions into TRAIL regarding infrastructure reliability need to be robust; they should be based on judgements of those responsible, and also take into account the level of usage under the future scheme even where no change to assets is involved. This will require the individuals who are responsible for providing the reliability of the asset being asked to predict what reliability can be expected. The modelling will then be able to inform on whether this level of predicted reliability meets targets. The significant incidents that TRAIL uses should also reflect the impact of planned level of usage on what can be expected to be significant.

5.2.2 TRAIL outputs of asset reliability should be used as an input to the RailSys, alongside appropriate use of historic TRUST delays.

5.3 Planning and timing

5.3.1 The timing of modelling work should be brought forward such that there is sufficient time in the process for the modelling results to feed into the planning process, and for management to take action if results show unsatisfactory performance predictions. This requires all stakeholders (including external project clients) to set their requirements in a timely manner.

5.3.2 Modelling within TRAIL can be started well in advance of the final timetable with the preparation of the asset failure data using the train service frequencies. Once a timetable (albeit not final) that is valid for modelling purposes is prepared, initial forecasts of performance can be made. This can take place in parallel with final timetable cleaning (using RailSys). These results can be beneficial both to the engineering teams in identifying and planning to manage critical assets, and to performance managers in identifying which failures require contingency plans. The contingency plans can be drawn up in parallel with the timetable de-confliction.

5.3.3 With such a process, managers / decision makers get early warning of the likely performance of the route, which will be refined as the timetable is finalised. A good quality timetable in place at T-45 will offer the best window for RailSys performance modelling and assistance with contingency plans.

5.4 Education of the modelling audience

5.4.1 The modelling audience (i.e. those managers / decision makers who use the outputs from the models) need to be educated about the questions asked of the models and the limitations to the results so they can make informed decisions. Educated managers will be able to make clear specifications of what they want from the modelling, and they will then understand the outputs from the models including their limitations.

5.4.2 In particular, we do not believe that any output from either RailSys or TRAIL should be regarded as directly forecasting PPM. For a variety of reasons TRAIL output may be closer to true PPM than RailSys, but it still requires a level of interpretation and processing to be a robust forecast of PPM.

5.4.3 This will result in best use of the modelling tools and no misunderstanding of the conclusions that are drawn.

5.5 Presentation skills and sharing expertise

5.5.1 Modellers need to present results in a way that is appropriate for the audience, clearly and with metrics that give a comparison to standard industry measures. The modellers need to state what question has been asked of the modelling work and what caveats or assumptions surround the results. The modellers should also explain how (if they can) these results can be compared to standard industry figures. To achieve this, modellers need to be able to present their results clearly, unambiguously, in a way that non-modellers can understand. They should seek to explain the implications of their modelling.

5.5.2 There would also be merit in modellers sharing expertise with those outside Network Rail in UK and overseas, which should result in improvements in best practice.

5.6 Transition

5.6.1 To aid smooth transition, events such as infrastructure development, timetable introduction, rolling stock changes, and franchise changes should be staggered where possible, so each can be managed and the impacts are not multiplied. The impacts of lack of experience and staff training can also be smoothed allowing optimal human response.

6 Glossary

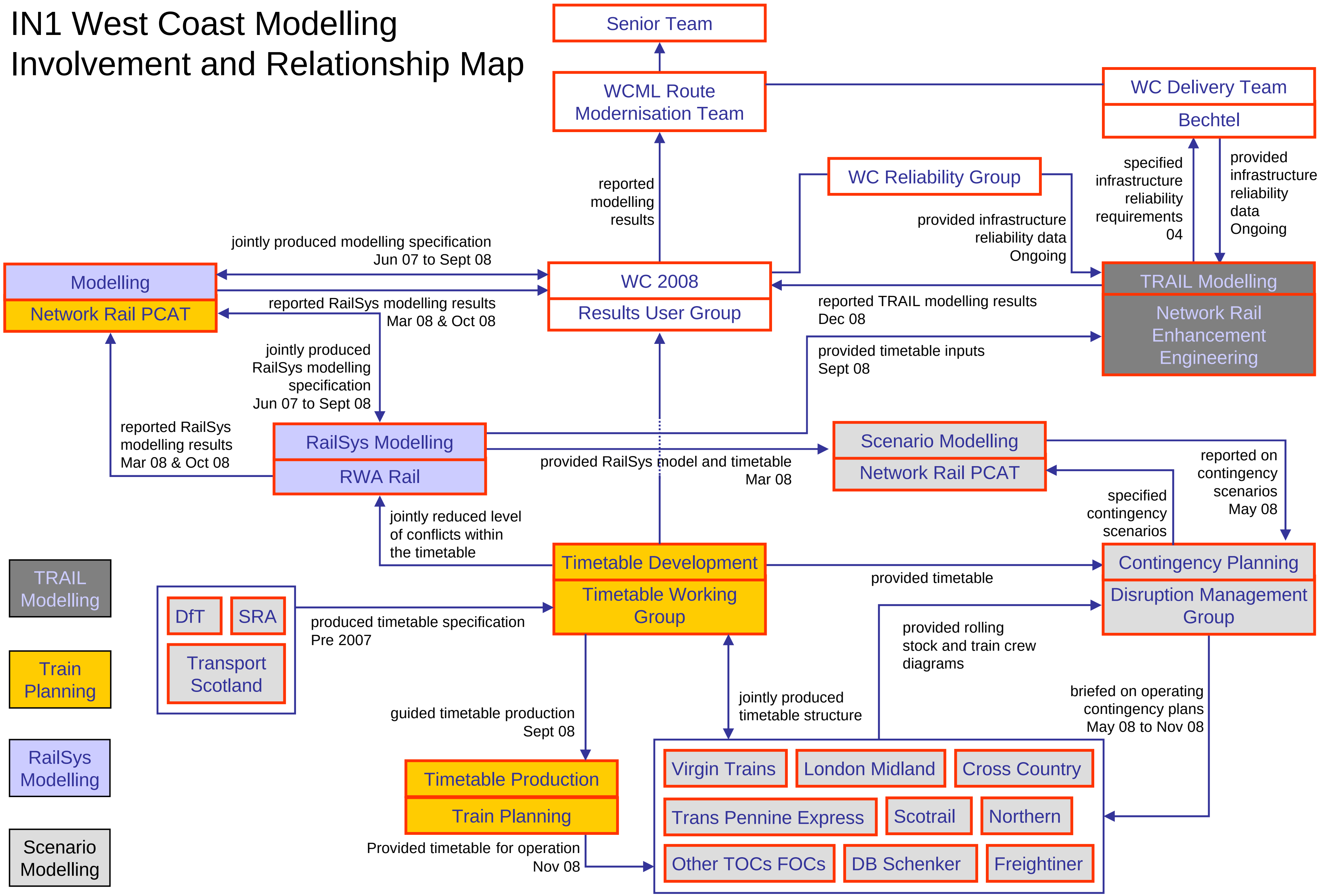
Table 6.1 - Glossary

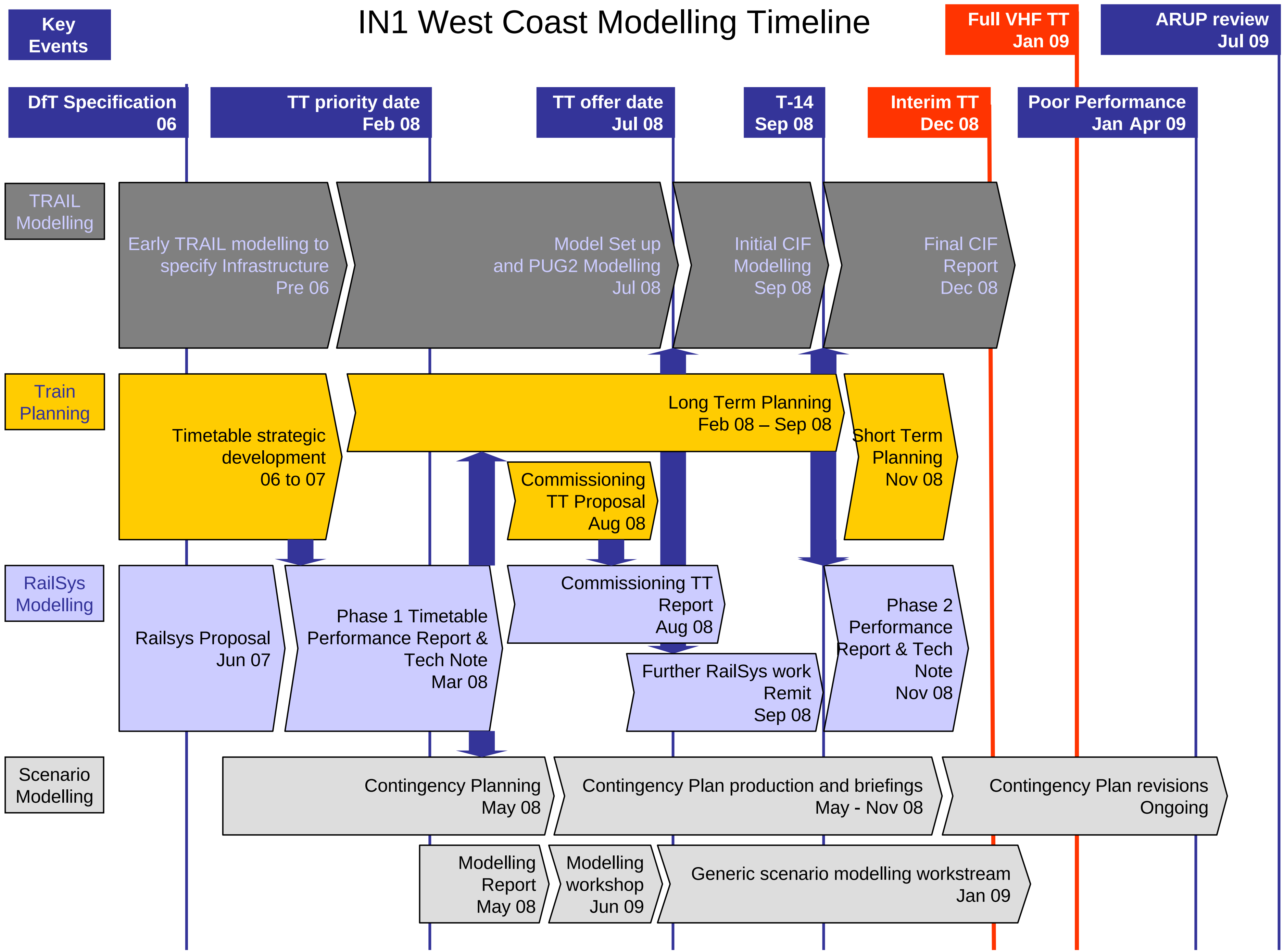
Abbreviation	Description
AML	Average Minutes Late - of franchised passenger trains arriving at their destination.
Bathtub curve	A colloquial description of the likelihood of technical failures over the life-cycle of equipment – implying a high rate of failure immediately after installation that falls rapidly to a low and steady level before rising again as life-expiry is approached.
CUI	Capacity Utilisation Index
Delay	Delay minutes represent the total number of minutes delay to passenger and freight trains, along their route, even if these are subsequently removed.
FOC	Freight Operating Company
GRIP	Guide to Rail Investment Projects – sets out stages for project planning and development, including required outputs at each stage to gain authority to pass to the next stage.
ICEC	Intercity East Coast
ITPS	Integrated Train Planning System
JPIP	Joint Performance Improvement Plan - Based on a two-way obligation of Network Rail and the train operating company (TOC) to improve performance.
Moderate Incidents	Incidents which cause less than 1000 minutes of delay.
MTBF	Mean Time Between Failures
MTTF	Mean Time To Fix
NR	Network Rail
OLE	Overhead Line Equipment
ORR	Office of Rail Regulation
PCAT	Performance Capacity Analysis Team
PPM	Public Performance Measure – PPM reflects not only punctuality but also other factors such as cancellations and termination short of destination, and failure to stop at stations, whether resulting directly from disruption events or as deliberate service recovery actions. The punctuality component of PPM is the percentage of franchised passenger trains arriving at their destination within a specified lateness margin (typically five or ten minutes). This measure captures all delay causes (Network Rail, train operators (TOCs) and others.
RailSys	Rail network simulation tool developed and marketed by RMCon and used by PCAT as well as a range of contractors.
RRDH	Railway Reliability Data Handbook
ROTP	Rules of the Plan – The rules regulating factors necessary to enable trains to be scheduled into the Working timetable, such as engineering and performance

Abbreviation	Description
	allowances.
RWA	Robert Watson Associates
Significant Incidents	Incidents which cause over 1000 minutes of delay.
TOC	Train Operating Company
TOPS	Total Operations Processing System – The system for recording live train running and punctuality monitoring which feeds the TRUST database.
TRAIL	Infrastructure and system performance simulation package developed for use by "process" industries including rail.
TRUST	Train RUnning System TOPS - A train running and punctuality monitoring database system, mainly fed by automatic inputs from signalling systems.
TSR	Temporary Speed Restriction
Very Serious Incidents	Incidents which cause over 5000 minutes of delay.
VHF	Very High Frequency
VISION	Rail network simulator developed by British Rail and retained in use for specific applications relating to the detailed analysis of UK multiple aspect signalling.
WCML	West Coast Main Line
WTT	Working Timetable – Drawn up by Network Rail showing, every train movement on the network. It shows the times of arrival and departure of trains at origin, destination, every intermediate point and appropriate passing points. It also details all the relevant time allowances.

Appendix 1 – Interaction Map

IN1 West Coast Modelling Involvement and Relationship Map





IN1 West Coast Modelling Timeline
Key Events
Full VHF TT Jan 09
ARUP review Jul 09
DfT Specification 06
TT priority date Feb 08
TT offer date Jul 08
T-14 Sep 08
Interim TT Dec 08
Poor Performance Jan Apr 09
TRAIL Modelling
Early TRAIL modelling to specify Infrastructure Pre 06
Model Set up and PUG2 Modelling Jul 08
Initial CIF Modelling Sep 08
Final CIF Report Dec 08
Train Planning
Timetable strategic development 06 to 07
Long Term Planning Feb 08 – Sep 08
Commissioning TT Proposal Aug 08
Short Term Planning Nov 08
RailSys Modelling
Railsys Proposal Jun 07
Phase 1 Timetable Performance Report & Tech Note Mar 08
Commissioning TT Report Aug 08
Further RailSys work Remit Sep 08
Phase 2 Performance Report & Tech Note Nov 08
Scenario Modelling
Contingency Planning May 08
Contingency Plan production and briefings May - Nov 08
Contingency Plan revisions Ongoing
Modelling Report May 08
Modelling workshop Jun 09
Generic scenario modelling workstream Jan 09

Appendix 2 – Data Analysis

Information Note

Project Title:	ORR NR WCML Lessons Learnt
MVA Project Number:	C3966400
Subject:	Data Analysis
Note Number:	IN2 Version: 3.0
Author(s):	John Segal
Reviewer(s):	William Barter, David Jowsey, Hal Bransby
Date:	05 May 2010

1 Introduction

1.1 This note presents the results of our preliminary analysis of the WCML performance data.

1.2 It covers analysis of:

- significant incident trends;
- significant incident analysis;
- modelling significant incidents;
- underlying trends, excluding the significant incidents;
- modelling modest delays;
- punctuality (PPM);
- modelling punctuality;
- cancellations.

1.3 Finally, it draws some conclusions based on the data analysis which need to be compared with those drawn from the other elements of the study.

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2 Significant Incident trends

2.1 Figure 1 shows the significant incidents (defined as greater than 1000 mins delay) per month, and their associated delay mins. It also shows the equivalent number and impact of significant incidents in 2006.

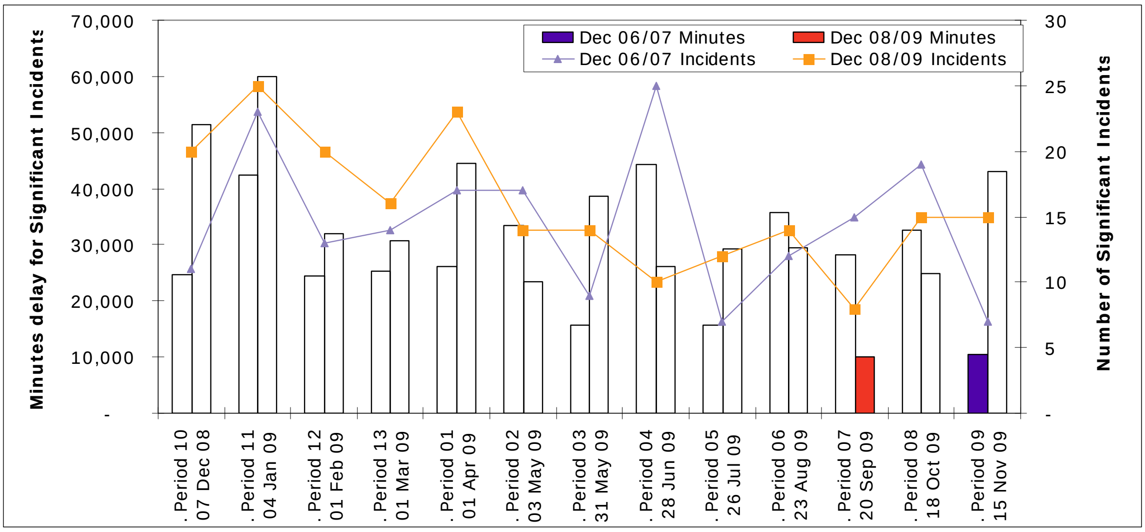

Figure 1 Significant Incidents and minutes by period

2.2 It can be seen that up to April, the actual number of incidents in the December 2008 timetables exceeds the 2006 incidents. There are two possible reasons for this:

- one reason is conversion of equivalent root incidents from sub-significant to significant in the new timetable because of number of trains;
- the other is more root incidents per se.

2.3 With a more intensive service, a given incident is likely to result in more delay. Analysis of the percentage of incidents resulting in greater than 100 mins delay shows that this has increased from 0.16% to 0.19% when comparing data from before the new timetable with that after its implementation. Before the new timetable, 0.19% of incidents resulted in delays greater than 900 mins. This indicates that an equivalent definition of significant incident for 2006 might be greater than 900 mins delay. Figure 2 shows this and their associated minutes compared to 2008.

2.4 Moving from a definition of greater than 1,000 mins to greater than 900 mins increases the number of incidents by 20% based on the 2006 figures. However, as the additional incidents are less severe on average than the other significant incidents, the increase in mins delay is less. This has been calculated pro rata to the delay caused in 2006 by these incidents. The increase in mins delay is only 16%. The figures for incidents and delays are given in Table 1.

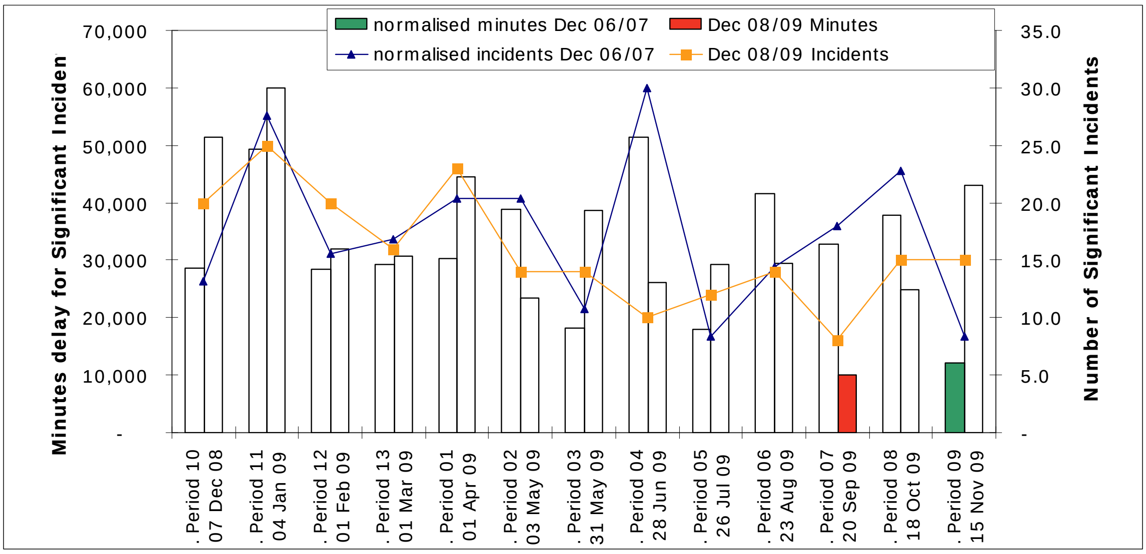

Figure 2 Significant Incidents (2006 adjusted) and minutes by period

2.5 Looking at the figure above, the indication is that the numbers of incidents in the early periods is similar between the two years, with rather less in later periods; however the number of minutes delay is greater in 2008/9, certainly for periods 10 and 11. The actual numbers are shown in Table 1, which confirms the above comments.

Table 1 Significant Incidents

	2006/7	2006/7 normalised	2008/9
Number of incidents	189	227	206
Minutes delay	359,000	417,000	444,000
Delay per incident	1,900	1,837	2,154

2.6 Over the whole year the number of significant incidents is slightly less (9%) in the more recent year, but the average minutes caused be each incident is larger (17%) during the 2008/9 year with a net result of 6.5% more minutes delay.

3 Significant Incident analysis

3.1 It is also interesting to examine the nature of the major incidents. Figure 3 presents this. It can be seen that in Periods 10 and 11 (the two worst) there were three major incidents that caused between them over 50% of the delays:

- the light aircraft crash;
- two OLE problems – Wembley and Rugby.

3.2 Without these three incidents the overall minutes would have been only slightly above the average of other periods up to and including Period 2.

3.3 Periods 1 to 4 all had significant problems with signalling and cable at critical locations. Period 9 suffered from severe flooding.

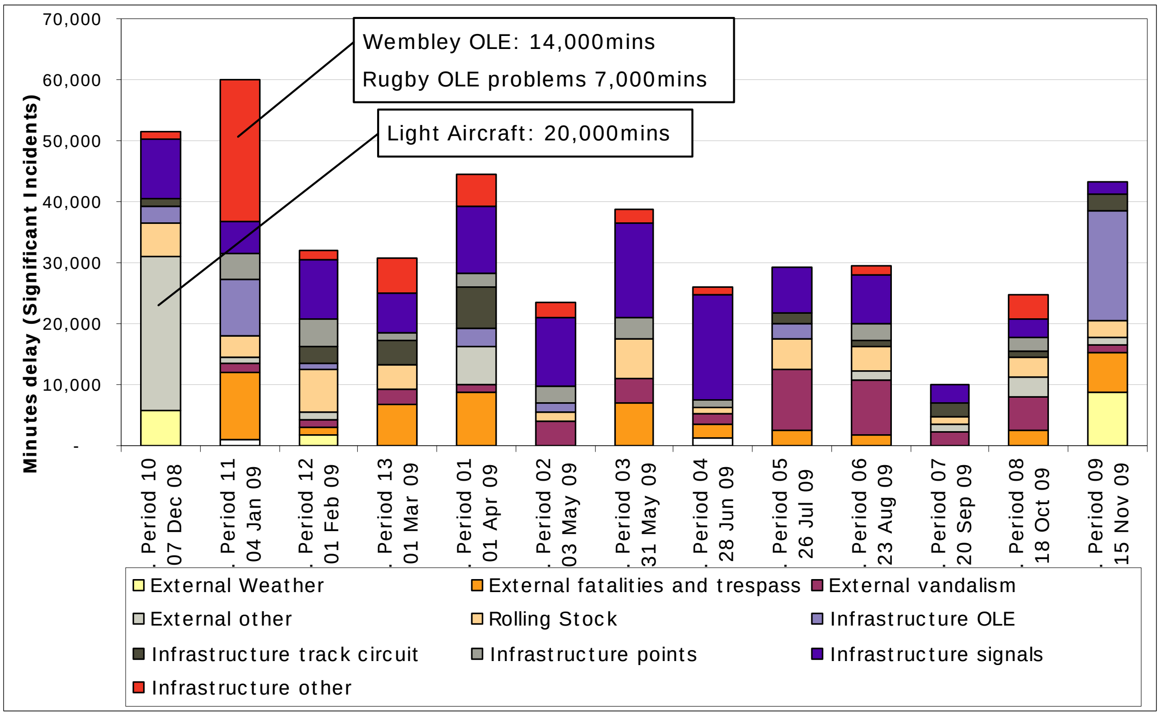

Figure 3 Major incidents by type

4 Modelling significant incidents

4.1 Significant incidents cannot be modelled in RailSys.

4.2 TRAIL modelling was undertaken to address this amongst other factors. Our understanding is that this was done by extrapolating the significant incidents of 2006/7 forwards, and adding these to the normal level of root failures. This may have resulted in 'losing' those incidents which were not significant in this year, but would have become so had the more intensive service of 2008/9 been in place. As explained in para 2.4, we estimate this as resulting in 20% more incidents and 16% more minutes delay.

4.3 There were two other categories not picked up by the TRAIL modelling:

- two major external incidents that clearly had nothing to do with the new timetable – the light aircraft crash (Period 10) and the flooding in Period 9;
- major infrastructure failures that resulted in very substantial delays, notably the OLE problems of Period 2 (one of which was the result of faulty installation), and possibly some signalling problems through Period 1 to 4.

4.4 Overall the TRAIL modelling resulted in 2.00m mins delay in 2008/9 (or 1.92m post-improvement). This compares to 3.09m observed in the same year. We are not certain of the reason behind this, but believe it is due to a different definition of delay. In the TRAIL report, most of the presentation of delay is in the form of PPM, although we do not believe that TRAIL really gives this, certainly for trains that run only partly on the WCML. However, this presentation in terms of PPM implies that it is delay at destination that is measured by TRAIL, whereas the actual figures (from TRUST) include delays en route which are subsequently recovered. This difference could explain the overall difference between TRAIL and actual quoted delays.

4.5 With the exception of these points, the TRAIL modelling seems to have been successful in modelling the likely delays, including those from significant incidents.

5 Excluding significant incidents – Underlying data

5.1 Having considered the major incidents, we turn our attention to the remaining delays. We do this in part because we know that RailSys cannot model major incidents, but we expect it to be able to address the more frequent lesser events.

5.2 Figure 4 shows the delay minutes when those due to major incidents have been removed. While the pattern is less marked than for major incidents, delays do reduce from April onwards, and indeed continue to do so throughout the period until we reach November when the very poor weather (we presume) took its toll (flooding and then snow). Over the good period the delays were reduced by almost a factor of 2.

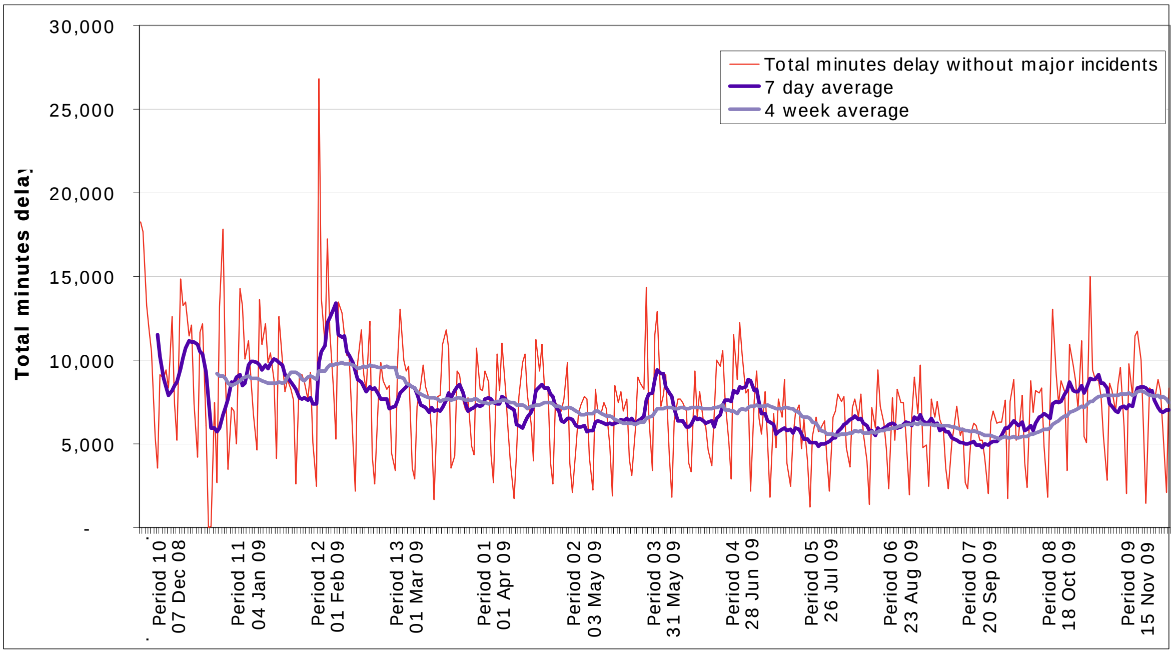

Figure 4 Delays excluding major incidents

6 Modelling modest delays

6.1 In principle the modest delays are modelled in both RailSys and TRAIL, but in different ways. The RailSys input on delay is taken from TRUST and applied at handover, dwell and departure to reflect in the model the delay that has already arisen from an incident. That is the delay (primary and some secondary) is an INPUT. What the system then generates is further secondary delay. The TRAIL input on delays is technical, eg distribution of probabilities for failure of different infrastructure elements and for time to fix. That is, it is the incident itself that is the input, and the model generates the primary delay as an OUTPUT, plus the secondary delay.

6.2 The figures presented by **RailSys** are for ‘added delay’. These are the delays resulting from the imposed additional time at stations (used to simulate delays en route) and resulting secondary delays due to subsequent conflicts (including those resulting from late entry to the area being modelled). Thus most of the delay in RailSys is actually input, with only some of the secondary delay being generated by the model.

6.3 The station delays are all small, and hence the standard RailSys runs exclude those delays that (while not ‘significant’ – ie greater than 1000 mins) are still substantial. To address this, a limited number of scenario tests were undertaken (eg a 30 minute line blockage, which was found to result in 194 mins delay), but no attempt was made to estimate the probability of such incidents, and hence to .forecast overall delays even excluding the significant incidents.

6.4 Unsurprisingly, the added delay forecast by RailSys (1.23m mins pa) is much less than the observed delay, even when significant delays are excluded (2.57m mins pa). It is worth noting that the observed delays of less than 100 mins sum to 1.48m mins pa – not very different from the RailSys figure. Indeed, the minutes attributed to observed delays of less than 100 mins for the period from June to October 2009 appear to be very close to the RailSys forecast added delay.

6.5 In **TRAIL** modest delays are generated by failure rates and repair times of infrastructure and rolling stock; whereas significant delays are input as specific events. However, the impacts of the different types of delay cannot be distinguished (at least in the outputs we have seen). As commented earlier, we also believe that TRAIL allows trains to recover from the delay and hence will have lower delay (particularly in the case of modest delays) than actually observed in TRUST.

7 Punctuality

7.1 Figure 5 shows Virgin Trains PPM, with the reasons for some of the worst days being noted. While there is not an exact relationship between PPM and delay minutes, we would expect a fairly close relationship.

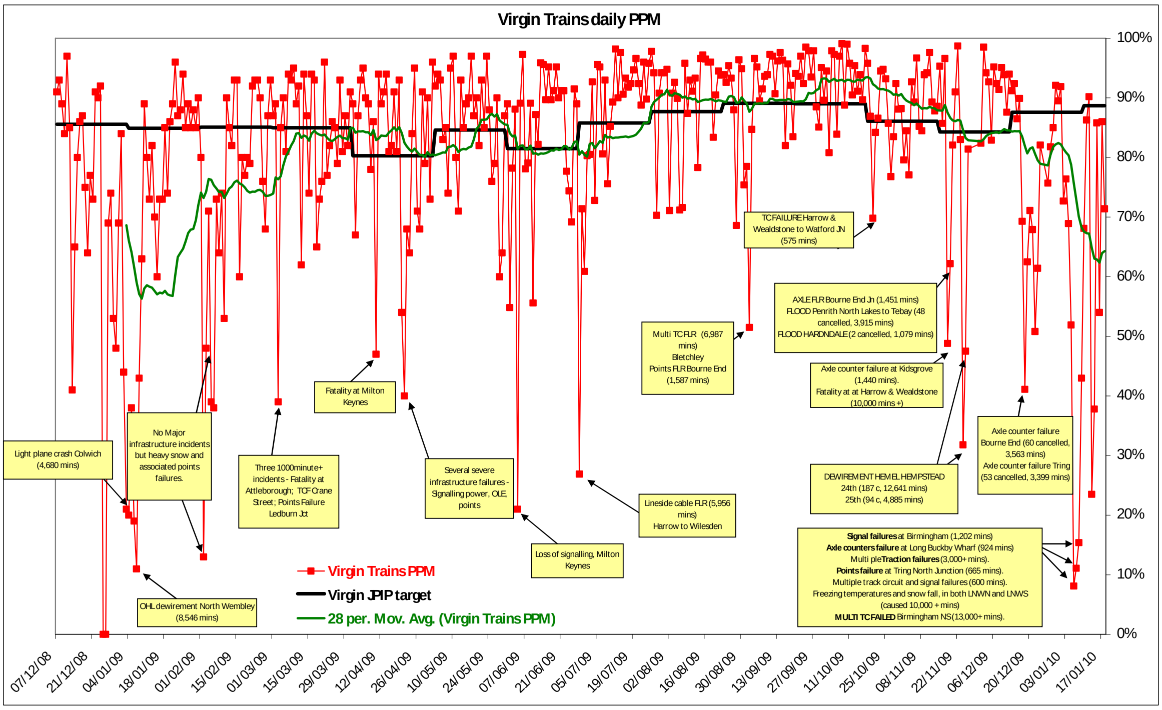

Figure 5   Virgin PPM

7.2 The next figure also includes London Midland as the only other TOC with a major presence on the WCML. It is significantly less badly affected by the major incidents. On the other hand it has not seen the marked improvement over the period seen by Virgin Trains.

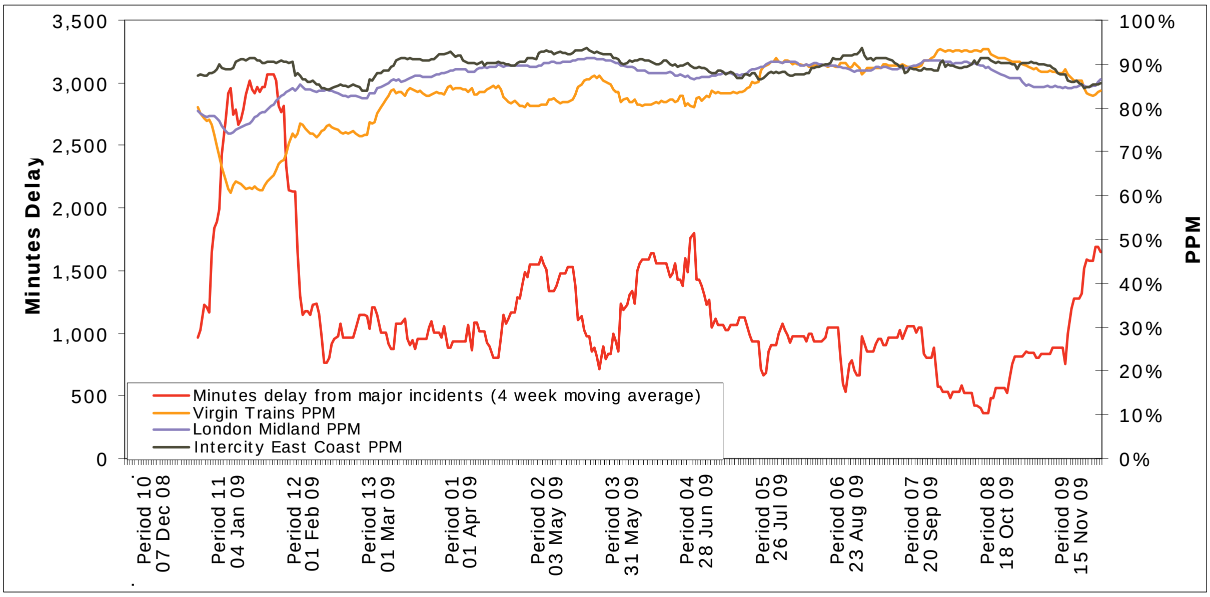

Figure 6   PPM compared with significant incidents (Virgin Trains, London Midland and NXEC)

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8 Modelling punctuality (PPM)

RailSys

8.1 Because RailSys only includes small delays, it cannot be used to estimate PPM. Furthermore, in a sectioned model (as for WCML) trains do not reach their destination, so PPM cannot be estimated.

TRAIL

8.2 It is possible to convert the modelled delays in TRAIL into PPM, and indeed this is done in the TRAIL report. We have already commented that we have concerns over this process, as there are a number of influences on PPM not included. Nevertheless as they are reported by Network Rail in their TRAIL report, we include them here.

8.3 The post-improvement timetable (which seems the most relevant model run) achieved a PPM of 82.4%, which is lower than that achieved by Virgin Trains over the period for which we have data (27 December 2008 to 30 November 2009) of 83.2%. We do not have figures for other TOCs just for the WCML, but that for London Midland as a whole is 87.3%, indicating it is substantially higher than Virgin Trains. For the latter period since 15 March, Virgin Trains has achieved 86.1% PPM; it could be argued that this should be compared to the TRAIL modelling with the time of failures halved due to the increased maintenance cover provided; the modelled PPM for this scenario was 84.1%.

8.4 We conclude that TRAIL punctuality outputs will systematically understate observed PPM. A possible explanation is that it does not take into account the contingency plans that are adopted for significant incidents, which are intended to substantially improve performance (and which our analysis in the following section appears to show is achieved). It is clear both from Figure 6 and from common sense that significant incidents have a major impact on PPM. We consider it misleading to use the term “PPM” for the outputs from TRAIL.

Comparison of RailSys and TRAIL for forecasting PPM

8.5 In conclusion, we consider that RailSys cannot forecast anything close to PPM due to its fundamental treatment of delay data. TRAIL comes closer to forecasting PPM, but there remain significant issues that mean it does not produce forecasts that are precisely equivalent to PPM.

9 Cancellations

9.1 Figure 7 shows the numbers of cancellations alongside the incidents due to major incidents and total minutes delay, just for two months of January and February 2009. The changing pattern here is very interesting:

- in the first week we see a major incident with no significant cancellation;
- in the second week we see both large delays due to major incidents and cancellations;
- thereafter we see spikes in cancellations with no significant minutes due to major incidents.

9.2 Our interpretation of this (which is supported by Jonathan Dunster) is that initially contingency plans were not implemented fully (or early enough), but by the fourth week in January, major incidents were being addressed by rapid implementation of contingency plans that resulted in substantial cancellations, but kept minutes delay under control. This is likely to have been an appropriate response.

9.3 Neither of the models properly addresses cancellations. TRAIL has a mechanistic process, but the reality is that the (appropriate) contingency plans involve significantly more cancellations but as a result substantially reduce delays. We therefore do not comment on modelled cancellations.

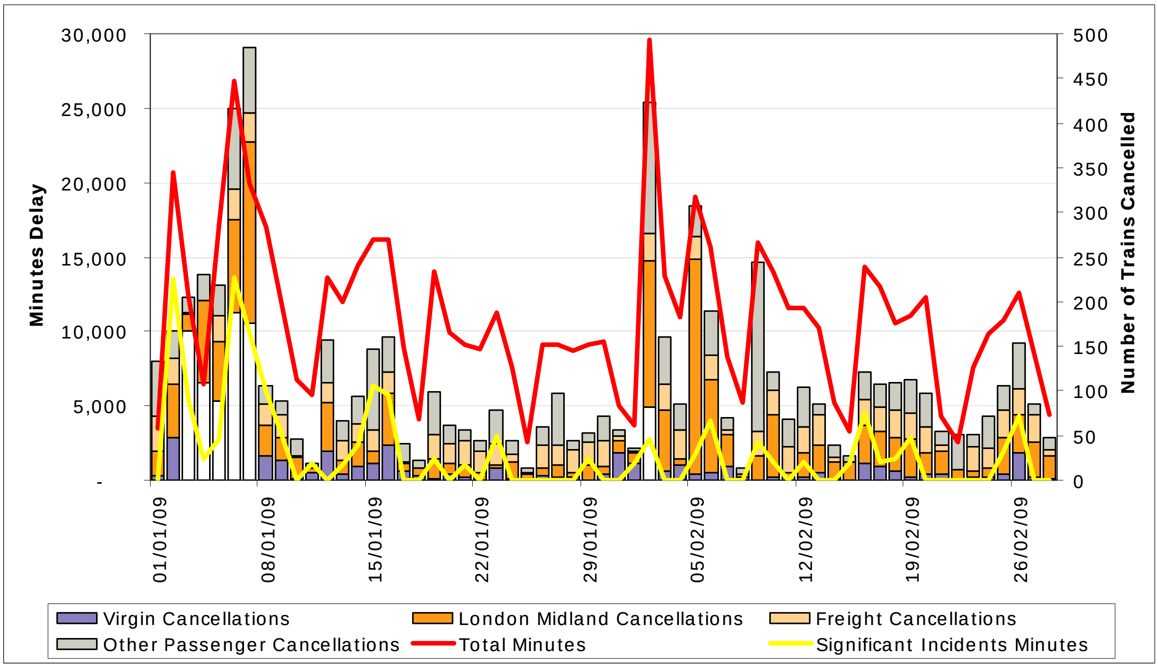

Figure 7 Cancellations by TOC and major incident in January and February 2009

10 Overall conclusions

Actual Performance

10.1 The very poor Period 10 and 11 figures result from three major events (one of which was entirely outside Network Rail's control), and coincided with the early period of a fundamentally new timetable, when control were still learning how best to implement contingency plans.

10.2 After this initial period, contingency plans were implemented by control in a very effective way. This resulted in further reductions in delays from both a large reduction in major incidents and to a lesser extent continuous improvement in the lesser delays. There is also evidence that the enhanced maintenance regime resulted in a reduction in delays, particularly the modest delays.

Modelling Performance

10.3 **RailSys** only models small delays. Our assessment is that (on the WCML) these are incidents typically resulting in less than 100 mins delay. Given the much greater interest in larger delays (both those categorised as 'significant' – greater than 1000 mins) and those between 100 and 1000 mins), it is of little use for forecasting either the average delay on the network or PPM.

10.4 However, RailSys was invaluable in developing a robust timetable which has proved to perform well in normal circumstances.

10.5 RailSys could be used to model contingency plans, but it cannot be used to generate them.

10.6 **TRAIL** appears to be a suitable modelling tool for specifying infrastructure performance to give required service performance, and looking at whole route outcomes that approach being PPM. However, we have certain caveats:

- it is necessary to take care when defining the appropriate inputs for significant delays when the timetable has a major change in intensity;
- the definition of delay needs to be clear and reconciled with that used for other measurements (eg TRUST) – is it delay at destination, or delay due to an incident?
- it cannot itself generate the contingency plans and other control responses that achieve the best balance between cancellations and delays;
- it cannot handle the extremely large incidents resulting in long term line closure (eg the light aircraft crash and the flooding).

Appendix 3 – Modelling Methods

Information Note

Project Title:	ORR NR WCML Lessons Learnt
MVA Project Number:	C3966400
Subject:	Modelling Methods
Note Number:	IN3 Version: 3.0
Author(s):	William Barter
Reviewer(s):	Hal Bransby, John Segal
Date:	05 May 2010

1 Introduction

1.1 The following document gives a more detailed picture of modelling theory and the modelling tools used for this study.

2 Modelling theory

2.1 Limitations of modelling need to be understood at the highest levels. A model is only as good as the assumptions on which it is based. In this case although models were run on the basis of rational assumptions as to numbers and severity of disruption events, the significant events affecting the early months of the WCML timetable were more frequent than assumed. The frequency of such events could not itself be predicted by the modelling.

2.2 In any modelling process the dilemma is that it must be:

- early enough to be useful and have scope to steer decisions;
- late enough to be valid through building on emerging inputs.

2.3 No model can strictly be said to model PPM. Reasons include:

- trains whose journey terminates outside the simulation area will not have punctuality captured at their ultimate destination;
- PPM encompasses items such as cancellations, trains turned short of their destination and failures to stop which are not captured in operation of the models;
- especially in the case of severe incidents, PPM depends largely upon the control response which is beyond the scope of models.

2.4 A model using a Monte Carlo approach rather than modelling individual specific events will generate average data that is valid over time. This average data however will not necessarily be valid for short periods or individual days, as the output will depend upon the precise incidents taken from the input distributions.

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2.5 The TRAIL output comes closer to being PPM than that of RailSys, because of the wider geographical area typically modelled, but it is still subject to the limitations above. We recommend that for the sake of avoiding misconceptions, the term PPM should not be used to describe any modelled output and be reserved for outcomes of actual operation.

2.6 The possible impact of such a greater frequency of severe events could be indicated by sensitivity tests in the modelling, for instance, taking an assumed frequency of disruption events and doubling it. Such sensitivity tests should become a routine feature of performance modelling.

2.7 In both the TRAIL and RailSys workstreams, uncertainty resulted until a very late stage as to the detail of the timetable. It is inevitable, given national access planning timescales, that a definitive timetable will not be available until 14 weeks before the implementation date. Therefore some uncertainty will always exist within project planning timescales. However, it should be possible to achieve a feasibility timetable that is representative in its essentials well before this milestone. The objective should normally be to have such a timetable available no later than one year before the Priority Date for the intended year of implementation.

2.8 This timetable should:

- be conflict-free;
- incorporate expected trains of all TOCs within the modelled area, including non-passenger services (ECS, freight, etc.) that can be reasonably predicted to operate;
- where non-passenger services cannot be specifically predicted, include representative numbers and nominal paths;
- reflect links between trips from rolling stock and crew workings so far as possible.

2.9 Any extent to which these criteria cannot be met will introduce uncertainty into the results, which must be acknowledged. However, the stages of access planning between the Priority Date and the Informed Traveller T-14 deadline will not reduce this uncertainty so much as to make delay worthwhile. Indeed even after T-14 uncertainty exists as rolling stock an d crew diagrams will not have been finalised.

2.10 The actual target date should be determined by the project sponsor - timetable development can and should be undertaken earlier where necessary.

3 The modelling tools used

3.1 RailSys is a rail network simulator (sometimes also referred to as a signal-berth simulator), and one of a range of products on the market with broadly comparable functionality. Key elements of such a simulator will be:

- Representation of the signalling down to the level of detail of individual track circuits, so that interactions between trains on route and at junctions due to interlocking are captured, together with a precise calculation of when conflicting routes are released;
- Modelling of train movements from a traction performance calculation. This may use the tractive effort : speed characteristic of the traction units (offset by train resistance : speed) matched with data on train mass and route gradients to calculate acceleration.

The acceleration available at the current train speed (or from rest) is calculated and applied over a time or distance step, after which new values for tractive effort and train resistance are taken based on the speed achieved at the end of that step. Alternatively, acceleration may be entered directly as a fixed value or as an acceleration : speed characteristic. Train speed is also moderated by route and vehicle speed limits.

- Ability to impose disruption events on the modelled movement of trains, so that the susceptibility of the modelled system to propagation of delay is captured.

3.2 Such a simulation may be run unperturbed, that is without disruption events. In that case it operates effectively as a spell-checker for timetables, in that if all trains start their journeys on time, they should run without delay compared with schedule, and terminate on time. In the event, however, of errors in respect of schedules or conflicting moves, the simulator will register late (or early) running and conflicts between trains. In such a simulator, the conflicts will be detected by caution aspects given to trains, that is, an infringement of the technical headway or technical junction margin. This is normally a more demanding criterion than infringement of Rules of the Plan (ROTP), as ROTP margins are rounded for ease of timetabling and inflated to give a contingency buffer (but it is not unknown for laid-down RoP margins to be less than technical margins). RailSys does not therefore check a timetable against RoP.

3.3 Delays to trains in an unperturbed simulation are termed Static Delay. In essence these are train planning errors, and the true objective should be elimination of such errors. It is a fair assumption that there is a link between perpetuation of such errors and ultimate performance of the train service, but there is no accepted quantified relationship. Changes in the level of static delay and number of conflicts indicated is therefore best regarded as an indication that a timetable has been improved or made worse compared with another.

3.4 Disruption events can be modelled in RailSys by adding delay to a modelled train:

- on entry to the simulation area from “the rest of the world”;
- during a station dwell time;
- at departure from a station.

3.5 There is no capability in RailSys for train movements to be modified between stations by disruption events, other than when an unplanned conflict arises and one train or another is checked or brought to a stand.

3.6 These disruption events are typically defined by entering probability distributions for each type of delay, and sampling the distribution every time each event outlined above takes place (Monte Carlo simulation). To obtain valid sampling from the distributions, it is normal to repeat the modelled time period a number of times, and take average values for output statistics.

3.7 A “run” of the simulation software should ensure valid sampling from the input distributions representing variable events. However, there may be value in deliberately undertaking analysis that focuses on an extreme sample, so as to understand the range of possible outcomes.

3.8 The essence of robustness of modelling is that valid input assumptions translate into forecast performance that is a reasonable match for actual outcomes. It is also important to ensure that the terms in which performance are forecast equate to the terms in which performance objectives are expressed, and that those terms reflect actual user requirements. Modelling techniques and methodologies found to be robust on one project can reasonably be expected to be transferable to other comparable projects.

3.9 TRAIL also contains a representation of the track layout and models movement of trains. However, train movements are based on pre-determined running times with arithmetic adjustments for unplanned stops, rather than resulting from an ongoing train performance calculation within the model. Some simplification of non-critical elements of the signalling is made. It also has a perturbed capability, in that disruption events are allocated from probability distributions in Monte Carlo simulation.

3.10 The key difference between the two simulators lies in the nature of disruption events that can be represented:

- In RailSys, the disruption events in effect represent the outcomes of delay causation events such as infrastructure failures, train failures and staff failures (Primary Delay). Given that train movements are then delayed compared with the timetable, the functioning of the simulator then captures the additional effect of unplanned conflicts as trains run out of course, that is, the Secondary Delay. Appropriate levels of Primary Delay are typically taken from TRUST data. The only type of Primary Delay that RailSys can be said to generate is station dwell delay, and even then the underlying causal event is not modelled, simply a set of values deriving from the historic incidence of such events;
- In TRAIL, input probability distributions are also used to generate frequencies and durations of failures for each infrastructure element. Durations can also be modelled on the basis of factors such as time to respond by maintenance staff. This still requires assumptions, drawn from historic data or forecast infrastructure performance, but it is valid to say that TRAIL models Primary Delay incidents specifically, and the delay to trains from these incidents is a simulation output rather than an input. It also then captures the Secondary Delay deriving from the unplanned conflicts consequent upon each such Primary Delay event.

3.11 The geographical scope of a model in either system is limited by technical factors such as model run times (related in part to computing power available as well as to the number of Monte Carlo runs deemed necessary for statistical validity), as well as project management factors such as ability for more than one person to work on the database at the same time. Typically, however, the geographical extent of a TRAIL model will be greater than RailSys, as the simplifications in train movements and signalling operations economise on computing power.

3.12 Each system has limited functionality for modelling service recovery effects. For instance:

- RailSys can accept input data on minimum values for items such as station dwell times and terminal turnround times. At terminals, links between inward and outward workings can be defined. Thus where the timetable allows time over and above the minimum values, delay can be recovered;
- TRAIL can dictate that after a certain period of delay a trip is abandoned;
- each can operate on the basis of pre-defined priorities for train regulation.

3.13 However, it is important to note that neither system will model more radical service recovery tactics such as deliberate cancellations, termination short of destination, or missing stops. These are essentially human decisions incorporated in the control response to disruption, rather than technical factors.

3.14 Both systems generate outputs relating to train delays and punctuality. In neither case, however, is it truly correct to say that they output forecasts of PPM, which is a compilation of pure punctuality as measured at the ultimate destination with other issues such as cancellation of trips (complete or partial i.e. termination short of destination), and failures to stop. As outlined above, these are likely components of the service recovery response to significant incidents in practice.

3.15 In this case, moreover, as the RailSys model was sectioned, most trains in each section were not modelled through to their ultimate destination, so that the punctuality figures captured on exit from the model would not be identical to the PPM contribution of each such train. Any model including TRAIL, unless it were to encompass the entire national network, would be subject to this limitation, but in this case the TRAIL model had a greater geographical scope so that the great majority of West Coast trains were modelled from origin to destination. We attribute this difference in geographical extent of models to:

- the early start made to the TRAIL modelling compared with the relatively late commissioning of the RailSys workstream;
- the simplification within TRAIL of train running time and signalling detail compared with RailSys. Note that the traction performance calculation in RailSys is made typically every 10 to 100 metres for every train and so represents a significant computing workload.
- greater computing power available for TRAIL than for RailSys which is essentially a standalone PC application.

3.16 Whilst clearly there is a relationship between modelled punctuality output and PPM, this will be subject to context-specific mediation by factors including:

- the difference between the geographical scope of the modelled and actual networks;
- the selected control responses to each incident, and;
- the degree to which this response is actually optimal.

3.17 In addition, in practice any modelling will take place on a timetable that has not been developed to the level of T-14 Informed Traveller with fully defined linkages arising from rolling stock and crew workings, simply due to modelling timescales compared with contractual timetable development timescales. There will therefore always be room for some difference between the modelled timetable and timetable as implemented. By definition, if the T-14 timetable were to be modelled, it would be too late to take any action on the outcomes of the modelling before the date of implementation in any way that affected the public timetable.

3.18 Table 1 summarises the differences between the two modelling packages.

Table 1 - Simulation comparison

Characteristic	RailSys	TRAIL
Signalling and interlocking	Modelled in detail based on train movements locking and releasing track circuits, thus preventing movement on conflicting routes directly	Based on block sections, with facilities to allow one block section to deny use of others in the case of conflicting routes
Traction performance	Dynamic calculation as part of simulator operation, based on train mass, plus data on acceleration or tractive effort characteristics	Uses pre-determined point-to-point running times, adjusted by user-defined factors for signal checks
Geographical coverage	Tends to be applied to limited areas rather than whole routes, partly to economise of simulation run time given the detail modelled, and partly for project management reasons to meet timescales.	Can be wider than RailSys, because of simplification of some detail economising on computing power
Perturbation capability	Applies delays to trains from input distributions for entry delay (i.e. handover at the simulation boundary), dwell delay (i.e. extended station dwell time) and departure delay (i.e. before departure from a station, used to represent delays that would be incurred in the section ahead). Thus assumes Primary Delay and models Secondary Delay. Delay inputs are user-defined but normally taken from historic TRUST data.	Generates blockages of lines to represent infrastructure or rolling stock failures from distributions of input data on MTBF and MTTF. Thus generates Primary Delay and then models Secondary Delay
"PPM"?	Does not forecast PPM, due to lacking the capability to mimic service recovery actions and contingency plans, or all components of PPM such as cancellations or termination short of destination. Further reasons in practice are the limited geographical scope not necessarily encompassing ultimate terminal arrivals, and dependence on historic data for Primary Delay.	Does not forecast PPM, due to lacking the capability to mimic service recovery actions and contingency plans, or all components of PPM such as cancellations or termination short of destination.

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