ORR review of the Serco report 'VTISM analysis to inform the allocation of variable usage costs to individual vehicles'

July 2013

Introduction

1.1 This paper provides a summary of the review that ORR and others have completed of the Serco report titled 'VTISM analysis to inform the allocation of variable usage costs to individual vehicles.' In this paper we refer to the report as the Serco report. The report is available on Network Rail's PR13 web site[1].

Background

1.2 Variable track access charges (VTAC), along with all other access charges, have been subject to review as part of setting charges for CP5, which forms part of the periodic review of Network Rail (PR13)[2].

1.3 Changes to variable charges have been considered widely e.g. through stakeholder consultation and by the VTAC development group. The VTAC development group comprises cross industry membership from ORR, Network Rail, ATOC, TOCs, FOCs, and by invitation DfT.

1.4 The variable usage charge or VUC is set to equal the maintenance and renewal costs that vary with traffic. It is significant in scale. In CP4 it represented 75% of charges levied on freight operators and 30% of the charges levied on passenger operators. One of ORR's objectives for the current periodic review has been to make charges more cost reflective i.e. reflective of the impact that users of the network impose on it.

1.5 As part of reviewing variable charges Network Rail commissioned Serco to use the Vehicle Track Interaction Strategic Model (VTISM), to 'inform the allocation of variable usage costs between passenger and freight vehicle types on a national average basis'. This work

[1] http://www.networkrail.co.uk/serco-final-report.pdf

[2] www.rail-reg.gov.uk/pr13

focuses on track damage costs associated with vertical forces (which account for approximately 70% of total track variable costs).

1.6 A working group formed as a sub group to the VTAC development group was involved in setting the broad scope of the work to be undertaken by Serco.

1.7 Serco's analysis uses the VTISM model to establish the relationship between traffic parameters – axleload, unsprung mass and operating speed – and the cost of maintaining the track to meet Network Rail's condition standards.

1.8 The VTISM model was developed for the Vehicle:Track System Interface Committee, Network Rail and the Rail Safety and Standards Board (RSSB) by Serco, DeltaRail and University of Huddersfield (UoH) to permit the analysis of different maintenance strategies on the cost of maintaining the track asset. It was developed from and incorporated existing established models of track damage and degradation.

1.9 The Serco Report was published in March 2013 following review by ORR and wider stakeholders. It concludes that the mass of a vehicle is a more important factor in track damage than had previously been reflected in variable usage charges, while speed is less significant.

Modelling track damage

1.10 In CP4 the element of the VUC relating to vertical forces was set using the following formula:

Equivalent Track Damage $= Ct * A^{0.49} * S^{0.64} * U^{0.19}$ *(per tonne.mile) * GTM*

Where:

Ct = is 0.89 for loco-hauled passenger stock and multiple units, and 1 for all other vehicles

A = Axle Load (tonnes)

S = Operating speed (mph)

U = Unsprung mass (tonnes/axle).

1.11 As part of its review Serco modelled 48 scenarios with varying axle load, operating speed and un-sprung mass and then performed regression analysis to fit a relationship to these runs. It proposed the following equation to represent track damage as a function of these three variables.

Relative damage (per axle mile) *= 0.473.$e^{0.133A}$ + 0.015.**S**.**U** - 0.009.**S** - 0.284.**U** – 0.442*

Where:

A = Axle Load (tonnes), within the range: 5-25 tonnes

S = Operating speed (mph), within the range: 25-100 mph

U = Unsprung mass (tonnes/axle), within the range: 1-3 tonnes

1.12 In order to enable comparison with the CP4 equivalent track damage formula, Serco also derived the power formula shown below.

VTISM power formula *= $A^{1.71}$ * $S^{0.27}$ * $U^{0.31}$ (per tonne.mile) * GTM*

Where:

A = Axle Load (tonnes), within the range: 5-25 tonnes

S = Operating speed (mph), within the range: 25-100 mph

U = Unsprung mass (tonnes/axle), within the range: 1-3 tonnes

GTM = Gross tonne mile.

1.13 However, this had a less good fit to the VTISM data and Serco recommended using the equation set out in 1.11.

1.14 Application of the new formula has a very significant impact on the allocation of variable usage charges to freight. This is because Serco's analysis shows that axle load has a greater impact on track than was previously understood to be the case and it is certain freight trains that carry the highest axle loads.

1.15 **Table A1: The impact of the Serco Report on the average VUC to freight and passenger operators**.

Average charge	Freight (£/kgtm)	Passenger (p/vehicle mile)
Network Rail April 2013 conclusions (no Serco)	1.80	11.6
Network Rail May 2013 with Serco	2.5	10.2
Variance	39%	-12%

Source: Network Rail letter to ORR, 3 May 2013, http://www.networkrail.co.uk/NetworkRailresponsetoORRletter.pdf

ORR Review

1.16 This paper records the review work that we and others have undertaken of the Serco report and how we reached our conclusion that the work is robust and should form a key input into the calculation of variable usage charges for CP5.

1.17 ORR was provided with early sight of a draft report in Mid October 2012 and gave some early feedback to Network Rail on the issues that it might wish to consider further. These were:

(a) Clarification questions on proposed method to review track damage formulae;

(b) Views on the equation used for apportioning civils costs, signalling costs in CP4;

(c) Views on method for defining vehicle operating speed used in other formulae;

(d) Most important issues to be addressed in current review; and

(e) Further research needed and our aspirations for further methods of apportionment.

1.18 At the October VTAC meeting Network Rail issued the draft report and provided an update on findings. Some members of the VTAC group expressed some concern about the complexity of the work and Network Rail indicated that a VTISM training session would be made available. At this session we advised Network Rail that given the significance of the findings we would review and challenge the report.

1.19 Following our initial review of the report and internal discussions we established a series of multidisciplinary workstreams to review the Serco report. These are discussed in the sections below.

Robustness of underlying VTISM model

1.20 As part of developing the scope of the work it had been agreed by the VTAC working group[3], that the VTISM model was the best available mechanism to use in establishing the relationship between track damage and vehicle types.

1.21 VTISM was originally developed by Serco, Delta Rail and UoH. Version 1 of the model was issued in 2007 and there has been ongoing development of it since that time. It is widely used by Network Rail and others, having been used for:

[3] VTAC working group membership consisted of representatives from Network Rail, ATOC, several freight operating companies and ORR. It included several vehicle engineers.

(a) Network Rail estimation of track maintenance and renewal costs for the SBP;

(b) for IEP by DfT and Thameslink;

(c) RSSB work on behalf of the industry;

(d) evaluating whole life costs of track quality improvement methods;

(e) a train mass study;

(f) a whole system costing case study; and

(g) vehicle track interface related studies such as RSSB's project *T807 Track quality sensitivity analysis using VTISM.*

1.22 The model outputs are also an important input to Network Rail's Strategic Business Plan. For instance VTISM was the integral tool used by NR in modelling track renewals and maintenance volumes for the SBP

1.23 As part of PR13, ORR had previously asked the independent reporter Arup to comment on the quality of Network Rail's asset policies and supporting information and the principles embedded in its tier 1 models (VTISM is a tier 1 model) [4] and to audit VTISM [5]

1.24 In relation to data quality, Arup noted that there were some areas for which there was little data available. However Arup concluded that track asset policy was technically robust.

1.25 In relation to the model audit Arup concluded that the suite of VTISM and related models is large and somewhat unwieldy containing a large number of datasets many of which have manual interfaces. They noted that this issue is made more difficult to manage because the model documentation was not completely up to date. Consequently the Reporters were unable to run the entire model but undertook some small scale sample and sensitivity testing which gave confidence that the model was performing as expected. They also noted that Network Rail has a very experienced user of the model who has a good grasp of it despite its scale and complexity. Overall Arup concluded that the model was fit for its role as a tier 1 model.

1.26 VTISM was not developed with the express purpose of informing the allocation of the VUC to individual vehicles. Internal discussions with our engineers supported the view taken by Network Rail and the VTAC working group that the VTISM model was the best available mechanism for Serco to use in its analyses.

[4] http://www.rail-reg.gov.uk/pr13/publications/consultants-reports.php

[5] AO/016 & AO/021: IIP Tier 0 & 1 Model Audits

1.27 Having reviewed Serco's draft report, some members of the VTAC working group raised some concern about the complexity of the Serco work. Network Rail acknowledged that this is a technical area and, as noted above, hosted a workshop on VTISM, run by Serco (one of the developers of the model). One of our engineers attended the workshop and as part of this asked Serco to explain the operation of the VTISM track database and the modelling of maintenance interventions. Our conclusion was that the session provided confidence that the analysis undertaken by Serco is robust.

1.28 Based on these reviews and discussions we concluded that the VTISM model is robust and the best available means by which to allocate relevant variable usage costs to vehicle types.

Specific queries on Serco method

1.29 Alongside discussions on the underlying model we were also considering the analytical methods adopted by Serco. Challenges from economics and vehicle engineering viewpoints covered:

(a) potential use of VTISM for a purpose for which it is not designed;

(b) transparency over fixed constraints and policy choices within the VTISM model;

(c) averaging effects within the model and their potential to bias the analysis;

(d) modelling underpinning the speed function; and

(e) robustness testing at different stages of the modelling (complementarity of results from different VTISM 'modules' feeding the main calculation).

1.30 In discussion Network Rail and Serco provided further explanation and assurances around our principal areas of challenge. It became clear that many of the areas of concern could be addressed with the addition into the report of a clearer and more detailed account of the methodology and process that Serco had employed.

1.31 Network Rail / Serco agreed to make the following changes to the report:

(h) Include more information to justify the use of VTISM for the purpose of developing allocation formulae i.e. that to do so is not beyond its scope and to reference examples where it has been used for a similar purpose;

(i) Note that the cross industry working group agreed that VTISM was the best tool available;

(j) In the interests of transparency set out where Serco had to make manual policy decisions when running VTISM;

(k) Include more text on sample selection to establish that it is representative and include a table showing a breakdown of the different track types included in the sample;

(l) Include more text on the provenance of VTISM, annex relevant documentation that demonstrates that VTISM has been validated / quality assured;

(m) Explain why the percentage fit of track formula to data is close to one; and

(n) Include confirmation that decimal place figures do not imply accuracy to that level on granularity.

The report was subsequently amended to reflect these points.

Statistical Review

1.32 The approach adopted by Serco was of necessity relatively complex mathematically so internal econometricians and colleagues at ITS Leeds [6] were also asked to undertake a high level review the approach to modelling.

1.33 Following this high level review they considered that the overall approach appeared sensible but raised a number of minor technical points e.g. on the number of data points, issues about the use of the quadratic form and the VTISM model parameters. Many of these had already been discussed with Network Rail and Serco and did not change our view that the analysis is robust.

Engineering perspective

1.34 The final element of our review of the report was more practical than theoretical. Our track engineers were asked to review the report and comment on it based on relevant engineering experience.

[6] These were econometricians who have been working with us on benchmarking of Network Rail's costs. The Institute for Transport Studies is a free-standing academic department of the University of Leeds and part of the Faculty of Environment. The Institute's primary purpose is to advance the understanding of transport activity, operations and use, and to develop skills and best practice among transport professionals and decision-makers

1.35 This review noted that VTISM is an industry acknowledged modelling tool and has been used extensively to understand and predict track damage by both Network Rail and by vehicle designers/maintainers/operators.

1.36 Our engineers considered that the range of cases used by Serco was reasonable covering reasonable variations of vehicle speed/load/unsprung mass and also the infrastructure variables. Overall our engineering review concluded that the results detailed in the report (basically that most damage is caused by high axle loads and high unsprung mass) are both sensible and sound and consistent with engineering experience.

1.37 Having reviewed the Serco report from a number of perspectives we concluded that the results were robust and should form part of our evidence base for setting charges in CP5.

1.38 We were also interested in Network Rail's response to the work. It concluded that the work was sound but the implementation should be delayed to the start of CP6 given the large shift in the allocation of costs between freight and passenger vehicles that the results implied. Network Rail's draft price lists were produced in April without taking the Serco report into account.

1.39 We challenged this approach[7] . We also asked Network Rail to produce revised price lists which took this analysis into account. Our PR13 draft determination used these revised price lists.

TTCI review of the Serco Report for Freightliner

1.40 Separately Freightliner retained TTCI to review the report. Transportation Technology Center, Inc. (TTCI) is a wholly owned subsidiary of the Association of American Railroads. It 'provides emerging technology solutions for the railway industry throughout North America and the world' [8].

1.41 TTCI carried out an initial high level review which suggested that the following factors may require additional investigation and could warrant a delay to the process:

(o) The data sampling method to select the routes and their representation of the population of track in the network;

(p) What period was used when calculating average traffic and tonnage. TTCI wanted to know if that period was representative of normal operations;

[7] Our letter can be found at: http://www.rail-reg.gov.uk/pr13/consultations/freight-charges.php

[8] TTCI website

(q) The simulation design uses three operating conditions with four levels for axle load, four levels for speed, and three for unsprung mass;

(r) If there is a correlation between the three vehicles factors (axle load, operating speed, and unsprung mass) – as this could artificially skew the regression analysis;

(s) Further analysis to determine the normality of the residuals and the variation of the fits versus the residuals;

(t) Further review of the underlying data to understand the best-fit lines on the charts illustrated on pages 19-21 of the Serco report; and

(u) Unexpected results at operating speeds of 100 mph under all axle loads considered and at 75 mph under 25-tonne axle loads

1.42 We noted that a number of the questions raised by TTCI had been raised by us previously. We also noted Network Rail's response to these points.

1.43 Network Rail provided a detailed response to TTCI's points in its April 2013 VUC conclusions document. Network Rail note the goodness of fit parameters are not intended to describe the accuracy of the formula (which is a VTISM validation issue) but rather the precision (how well can the formula reproduce the VTISM results).

1.44 Network Rail confirmed Serco used a standard 'least squares fit' to the VTISM results which produced a reasonable fit using the hybrid equation. Compared with the other equations, the hybrid equation has the best correlation and R-squared as well as a normal distribution of residuals with lowest standard deviation of 23% and mean of the residuals closest to zero (i.e. it predicts the VTISM results closest to the target and with smallest spread / highest precision around the target).

1.45 The best-fit lines were established using a standard 'least squares fit' to the VTISM results (i.e. minimising the sum of the squared residual). As stated in section 3.3 of the Serco report, several different forms of equations were trialled (including power, quadratic, exponential and cubic functions) and it was determined that the most appropriate, robust function was a hybrid.

1.46 Network Rail did acknowledge that if unit cost data disaggregated by route type was available then there could be merit in using this to refine the Serco analysis. This information is not however available at the current time.

1.47 Our conclusions on application of the Serco Report in CP5 were not changed by the TTCI review given the work that we had undertaken previously and Network Rail's response to the TTCI report.

Conclusions

1.48 Alongside industry colleagues we were involved in the broad specification of the work that Serco has undertaken on behalf of Network Rail. As part of our wider preparation for this periodic review we also have considered Network Rail's asset policies, asset information and models. In respect of the Serco report we concluded that VTISM is the most appropriate modelling tool to use in this analysis.

1.49 We have undertaken a wide ranging review of the Serco Report that has challenged the approach and methods adopted by Serco. Network Rail and Serco have responded to our questions and Serco has clarified a number of points in its final report. We have also considered the report's conclusions alongside engineering experience and found the two to be consistent.

1.50 We note that others have reviewed the report e.g. TTCI for Freightliner, raising similar questions to our own and that Network Rail has specifically responded to these points and remains of the view that the analysis is sound. We also note that Network Rail and Serco sought to carry out this work in a transparent manner with a high level of industry engagement.

1.51 As a result of our challenge processes we have concluded that the Serco Report is robust and, consistent with our objective of improving cost reflectivity in CP5, we have determined that the results should be applied to access charges specifically the VUC.