

RDG Sch8 Audit - Final report

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vivacity RAIL CONSULTING

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VERSION HISTORY

Version	Date	By	Notes
0.1	21/11/2018	GM / PJ	First draft

0 Executive Summary

Network Rail and TOC Benchmarks, TOC Payment Rates and SPP Thresholds have been calculated correctly and in accordance with the agreed methodology

0.1 AUDIT SCOPE AND PURPOSE

Further to our earlier audit of the calculation of Network Rail Payment Rates, Vivacity Rail Consulting (VRC) have now audited the processes and models used by Steer to calculate Network Rail and Operator Benchmarks, TOC Payment Rates and the Sustained Poor Performance Thresholds.

For each of the parameters calculated, our review has covered the methodology used, the data preparation pipeline, the reference data used in the spreadsheet models, the formulae used in the models and the processes used to create an audit trail to verify correctness of the process.

Our audit has been geared towards answering two questions for each calculation:

- Has the calculation been tackled in the way agreed with stakeholders and described in Steer's methodology documentation - i.e. has the right calculation been done?
- Are there any mistakes in the calculation - i.e. has the calculation been done right?

SECTION 2 of the report gives more detail on the process VRC used to carry out the audit.

0.2 OVERALL CONCLUSIONS OF THE AUDIT

Steer have conducted the calculation of all the Schedule 8 parameters in a competent and knowledgeable fashion.

The methodology for each stage has been reasonably well-documented.

The data processing code and spreadsheet models have been constructed generally to a high standard and in accordance with recognised best practice.

Data flows through the processes and models have been clear and straightforward to audit.

No significant errors have been found in the calculation of any of the parameters.

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All clarification questions and issues raised with Steer have been addressed.

VRC are comfortable that the Industry can have confidence in the results of the calibration.

SECTIONS 3 TO 0 of this report give more detail on our findings for each of the Schedule 8 parameters; **SECTION 7.1** has more detail on our conclusions.

0.3 RECOMMENDATIONS FOR FUTURE CALIBRATIONS

We have the following recommendations for future Schedule 8 calibration exercises:

- Future Schedule 8 recalibrations should include an external audit
- Audit considerations should be included in the ITT for future recalibrations
- Sets of test data and expected results should be prepared ahead of time and made available to modellers.

See **SECTION 7.2** for full details of our recommendations.

1 Introduction

This document is Vivacity Rail Consulting's audit report on the calculation of Benchmarks, Operator Payment Rates and Sustained Poor Performance Thresholds carried out by SDG/Steer as part of the PR18 Schedule 8 recalibration

1.1 BACKGROUND

RDG is managing the recalibration for Control Period 6 (CP6) of the parameters used in the performance regime formalised in Schedule 8 of the Track Access Agreement between Network Rail (NR) and each Train Operating Company (TOC). These parameters are:

- Network Rail Payment Rate (NRPR): the cost per day for each service group of the change in NR-caused weighted average lateness of 1 minute. This represents revenue presumed lost to the operator because of delays and cancellations to its trains caused by NR and other operators.
- Network Rail and Operator benchmarks (performance points): the expected levels of service group average lateness caused by Network Rail and the Operator. The Network Rail levels are set for each year of CP6 to be consistent with the regulatory targets NR will be set.
- TOC Payment Rate (TPR): the cost per day for each service group of the change in TOC-caused weighted average lateness of 1 minute. This recoups for Network Rail the liability it faces by delays caused by this service group to other operators.
- Sustained Poor Performance Threshold (SPP): the level of lateness caused by NR at which TOCs become eligible to recover additional amounts, under the assumption that the normal Schedule 8 entitlement is inadequate.

The bulk of the work in calculating these parameters is being carried out by Steer Davies Gleave (Steer), with the exception of a small number of operators where a significant service change is taking place, where the work is being done as bespoke recalibrations by other consultants.

1.2 THE AUDIT - TERMS OF REFERENCE

RDG require that the recalibration work be audited by a third party. The purposes of the audit are

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- To verify that the correct input data have been used and flow correctly through the calculation models
- To check that any data manipulation is appropriate
- To check that the models used conform to the methodology agreed between Steer and the Schedule 8 Working Group
- To check that formulae in the models are correct
- To check that assumptions used in the models are valid and appropriate.

Vivacity Rail Consulting (VRC) have been engaged by RDG to carry out this audit. The VRC team have been involved in several previous Schedule 8 recalibrations, including the PR13 national recalibration for Control Period 5.

1.3 THIS REPORT

This report covers VRC's audit of the calculation of Network Rail and Operator Benchmarks, Operator Payment Rates and Sustained Poor Performance Thresholds. It is structured as follows:

- **SECTION 2** describes VRC's approach to the audit, in broad terms and specifically with regard to each of the Schedule 8 parameter calculations being audited
- **SECTION 3** covers our audit of the calculation of Operator and "Raw" Network Rail Benchmarks
- **SECTION 0** covers our audit of the process to adjust Network Rail Benchmarks to match regulatory performance trajectories
- **SECTION 5** covers our audit of the calculation of TOC Payment Rates
- **SECTION 0** describes our audit of the calculation of Sustained Poor Performance Thresholds
- **SECTION 7** summarises our conclusions and recommendations for future work of this type

Appendices contain background details of the work done:

- **APPENDIX A** lists all the Steer-provided and background documents referred to during the audit
- **APPENDIX B** lists all the points of documented methodology checked during the review of each Schedule 8 parameter's calculation

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- **APPENDIX C** summarises the issues raised with Steer during the audit and their resolution

2 Audit Approach

2.1 VRC'S OVERALL AUDIT APPROACH

VRC's approach to the audit task is three-stage, aiming at all times to pre-empt possible audit issues as early in the recalibration process as possible. The three stages are:

1. Early engagement: meeting with the modelling team to set out audit expectations and make suggestions about the model development process and data pipeline to a) minimise the likelihood of errors creeping in; b) simplify the later audit by providing a clear audit trail and simple model structure.
2. Continuous monitoring: regular contact with the modelling team to discuss emerging issues and apply any audit-related course corrections while they can still have an impact; early sight of models as they hit internal review points prior to formal delivery to maximise the time available to resolve any issues found.
3. Formal audit: review following draft delivery of the inputs, methodology, data pipeline and spreadsheet models.

2.2 AUDIT PROCESS - BASE BENCHMARKS

2.2.1 INTRODUCTION

This section describes the audit of the process to calculate "base" Network Rail and Operator benchmarks based on actual performance in the agreed historic period - the process described in Section 3 of the Steer methodology document¹ as Stage 1 and Stage 2 of the benchmark calculation process.

The Operator benchmarks calculated in this stage are used directly in Appendix 1 of Schedule 8; the Network Rail results are passed forward to the process to apply regulatory trajectories - Stage 3 of the documented process: this is described in [SECTION 2.3](#).

VRC intended its audits of the calculation to be done alongside the work itself so that audit considerations could be addressed as it progressed, as we have described in [SECTION 2.1](#). However, the audit materials for this element of the work were only delivered to VRC after the results had been issued to the industry for review. This has meant that we have had no opportunity to influence the way the work was done; and we were given less

¹ "Schedule 8 - National Recalibration Methodology (Control Period 6) v0.90.pdf"

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time than ideal to complete the audit. Although we have inspected the whole calculation process from end to end, we have not been able to be as thorough in our investigation as we originally intended.

2.2.2 OVERVIEW OF THE STEER PROCESS AND MODEL ARTIFACTS

Steer have used a composite process to calculate benchmarks - a data processing pipeline based on MS-Access to do the upstream data manipulation, and an MS-Excel spreadsheet model to do the actual benchmark calculation.

Where historic stops / lateness / cancelled stops data exists in PEARS for the monitoring points to be used in CP6, Steer have used this data. Where new monitoring points have been proposed for CP6, Steer have synthesised equivalent data based on timing events sourced from PSS.

Steer have adjusted the historic CP5 data to cater for differences between CP6 and CP5 in the following ways:

- Changes in monitoring point weightings, which affect the contribution of each monitoring point to the overall total for a service code / direction / peak split
- Changes in berthing offsets, which affect the overall level of recorded lateness at the monitoring points
- Changes in cancellation minutes, which affect the equivalent minutes late used for a cancelled monitoring point stop
- Service Group re-mappings (in a small number of cases)

The data processing in MS-Access is done using SQL commands contained in VBA modules. The code is reasonably easy to understand and free of obvious traps for the unwary. The MS-Access process generates an output file in .csv format which then forms the input to the spreadsheet model.

There are 3 separate MS-Access models - one for Scotrail HA, one for East Coast HB, and one for all other operators.

The first stage of the spreadsheet model processes these historic PEARS data to produce a set of "base" benchmarks which are used as follows:

- They are used later in the same model to calculate "tightened" NR benchmarks which have had a regulatory trajectory applied. See [SECTION 0](#) for our audit of this trajectorising process.
- They are passed forward to the TOC Payment Rate model. See [SECTION 5](#) for our audit of the TOC PR calculation.

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To calculate the base benchmarks from the historic PEARS data, the model carries out the following steps:

- Applies changes to Cancellation Minutes to the Deemed Minutes Late element
- Applies changes to Berthing Offsets to the AML elements
- Applies changes to Monitoring Point Weightings to the AML and DML elements
- Applies any adjustment because of service group remapping (specifically, for some Transpennine and East Coast services)
- Distributes lateness due to any minutes in dispute pro-rata to Network Rail and Operator
- Applies any specific operator-level adjustments such as for timetable differential changes.
- Feeds in the inputs of benchmarks from separately-done bespoke calibrations (for Great Western / Heathrow Connect / Crossrail; and for GTR/LSER).

An important additional input into the benchmark calculation process is the list of new monitoring points and their weightings. There is a spreadsheet which calculates these, starting from a basic list provided by RDG. This does the following adjustments:

- Corrects for where service groups have been changed from Peak / Off-Peak in CP5 to All Trains in CP6
- Suppresses any monitoring points for which there are no trains in the historic data
- Maps any changes of service group for specific monitoring points
- Identifies where timings data needs to be picked up from PSS rather than PEARS
- Identifies where timings data should be taken from a nearby proxy location.
- Re-scales the weightings to 1.0000 where monitoring points are suppressed or removed.

The end result is a complete set of CP6 monitoring points, all having timings data for them and all correctly weighted.

2.2.3 AUDIT TASKS

To audit the calculation of base benchmarks, VRC have carried out the following tasks:

- Inspected the data sources and code for the MS-Access data processing pipeline
- Inspected the spreadsheet module which calculates the monitoring points and weightings to be used
- Inspected the spreadsheet model
- Made some sense-checks of some of the data inputs and outputs

At each stage, VRC have been taking care to:

- Look for compliance with stated methodology
- Note any unstated assumptions
- Look for incorrect or risky calculations or deviations from accepted best practice.

APPENDIX A contains a complete list of the documents reviewed.

SECTION B.1 in APPENDIX B lists all the elements of the Steer methodology that we have verified.

2.3 AUDIT PROCESS - NETWORK RAIL TRAJECTORIES

2.3.1 INTRODUCTION

The calculation of Network Rail benchmark trajectories is done in the same spreadsheet model as the calculation of base benchmarks.

Regulatory trajectories have been set at the operator level by ORR. These are expressed for CP6 in terms of Network Rail delay minutes per 100 train km. These need to be converted to service group level changes in the Network Rail components of the Benchmark.

Other adjustments need to be made to the NR benchmarks as well:

- The component of the benchmark due to Freight-caused delay is to be uplifted to account for a higher-than-historic level of Freight-on-TOC delay in recent periods.
- Similarly, the component due to Charter-caused delay is to be uplifted.

Factors have been provided for these uplifts.

The basic process is:

- Split the “Network Rail” benchmark into the components caused by Network Rail itself, by Freight operators, by Charter operators and by other passenger operators. This is done by using delay totals data for each affected service group from the Responsibility Matrix.
- Identify and apply a change to the Network Rail part due to regulatory tightening. The change is calculated using either a regression relationship (if a good one exists) between AML and delay per 100km, or by direct proportion if there is no relationship.
- Apply the required uplifts to the Freight and Charter elements of the benchmark.
- Add the elements back together to form the final NR benchmark.

2.3.2 AUDIT TASKS

To audit the NR trajectory process, VRC have carried out the following tasks:

- Verify the data inputs to the spreadsheet, where possible
- Step through the spreadsheet model, verifying that it implements the documented methodology
- Looking out for any risky elements of the spreadsheet which might make the results suspect.

The methodology points covered are listed in [SECTION B.2](#) of [APPENDIX B](#).

2.4 AUDIT PROCESS – TOC PAYMENT RATES

2.4.1 INTRODUCTION

TOC payment rates are calculated in a spreadsheet model which uses a macro to iterate through the list of service groups, and a calculation sheet which calculates the rate for the selected one.

The calculation is based on the standard approach of working out:

- the proportion of the “NR” benchmark lateness for each affected service group that is caused by the selected causing service group. This is assumed to be the same as the proportion of total NR+TOC on TOC delay caused by the causing service group
- the financial cost of that proportion = that proportion of the affected service group’s Network Rail Payment Rate

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- the total of these financial costs across all affected service groups, including freight and charter ones which have a special calculation of their own
- a rate per minute of lateness of the causing service group's trains, which is the total financial cost divided by the causing service group's TOC benchmark.

The spreadsheet model also contains a set of diagnostic calculation and presentation sheets which explain the changes in TOC payment rate for each service group. We have not audited these.

2.4.2 AUDIT TASKS

VRC have audited the spreadsheet model and aspects of the data preparation pipeline which prepares the data inputs for the model.

For the spreadsheet model:

- We verified that the calculation steps were in accordance with the Steer methodology document.
- We checked that the model has been built in accordance with best practice.

For the data preparation pipeline:

- We reviewed samples of the R code used to process the data
- We carried out some sense-checks on the responsibility matrix.

2.5 AUDIT PROCESS - SUSTAINED POOR PERFORMANCE THRESHOLDS**2.5.1 INTRODUCTION**

The Sustained Poor Performance threshold is set at the financial impact of NR performance an agreed level worse than the NR benchmark - for CP6, 20%. It is expressed as an annual rate per operator, observed at four points during each rail year. It changes through CP6 as the NR benchmark moves because of regulatory targets (as calculated in NR Trajectories).

The thresholds are calculated using a spreadsheet model which calculates the thresholds for each service group of a selected operator, per year into CP6, then sums these for the whole operator while calculating the moving annual amount for the 4 selected periods into each CP6 year.

Network Rail Payment Rates are indexed to 2017/18 prices for this calculation.

The calculation for the first year of CP6 has to take account of the change in calculation method between CP5 and CP6.

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The spreadsheet model uses a macro to iterate through a list of operators, calculating the rate for each in turn and writing the results to an output spreadsheet for that operator.

2.5.2 AUDIT TASKS

VRC audited this calculation by carrying out the following tasks:

- Checking the inputs to the model, in the form of NR benchmarks for CP5 and CP6 and the Network Rail Payment Rates for CP6.
- Checking the model calculation for conformance with the stated methodology and with accepted best practice.

3 Review and Findings

-Base Benchmarks

3.1 AUDIT OF THE BENCHMARKS DATA PROCESSING PIPELINE

We reviewed the MS-Access databases that process PEARS / PSS timings data to generate the timings input for the Benchmark spreadsheet model.

3.1.1 CODE FUNCTION

The first stage VBA code does the following:

- Iterates through a list of TOC-level PEARS data extracts provided by Network Rail, copying the daily MP totals and daily Service Group delay minutes figures into holding tables for rail years 2016 and 2017
- Calculates how many periods of data each service group is represented in the data
- Extracts data for each TOC from a table of PSS location train event counts, formats it the same as the PEARS data and appends to the data file. This is for new monitoring point locations which do not have PEARS data.
- Calculates the Cancellation Minutes effective in each period by reverse-engineering from the numbers of cancelled stops and the deemed minutes late

This is followed by a second stage which iterates through the holding tables created in the first stage, operator by operator. For each operator it does the following:

- Extracts the unweighted minutes of lateness and numbers of cancelled stops
- Prepares adjusted sets of lateness minutes and deemed minutes late by applying in stages the CP6 cancellation minutes and CP6 monitoring point weightings
- Prepares further adjusted sets of lateness minutes by applying berthing offset changes

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- Summarises the data by period and then over the whole benchmark calibration timespan.
- Generates an output table for use by the spreadsheet model.

3.1.2 OBSERVATIONS

The code appears sound. It works by executing a series of SQL queries against data in an input table, storing the results in a temporary output table which is then used as the input of the next query. At each stage, row counts and totals are kept to check for data loss or duplication.

We wished to investigate the following specific aspects of the code and its working:

- Were the correct columns of data used from the PEARS source? PEARS column names are opaque and all look very similar to each other, so it is easy to pick the wrong ones by mistake.
- There are two code modules which differ only by the filter they use for the TOCs they process. Were the two sets of code otherwise identical?
- There are repeated sections in the code where the same columns are used with minor differences in filter criteria. Do they actually do the same thing?

We found no problem with any of these aspects, though would note that these issues represent deviations from good practice that introduce risks if the code needed to be changed in future: all the copies of the same code would need to be changed in step.

3.2 AUDIT OF THE INPUT DATA TO THE BENCHMARKS CALCULATION MODEL

3.2.1 MONITORING POINT STOPS AND TIMING DATA

The benchmarks calculation spreadsheet takes the output from the MS Access databases into input sheets. We checked that these data made sense.

All the MS Access database outputs appear twice in the inputs to the spreadsheet: once with disputes set to Operator, and once with disputes set to "Railtrack" = Network Rail. We could not see how the Disputes to Operator data set could have been produced, as there is no mechanism in the MS-Access code to do it. We concluded that a different version of the code would have had to be used, using source data columns tagged "_TB" for TOC bias, rather than the observed use of "_RB" for Railtrack = Network Rail bias.

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We checked that the two sets of data were identical apart from small shifts in responsibility from TOC to NR: they were.

3.2.2 MONITORING POINT WEIGHTINGS

Also input to the spreadsheet model is a set of monitoring point weightings. These are generated in a separate spreadsheet model.

We checked the working of this model, which manipulates a raw list of Monitoring Points and their weightings provided initially by RDG. The manipulations are done to allow for remappings, the addition of proxy locations to remove points where trains will not call in future and to apply some operator-specific overrides.

All of the changes to the data are documented in the model. The processing appears to be consistent with the documented changes. There are some complex formulae in some places and other minor deviations from best practice (such as the use of constant values in formulae) but we did not see any that created error.

We carried out some sense-checks on the output data:

- Are all service groups represented?
- Do the monitoring point weightings for each service group / peak split sum to 1.000?

We found no issue of note, apart from some minor rounding differences leading to sums of 0.9998 or similar for some service groups - i.e. small values in the 4th decimal place. Whilst these would be undesirable in published Schedule 8 appendices, they have negligible impact on the benchmark calculation so were not deemed material.

3.3 AUDIT OF THE BENCHMARKS CALCULATION MODEL

We audited the spreadsheet model which calculates the raw benchmarks.

3.3.1 SPREADSHEET FUNCTION

The spreadsheet is constructed using a standard Steer template and mostly using their normal best practice. It uses a macro to iterate through the service groups, calculating the benchmark from the input data and also drawing a set of diagnostic graphs to indicate the impact of the various adjustments which lead to difference from the CP5 values.

The spreadsheet is basically simply assembling data from the input sheets for the given service group - it carries out no calculation of its own.

3.3.2 OBSERVATIONS

The spreadsheet has been well-constructed with a clear data flow and straightforward formulae which proved simple to audit.

No issues were found with the spreadsheet model.

4 Review and Findings

– Network Rail

Trajectories

4.1 MODEL REVIEW

We reviewed the sections of the TOC and NR benchmark model v.90 relevant to the calculation of trajectories. These were the NR Benchmark sheet where the regressions are calculated and applied to the AML, and the three input sheets TOC Trajectories, I_Trajectories and I_Regression Inputs.

This section of our review does not include the analytical stages relating to the trajectories so does not extend beyond the benchmark trajectory with regression modelling calculation in row 328 of NR Benchmark, where the NR portion of AML with regression applied is added back to the other parts that make up the benchmark.

We also have not included the calculation sheet C_Trajectories which comes after this stage.

We found that the functionality we observed in steps 5, 7 and 8 and the following benchmark calculation section carried out the following functions which conform to the methodology document:

- set a base historic position based on one year's delay minutes or an average of two depending on the set years
- apply the target delay minutes for a TOC to the service group level by applying a TOC:SG conversion factor
- inputs service group and period historic delay minutes and AML from performance trajectories data processing tool in order to calculate regression between them
- calculates regression slope, intercept and r-squared values using Excel functions
- adjusts r-squared down according to the size of the sample and uses the value to reject the regression-based approach where r-squared is less than a set value (currently 70%)

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- applies regression to base historic position delay minutes to get regression AML for the service group
- modifies the slope to account for changes not included in the regression such as Monitoring Point Weighting changes, signal berth offset changes and service group remapping.
- applies the intercept and converted slope to base position delay minutes for the NR part of overall NR AML.
- calculates all parts of the nr pm by adding this to the other parts which make it up.

4.2 INPUT DATA REVIEW

We also checked the following input data:

- Performance trajectories - data processing tool v0.84 used to provide the historic delay minute inputs to i_regressions, were found to be accurately input.
- Crm_p model v 11 (04/10/18) from nr delay per 100_041018, used to provide input to toc trajectories, were found to be accurately input.
- A source was not provided for version 9 of crm_p model which was also used as an input in some cases.

5 Review and Findings

– TOC Payment Rates

5.1 AUDIT OF DATA PREPARATION PIPELINE

5.1.1 DATA PREPARATION PROCESS

The data preparation pipeline for TOC Payment Rates uses a set of R scripts to process PSS train mileage and delays / cancellations data into the data inputs needed for the TOC Payment Rate spreadsheet model. They essentially build a Responsibility Matrix which shows the affected and causing service group / peak split for each delay and cancellation event.

The pipeline has to do the following:

- For each timetabled train in the PSS mileage data, assign a Peak status and Direction. These attributes are used later in the process. For the purposes of the responsibility matrix, only Peak is relevant.
- Create the responsibility matrix
- Create a set of totals of NR, TOC on TOC, Freight on TOC and Charter on TOC delay for each affected service group.

5.1.2 REVIEW OF R SCRIPTS

We reviewed only one of the R scripts – the one used to assign peak type to the train mileage data. The script is well-formed and documented and it was clear to see how it worked. It steered clear of known pitfalls associated with merging of data streams.

We raised one issue on the script, regarding the absence of any logging of input and output row counts and totals to provide an audit trail. This was not implemented on this particular script, but Steers did implement this type of audit trail on subsequent scripts that they created.

5.1.3 OBSERVATIONS ON THE RESPONSIBILITY MATRIX METHODOLOGY

We have checked the steps described by Steer in Sections 4.12 to 4.36 of the methodology document. These conform to the process used by Halcrow in CP5 and to current accepted practice in this area.

We have not been able to check the actual R code that implements the process.

5.1.4 SENSE CHECK OF RESPONSIBILITY MATRIX DATA

We carried out some checks to verify that the delay minutes and cancellation events figures in the responsibility matrix and NR totals were compatible with each other.

5.2 AUDIT OF TOC PAYMENT RATE MODEL AND METHODOLOGY

5.2.1 SPREADSHEET MODEL

We investigated the TOC Payment Rate model v0.25 in relation to the documentation in section 4 of the methodology document Recalibration of Schedule 8 for CP6 Methodology v0.30.

We checked that the functionality of the model matched that described in the methodology; ie "is it doing the right calculation?". We also identified to what extent the methodology supported and currently explained the workings of the model.

5.2.2 OBSERVATIONS

We are content that the model does what it says it does in the methodology and with the general correctness of this functionality as part of the Schedule 8 process.

The formulae in the model do the same thing as the formulae in the methodology section 4.4 and the examples in section 4.5. The full list of definitions of calculation elements in section 4.4 was also reviewed and found to be correct.

However, we raised an issue relating to the handling of Freight and Charter which is different to CP5. There are assumptions which are neither documented nor explained in the methodology and we have asked for this to be done in order to have confidence in the correctness of this aspect.

We raised a further issue to require that the methodology should document the time aspect of the various data items that are used in the calculations, particularly where the calibration years for a service group are overridden.

A complete point-by-point comparison of the model against the stated methodology is shown in [SECTION B.3](#) of [APPENDIX B](#).

Issues raised in this part of the review are shown in [APPENDIX C](#).

6 Review and Findings

– SPP Thresholds

6.1 MODEL REVIEW

The SPP thresholds model is a relatively simple one with only two calculation sheets. It has been constructed using what appears to be a new Steers-branded template (rather than the other spreadsheet models which have older SDG branding and styles).

We found a significant number of divergences from best practice in this model, which suggests that it had been constructed by a less-experienced modeller than the other models in the Schedule 8 suite. These included:

- The inappropriate use of the risky Excel function INDIRECT()
- Hard-coded constants in formulae
- Hard-coded lists of service groups and operators in calculation sheets
- Inconsistent formulae across columns.

Notwithstanding these issues, we are comfortable that the model is calculating the correct results and implements the stated methodology.

A detailed point-by-point check against the Steer methodology document is in [SECTION B.4](#) of [APPENDIX B](#).

7 Conclusions and Recommendations

7.1 CONCLUSIONS

We can draw the following conclusions from this audit.

1. The Schedule 8 recalibration has been carried out in a professional manner.
2. The Steer team have shown themselves to be competent and knowledgeable.
3. The general standard of the work products is high. Any deviations from best practice are minor and we have verified that they have no impact on the results
4. The process has been well documented and conformance with the actual calculations is very good
5. The flow of data through the process is clear and has been straightforward to audit
6. We have found no errors of any significance in the calculation of any of the parameters.
7. All the clarification questions and issues have been addressed in an acceptable way.
8. **The industry can have confidence in the Benchmarks, TOC payment rates and SPP thresholds calculated in this work.**

7.2 RECOMMENDATIONS

We have the following recommendations for future Schedule 8 recalibrations based on our experience in carrying out the audit:

- We believe that including an external audit to the calibration process adds value because it encourages the modellers to consider audit requirements in their work and therefore build the quality in at the start. We would recommend that future recalibrations include an external audit, even though it adds to overall project cost.
- The ITT for Schedule 8 recalibration should specify in more detail the requirements for audit trails and visibility of the process. This

would make the audit simpler and therefore cheaper; and would also encourage modellers to build in the audit requirements from the start rather than have to retro-fit them.

- In the NRPR audit, we constructed a test harness to provide an independent check of the model calculations by testing all expected function points. Time pressure meant that we were not able to build a similar harness for the benchmark and TOC PR calculations. However, we are strongly of the view that this type of harness is the best way to guard against calculation errors and would recommend that a set of test data and expected results are prepared and made available to modellers at the time of bid for new recalibrations.

Appendix A Items Reviewed

The tables in this Appendix list the items reviewed as part of the audit.

TABLE 1 REVIEW ITEMS - BACKGROUND AND METHODOLOGY DOCUMENTATION

Item	Document reference	Relevance
Steer Methodology document	Schedule 8 - National Recalibration Methodology (Control Period 6) v0.90.pdf	Overall description of methodology
Benchmark PEARS source data	EA.mdb	Sample TOC input file with MP stops and SG delays data by day
Benchmark MS Access Databases	Benchmark Comparison.accdb, Benchmark Comparison (HB only).accdb, Benchmark Comparison (HA only).accdb	Data processing pipeline for benchmarks
Benchmark model	TOC and NR Benchmark Model v0.90.xlsm	Calculation of Benchmarks
TOC PR Reference data	L_Direction.csv, L_Peak_Defns_Circ.csv, L_Peak_Stations_MFO.csv, L_PkTypeAllTrains.csv, L_Stanox.csv, L_WkendPeaks.csv	Lookup data used in calculation of peak type
TOC PR R script	SPG_PeakTypeAndDirection_v1.0.R	Assignment of peak status to PSS trains in Mileage data
TOC PR Model	TOC PR Model v0.25	The model that carries out the TOC PR calculation
SSP Model	SPP v0.4 Updated Benchmarks.xlsm	Spreadsheet model to calculate SPP

Appendix B Methodology Checks

In this Appendix we list the points of methodology that VRC have checked to have been correctly handled in the various model suites.

B.1 METHODOLOGY CHECKS - BENCHMARKS

In **TABLE 2**, the Reference column refers to the Steer document "**SCHEDULE 8 - NATIONAL RECALIBRATION METHODOLOGY (CONTROL PERIOD 6) V0.90.PDF**" and the Checked In column refers to the item(s) in the modelling suite where we verified the application of the methodology point.

In the Note column, absence of a note means we have confirmed by inspection that the methodology point has been applied in the calculation. A note may refer either to a more in-depth test that VRC have done, an indication of any aspects that we have not checked, or any discrepancies we have observed.

TABLE 2 METHODOLOGY CHECKS - BENCHMARKS

Ref	Methodology point	Checked in	Note
3.5	Average PM using CP5 cancellation minutes and MP weights	Access Database	
3.6	3 sources for lateness - PEARS	Access Database	
	PSS for existing MPs	"Proposed CP6 MPWs v1.0.xlsm"	This is a very large spreadsheet (over 100Mb), making it difficult to check reliably
	Rescale for MPs with no data		

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Ref	Methodology point	Checked in	Note
3.7, 3.8	Daily PEARS MP data	Access database	
3.9	PSS Timings Data	Access database	
3.10	Extension: use nearby MP		
	New services: normalise existing MPs to 1		
3.11	Calculate MP-level values	Access database	
	1E (i) import PEARS data		
	1E (ii) Filter for years		
	1E (iii) Calculate number of periods		
	1E (iv) split by delay proportion		
	1E (v) calculate with CP5 canc mins		
	1E (vi) augment data with CP5 canc mins results		
	1E (vii) Coerce PSS		

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Ref	Methodology point	Checked in	Note
	data into PEARS form		
	1E (viii) Combine PSS data with PEARS		
	1E (ix) Calculate CP6 canc mins and MP weighted values		
	1E (x) export for spreadsheet		
3.12	Transfer to spreadsheet	Benchmark model "TOC and NR Benchmark Model v0.90.xlsm"	
3.18	2E (i) load data		Methodology document suggests that these steps are done in the spreadsheet. In fact they are done in the Access database
	2E (ii) Unaverage AML and DML to give Lateness and Deemed minutes		
	2E (iii) Apply MP weights		
	2E (iv) Sum lateness		

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Ref	Methodology point	Checked in	Note
	minutes and trains by period		
(3.28)	2E (v) Apply berthing offset changes		BO changes are specified to apply from a particular period
	2E (vi) Calculate 1-year and 2-year sums by MP		
	2E (vii) Calculate averages by MP		
	2E (viii) Calculate AML, DML, PM by Service Group		
3.23	Calculated adjustment for CP6 cancellation minutes		
3.28	Calculate l ateness at new MPs		
3.35	Remap service groups		
3.37	Allocate disputed minutes		

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Ref	Methodology point	Checked in	Note
3.40	The TOC-on-TOC contribution to the NR Benchmark is kept constant throughout CP6. It is the average PM suffered by the Victim Service Group within the Recalibration Timeframe.	TOC and NR Benchmark Model v0.90 / NR Benchmark	TOC on TOC uplift factor G118 set to 1.0. Applied to NR AML and NR DL caused by TOC on TOC in G121 and G124.
3.41	The Freight-on-TOC (FOT) contribution to the NR Benchmarks is uplift by 1.255. This is based on an assumption provided to Steer by Rail Delivery Group	As above	Freight on TOC uplift factor H118 set to 1.2550. Applied to NR AML and NR DL caused by Freight on TOC in H121 and H124.
3.42	The Charter-on-TOC (COT) contribution to the NR Benchmarks is uplift by 1.171. This is based on an assumption provided to Steer by Rail Delivery Group	As above	Charter on TOC uplift factor I118 set to 1.1710. Applied to NR AML and NR DL caused by Charter on TOC in I121 and I124.
3.44	Definitions of CRM_P given.		Not within the scope of this review
3.47	The Network Rail Delay per 100km (NRDp100k) trajectory inputs at a TOC-level are applied at a Service Group (SG) through adjusting the TOC-level CRM-P by the following factor:	As above	E146 "Conversion Factor" contains (E141/E139-1) which is (SG-level NRDp100km Actual) / TOC-level NRDp100km Actual minus one I153:N153 contains I132 * (1+E146) which is future TOC NRDMp100 * (1+ the TOC:SG conversion factor) E146 "Conversion Factor" contains (E141/E139-1)

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	$\text{SG-level NRDp100km}_{\text{Future}} = \frac{\text{TOC-level NRDp100km}_{\text{Future}} * (\text{SG-level NRDp100km}_{\text{Actual}})}{\text{TOC-level NRDp100km}_{\text{Actual}}}$		<p>which is (SG-level NRDp100km Actual) / TOC-level NRDp100km Actual</p> <p>I153:N153 contains I132 * (1+E146) which is future TOC NRDMp100 * (1+ the TOC:SG conversion factor)</p> <p>This is the same equation as in the methodology.</p>
3.47	<p>Where</p> <p>TOC-level NRDp100k Actual = The TOC NRDP100km in the Recalibration Timeframe. Where the Recalibration Timeframe is two years then it is an average of the TOC-level NRDp100k 2015/16 and TOC-level NRDp100km 2016/17.</p>	As above	<p>E139 "Base Historic Position" for TOC. The historic position is the TOC NRDMp100 from TOC Trajectories for average of (15/16 and 16/17) if 1617 is in _SelectYear cell, for 1516 if 16 is selected and 1617 if 17 is selected</p>
3.47	<p>and</p> <p>SG-level NRDp100k Actual = The Service Group NRDP100km in the Recalibration Timeframe. Where the Recalibration Timeframe is two years then it is an average of the Service Group-level NRDp100k 2015/16 and Service Group-level NRDp100km 2016/17.</p>	As above	<p>E141 -same set up as for E139 above, but values come from the SG level NRDMp100.</p>
3.47	<p>and</p> <p>TOC-level NRDp100k Future = The NRDp100km at a TOC-level as provided to Steer by Network Rail for each year in Control Period 6.</p>	As above	<p>Row 132, comes from TOC Trajectories, comes from CRM_P model</p>

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3.47	and SG-level NRDp100k Future = The NRDp100km at a Service Group-level as calculated by Steer for each year in Control Period 6.	As above	Calculation outlined above
3.48	The Service Group-level NRDp100km is then applied to the NR proportion of the NR Benchmark using a regression between NR proportion of Actual Minutes Lateness and NRDp100k.	As above	"NR proportion of the NR Benchmark" = row 316 "NR Part of the overall NR AML" in Benchmark Trajectory. Row 316 has the slope and intercept applied to it whereas the other parts don't. "regression between NR proportion of Actual Minutes Lateness and NRDp100k." = the slope E309 and intercept F297 results from step 7.
3.49	We estimate the NR proportion of Actual Minutes Lateness for each Service Group and Period through the following formula: AML NR only = AML NR+TOT+FOT+COT * (Delay Minutes NR) ÷ Delay Minutes NR+TOT+FOT+COT	As above	NR AML Suffered by Cause in row 107 is Delay Minutes _{NR} /Delay Minutes _{everything} row 50 * NR AML Base position E100 ie the base position is multiplied by the ratio between delay minutes for all and delay minutes for NR to give the AMLNR only. This figure then used in the uplift section in step 4 and for Actual Network Rail AML base E305. E305 is then used to calculate the NR part

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			of the overall NR DML directly, and NR part of the overall NR AML indirectly via application of the slope in E307 and E309.
3.49	Where AML NR+TOT+FOT+COT = the recorded, official Schedule 8 NR AML in each period attribute to NR, which includes NR, TOT, FOT and COT.	As above	NR AML Base position E100, this comes from TOC BM and NR Base sheet F65 and F51 ie "Control Period 6 TOC BM and NR Base Position"
3.49	and AML NR only = The estimated AML assigned to just the NR component of the NR AML	As above	E107:J107 - for each cause, the NR part of the AML is calculated according to the ratio between delay minutes for all and delay minutes for NR only as explained above.
3.49	and Delay Minutes NR = The delay minutes attributed to NR	As above	Cell F48
3.49	and Delay Minutes NR+TOT+FOT+COT = The delay minutes attributed to NR, TOT, FOT, and COT.	As above	Cell J48 - the sum of delay minutes for all causes.
3.50	Regression analysis was undertaken to evaluate the relationship between AML NR only and NRDp100km at a Service Group-level; Independent variable (also known as X variable): NRDp100km at a Service Group level	As above	

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	Dependent variable (also known as Y variable): NR proportion of NR AML		
3.51	The regression relationship is determined by an Ordinary Least Squares at a Service Group level. The following model was estimated for each service group.	As above	Ordinary least squares means linear regression
3.51	AML NR only = $a_0 + a_1 \text{NRDP100k}_{it} + \sum_{it}$	As above	Base AML + gradient * difference in Delay Mins + intercept, for each sg and year
3.51	Where: 'i' represented service groups and 't' represented time (Period);	As above	
3.51	Average Minutes Lateness (NR Only) _{it} measured Actual Minutes Lateness (NR only) for Service Group 'i' at time 't'.	As above	
3.51	NRDP100k _{it} measures NRDP100k for Service Group 'i' at time 't'	As above	
3.51	a_1 is the coefficient of the independent variable.	As above	
3.52	In the first stage of the estimation process, we estimated the coefficient of correlation. We found for most Service Groups as high positive correlation between the two variables. The model was then estimated using Ordinary Least Square line for each	As above	

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	<p>service group. The coefficients for 'Route Performance Measure' were generally as we expected i.e. positive and statistically significant at 5 percent level of significance, meaning that the delay in a service would increase average minutes lateness.</p>		
3.53	<p>Where the regression did not provide a good fit we did not apply this to the trajectory calculation. The regression was not appropriate if:</p> <p>the R-squared value was below 70%</p> <p>the historic data was not available due to the large amount of remapping between Service Groups:</p> <p>ScotRail Service Groups: HA05, HA06 and HA08</p> <p>GTR Service Groups: ET12 and ET13</p>	As above	<p>If adjusted R square value in I297 is greater than or equal to 70 (set parameter), and the "Use Regression" dropdown in Control is set to yes, the value of AML that is taken forward is one using the regression; otherwise the value of AML not using the regression is used.</p> <p>Is there an automated way in which the regression is not used if the particular service groups are selected? Or does it rely on the user to set this in Control sheet?</p>
3.54	<p>The Deemed Minutes Lateness is assumed to have the same trajectory as Actual Minutes Lateness. There were no alternative suggestions to this at the Recalibration Working Group.</p>	As above	<p>Row 319 (NR Part of the overall NR DML) is the ratio of AML with regression H316 and AML before uplifts F107 times DML with uplift F124. So both the regression and uplift ratio for AML is applied to DML</p>

B.3 METHODOLOGY CHECKS - TOC PAYMENT RATES
TABLE 7 METHODOLOGY CHECKS - TOC PAYMENT RATES

Ref	Methodology point	Checked in	Note
4.1	Introduction	TOC PR Model v0.25	The definition of TOC Payment Rate being the amount from that a TOC must pay in relation to one of its Service Groups perpetrating disruption on all victim service groups. This matches the functionality of the model up to the point of the sheet O; Outputs.
4.2	Introduction	TOC PR Model v0.25	We can see that the explanation of the use of TOC Payment Rates accurately reflects at a high level the functionality described in section 4.4 and that of the model.
4.4	TOC Payment Rates	TOC PR Model v0.25	We have verified that the formulae in the model carry out the calculations shown in this section for TOC PR, PRC Delay and PRC Cancellations. The definitions of calculation elements in were reviewed and agreed to be correct.
4.5	Example	TOC PR Model v0.25	The illustrative examples of the calculations were reviewed and agreed to be correct.

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4.6	TOC Responsibility Matrix		See Section 5.1.4
n/a	Methodology Completeness		There were some areas where we noted that the methodology should provide more information about the workings of the model and assumptions.

B.4 METHODOLOGY CHECKS – SUSTAINED POOR PERFORMANCE THRESHOLDS

Ref	Checke d in	Note
5.2	<p>There are three steps of calculation:</p> <ul style="list-style-type: none"> Step 1: Service Group Period SPP Step 2: TOC Period SPP Step 3: Annual Periodic Liability TOC 	<p>SPP v0.4 Updated Benchmarks / C; TOC Calculations</p> <p>All carried out in C; TOC Calculations sheet.</p>
5.4	<p>The Service Group Period SPP is calculated as follows:</p> $\text{SPP}_{\text{SG, Period}} = \text{NRBM}_{\text{SG}} * \text{NRPR}_{\text{SG}} * \text{Busyness Factor} * \text{Threshold}_{\text{SPP}}$	<p>As above</p> <p>C; CP6 Start Positions and C; TOC Calculations calculate as follows:</p> <p>SPP Threshold per period col K = 0.1 * Trajectory PM * PR * Busyness Factor. All at Service Group level.</p> <p>Where 0.1 is the Threshold and Trajectory PM = NRBM it can be seen this matches the methodology.</p>

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5.4	<p>Terms above are defined as follows:</p> <p>NR BM_{SG} = Network Rail Benchmark for the Service Group in a year</p> <p>NRPR_{SG} = Network Rail Payment Rate for the Service Group in a year</p> <p>Busyness Factor = A parameter to convert daily NR Payment Rates to a periodic figure. This is a constant value of 28.</p> <p>Threshold_{SPP} = The constant parameter that defines at what deviation from the Benchmarks should the Sustained Poor Performance regime be triggered. This threshold has been set at 20% for Control Period 6.</p>	As above	<p>We are satisfied that the definitions are accurate.</p> <p>However we note that the value that is being calculated, SPP, is not defined, and is named "SPP Threshold" in the model, as well as being referred to as a "cost" in the methodology.</p> <p>A definition statement clarifying the difference between the parameter "Threshold_{SPP}" and the calculated value "SPP Threshold", and that the latter is a cost which acts as a threshold, would be beneficial.</p>
5.5	<p>The TOC Period SPP is calculated as follows:</p> $SPP_{TOC, Period} = \sum SPP_{SG, Period}$	As above	<p>C; TOC Calculations calculates as follows in column M:</p> <p>Sum of all SPP Threshold per Period by year (dropdown at top has already filtered by TOC)</p>
5.6	<p>The Period data is summed across the Service Groups by year to give the annual cost of being 20% above the Trajectory Benchmark across the entire TOC.</p>	As above	As above.

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5.7	<p>Annual Periodic Liability (APL) is provided for the third, sixth, tenth and thirteenth reporting period and gives a moving annual cost of being 20% above the Trajectory Benchmark based on the number of the 13 periods that fell in the previous year (multiplied by that year's rate) and the number in the current year (multiplied by that year's rate). This is done as follows:</p> $\text{APL}_{\text{Year X, Period 3}} = 10 * \text{SPP}_{\text{Year X-1}} + 3 * \text{SPP}_{\text{Year X}}$ $\text{APL}_{\text{Year X, Period 6}} = 7 * \text{SPP}_{\text{Year X-1}} + 6 * \text{SPP}_{\text{Year X}}$ $\text{APL}_{\text{Year X, Period 10}} = 3 * \text{SPP}_{\text{Year X-1}} + 10 * \text{SPP}_{\text{Year X}}$ $\text{APL}_{\text{Year X, Period 13}} = 0 * \text{SPP}_{\text{Year X-1}} + 13 * \text{SPP}_{\text{Year X}}$	As above	<p>C; TOC Calculations calculates as follows in column R, S, T, U:</p> <p>Produces an average period value for each year starting at periods 3, 6, 10 and 13. The average is calculated using SPP/13, however to account for the periods that fell in the previous year, the SPP part is made up of a proportion of the year and the previous year's SPP.</p> <p>For example at period 3, $((10 * \\$M13) + (3 * \\$M14)) / 13$ where 10 periods of previous year and 3 periods of current year make up the numerator.</p> <p>The calculation in the model makes sense however we don't believe the methodology accurately reflects this. Methodology talks about an annual cost and shows the calculation as being a sum of periods without being divided by periods to get a periodic average.</p>
5.8	<p>In the first year of Control Period 6, the APL = $13 * \text{SPP}_{\text{Year X}}$</p>	As above	<p>The calculation in the year 2019 /2020 is altered according to the selection or not of "sloped introduction". Where this has been selected the first year is calculated using $(x * \text{this year SPP at new threshold \%}) + (y * \text{this year SPP at old threshold})$</p>

		<p>This is not shown at all in the methodology and in fact sloped introduction is not explained where it occurs in the parameters sheet either.</p> <p>Where a sloped introduction has not been set, the value is just the SPP Threshold per period and not multiplied up by 13. As in the previous section, the methodology shows this as an annual figure and not a periodic figure as it is in the model.</p>
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Appendix C Issues Raised

This Appendix summarises the issues raised with Steer by the audit team. Issues were raised in a Github repository which meant that Steer could comment on them directly. Read-only access to the Github repository was also granted to RDG so that they could see work in progress.

Num-ber	Title	Area	Severity	Resolved
18	Peak /Off-Peak calculation - direction of travel CQ	TOCPR - R	CQ	Y
19	TOC PR Peak processing - R code logging and checking	TOCPR - R	CQ	Y
20	TOC PR Processing - handling of intermediate peak location	TOCPR - R	CQ	Y
21	TOC PR - Freight and Charter	TOCPR	CQ	Y
22	TOC PR - time attributes of data in PR calculation	TOCPR	CQ	Y
23	Uplift for Freight and Charter in Bespoke benchmark calculations	TOCPR	CQ	Y
24	SSP model - deviations from spreadsheet best practice	SSP	4	Y
25	SSP model - verification of inputs	SSP	CQ	Y

Note - issues 1-17 were raised during the NRPR phase of the work

The Github repository is at

https://github.com/VivacityRail/RDG_PR18_Ph3/issues.