Independent Reporter A

Reporter Mandate – Variable Usage Costs

Final Report

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Contents Amendment Record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Initial
0	1	Draft Report compiled	16/11/07	PRE/RS
0	2	Draft Final Report	20/12/07	PRE/RS/MG
1	0	Final Report for Comment	14/01/08	PRE/RS/MG
1	1	Final Report with ORR comments incorporated	19/01/08	PRE/RS/MG
1	2	Final Report	12/02/08	PRE/RS/MG

Content

1 Introduction

1.1 Details of Review

1.1.1 As part of its role as Independent Reporter, Halcrow has been appointed jointly by Network Rail and ORR to undertake an assessment of Network Rail's variable cost estimates which will be reflected in CP4 variable usage charges. ORR has given Halcrow a remit to review the following key elements of Network Rail's cost assumptions:

- Carry out an assessment of the accuracy of the approach used by Network Rail to forecast cost variability
- Carry out an assessment of the accuracy of the overall level of cost variability. This should be viewed in the context of the growth in traffic forecast by Network Rail by the end of CP4.
- Carry out an assessment of the accuracy of Network Rail's estimates of variability by asset type e.g. Plain Line track renewal, S&C track renewal etc.
- Carry out an assessment of the relative variable costs of freight and passenger traffic.
- Carry out an assessment of variability of cost by geographical area in particular Scotland versus England and Wales, and by type of route, e.g. Primary, Secondary, Freight etc.
- Carry out an assessment of the variable usage charge model by vehicle type, in particular the implications of the new lateral forces term.
- Carry out a comparison of Network Rail's estimates of cost variability with the findings of earlier work carried out by Booz Allen Hamilton, and in particular the differences in the variability estimates by asset type.
- Carry out an assessment of the accuracy of Network Rail's estimates based on experience from the UK and elsewhere to identify if costs are too high or too low and the degree to which this is the case.
- Where cost estimates are not thought to be robust, identify the key issues for Network Rail to address to identify robust cost estimates.

1.1.2 Our review has been largely focussed on the methodology and analysis underpinning Network Rail's estimates. Version 2 of Network Rail's Infrastructure Cost Model (ICM) has been presented to the Office of Rail Regulator and a review of the key changes from ICM V1 to ICM V2 is included in our report.

1.1.3 In conducting our review we have had a number of meetings with both ORR and with Network Rail. In addition we have also met with TTCI and Alstom. A full list of meetings is given in Appendix A.

1.2 Background

1.2.1 A key element of the track access charges is the structure and level of variable usage charges. A key principal in the determination of variable usage charges is that they should reflect variable costs. A good understanding of variable costs is therefore important to setting variable charges. The purpose of this mandate is for the Reporters to assess the accuracy and reasonableness of Network Rail's estimates of variable usage costs.

1.2.2 Variable usage costs are costs associated with the impact of incremental traffic and assume that the existing capacity and capability has to be maintained anyway. Therefore, the estimated costs are those which increase as a result of additional traffic and are not driven by factors such as age, operational flexibility requirements or whole life cost optimisation.

1.2.3 More specifically, variable costs are the incremental maintenance and renewal costs incurred by passenger and freight traffic. Existing variable usage charges are based on the following approach developed at Periodic Review 2000 (PR2000):

- Costs of assets judged to be variable with usage are established first;
- These costs are then allocated between vehicle types based on the vehicle characteristics that impact on cost, for example vehicle weight and speed.

1.2.4 PR2000[1] identified some key areas which could be developed to provide better reflectivity of costs, namely:

- A better understanding of vehicle characteristics and their potential to cause wear and tear to the infrastructure,
- A fairer distribution of charges if route based charging were introduced rather than relying on network averages; and
- The level of track and vehicle maintenance (not taken further at present).

1.2.5 As part of the structure of costs and charges review 2005[2] (SOCC2005), Booz-Allen-Hamilton (BAH) were appointed to assess variable usage and electrification asset usage charges. BAH sought to build on the work done for the 2000 periodic review and apply this to the improved cost data available from Network Rail.

1.2.6 BAH considered the following enhancements to the model:

- The use of more detailed cost data (e.g. activity based maintenance costs) to support the analysis.
- The inclusion of a rail surface damage caused by horizontal (or tangential) track forces.
- The inclusion of an electrification asset usage charge in the model (rather than being calculated as a mark-up on the traction electricity charge).

1.2.7 BAH concluded that, at that time, the information available was still not sufficiently robust to warrant a change in variable usage charges. They reported that there was insufficient information available to support a better estimation of long run efficient costs and the relative proportion of these costs which are usage related and how they disaggregate down to routes or local level.

Periodic Review 2008 (PR08)

1.2.8 Network Rail's approach to estimate variable costs for the next periodic review (PR08) has been to use the Infrastructure Cost Model (ICM) to model the impact on costs generated by changes in traffic. The ICM includes a number of cost elements that change with traffic (such as track maintenance, track renewals).

1.2.9 Network Rail's approach to allocate the variable costs estimated is to determine the characteristics of the vehicle types by their impact on track and structures. For track the allocation has been made by looking at both vertical and lateral forces and introducing a new term, using a rail surface damage (RSD) term. This is discussed in section 5.

1.2.10 Network Rail have made an initial estimate of variable costs based on the ICM and where data from the ICM was not available, expert judgement was used.

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[1] Details of PR2000 available on ORR's Website at http://www.rail-reg.gov.uk/server/show/nav.165

[2] Details of SOCC2005 available on ORR's Website at http://www.rail-reg.gov.uk/server/show/nav.176

1.2.11 We reviewed Network Rail's initial variable cost estimates in December 2006[3], with an update in February 2007[4]. We recommended that Network Rail do further work to justify their estimates in particular highlighting concerns over track renewals variability. Following this work we undertook further analysis of the service life of track assets[5].

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[3] Independent Reporter A - Reporter Mandate - Freight Cost Variability - Final Report, December 2006
[4] Independent Reporter A - Reporter Mandate - Freight Cost Variability Addendum 1 to Final Report, January 2007
[5] Independent Reporter A - Track Service Life Project Final Report, April 2007

2 Network Rail’s approach to variable usage costs

2.1 Network Rail’s variable cost modelling methodology

2.1.1 In developing their estimates of variable costs, Network Rail have relied on two elements of analysis:

- Use of the Infrastructure Cost Model (ICM) for calculation of maintenance and renewal costs. The ICM contains estimates of long term costs by asset type for each Strategic Route Section (SRS), based on assumptions regarding asset life derived from asset type, usage and asset management policy. Each SRS is differentiated by route type[6].
- Adjustment of the ICM costs to separately identify variable costs that are not subject to detailed modelling and adjust costs to be more reflective of local variations.

2.1.2 In the following sections we discuss the overall approach adopted, considering first the key assumptions and method for cost allocation used for the major cost elements (covering both ICM calculations and subsequent adjustments in more detail) and then the specific adjustments made to the costs extracted from the ICM to calculate variable usage costs.

2.2 Network Rail’s modelling of Variable Costs

2.2.1 Network Rail’s modelling of variable costs is based on a bottom-up assessment of the impact of usage on asset degradation, which leads to activity increments and incremental costs. Modelling this using ICM provides a bottom-up approach which can be refined with expert assessment.

2.2.2 Network Rail’s approach has been to use the capability of the ICM for initial “bottom-up” analysis of the variability of costs with systematic changes in the level of traffic and supplement this analysis with expert assessment of the elements of their cost base which are known to be variable with traffic.

2.2.3 ICM has been set up to model a range of maintenance and renewal activities in detail and the level of traffic is a key input to the modelling process. The impact of traffic on costs is predominantly associated with track maintenance and renewal activity, with 44% and 46% of the total variable cost respectively. See Appendix B which shows a Flow Chart for the variable usage charge process.

2.2.4 For the non-track activities which have a variable cost component, including Civils (Metal Underbridges and Embankments) and Signalling, the variable costs are calculated outside of ICM using the total expenditure from ICM factored by the BAH SOCC 2005 variability assumptions. Together these components make up the remaining 10% of the variable cost.

2.2.5 It can be seen from this Flow Chart that the variable cost estimates from the ICM feed into the TTCI vehicle damage model to produce the variable usage charges. This is discussed further in section 5.

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[6] Each Strategic Route Section within ICM has a route classification – Primary; London and South East; Secondary; Rural; Freight

2.3 ICM Developments

2.3.1 Network Rail have developed a version 2 of ICM to incorporate a range of modifications in the way in which costs are modelled. The major improvements within version 2 of the ICM have related to the overall structure of the model, and the modelling method used for track maintenance and renewals. Version 2 of the model predicts the impact of different levels of traffic usage that can be accommodated within the current network capacity and capability.

2.3.2 There have been many changes since ICM Version 1 driven by the need for better reflectivity of costs and the changes in Network Rail's Strategic Business Plan particularly related to its policies for track asset management. Examples of developments in Version 2 are given as follows:

- Network Rail have considered track costs over 3,000 sections of track. For these sections they have modelled costs over a 35 year period from CP4 to CP10 inclusive for each Strategic Route Section.
- Track Maintenance activities have been expanded to provide a more accurate reflection of costs.
- Track Renewals assumptions have been changed by a more sophisticated approach to track service lives and how these influence the modelled volumes of track renewal
- A 'piecemeal' renewal approach has been introduced for those lines which are chosen (or 'opted out') because of a more focussed strategy on the lightly used Rural and Freight Only lines. This approach models the individual spot renewal of components on 'opted out' lines instead of the 'composite renewal of track system' approach which has traditionally been applied to these lines.
- Route Classifications have been reviewed and consolidated into Primary, Secondary, Rural & Freight to reflect new Strategic Business Plan strategies.
- The assumptions previously made for Freight Only lines costs have been reviewed and updated.

3 Cost Modelling Elements

3.1 General

3.1.1 The impact of traffic on costs is predominantly associated with track maintenance and renewal activity. Changes in the level of traffic affect specific activities in the ICM including:

Track Maintenance

- Inspection and ultrasonic testing
- Rail changing, spot resleepering, part replacement of S&C units, S&C bearers and insulated joints
- Geometry correction: tamping, stoneblowing and manual correction
- Rail grinding
- Wet bed removal, weld repairs and ballast profiling

Track renewals

- Rail, sleepers, ballast and S&C

3.1.2 However, there are a number of elements of cost which are known to be variable with traffic, but where usage relationships have not yet been incorporated in the ICM, either because of the difficulty of specifying and validating the necessary algorithms, or because of the relatively low profile. These include, for example:

- Electrification contact equipment – wear of third rail and OLE contact wire;
- some Signalling maintenance activity; and
- Underbridges – fatigue impact of traffic loading, particularly for metallic bridges.

3.1.3 For ICM V2, Network Rail have considered Track Maintenance and Track Renewals over 3,000 sections of track. For these sections they have modelled costs over a 35 year period from CP4 to CP10 inclusive for each Strategic Route Section (SRS). It would be appropriate to consider the whole service life of track assets when modelling cost, this is likely to involve a period longer than 35 years.

3.2 Track Maintenance

3.2.1 The key activities that drive changes in track maintenance variability costs are shown below. Network Rail have calculated that the variability of costs with respect to traffic is around 29% of total track maintenance costs.

Maintenance Activities	£/kgtkm (2006/07 prices, pre-efficiency)	Cost variability
Ballast reprofile	0.01	76%
Wet bed removal	0.01	17%
Manual geom correction	0.02	85%
Plain Line tamping	0.06	76%
Stoneblowing	0.01	98%
Manual geom correction	0.02	113%
Vis Inspection Basic	0.03	15%
Vis Inspection Super	0.00	3%
Ultrasonic - Manual	0.01	17%
Ultrasonic - Train based	0.08	49%

Maintenance Activities	£/kgtkm (2006/07 prices, pre-efficiency)	Cost variability
Geometry - train based	0.00	38%
Other	0.21	30%
Rail change	0.03	70%
Rail transpose	0.05	70%
Rail change due to defects	0.04	70%
Weld repairs	0.01	70%
Grinding	0.08	86%
Rail adjustment	0.00	127%
Fish plate lubrication	0.00	-2%
Insulated Block Joint replacement	0.00	-41%
Half set replacement	0.01	33%
Crossing replacement	0.02	30%
Crossing weld repair	0.00	16%
Replace timber bearers	0.01	26%
S&C tamping	0.04	88%
Manual S&C geometry correction	0.00	79%
Re-sleeper (reactive)	0.02	21%
Replace pads and insulators	0.01	7%
Total	**0.78**	**29%**[7]

Figure 3.2.1 £/kgtkm and cost variability by maintenance activity

3.2.2 The number of Track maintenance activities has been expanded so that 62% of the costs are now modelled (which is a significant increase over version 1 of the ICM). The negative numbers shown above indicate a nil effect on variable costs. However, some activities need to be checked as small and negative percentages of variability are not expected for items that are clearly influenced by traffic (IBJ replacement, Rail Pads and insulators etc.). IBJ replacement in particular is modelled at half life replacement to plain rail, (Functional Specification refers) so the variability percentage must be the same as Rail Changing.

Unit Rate of Track Maintenance activities

3.2.3 Track maintenance costs are sensitive to their unit cost rate which is a national average rate. Network Rail have established a recording framework for these activities and is building up data to progressively improve the quality of the data used. Network Rail have produced an ‘inputs log’ for the Strategic Business Plan which includes their assumed unit rates. Again, these activities and unit rates are based on actual work rather than bottom up estimates.

Commentary on Modelling Approach

3.2.4 Before the maintenance activities are modelled, ICM calculates the renewal volumes for the CP4 control period first, updating the asset data to take into account of what has been renewed. The maintenance for CP4 is then evaluated as described below.

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[7] The calculation of the 29% includes all maintenance activities, including those which have not cost variability.

3.2.5 The volumes of maintenance activity for each year are calculated by SRS and then totalled. The cost is calculated by multiplying the unit cost of the activity by the volumes. A cost factor is then applied to cover all other direct track maintenance activity, covering a large number of relatively minor activities which are not explicitly modelled.

3.2.6 The number of rail defects for plain line and S&C is calculated using the formula:

$$\text{Track Km} \times \text{Usage} \times \text{Cumulative Tonnage}^{m} \times \text{Age}^{n}$$

(Where m = tonnage parameter and; n = age parameter)

Where Cumulative Tonnage = usage x service life in years x % service life used.

This defect volume is used to feed into some of the maintenance activities.

3.2.7 The following table describe Network Rail's approach for the 35 No. maintenance activity types under the activity headings; Inspections, Rail, Sleepers, Ballast and S&C.

Activity	Activity Type	Description of Unit Calculation
Inspections	Visual Inspection	Defined frequency (from Standards) by Track category and rail type. This is multiplied by the volume of track km.
	Ultrasonic – Manual	Defined frequency (from Standards) by Track category and rail type. This is multiplied by the volume of track km.
	Ultrasonic - Train based	Defined frequency (from Standards) by Track category and Route Classification. This is multiplied by the volume of track km.
	Geometry - train based	Defined frequency (from Standards) by Track category and Route Classification. This is multiplied by the volume of track km.
Rail	Rail change	Curved rail changed at half life due to side wear x proportion changed by Route classification.
	Rail transpose	Curved rail changed at half life due to side wear x proportion changed by Route classification.
	Rail change - defects	Internal defects x KM renewed per defect x proportion changed by Route classification due to defects.
	Weld repairs	Internal defects x proportion repaired by Route classification due to defects.
	Grinding	Track km based on a defined EMGT passed over track.
	Lubrication	For curved track: frequency per year * lubricators per track km.
	Rail adjustment	For jointed track on softwood sleepers: Track km based on a defined EMGT passed over track.
	Fish plate lubrication	Annual frequency on jointed track x track km.
	Insulated block joint replacement	Number of IBJs on a section when rail reaches half service life.
Sleeper	Re-sleeper (reactive)	Track km on a section when sleeper reaches half service life.
	Replace pads and insulators	Track km on a section when sleeper reaches half service life.
	Long timber	Percentage maintained per year * track km of longitudinal timbers
Ballast	Ballast reprofile	Percentage of track km re-profiled as part of tamping process.
	Wet bed removal	Number of bays of wet beds removed per km @ 100% x current ballast service life usage after a defined service life point that wet beds start to occur.
	Tactical reballast	Annual percentage of track km by Route classification.

Activity	Activity Type	Description of Unit Calculation
	Plain Line Tamping	Track km based on a defined EMGT passed over track by Route classification and rail type. The activity is linked to stone blowing with either activity happening either side of a point in the asset service life. For example a section of CWR primary track will be tamped every 30 EMGT until 80% of its service life followed by stone blowing every 30 EMGT.
	Plain Line Tamping (weakbanks)	Additional tamping percentage for weak banks.
	Stoneblowing	Track km based on a defined EMGT passed over track by Route classification and rail type. The activity is linked to tamping with either activity happening either side of a point in the asset service life. For example a section of CWR primary track will be tamped every 30 EMGT until 80% of its service life followed by stone blowing every 30 EMGT.
	Geometry - manual	Similar to tamping and stone blowing on certain tertiary routes.
S&C	Half Set Replacement	Number of units replaced based upon points in S&C service life.
	Crossing Replacement	Number of units replaced based upon points in S&C service life.
	Switch Weld Repair	Number of switches having weld repair based upon points in S&C service life.
	Crossing Weld Repair	Number of crossings having weld repair based upon points in S&C service life.
	Replace Timber Bearers	Average number of bearers replaced per year * number of S&C units. This is triggered after a certain point in the S&C unit service life.
	S&C Tactical Ballast	Percentage of S&C units re ballasted per year by Route classification.
	S&C Tamping	Based on line speed and bearer type tamping happens at certain EMGT trigger points.
	Manual S&C geometry correction	Based on line speed and bearer type manual correction happens at certain EMGT trigger points instead of tamping.

Figure 3.2.2 Maintenance Rules

3.2.8 Using this methodology, ICM V2 has modelled the cost over CP4 to CP10. The total cost of the 'core' maintenance activities are summarised below for CP4 and CP5.

Costs (£m 2006/07 prices)	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19
Inspections	64.5	62.3	60.6	59.3	58.7	57.8	56.7	55.6	54.6	53.6
Rail	45.0	42.3	40.3	39.3	39.3	38.9	37.3	36.1	35.3	34.4
Sleeper	74.2	64.2	59.4	56.0	53.9	52.4	49.4	47.2	44.8	42.6
Ballast	17.0	15.7	14.9	14.3	13.9	13.5	13.1	12.8	12.4	12.0
Geometry	17.2	15.5	15.7	15.7	15.9	15.8	16.7	17.1	15.9	16.8
S&C	31.6	29.9	27.8	26.9	27.5	26.3	25.7	25.4	24.5	26.3
Core Activity Total	**249.5**	**229.9**	**218.7**	**211.5**	**209.2**	**204.7**	**198.9**	**194.2**	**187.5**	**185.7**

Figure 3.2.3 Maintenance Activity Costs for CP4 and CP5

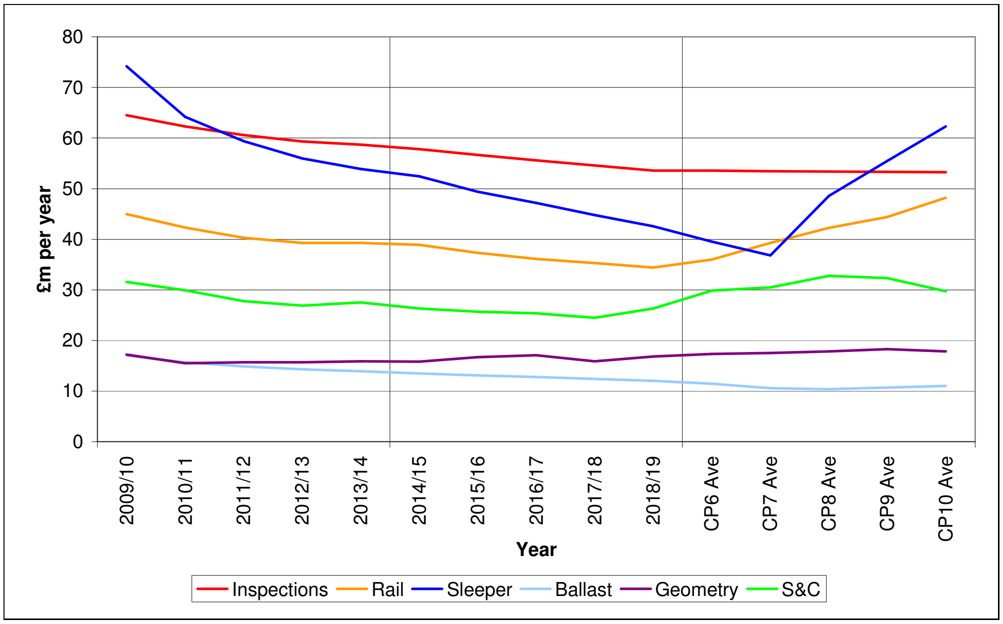

Figure 3.2.4 Core Maintenance Activity Costs for CP4 and CP5

3.2.9 The above chart shows maintenance costs are forecast to fall over this 10 year period. Sleeper renewal has the biggest decrease which in part is due to wooden sleepers being replaced with more robust replacement components. However, the increase in sleeper costs in CP8 to CP10 cannot be easily explained without further work by Network Rail.

3.2.10 The decrease in rail is less dramatic, as a high proportion of re-railing has been traditionally carried out as part of rail renewals, therefore the shift has less of an impact.

3.2.11 The decrease in inspection cost reflects Network Rail's efficiency proposals to reduce patrolling frequencies on the Continuously Welded Rail (CWR) lines which reduces patrolling resource costs by around 4%. Network Rail also plans to benchmark patrolling frequencies against other European rail systems that for some lines have less frequent patrolling frequencies on lines with a high standard of track specification. However, we believe that additional train-borne inspection and the inspection of Switches & Crossings maybe more costly with a new enhanced inspection regime planned and therefore we are yet to be convinced that these additional costs have been factored in.

3.3 Track Renewals

3.3.1 Specifically for track renewals, Network Rail have considered the service lives of the track asset types, namely Rail, Sleepers, Ballast and Switches & Crossings in order to model the volumes of track renewal for CP4 in accordance with their renewal strategy and policies.

3.3.2 Network Rail have created sub-divisions of the Rail, Sleepers and S&C asset types using 'simplified GEOGIS' categories so that it can apply a more specific approach that reflects its' track renewal policy as stated in the Strategic Business Plan (SBP) document.

3.3.3 The 'simplified GEOGIS' categories are as follows:

Asset Type	Simplified GEOGIS Categories
Rail	Plain Line CWR – pre 1975
Rail	Plain Line CWR – post 1975
Rail	Plain Line Jointed
Sleepers	Concrete/ Hardwood – pre 1979 – Non-Preferred
Sleepers	Concrete/ Hardwood – pre 1979 –Preferred
Sleepers	Concrete/ Hardwood – post 1979
Sleepers	Softwood – Bullhead
Sleepers	Softwood – Flatbottom
Sleepers	Steel
S&C	Vertical
S&C	Inclined

Figure 3.3.1 Simplified GEOGIS Categories

3.3.4 Network Rail considers that the criteria for track renewals will follow that stated in their Strategic Business Plan (SBP) and Track Asset policy document and that timing of each renewal will broadly follow the service lives they have determined within each of the asset types/'simplified GEOGIS' categories.

3.3.5 Also in line with the SBP, Network Rail have reassessed its composite renewals strategy. Network Rail have asked the Territories to identify routes where they could 'opt out' of composite renewals and apply a 'piecemeal renewal' approach. This would typically apply to Rural and Freight Only routes with a low Track Category and very low annual tonnages.

3.3.6 Network Rail's strategy for renewing complete Switches & Crossings (S&C) layouts has generally not changed, however some refurbishment works (partial S&C renewals) have been added to extend service life on Secondary Routes. S&C has been sub-divided into two categories, Inclined and Vertical. For re-railing, a general assumption has been made that the service life of rail is reduced to 51% for curves sharper than 2500m radius.

3.3.7 Network Rail have calculated that around 25% of Plain Line Renewal costs and 17% of S&C Renewal costs are variable with traffic.

Commentary on Modelling Approach

3.3.8 We make the following observations on Network Rail's modelling approach:

Track Asset Service Life

3.3.9 Network Rail published the following table of Track Asset Service lives (years) in their Track Asset Policy document dated 30th June 2006.

Cat	CWR	Jointed Rail	Hardwood Sleepers	Concrete Sleepers	Softwood Sleepers	Steel Sleepers	Slab track	Ballast	S&C
1A	30	40	30	35	35	30	35	25	25
1	30	40	30	35	35	30	35	25	30
2	40	40	40	40	35	40	40	40	35
3	45	40	45	45	35	45	45	45	40
4	50	45	50	50	40	50	50	50	45
5	70	60	50	55	40	50	55	60	50
6	70	60	50	65	40	50	65	65	60

Figure 3.3.2 'Leiden' Track Service life (years) table published in June 2006

3.3.10 However, since this time, Network Rail have further studied and consulted on the appropriateness of their service life assumptions. The result is that this table has been adjusted to reflect the new Strategic Business Plan policies and strategies in order to apply the new adjusted service lives so that they can be extrapolated to provide input to ICM V2.

Track Cat	Average EMGTPA	CWR	Jointed Rail	Concrete Sleepers	Softwood Sleepers
1A	25	(30)	40 (**25**)	(35)	35 (**20**)
1	Not averaged	30	40	35	35
2	11	(40)	40 (**35**)	(40)	35 (**30**)
3	Not averaged	45	40	45	35
4	3	50	45	(50)	40 (**35**)
5	Not averaged	70	60	55	40
6	2	70 (**100**)	(60)	65	40

Notes:
Figures in normal font are original Leiden values
Figures in bold are adjusted values
Figures in brackets are used in the ICM

Figure 3.3.3 Adjusted Track Service life (years) table

3.3.11 Using the above table, Network Rail have selected appropriate service lives to determine the service life curves for the asset types (CWR, Jointed Rail etc.). These asset types have then been sub divided into the 'simplified GEOGIS' categories as stated earlier.

3.3.12 The 'simplified GEOGIS' categories have been developed to reflect the various strategies they wish to apply to these asset types. For example, pre 1975 manufactured rail has a higher risk of failure and will have a reduced service life in terms of its Equivalent Million Gross Tonnes Per Annum (EMGTPA) when compared to post 1975 rail.

Asset Type	Simplified GEOGIS Categories	EMGTPA				
		0	2	3	11	25
Rail	Plain Line CWR – pre 1975	100	100		40	30
Rail	Plain Line CWR – post 1975	100	100		45	35
Rail	Plain Line Jointed	60	60		35	25
Sleepers	Concrete/ Hardwood – pre 1979 – Non-Preferred	60		40	35	30
Sleepers	Concrete/ Hardwood – pre 1979 – Preferred	75		50	40	35
Sleepers	Concrete/ Hardwood – post 1979	90		60	45	40
Sleepers	Softwood – Bullhead	40		35	30	20
Sleepers	Softwood – Flatbottom	40		35	30	20
Sleepers	Steel	75		50	40	35

Figure 3.3.4 Track Service life (years) for 'Simplifed GEOGIS' categories table

3.3.15 Network Rail have derived service life curves by multiplying an assumed average Equivalent Million Gross Tonnes Per Annum (EMGTPA) for each track category by a selected exponent for each asset type.

Formula is: Constant x (EMGTPA^ Exponent)

3.3.16 Halcrow have independently used a recognised industry formula taken from W.W.Hay's 'Railroad Engineering' to check the rail life assumptions that Network Rail have made. This comparison is based on the 'fixing' of the W.W.Hay curve at the 25 EMGTPA points that Network Rail have used, for both Plain Line CWR rails and Plain Line Jointed rails at 35 years and 25 years respectively.

3.3.17 This shows that jointed rail will last longer with a reduced EMGTPA and CWR life is less with a reduced EMGTPA. However this is determined from the W.W.Hay exponent 0.565 whereas Network Rail have used 0.503. The shape of the curve and the appropriateness of the exponent are determined by testing the engineering judgements made against the behaviour and treatment of particular rail systems. Given the margin between these two comparisons we can conclude that the Network Rail curves will have their own variations which can be explained, but generally follow a similar curve to W.W.Hay's formula.

3.3.18 The W.W. Hay formula and computations which has been used for this comparison are shown in Appendix E. The chart below shows how this compares to Network Rails curves.

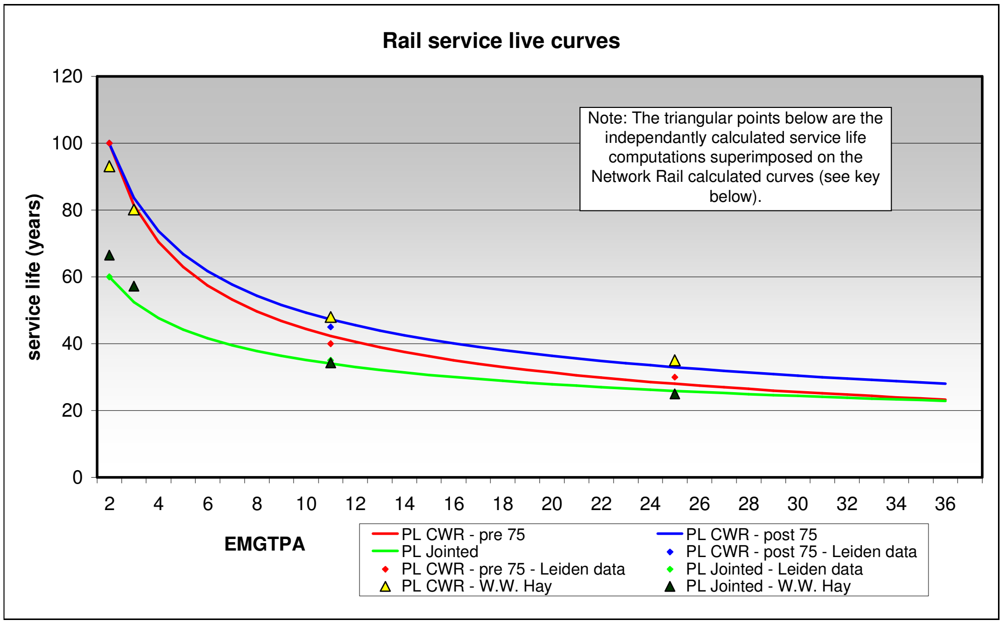

Figure 3.3.5 Rail Service life curves (EMGTPA) for 'Simplified GEOGIS' categories

3.3.19 However, we have reservations about the use of the same constant and exponent (and therefore same shaped service life curve) for rail below 2500m radius as for flatter radii. As stated previously, a general assumption has been made that service life is halved on curved track with a sharper radius than 2500m. However we feel a more accurate approach is achievable by selecting the most appropriate constant and exponent for the two ranges of curved track.

Asset-Type	Sub-Type	Constant	Exponent
Rail	PL CWR - pre 75, below 2500m radius	141.533	0.503
Rail	PL CWR - pre 75, any higher radius and straight	141.533	0.503
Rail	PL CWR - post 75, below 2500m radius	135.366	0.439
Rail	PL CWR - post 75, any higher radius and straight	135.366	0.439
Rail	PL Jointed below 2500m radius	75.650	0.333
Rail	PL Jointed, any higher radius and straight	75.650	0.333

Figure 3.3.6 Rail Service life curves Exponents for 'Simplifed GEOGIS' categories

3.3.20 As previously stated, Network Rail have reassessed their composite renewals strategy and have asked the Territories to select routes for which they wish to 'opt out' of composite renewals and apply a 'piecemeal renewal' approach.

3.3.21 The Territories collectively have selected 324 No. track sections (out of the total 3,400 sections of track) that they wish to 'opt out'. These are generally Rural and Freight Only routes with a low Track Category and very low annual tonnages.

Territory	Track Sections
South East	68
LNE	85
Western	47
LNW	71
Scotland	53
Total	**324**

Figure 3.3.7 Summary of 'Opted Out' track sections by Territory

3.3.22 For those sections of track that are 'opted out', there is a continual 'piecemeal' renewal policy of individual track components as and when required, rather than composite renewal of rail, sleepers and/or ballast. The following tables are used to determine the average service life of individual track asset types.

Asset type	Sub Asset type	% per year
Rail Replacement	All	1.00%
Sleeper Replacement	Concrete/Hardwood - pre 1979 - Non-Preferred	0.20%
Sleeper Replacement	Concrete/Hardwood - pre 1979 - Preferred	0.10%
Sleeper Replacement	Concrete/Hardwood - post 1979	0.10%
Sleeper Replacement	Softwood - Bullhead	2.50%
Sleeper Replacement	Softwood - Flatbottom	2.50%
Sleeper Replacement	Steel	0.10%

Figure 3.3.8 Average 'Piecemeal' Renewal frequency for 'Opted Out' Sections

3.3.23 There is an additional overlay for renewal works on routes that have opted out, if it is known this will be carried out during CP4.

3.3.24 Sleeper Replacement assumes some extreme examples of longevity (0.10% equals once in a thousand years). As both Concrete and Hardwood sleepers laid in since the introduction of both will not exceed 100 years in the control periods being modelled. Therefore a more appropriate percentage could be applied even though it would not have any effect until successive control periods are modelled.

3.3.25 The continual 'piecemeal' renewal policy does not include ballast and this omission presumably is based on the marginal need to replace ballast on some rural and freight only lines. However a percentage of reballasting (or perhaps composite renewal including reballasting) should be allowed as spillage and formation failure will contaminate ballast sufficiently to affect the condition of components and track geometry such that some remedial action will be necessary. Particularly as there is now a mechanism to recover the cost of treating coal spillage sites, through the 'Coal Spillage Charge'.

3.3.26 We are concerned by the negative values in the modelling results. We understand from Network Rail that they would expect negative values due to reducing maintenance as a result of early renewal. However, as can be seen from the table below, the SRSs with the highest negative values have this negative within the renewals variable costs.

SRS	SRS Name	Route Class	Max line speed (mph)	Section KM	% Opted out	Total MGT km	Variable Cost (£m)		
							Track renewal plain line	Track renewal S&C	Track Mtce
08.09	Newcastle - Border	Primary	125	228	0%	1,747	-2.87	0.16	1.30
07.05	Shenfield - Southend Victoria / Southminster	London & SE	80	97	0%	518	-1.38	-0.00	0.45
12.03	Exeter St Davids - Plymouth	Primary	100	173	0%	890	-1.48	-0.13	1.03
08.05	Doncaster - Holbeck W Jcn	Primary	100	89	0%	924	-0.53	-0.00	0.26
24.11	Other freight	Freight	40	58	42%	158	-0.39	0.00	0.09
26.14	Gretna Jn - Scottish Border	Secondary	80	13	100%	117	-0.21	0.00	0.04
16.03	Aylesbury - Great Missenden	London & SE	75	41	0%	52	-0.20	0.00	0.07
02.04	Three Bridge - Littlehampton Jcn	London & SE	85	99	0%	474	-0.20	0.00	-0.19
12.06	Paignton Branch	Secondary	60	28	0%	32	-0.28	0.00	-0.09
11.07	Black Carr - Trent Jcn	Secondary	70	60	0%	83	-0.28	0.00	-0.01
11.03	South Kirkby Jcn - Swinton	Secondary	100	29	0%	183	-0.01	-0.08	-0.09

Figure 3.3.9 - Variable Cost by SRS for negative values

3.3.27 We are also concerned as to why the results from the model are showing that some of the SRSs that are 100% ‘opted out’ still have a variable cost for track renewal. The table below shows a total of £0.22m in variable cost for track renewals. Although this may not be a significant amount, it raises concerns regarding the modelling methodology.

SRS	SRS Name	Route Class	Max line speed (mph)	Section KM	% Opted out	Total MGT km	Variable Cost (£m)		
							Track renewal plain line	Track renewal S&C	Track Mtce
11.16	Immingham and Killingholme Docks	Freight	40	4.09	100%	106	0.12	0.00	0.00
25.02	West Highland Line	Rural	70	290.05	100%	174	0.10	0.00	0.00
17.23	Stourbridge Branch	Secondary	20	1.16	100%	3	0.06	0.00	0.00
09.09	Blyth and Tyne Network	Freight	45	56.58	100%	53	0.03	0.00	0.00
13.24	Freight Lines (Wales)	Freight	20	22.84	100%	11	0.03	0.00	0.00
23.06	Roses Line and Branches	Rural	70	204.83	100%	149	0.02	0.00	0.00
20.12	Blackpool North and South Branches	Rural	75	74.14	100%	173	-0.02	0.00	0.00
12.14	Freight Lines	Freight	40	43.38	100%	86	-0.04	0.00	0.00
20.14	Southport / Kirkby - Wigan Wallgate	Rural	70	85.41	100%	65	-0.08	0.00	0.00
Total							**0.22**	**0.00**	**0.00**

Figure 3.3.10 Variable Cost by SRS for Opted out sections

3.3.28 Network Rail have accepted our concerns on these two issues and have recognised that further work is required to explain these anomalies in the modelling.

3.4 'Non-Track' Assets

3.4.1 Network Rail have carried out a review of the 'Non-Track' assets and has considered them to be the least affected by variations in traffic. As a result of their review they have decided to not make any changes to the method of modelling 'Non-Track' asset costs in ICM V2.

3.4.2 The 'wear and tear' factor involved in Civils, Signalling, Electrification & Telecomms is very limited, therefore the 'Non Track' assets are considered to be low impact and Halcrow consider that they would not vary much as a result of a detailed review of their cost.

3.4.3 Although the modelling of costs for Non Track Assets is small, the variability calculated for Metallic Underbridges has significantly changed from 8% in the ISBP to 20% in the SBP. This is shown further in the graph in Section 4.3.2.

4 Variability Computations

4.1 Network Rail's Modelling Methodology

4.1.1 As previously stated, Network Rail have used two methods for calculating cost variability. These are:

- Use of ICM for testing sensitivity for track renewals and maintenance; and
- "Offline" calculations based on engineering judgement on activity and cost variability and costs from ICM for other disciplines.

4.2 Overall Variable Costs

4.2.1 Network Rail have stated that, based on traffic levels predicted for 2009/10, they expect a variable cost of £301M. The following figure shows the split of this amount by work type.

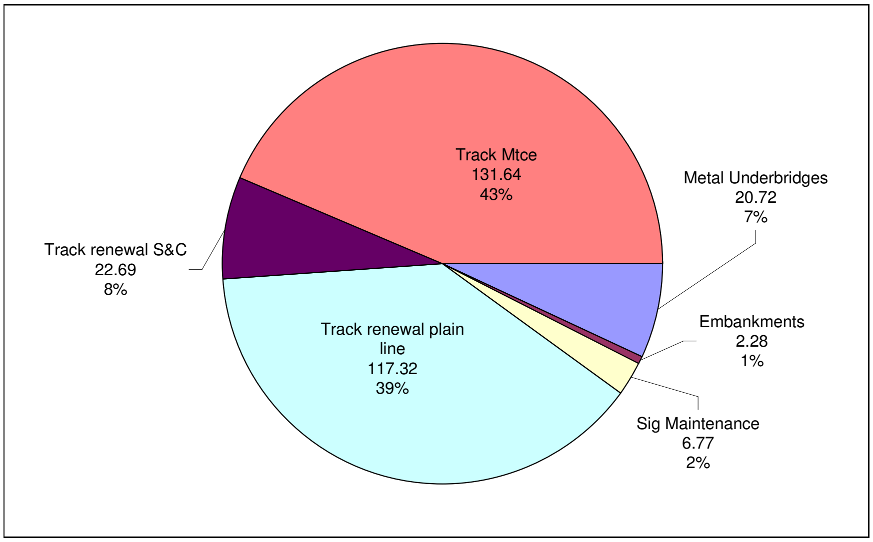

Figure 4.2.1 Split of Variable Cost by work type

4.3 Change in variability from previous estimates

4.3.1 The following table compares the variability percentages which have come from Network Rail's modelling for the current SBP with the previous estimates of variability made for the ISBP, SOCC2005 and PR2000. The estimates from the SOCC2005 review were BAH provisional conclusions and were not implemented as they were not felt to be sufficiently robust.

Asset/ Work Type	ACR2000	SOCC2005	ISBP	SBP
Track - Maintenance	30%	28%	31%	29%
Track - Plain Line Renewals	36%	44%	22%	25%
Track - S&C Renewals	25%	47%	38%	17%
Signalling - Maintenance	5%	3%	5%	5%
Civils - Metallic underbridges	10%	16%	8%	20%
Civils - Embankments		5%	5%	6%

Figure 4.3.1 Percentage variability by asset area compared to previous estimates

4.3.2 These percentages are presented graphically in the following figure:

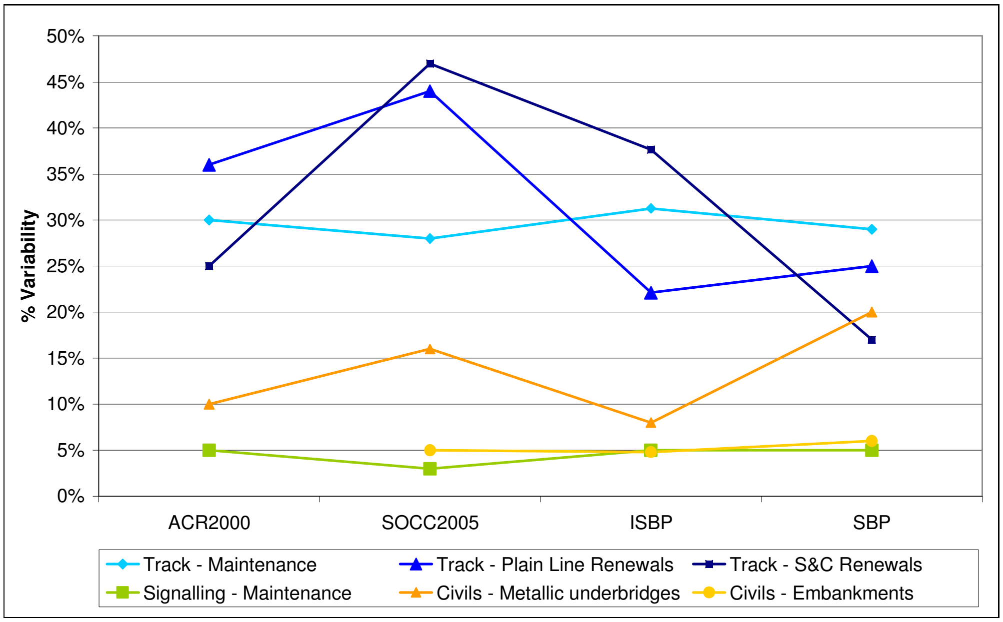

Figure 4.3.2 Graph of % variability by asset area compared to previous estimates

4.3.3 It can be seen from this graph that the understanding of the variability of the track renewal items and Metallic Underbridges has changed significantly over these reviews. Network Rail have said that the latest variability percentages for track are derived from the bottom-up calculation of cost within ICMv2, and therefore their confidence in them is greater then previous percentages, which were determined from engineering judgement.

4.3.4 The annual variable costs are given in the following table:

Asset/ Work Type	ISBP (05-06 prices)	SBP (06-07 prices)
Track - Maintenance	146	132
Track - Plain Line Renewals	79	117
Track - S&C Renewals	59	23
Signalling - Maintenance	6	7
Civils - Metallic underbridges	16	21
Civils - Embankments	2	2
Total	**308**	**301**

Figure 4.3.3 Variable cost by asset area compared to ISBP estimates

4.3.5 This table shows that the biggest change in the variable cost are within the track renewal items. The aggregate amount for track renewals has remained relatively constant; however there has been a shift of around £36m from S&C to plain line renewals. The traffic growth assumptions are different between the ISBP and SBP but this does not account for the shift from S&C to Plain Line.

4.3.6 As shown in Network Rail's service life tables in 3.3.9 and 3.3.10, S&C generally has a shorter service life than continuously welded 'Plain Line' track. This is due to a number of factors, but one of the main reasons is that there is a much larger proportion of timber bearer layouts compared to concrete bearer layouts. Whereas on Plain Line track it is the reverse and concrete sleepers are much more prevalent. The result of this is that S&C renewal is influenced more heavily than Plain Line by environmental decay (split/rotten timbers) and less by the impact of traffic. Of course the impact of traffic on S&C is significant but much of this impact is dealt with by weld repairs, refurbishment or replacing the ironwork under maintenance rather than by renewal.

4.3.7 Therefore the variability element of S&C renewals (which is the element influenced by traffic) we would expect to be less than for Plain Line. As Network Rail's latest variability calculations show S&C as a smaller percentage than Plain Line, we would consider this to be more logical than that previously shown in ICM V2 where the reverse was calculated. However, the shift of around £36m from S&C to 'Plain Line' renewals we feel requires more of an explanation than this.

4.4 Traffic Mix

4.4.1 The following table of traffic data by route type for the predicted traffic levels in 2009/10 was taken from the ICM:

Route Type	Million Gross Tonne km		% of Total	
	Freight	Passenger	Freight	Passenger
Primary	30,657	72,232	18%	43%
London & SE	2,027	21,407	1%	13%
Secondary	15,752	18,233	9%	11%
Rural	475	2,667	0%	2%
Freight	4,494	176	3%	0%
Total	**53,405**	**114,715**	**32%**	**68%**

Figure 4.4.1 Traffic Data by Route Class for 2009/10

4.4.2 These numbers are noticeably different than the figures used in ICMv1. The overall MGTkm remains relatively constant (small reduction of 0.3%), however the freight percentage reduces from 35% to 32%, which is transferred to passenger within the Primary and Secondary Routes.

4.5 Overall Variable Cost Accuracy with Traffic Growth

4.5.1 Network Rail have provided analysis of the sensitivities of the chosen variable growth rate of +5%. This analysis has tested the scenarios of -5% and +10% for Track Renewal and Maintenance. The resulting £/kgtkm (06/07 prices, pre-efficiency) are shown below.

Activity	Scenario	National Total	Primary	London & SE	Secondary	Rural	Freight
Track Renewal	-5% Traffic	0.79	0.65	0.68	1.35	0.33	0.57
	+5% Traffic	***0.82***	***0.61***	***0.77***	***1.56***	***0.77***	***0.59***
	+10% Traffic	0.79	0.59	0.64	1.51	0.56	0.79
Track Maintenance	-5% Traffic	0.64	0.41	0.69	0.91	3.90	1.43
	+5% Traffic	***0.78***	***0.49***	***0.84***	***1.13***	***4.80***	***1.70***
	+10% Traffic	0.74	0.46	0.84	1.10	4.10	1.73
Total Track	-5% Traffic	1.42	1.06	1.37	2.27	4.23	2.00
	+5% Traffic	***1.60***	***1.10***	***1.61***	***2.69***	***5.57***	***2.29***
	+10% Traffic	1.53	1.05	1.49	2.61	4.66	2.52

Figure 4.5.1 Track Sensitivities of Traffic Growth by Route Class

4.5.2 To show the sensitivity within this analysis, we have multiplied these £/kgtkm by the 2009/10 total traffic levels given in Figure 4.4.1. The following table provides the resulting variable costs (£m) and the variance from the +5% scenario.

Activity	Scenario	National Total	Primary	London & SE	Secondary	Rural	Freight
Track Renewal	-5% Traffic	132 (-5%)	67 (7%)	16 (-12%)	46 (-13%)	1 (-57%)	3 (-4%)
	+5% Traffic	***139***	***63***	***18***	***53***	***2***	***3***
	+10% Traffic	132 (-5%)	61 (-4%)	15 (-17%)	51 (-3%)	2 (-27%)	4 (33%)
Track Maintenance	-5% Traffic	107 (-18%)	42 (-17%)	16 (-18%)	31 (-19%)	12 (-19%)	7 (-16%)
	+5% Traffic	***131***	***50***	***20***	***38***	***15***	***8***
	+10% Traffic	125 (-5%)	47 (-6%)	20 (-0%)	37 (-2%)	13 (-15%)	8 (2%)

Figure 4.5.2 Variable Cost (£m) for 2009/10 and variance from +5% scenario

4.6 Relative Cost Variability for Freight and Passenger Traffic

4.6.1 The following table gives the variable cost from ICMv2 for each asset area by route type for the predicted traffic levels in 2009/10, using average charges (not route based).

Route Type	Metal Under bridges	Embank-ments	Sig Mtce	Track renewal plain line	Track renewal S&C	Track Mtce	Total Variability
Passenger							
Primary	4	0	2	34	8	35	**83**
London & SE	3	0	1	14	3	18	**39**
Secondary	6	0	1	32	4	20	**64**
Rural	1	0	1	1	0	13	**17**
Freight	0	0	0	0	0	0	**0**
Total	**15**	**1**	**5**	**82**	**15**	**86**	**204**
Freight							
Primary	2	0	1	17	4	16	**39**
London & SE	0	0	0	1	0	2	**4**
Secondary	3	0	1	15	2	18	**39**
Rural	0	0	0	1	0	2	**4**
Freight	1	0	0	2	1	8	**12**
Total	**6**	**1**	**2**	**35**	**8**	**46**	**97**

Figure 4.6.1 Summary of variable cost (£m) for 2009/10

4.6.2 It can be seen from this table that the majority of the variable costs are caused by passenger traffic, specifically within the Primary, L&SE and Secondary route types. Of the cost allocated to freight traffic, approximately 80% occur on Primary and Secondary route types.

5 Allocation of Variable Costs

5.1 Rail Surface Damage term developed by TTCI

5.1.1 In 2005 BAH rejected the suggestion of adding a horizontal Rail Surface Damage (RSD) term to the established vertical damage term on the basis of insufficient supporting evidence from the industry. However, in October 2006, Network Rail appointed TTCI to further develop the RSD model so that the effects of the forces in the horizontal plane can be included in the charging regime from 2009.

5.1.2 Network Rail have now concluded this more detailed work with TTCI and produced a detailed model to calculate by vehicle type the proportion of variable track charges that are due to lateral forces at the wheel/rail interface (the RSD model).

5.1.3 TTCI's analysis demonstrates that RSD is a function of the horizontal forces (T) and creepage force (gamma, γ) between the wheel and the rail. This function depends on the curving performance of a vehicle and cannot be expressed as a simple relationship with vehicle properties, as can the functions that describe vertical forces.

5.1.4 Sufficient information now exists for a set of assumed Tγ tables to be produced for each vehicle type over a range of track curvatures and cant deficiencies.

5.1.5 The current method for evaluating the damage caused by a single vehicle is based on the Equivalent Gross Tonne Miles (EGTM) operated by the vehicle. EGTM are calculated by factoring the Gross Tonne Miles (GTM) by:

- Speed
- Axleload
- Unsprung mass
- Vehicle group (loco, multiple unit, 2-axle freight)

5.1.6 Vehicle Groups are split into 'Curving Classes' which allow specific vehicle characteristics to be separated into classes of vehicle which have various impacts on a range of curves. For conventional designs of passenger vehicles, curving performance can be estimated from two key vehicle properties: axle spacing and primary yaw stiffness. Some manufacturers regard Yaw Stiffness values as commercially sensitive and do not wish to have them published or measured.

5.1.7 A key feature of the methodology is that it combines the surface cracking and wear produced by a vehicle; treats vehicles independently from one another; considers the steady-state curving performance of the vehicle; and accounts for the beneficial effects of grinding on rail life.

5.1.8 In order to understand this work more closely, separate meetings were held with John Tunna of TTCI and Neil Harwood of Alstom who is a vehicle engineer and sits on the rail industry Vehicle-Track System Interface Committee (V-T SIC). Also a review of technical papers was made and these are referenced in the Appendices.

5.1.9 TTCI have further recommended to Network Rail that their model can allocate variable costs to routes, leading to a route based charging model.

5.1.10 Rolling Stock manufacturers have acknowledged the good work that TTCI have done on the rail surface damage term in the time available. However, the following are some areas that they would like to see further development work done in the future:

- The coefficient of friction used (0.4) is a network-wide annual average. Rail adhesion is an issue for rolling stock maintainers and this will vary with seasonal rail conditions. However, 0.4 is considered to be high and they would like to see that further studies were carried out to give further confidence in this figure, noting that the lower value of 0.2 is used for the high rail of curves up to 1500 metres to account for rail lubrication.

- Axle spacing is accounted for by TTCI, but the bogie wheelbase also affects the steering characteristics of the vehicle. Although TTCI have categorised the different vehicle types, there is a lack of confidence that the variation in bogie wheelbase has been taken into account.
- Wheel radius and wheel profiles – TTCI acknowledge the variations that can exist using different wheel profiles but it is felt that the same emphasis should be placed on encouraging optimum wheel profiles to be used, as there is on Primary Yaw Stiffness development. Conicity of the wheel in particular is an important influence on the steering characteristics of the vehicle, therefore it is thought that this should be factored into the algorithms to recognise that there is a choice available within Railway Group standards to use either high or low conicity profiles.
- Tilting Trains – again TTCI recognise that this is an issue, but the higher cant deficiency available to tilting trains should cause a relatively slower propagation of RCF cracking and should therefore be included as a separate vehicle class with a charge which reflects this. It should be noted that this slower rate of propagation will only be found where high cant deficiency curves are travelled at the designated Enhanced Permissible Speed for the tilting train.

5.1.11 The unique treatment within the variable cost model for titling trains is an interesting issue for the future as both rolling stock owners and Network Rail understand their respective actual maintenance costs of trains and infrastructure applicable to the operation of trains at Enhanced Permissible Speeds.

5.1.12 Halcrow has reviewed the drivers for the proposed cost model, and believe it to be an equitable means whereby Network Rail can highlight and recover those costs it expects to incur in managing a whole life cost approach to its track assets as a consequence of RCF in CP4, based on today's knowledge.

5.1.13 The cost model alone does not incentivise individual train operators, nor its own maintenance and renewal functions, to deliver on a day to day basis initiatives that will reduce the instance or severity of RCF and therefore efficiency in the management of RCF.

5.1.14 Network Rail's ability to deliver its own asset policy requirements will be measured through KPIs agreed with the Office of Rail Regulation. (see Appendix C)

5.1.15 Individual owners and managers of rolling stock maintenance plans are more likely to be influenced by factors of cost in considering any new initiatives. Their objective will be to manage their budgets for the safe maintenance of the trains under their control. It is therefore opportune that a cost mechanism be derived whereby a train operator, who adopts an industry approved initiative to reduce the likelihood of his trains contributing to RCF on Network Rail's track, be rewarded financially.

5.1.16 As Network Rail's proposed RSD cost model derives a charge by individual train type per equivalent thousand kilometres, it seems reasonable to derive a cost reduction should a train operator adopt a strategy for RSD reduction by his train fleet, such as on board wheel lubrication or the adoption of track friendly wheel profiles.

5.1.17 In order to structure such a cost reduction, cognizance should be taken of the number of trains needed to adopt an RCF reduction initiative for it to be effective and that Network Rail are unlikely to reduce their rate of spend to combat RCF on their rails until a definite reduction in propagation is observed.

5.1.18 We believe the work completed to date by TTCI for a RSD track access charge, and included by Network Rail in their total variable track access charge, is based on sufficient evidence to be accepted for CP4. Further refinement and experience by the industry could lead to the adoption of route based track access charges in CP5 and beyond.

5.1.19 A table summarising the known train and track engineering activities that cause or impact upon rolling contact fatigue in rails is at Appendix C.

5.2 Review of charges by vehicle type

5.2.1 In order to review the charges by vehicle type, comparison has been made with the charges reviewed by BAH in their report dated June 2005[8]. For passenger vehicles, the ten types with the greatest annual mileages have been chosen.

5.2.2 A table has been drawn up based on work by TTCI (see Appendix F) and the following can be deduced:

(a) The annual mileage for these ten vehicle classes increases in 2009/10 by 12%. Therefore the charge per vehicle mile in 2009/10 would be expected to reduce if it were unchanged. In fact the proposed total passenger variable charge will be £208m compared to the predicted 2005 charge of £225m (Scenario A in BAH 2005 report), a reduction of 7.5%. should compare to current charge which I have sent you

(b) Noting the lower overall variable charge for passenger traffic and that the forecast annual mileage of the top ten passenger vehicles has increased, with the exception of mark 3 coaches and class 158 DMUs, the pence per mile attributed costs have also increased.

5.2.3 This increase is a consequence of applying the new rail surface damage calculations such that total variable track costs to passenger and freight users are allocated by computed vertical damage forces (as before) and a new rail surface damage factor described in section 5.1 above.

5.2.4 The table below shows how the proposed variable track access charges vary for passenger train types. The damage factors are calculated from vehicle data that includes the curving characteristics of the bogies and the impact they have on track at different curve radii. A higher number indicates greater damage. The proposed costs are based on damage factors and miles travelled.

Vehicle type	Proposed VTAC Pence/mile	Structures damage Factor	Vertical Track Damage factor	Rail Surface Damage Factor/mile
Eurostar 373/0	63.68	12.29	5	0.304
HST power car	42.35	8.58	4	0.304
Pendolino power coach	20.98	4.16	3	0.101
Pendolino coach	19.9	3.65	3	0.101
Voyager (221) power coach	18.17	2.26	2	0.118
Mark 4 coach	18.06	2.34	3	0.11
Eurostar coach	14.64	0.77	2	0.136
Class 170 DMU power coach	10.86	1.25	3	0.04
Class 377 EMU power car	10.15	1.13	2	0.04
Mark 3 coach	9.84	0.77	2	0.053

Figure 5.2.1 Analysis of the infrastructure damage factors used by NR for the ten passenger vehicle types attracting the highest annual variable track access charges

5.2.5 It can be seen from the data that those vehicles designed for high speed have the highest damage factors and consequentially will attract proportionally higher variable charges.

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[8] Booz Allen & Hamilton / TTCI (UK): Revision of variable usage and electrification asset usage charges, final report

5.2.6 The introduction of a component charge for RSD and allocating it to vehicles by virtue of their calculated lateral damage factor and their annual mileages have created two track charges, for vertical and lateral forces respectively. Whilst passenger vehicles may not be those with the highest individual vertical or lateral track damage factors, the higher annual mileages produce higher totals (see table below) and consequently reduced charges for freight, except for structures, where vertical forces continue to dominate.[9]

Sector	**CP4 proposed VTAC (£000)**			
	Track (Vertical)	**Structures (Vertical)**	**Surface (Lateral)**	**Total**
Passenger	131,179	9,650	67,313	208,143
Freight	65,741	13,350	14,179	93,271
Total	**196,920**	**23,001**	**81,493**	**301,413**

Figure 5.2.2 Proposed VTAC for CP4

5.2.7 The next table looks at the ten vehicle classes with the highest surface damage factors across freight, passenger and vehicles owned by Network Rail.

Vehicle Type	**Vehicle Curving Class**	**Computed maximum surface damage factor**	**Radius beyond which max. damage reduces**	**Surface Damage factor/mile**
Eurostar 373/2	Artic 3	1369.6	800	0.383
Class 20; 43; 67; 73; 86; 87; 90; 91	Loco2_50	1081.9	800	0.304
Class 60	Class 60	978.4	800	0.249
Eurostar coach	Artic2_80	683.9	800	0.136
Freight wagons type MBAB; MBAC; MCAA; MDAA; MLAA; MOAA; MRAA-AF	NACO_ Loaded	661.1	800	0.135
NR owned vehicle	Coach_64_60	867.1	800	0.127
Approx 50 freight vehicle types with 3 piece bogies	3 Piece_loaded	692.3	800	0.126
Class 221	Coach_50_60	**	800	0.118
NR owned vehicle	Coach_48_60	807.9	800	0.117
NR owned vehicle	Coach_128_50	760.7	800	0.116
** vehicle owners not able to supply data relating to primary yaw stiffness for intellectual property reasons. TTCI have therefore used available information and modelling results.				

Figure 5.2.3 Surface damage factors by vehicle classes

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[9] A Revised Methodology for Variable Usage Charging - UK NR Report No. 07-003 By John Tunna TTCI(UK), Ltd.

5.2.8 The table shows that although there are some vehicle designs being operated on the network that have very high RSD tendencies, these vehicles may not be those that have the highest total variable charges allocated to them due to lower annual mileages and where they are positioned in overall track and structures damage factors.

5.2.9 We have also reviewed the changes in charges proposed for vehicle type. This has been done by listing the 30 passenger and freight vehicle types by high annual mileage and showing the percentage increase or reduction in charges that Network Rail is proposing for CP4.

5.2.10 The charts are at Appendices F (passenger) and G (freight) and the vehicles have been sorted by RSD factor.

5.2.11 As Network Rail's overall cost for the maintenance and renewal of its infrastructure is reducing, so the total variable cost is falling.

5.2.12 Network Rail have demonstrated that the calculations to apportion these costs to individual vehicle types are both detailed and reliant on fewer assumptions than in the past. This has been demonstrated particularly in the case of the new proposed rail surface damage (RSD) charges.

5.2.13 However, whilst the calculations for vertical track damage and structures damage have not changed from those used for CP3, a number of other inputs to the cost apportionment model have been updated in specific cases. These include annual mileage, average speed and, particularly for freight, laden weight.

5.2.14 Network Rail is proposing that 32% of the passenger fleet variable costs should be attributable to RSD. This leads to a generalisation that those vehicles with high RSD factors generally are those with increased charges for CP4. The exceptions are likely to be those vehicles whose other characteristics have changed since the CP3 calculations were made.

5.2.15 For freight vehicles the vertical damage factors for track and structures continue to influence the charges. Network Rail is proposing that the RSD appropriation is 15%, slightly less than half the figure for passenger vehicles. This leads to a more complex chart at appendix G, where again the top 30 vehicles by annual mileage are listed by RSD factor. The proposed changes in freight vehicle charging show no particular significant cause between structures, track and RSD. For example, we were advised by Network Rail that the increase in 'Domestic Intermodal' charges was due to a re-appraisal of laden weight for CP4.

5.2.16 As this report is being completed, Network Rail is undertaking industry consultation over its proposed individual vehicle charges for CP4. Since the proposed vehicle variable usage charges were published, it has reviewed the data input for certain freight vehicles (class 60, FSAO, TEAK, and HAAV) and the following passenger classes: 313, 321/322, 220, 222, 444, 450 and 465. This has resulted in the class 444 and 450 vehicles being modelled with new (stiffer) curving classes leading to a higher charge of 15.90 pence per mile rather than 13.93.

5.2.17 Curving performance is also a critical factor with the class 465. These vehicles have relatively low axleload and operating speed, but very poor curving performance. This results in the model calculating a small reduction in charge due to vertical damage but a higher increase due to RSD. The overall result is an increased charge for CP4.

5.3 Impact of changes in freight access charges

5.3.1 Network Rail's estimates of variable usage costs for CP4 indicate a reduction from current charges of 13% for passenger traffic and 3% for freight traffic after allowing for growth in the two traffic types. It is also worth noting that this is at end of CP3 efficiency and the charges would fall further with further efficiency gains in the future.

5.3.2 Appendix G gives the changes in charges for main individual freight vehicle types. The Domestic Intermodal vehicle types are of particular interest since MDS Transmodal's work[10] has identified this market (unlike Coal ESI, for example) as particularly competitive and price sensitive.

5.3.3 The changes in access charges for different Domestic Intermodal wagon types range between +30% and -23%. The largest charge increases apply to older flat wagons with 60' loading lengths – classes FSA, FTA, KFA introduced in the 1980s or early 1990s. The proposed charges for these wagon types range between £2.93 and £3.16 per kgtm. The newer, comparable FEA wagon type – introduced in 2003, with a higher carrying capacity and apparently costing around £40-50,000 per coupled pair – has a proposed 12% reduction in access charge down to £2.05 per kgtm, around £1 per kgtm lower than the older wagon types.

5.3.4 The proposed changes in charges should provide an incentive to make more use of newer FEA wagon types

5.3.5 Across the Domestic Intermodal wagon types referred to in Appendix G, the combination of current and proposed charges and current Gross Tonne Miles by vehicle type would give an average increase in access charges for Domestic Intermodal wagons of around 9%. This may be offset, to a degree, by reduced charges for suitable locos, e.g. class 66. The MDS Transmodal work, reported by ORR[11], suggests that a 9% increase in access charges for Domestic Intermodal and Maritime Container traffic might reduce rail freight traffic by between 2% and 3%. While this would be undesirable, change in the use of different wagon types could act to bring down the average charge paid.

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[10] 'Impact of track access charge increases on rail freight traffic', MDS Transmodal Limited, November 2006

[11] ORR's Consultation on Caps for Freight Track Access Charges, December 2006

6 Variable Cost by Route or Geography

6.1 Network Rail's Route Policy

6.1.1 A core component of Network Rail's technical policy is the need to support the range of outputs across the network, as defined primarily by the RUS process. This is achieved by differentiating the network by route type, reflecting the volume and general nature of the traffic carried, as follows:

6.1.2 Primary and key L&SE routes are intensively used and support high speed traffic. Passenger revenues are high, as are the compensation payments for train delays. There is often a demand for increases in capacity and capability on these routes;

6.1.3 Other L&SE, all secondary routes and key freight trunk routes are characterised by lower line speeds, a broader range of passenger revenue and train delay penalties and generally a more limited demand for route capability enhancements; and

6.1.4 Rural and freight only routes are typically lower speed routes, lightly used, with low train service revenues and low train delay penalties, although freight services on some routes may have high axle weights.

6.1.5 Therefore the five route categories, Primary, London and South East commuter, Secondary, Rural and Freight-only have been reduced to four to allow asset policies to be differentiated, where appropriate, by the type and nature of traffic carried and make certain that decisions on routes with similar usage characteristics are managed in a consistent manner across the network.

6.2 Route Based Charging & Geographical Variations

6.2.1 The existing variable asset charges are national rates that apply uniformly to operation over any section of the network. ORR has asked Network Rail to consider whether any desegregation of charges is appropriate, either by:

- Route capability / characteristics: e.g. difference in marginal costs between a high-speed main line route and a rural branch line; and
- Geography – where routes are related to different customers or funders.

Route Based Charging

6.2.2 Differentiation of charges by route capability and characteristics may be appropriate where there are material differences in the costs involved. There is a balance to strike between the implications of route specific prices set by the charge against the additional complexity that differentiated charges could imply

6.2.3 Network Rail have proposed to use ICM to explore the variations in marginal costs between routes by comparing costs between:

- The five route categories: Primary, London and South East commuter, Secondary, Rural and Freight-only; and
- The 300 plus Strategic Route Sections defined in the ICM.

6.2.4 How Network Rail approach route-based charging will determine whether there is sufficient benefit that would improve cost reflectivity or create incentives which are positive and not perverse. They have explored options, and are looking to sub divide charges by route classification (Primary, L&SE, Secondary, Rural and Freight) and by three curvature categories.

6.2.5 The following table summarises the indicative results according to these categorisations.

	All Curvature	Straight	Mixed	Curvy[12]
System-wide	1.79	1.48	2.24	3.20
Primary	1.30	1.10	2.12	
L&SE	1.84	1.61	2.29	
Secondary	3.04	2.88	3.00	6.19
Freight	2.58	1.81	3.13	
Rural	6.44	5.27	6.63	9.58

Figure 6.2.1 Table of Route & Curvature charges (£/kgtkm)

6.2.6 These values are reflective of the characteristics of each route (asset type, age and condition) and the effect of the mix of curves that will vary vehicle behaviour. The graph below shows how each route classification charge will vary through the mix of curves.

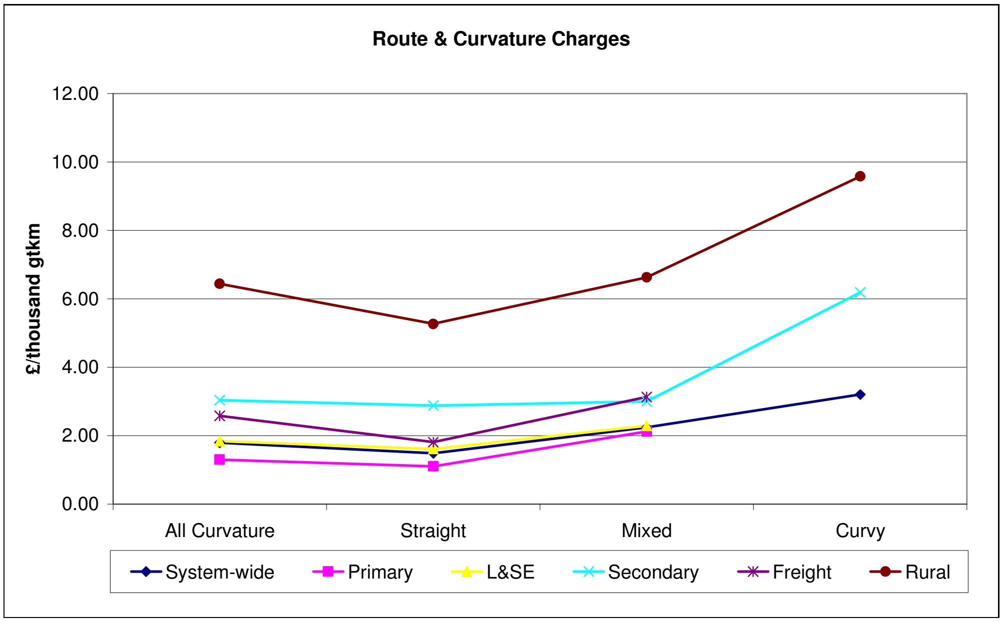

Figure 6.2.2 Graph of Route & Curvature charges (£/kgtkm)

6.2.7 What is unexpected is the insignificant sampling on Primary and LSE routes particularly, in the 'Curvy' category. From our experience and knowledge, there is significant 'curvyness' on. Primary and LSE routes which raises the question of the validivity of the data.

6.2.8 There is also a large difference between Rural and the other routes. This is maybe because the Rural lines are subject to much higher track forces (because of the jointed track volumes) than other lines carrying passenger traffic. However, this will need to be validated if it is to be justified, and if confirmed may create a perverse incentive for passenger services to use the cheaper more congested routes where there is an alternative.

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[12] Network Rail have stated that the figures for Primary, L&SE and Freight for the Curvy category are insufficiently robust to be quoted due to the small sample size used.

Geographical Variations

6.2.9 Network Rail have assessed the variations between England & Wales and Scotland and considered whether there is sufficiently robust data and justification for any further desegregation. The figure below gives the variability for Scotland and England & Wales.

National Average	England & Wales	Scotland
1.79	1.71	2.65

Figure 6.2.3 Variability for Scotland and England & Wales (£/kgtkm)

6.2.10 In providing these numbers, Network Rail have raised the following concerns:

- The England/Wales and Scotland differential is based on the indicative numbers presented in their October 2007 SBP. As such they are influenced by cost variation between route-categories that have been treated as 'unproven'. Network Rail are undertaking substantial work to review and revise these numbers.
- In keeping with their thinking in relation to route-based charging, Network Rail has queried whether these numbers form an appropriate basis for charging.

6.2.11 We note that the variability for Scotland is much higher than that for England & Wales. Network Rail have advised that this is due to the route category mix, eg. a higher proportion of secondary and rural route within Scotland's SRSs.

6.2.12 As part of the Track Service Life study carried out by the Reporter, it was found that in the Inverness area in particular track assets were showing much longer life spans for rail and ballast as compared to the assumed average service lives. Many sections of Bullhead Jointed track laid in the 1930's and 1940's have been kept going beyond their life expectancy by the component specific renewal of sleepers and an appropriate level of maintenance.

6.2.13 On the Far North and Kyle Lines it was found that a different approach for track renewals was appropriate when comparing them with many other Rural lines on the network as they were lines that had the characteristics which contribute to component life longevity.

6.2.14 Particularly on lightly used rural lines, well maintained Bullhead Jointed track was found to have a high life expectancy and can exceed the assumed average service life greatly provided that component specific renewal keeps the average age profile of sleepers down to co-exist with the service life of the rail and ballast.

6.2.15 Conversely, on most other lines, Jointed Bullhead track can often be in discrete sections within a predominately CWR railway and subject to moderate to high tonnages and speeds. In this scenario it is appropriate to have a strategy to replace it with CWR. However, as a predominate light rail track system in an area with skilled and dedicated resources geared up to maintain it, there is a strong case for perpetuating this component type and keeping the bullhead jointed track system unless there is a business case to change it.

6.2.16 The Bullhead track system is a proven system on well maintained light rail rural routes such as those found in Scotland and therefore perpetuating the Bullhead track component system is wholly appropriate as part of a low cost maintenance and 'piecemeal renewal' strategy. Provided that traffic conditions remain unchanged (i.e. without heavier and less track friendly vehicles), the Bullhead Jointed track system can exist as a perfectly satisfactory component system on lines such as these.

7 Other UK and Overseas practice

7.1 Wheel/rail interface

7.1.1 At the Austrian Society of Transport Technology (ŐVG) international rail conference in Salzburg this autumn, Professor Riessberger of the Technical University of Graz, Austria, presented a paper demonstrating that today's problems at the wheel/rail interface, leading to Rail Surface Damage, are not without coincidence.[13]

7.1.2 His paper highlighted the differences in the Heavy Haul and High Speed rail networks during the 1980s and 1990s. He went on to demonstrate that as we move towards 2010 those differences, especially in rail management, are reducing as new freight and passenger traction units are delivered onto the mixed traffic European rail networks.

7.1.3 He argued that to engineer minimum whole life costs for vehicles and track there is a requirement to define a "conformal" wheel profile which must combine low wear, reasonable curving and running stability for bogies.

7.1.4 For the track the higher forces require careful matching of the wheel/rail profiles, timely correction of rail wear and concentration on details like geometry faults at rail welds, geometry and condition of turnouts and attention where there is a variation in the stiffness in the track system.

7.1.5 The detailed chart that accompanied Professor Riessberger's paper is included at appendix D and shows that modern traction on the mixed traffic railway in Europe is now producing forces at the wheel/rail interface that were previously considered unique to the Heavy Haul railway

7.2 Traction charge calculations of the Austrian Railways

7.2.1 The Austrian Railways (ŐBB) have posted their variable track access charging regime on their internet site under the heading "one stop shop".[14]

7.2.2 Whilst the ŐBB do not make a specific charge for rail surface damage, they do produce individual calculations for vehicle damage that include factors for both vertical dynamic wheel forces and quasi-static lateral wheel forces per axle for each of three groups of curve radii; 250m-400m; 400m-600m and over 600m. The resultant damage indices are then put into one of three categories for traction units. The price charged per train-km covered is increased or decreased by the corresponding traction unit markup or markdown whereby those exciting the greater damage pay more.

7.2.3 It is interesting to compare the approach of Austrian Railways to track damage due to curving. Perhaps with experience of heavy sidewear on the tighter radius curves found on their mountain passes they have chosen to look at three ranges of curve above and below 600 metres radius, whereas Network Rail have selected 2,500 metres as the critical point to judge differential track wear.

7.2.4 We consider that more engineering analysis is required to substantiate Network Rail's choice of 2,500 metres radius as the critical point for general track wear used in their calculations.

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[13] Wheel/rail problems in high-speed and heavy haul transport – without coincidences? Paper by Professor Riessberger, Technical University of Graz, read to the OEVG international conference in Salzburg

[14] Austrian Railways Track Access Charges as shown on their "one stop shop" internet site http://www.railnetaustria.at/de/OneStopShop/index.jsp

8 Conclusions

8.1 General

8.1.1 We recognise that Network Rail have invested considerable time and resources in the development of their track maintenance and renewal policies and the translation of these policies into the modelling of costs for CP4. The development of ICM from version 1 to version 2 has been a significant piece of work and Network Rail should be commended for the quality of the input and commitment from the Engineers and the architects/modellers of the Infrastructure Cost Model.

8.1.2 We have also been impressed by the development of the new lateral forces term for Rail Surface Damage and the degree of accuracy and traceability that Network Rail and TTCI have applied to developing the new term and charging mechanism.

8.1.3 We have found areas of this work which can be further developed for successive control periods in order that the modelling process is refined and become more accurate in it's reflection of true costs. However, in the time that was available a view has to be taken on what degree of development is achievable and with the exception of some of the following points we wish to make, we endorse the good work that has been done to model the variable track access charges for CP4.

8.2 Modelling of Track Costs

8.2.1 We have reservations about certain levels of detail, such as the predicted cost of track inspections decreasing year on year. The Strategic Business Plan details the greater use of train-borne inspections enabling manual patrolling frequencies to be relaxed where appropriate. We see this as having greater efficiencies on the Primary and Secondary routes but less so on the Rural and Freight routes because of the volumes of jointed track. Also the enhanced S&C inspection regime proposals and additional resource requirements for this may impact adversely on the assumed reduction in costs.

8.2.2 We have reservations about the rise in the cost of maintenance sleeper replacement in CP8 to CP10. Given that the cost is decreasing prior to CP8 partially due to wooden sleepers being replaced with more robust replacement components when renewed, there is no explanation for a reverse in this trend.

8.2.3 We have reservations about the use of the same constant and exponent (and therefore same shaped service life curve) for rail below 2500m radius as well as for above 2500m radius. As stated previously, a general assumption has been used by Network Rail applying a 51% factor to the service life of rail for tactical re-railing on sharper curves.

8.2.4 As stated in 7.2.4 above, we consider more work should be undertaken justify the selection of 2,500 metres radius as the critical radius where rail service life changes. We consider that a more reflective approach is achievable by selecting the most appropriate constant and exponent for the two ranges of curved track and applying this to the volumes below and above the selected critical radius

8.2.5 We also have concerns about the exclusion of ballast renewals from those sites 'opted out' from the conventional composite renewal policy. If the continual 'piecemeal' renewal policy does not include any ballast renewal on many of the Rural & Freight only lines, the treatment of contaminated ballast will not be modelled, particularly as there is now a mechanism to recover the cost of treating ballast on coal spillage sites, through the new 'Coal Spillage Charge'.

8.2.6 Also, the sleeper replacement assumptions made for those sites that are 'opted out' do not satisfy the average service life expectations despite the longevity of components on these lines. Although this is unlikely to affect CP4, a review for the next control period will be necessary.

8.3 Variability Calculations

8.3.1 The variability calculations which have resulted in a shift from S&C renewal to Plain Line renewal have been quite dramatic for ICM V2 compared to ICM V1. Whereas we think this is the correct way around (i.e. S&C renewal percentages being less than Plain Line renewals rather than the other way around), we are still concerned about the significant shift between the two versions of ICM.

8.3.2 The variability calculations which have resulted in an increase for Metallic Underbridges from 8% to 20% are difficult to explain. The earlier estimate of 16% in 2005 is much nearer to the latest calculation, but casts some doubt on the validity of the ISBP calculation. However, the overall impact of Metallic Underbridges on Variability is small but failure to explain these sort of increases shows a weakness in the traceability of the assumptions made.

8.4 Allocation of Variable Costs

8.4.1 The calculation of a rail surface damage cost is a step towards understanding the true cost of operating particular vehicle designs on the rail network, and also has the potential to incentivise train operators to develop more track friendly vehicles.

8.4.2 As we have shown in section 5.2, some further work is needed in resolving a small number of anomalies in the charging outputs from the appropriation of costs to individual vehicles. We consider that Train Operators should expect a considered justification for increases in the variable charges for CP4.

8.4.3 However, whilst we endorse the use of a rail surface damage charge for CP4, we consider that this charging mechanism alone may not produce the business case for train manufacturers to develop more track friendly vehicles.

8.4.4 We also have concerns about the concept of route based charging shown in the table published in Network Rail’s SBP Structure of Charges ‘Supporting Document’. How Network Rail approach route-based charging will determine whether there is sufficient benefit that would improve cost reflectivity or create incentives which are preferable and not perverse. The data in the table as explained in items 6.2.7 and 6.2.8 will need further validation before it is generally accepted as valid data.

8.4.5 It is difficult to see where the benefit of route based charging incentivises train operators unless separate charges are made against the three curve categories. As the strategic route sections would need to be classified as either straight, mixed or curvy, this would reflect route characteristics in terms of curvature only (and not include jointed track profiles, track condition etc.).

8.4.6 Our conclusion on route based charging is that more work by Network Rail is required together with full industry consultation leading to its possible introduction in CP5. We do believe this to be a further step towards more accurately charging users of the Network for direct costs incurred by the infrastructure owner.

9 Recommendations

9.1 General Recommendations

9.1.1 That the work undertaken thus far by Network Rail to produce variable track access charges for CP4 be endorsed.

9.1.2 That the principal of appropriation of variable charges derived from the ICM model version 2, to individual vehicles operating on Network Rail's infrastructure, by application of the detailed calculations in the model developed by TTCI and including an appropriation for rail surface damage be endorsed.

9.2 Recommendations for further work

9.2.1 That further work is continued by Network Rail to validate the following cost modelling assumptions made within ICM:

- Additional train-borne inspection and the inspection of Switches & Crossings maybe more costly with a new enhanced inspection regime planned and therefore we are yet to be convinced that these additional costs have been factored in.
- Maintenance sleeper replacement costs fall partially due to the population of wood versus concrete sleepers shifting due to renewal using concrete sleepers. However, this does not explain the increase in resleepering costs from CP8 to CP10.
- For 'opted out' sites, sleeper replacement assumes some extreme examples of longevity (i.e. 0.10% equals once in a thousand years). We are not convinced that these are appropriate assumptions to make.
- For 'opted out' sites, the continual 'piecemeal' renewal policy does not include renewal of ballast. A percentage of reballasting (or perhaps composite renewal including reballasting) should be considered, as spillage and formation failure will contaminate ballast sufficiently to affect the condition of components and track geometry such that some remedial action will be necessary.
- The general assumption that has been used by Network Rail of applying a 51% factor to the service life of rail for tactical re-railing on sharper curves. We recommend that this should be refined as we suspect that sharper curves have a different shaped plot when drawing the graph of EMGTPA against Service Life (years).

9.2.2 That further work is continued by Network Rail to validate the following variability assumptions:

- The variability shift from S&C renewals to Plain Line renewals
- The variability shift for Metallic Underbridges from the ISBP to the SBP and justification for the large step change.

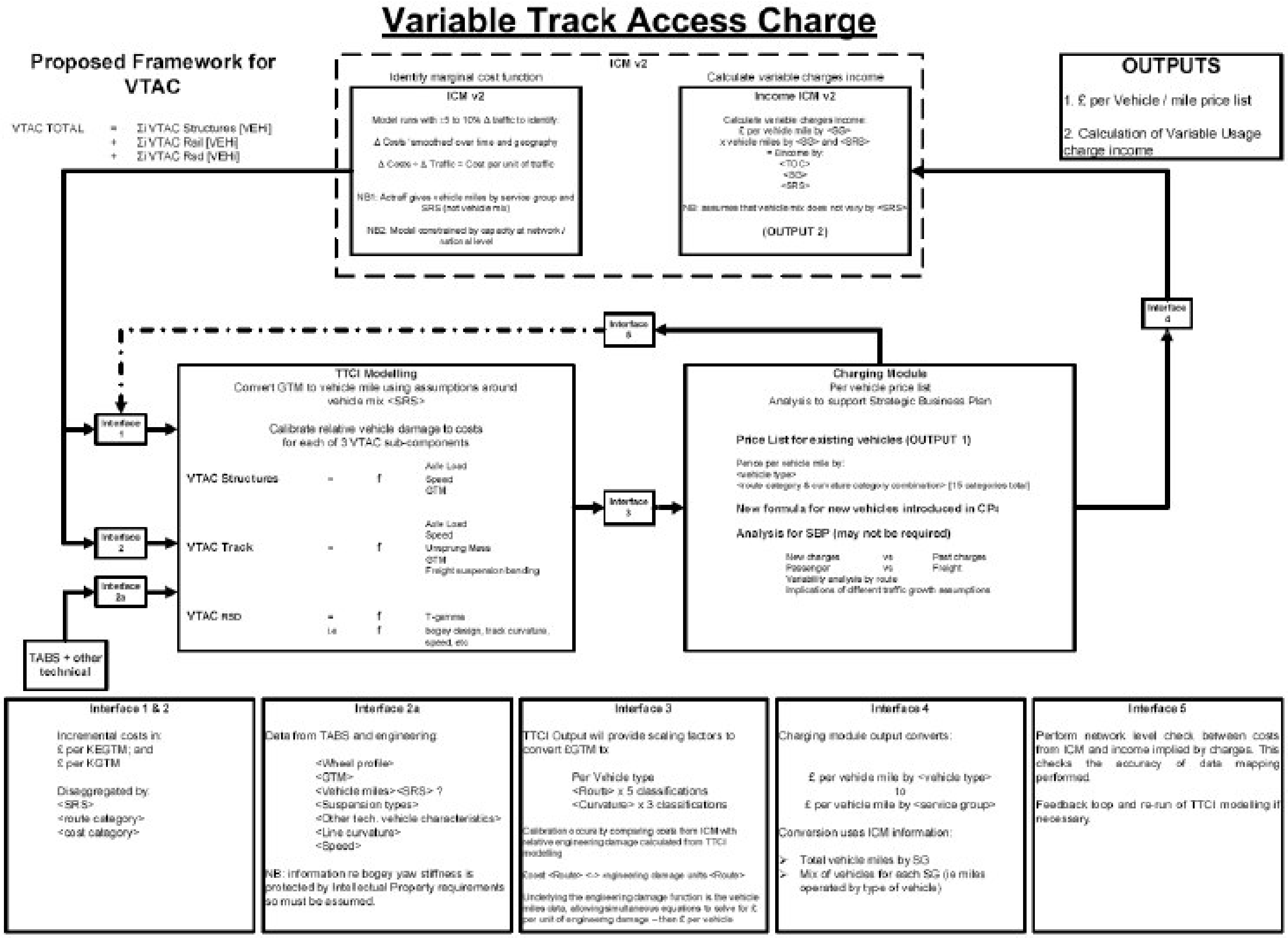
9.2.3 That further work is continued by Network Rail and TTCI to review possible anomalies in the output of the vehicle charges model and the route and curvature table before a final set of proposed charges is published to ORR.

9.2.4 That the concept of route based charging be explored by Network Rail and the industry with a view to produce a more detailed charging regime for CP5, where train operators can be assured that they are being charged for costs which are reflective of those directly incurred by their vehicles on the routes they travel.

10 Appendix A: Meeting schedule

Date	Venue	Attendees
09/10/07	ORR Office	• Tim Griffiths, ORR • Iain Morgan, ORR • Phil Edwards, Halcrow • Megan Gittins, Halcrow • Richard Spoors, Halcrow
18/10/07	Network Rail's Office	• John Tunna, TTCI • Amanda Hall, Network Rail • Geoff Jones, Network Rail • Phil Edwards, Halcrow • Megan Gittins, Halcrow
06/11/07	Network Rail's Office	• Bill Davidson, Network Rail • Dan Boyde, Network Rail • Geoff Jones, Network Rail • Ian Marlee, Network Rail • Tim Griffiths, ORR • Chris Littlewood, ORR • Peter Doran, ORR • Iain Morgan, ORR • Sareen Ekta, ORR • Megan Gittins, Halcrow • Richard Spoors, Halcrow
08/11/07 AM	Network Rail's Office	• Dan Boyde, Network Rail • Andy Jones, Network Rail • Geoff Jones, Network Rail • Mark Bradbury, Network Rail • Chris Madden, Network Rail • Phil Edwards, Halcrow • Megan Gittins, Halcrow • Tim Griffiths, ORR • Chris Littlewood, ORR • Andrew Wallace, ORR
08/11/07 PM	Halcrow's Office	• David Mullins, Halcrow • Phil Edwards, Halcrow • Neil Harwood, Alstom
19/11/07	ORR Office	• Tim Griffiths, ORR • Iain Morgan, ORR • Sareen Ekta, ORR • Chris Littlewood, ORR • Andrew Wallace, ORR • Phil Edwards, Halcrow • Megan Gittins, Halcrow • Richard Spoors, Halcrow
17/12/07	ORR Office	• Tim Griffiths, ORR • Iain Morgan, ORR • Phil Edwards, Halcrow • Megan Gittins, Halcrow • Richard Spoors, Halcrow
18/12/07	Network Rail's Office	• Dan Boyde, Network Rail • Phil Edwards, Halcrow • Megan Gittins, Halcrow • Richard Spoors, Halcrow
09/01/08	Network Rail's Office	• Amanda Hall, Network Rail • Geoff Jones, Network Rail • Chris Madden, Network Rail • Richard Spoors, Halcrow • Megan Gittins, Halcrow

11 Appendix B: Flow Chart - Variable Track Access Charges



Proposed Framework for VTAC

VTAC TOTAL = Σi VTAC Structures [VEH]
+ Σi VTAC Rail [VEH]
+ Σi VTAC Rsd [VEH]

Identify marginal cost function

ICM v2

Model runs with ±5 to 10% Δ traffic to identify:

Δ Costs 'smoothed' over time and geography

Δ Costs ÷ Δ Traffic = Cost per unit of traffic

NB1: Actraff gives vehicle miles by service group and SRS (not vehicle mix)

NB2: Model constrained by capacity at network / national level

Calculate variable charges income

Income ICM v2

Calculate variable charges income:
£ per vehicle mile by <SG>
x vehicle miles by <SG> and <SRS>
= £income by:
<TOC>
<SG>
<SRS>

NB: assumes that vehicle mix does not vary by <SRS>

(OUTPUT 2)

OUTPUTS

1. £ per Vehicle / mile price list

2. Calculation of Variable Usage charge income

TTCI Modelling

Convert GTM to vehicle mile using assumptions around vehicle mix <SRS>

Calibrate relative vehicle damage to costs for each of 3 VTAC sub-components

VTAC Structures	=	f	Axle Load Speed GTM
VTAC Track	=	f	Axle Load Speed Unsprung Mass GTM Freight suspension banding
VTAC RSD	=	f	T-gamma
	i.e.	f	bogey design, track curvature, speed, etc

Charging Module

Per vehicle price list

Analysis to support Strategic Business Plan

Price List for existing vehicles (OUTPUT 1)

Pence per vehicle mile by:
<vehicle type>
<route category & curvature category combination> [15 categories total]

New formula for new vehicles introduced in CP4

Analysis for SBP (may not be required)

New charges vs Past charges
Passenger vs Freight
Variability analysis by route
Implications of different traffic growth assumptions

Interface 1 & 2

Incremental costs in:
£ per KEGTM; and
£ per KGTM

Disaggregated by:
<SRS>
<route category>
<cost category>

Interface 2a

Data from TABS and engineering:

<Wheel profile>
<GTM>
<Vehicle miles><SRS> ?
<Suspension types>
<Other tech. vehicle characteristics>
<Line curvature>
<Speed>

NB: information re bogey yaw stiffness is protected by Intellectual Property requirements so must be assumed.

Interface 3

TTCI Output will provide scaling factors to convert EGTM to:

Per Vehicle type
<Route> x 5 classifications
<Curvature> x 3 classifications

Calibration occurs by comparing costs from ICM with relative engineering damage calculated from TTCI modelling

£cost <Route> <-> engineering damage units <Route>

Underlying the engineering damage function is the vehicle miles data, allowing simultaneous equations to solve for £ per unit of engineering damage – then £ per vehicle

Interface 4

Charging module output converts:

£ per vehicle mile by <vehicle type>
to
£ per vehicle mile by <service group>

Conversion uses ICM information:

- Total vehicle miles by SG
- Mix of vehicles for each SG (ie miles operated by type of vehicle)

Interface 5

Perform network level check between costs from ICM and income implied by charges. This checks the accuracy of data mapping performed.

Feedback loop and re-run of TTCI modelling if necessary.

12 Appendix C: Factors that influence RCF

Table illustrating factors in the maintenance of trains and track that influence the degree of Rolling Contact Fatigue damage to rails[15]

Responsible Body	Maintenance Factor	Impact on RCF
TOC/FOC	Wheel profile	Research has shown a worn P8 profile to be least likely to propagate RCF. Vehicles have better riding performance on new profiles.
TOC/FOC	Wheel profile	The cross industry Vehicle Track System Interface Committee is recommending a new wheel profile based on recent research. TOC/FOC will face increased costs in introducing this new profile to their fleets.
TOC/FOC	Primary Yaw Stiffness	Each vehicle type should have an optimum PYS established taking account of the routes and speeds in the UK where it will operate. Evidence has shown that some new vehicles are imported to the UK with higher than optimal PYS values for the UK network
Network Rail	Rail Lubrication	The Track Asset Policy requirements should be met. This states that on Primary and Key LSE routes all curves up to 1500 metres radius should have non-contact lubrication of the high rail and on Secondary and other LSE, all curves below 800 metres shall be lubricated. For secondary, rural and freight rural and freight only routes all curves 800 metres or less shall be lubricated where rail life would be less than 5 years without lubrication.
Network Rail	Rail Grinding	The Track Asset policy requires rail to be ground to restore the specified transverse and longitudinal rail head profiles at regular intervals depending on curvature, specified tonnages, and track category.
Network Rail	Track Alignment	The alignment of track should be managed to eliminate discreet faults in track geometry. Action taken on curves up to 1500 metres radius will be a secondary mitigation to rail grinding. Action taken on shallower curves and straight track may be the primary action to reduce the severity of RCF.
Network Rail	Gauge Variation	Maintaining track to the gauge tolerances specified in Network Rail's standards is important, especially in S&C. When track geometry is maintained by tamping machines, one rail is chosen as the datum rail. As this rail is put to a smooth alignment, if there is gauge variation, the opposite rail may offer a less smooth contact to the train wheel, inciting lateral movement of the bogie leading to RCF.
Network Rail	Cant Deficiency	RCF is less likely to develop and propagate on curved track where for a given vehicle speed there is high cant deficiency. This is due to both wheel sets generating outward lateral creep forces.

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[15] Rolling Contact Fatigue: the solution has emerged but the problem remains. Paper by Mark Dembosky published in the Journal of the Permanent Way Institution

13 Appendix D: Summary of European Vehicle types effect on Track forces (Professor Riessberger, Technical University of Graz)

Table drawn up to show how modern traction development is leading to higher forces at the wheel rail interface

Motive Power	Power	Purpose	Approx Year Built	Power Output	Number of powered axles	Axle Weight	Wheel Diameter	Maximum Speed	Wheel/Rail Traction Contact Patch	Power per Axle	Traction-Power Value
	Electric Diesel or Steam	High Performance High Speed Heavy Haul	[-]	kW	[-]	Tonnnes	mm	km/h	mm^2	kW	kW/mm^2
ES 64 U2 2nd generation Euro Sprinter Locomotive	E	HP	2000	6400	4	21.5	1150	230	138	1600	5.8
Bombardier Traxx P160AC locomotive	E	HP	2000	4200	4	20.5	1250	160	136	1050	3.9
OEBB BR 1044/1144 locomotive	E	HP	1975	5200	4	21	1300	160	141	1300	4.6
OEBB BR 1042	E	HP	1965	3808	4	20.8	1250	130	137	952	3.5
DB BR 103	E	HS	1970	7440	6	19.3	1250	190	131	1240	4.7
ICE 1	E	HS	1990	4800	4	19.4	1030	280	124	1200	4.9
ICE 3	E	HS	2000	8000	16	17	920	330	109	500	2.3
TGV Sud-Est	E	HS	1980	6450	12	17	920	300	109	538	2.5
TGV Atlantique	E	HS	1990	8800	8	17	920	300	109	1100	5.1
South Africa Class 9E Co-Co AC loco	E	HH	1980	3840	6	28	1220	90	166	640	1.9
South Africa class 11E Co-Co AC loco	E	HH	1985	4500	6	29	1220	90	169	750	2.2
Dispolok Bo-Bo class ER20 diesel electric	D	HP	2000	2000	4	20	1100	140	128	500	1.9
Voith diesel hydraulic class Maxima 40CC	D	HP	2000	3600	6	20	1150	160	131	600	2.3
EMD Class 66 (Europe) JT42CWRM	D	HP	2000	2268	6	21.6	1067	120	134	378	1.4
IORE MTAB Swedish Co-Co	D	HH	2000	10800	12	30	1300	80	179	900	2.5
Alco M-637 US Diesel locomotive	D	HH	1970	2700	6	31.8	1016	110	171	450	1.3
Union Pacific DD 40AX diesel loco	D	HH	1970	4920	8	31	1016	140	169	615	1.8
EMD SD 40-2	D	HH	1970	2240	6	27.8	1067	105	159	373	1.2
German 2-10-0 steam loco	S	HP	1950	1200	5	17	1400	80	124	240	1.0
Austrian 4-8-2 steam loco	S	HP	1930	1985	4	18	1940	120	143	496	1.7

14 Appendix E: Rail Service Life comparison

Computation of Rail life

(taken from W.W.Hay's 'Railroad Engineering')

$L = K \times W \times (D \wedge 0.565)$

Where:
L = rail life in million gross tons
W = weight of rail in pounds per yard
D = traffic density in millions of gross tons per year
K = "level of maintenance" factor

Assumptions:
1. Formula is based on Straight Track. (To compute rail life over a track segment containing curves of different radii, an adjusted track mile total for the segment is computed by using an adjusted value for K over each curve segment).
2. In the tables below, the K value has been adjusted to coincide with the Cat.1A rail life chosen by Network Rail. All other track categories are calculated using the above rail life formula but with the same K value.

CWR

Track Cat.	Mtce. Factor (K)	Rail Weight (W) lb/yd	Traffic Density (D) mgtpa	Traffic Density to power *0.565*	Rail Life (L) mgt	Rail Life (L) Years	EMGTPA
1A	1.0375	113	16.10	4.81	563.54	35.00	25.00
2	1.0375	113	7.80	3.19	374.20	47.97	11.00
4	1.0375	113	2.40	1.64	192.26	80.11	3.00
6	1.0375	113	1.70	1.35	158.22	93.07	2.00

K Value	Track Type
1.0375	PL - CWR
0.7410	PL - Jointed

Jointed

Track Cat.	Mtce. Factor (K)	Rail Weight (W) lb/yd	Traffic Density (D) mgtpa	Traffic Density to power *0.565*	Rail Life (L) mgt	Rail Life (L) Years	EMGTPA
1A	0.7410	113	16.10	4.81	402.49	25.00	25.00
2	0.7410	113	7.80	3.19	267.26	34.26	11.00
4	0.7410	113	2.40	1.64	137.31	57.21	3.00
6	0.7410	113	1.70	1.35	113.01	66.47	2.00

15 Appendix F: Passenger vehicle charge comparisons

Change in Passenger vehicle track access charges proposed for CP4 with those current in CP3 for the 30 vehicle types with the highest annual mileages ranked by the new RSD factor

Vehicle Class	Vehicle-miles per annum (000)	Vehicle Type	Structures damage Factor	Vertical Track damage factor	Rail Surface Damage Factor	CP4 £/kgtm 2006/07 prices	Change
043/0	***31,127***	***Loco (HST)***	***8.58***	***4.15***	***0.304***	***6.05***	***1%***
373/C	****93849***	***Eurostar Coach***	***0.77***	***2.47***	***0.136***	***3.98***	***23%***
221/M	54,153	Class 221 DMU	2.26	2.42	0.118	3.03	-38%
4	77,305	Coach	2.34	3.39	0.11	4	-12%
390/M	81,042	using latest data ex Virgin (@125).	4.16	3.36	0.101	3.73	-29%
390/T	40,521	using latest data ex Virgin (@125).	3.65	3.26	0.101	3.66	-27%
465/M	***23,102***	***Elec MU***	***0.21***	***1.59***	***0.089***	***2.47***	***20%***
465/T	***23,908***	***Elec MU***	***0.09***	***1.20***	***0.065***	***2.06***	***33%***
317/T	***34,895***	***Elec MU***	***0.2***	***1.64***	***0.055***	***2.19***	***3%***
455/T	***37,245***	***Elec MU***	***0.11***	***1.26***	***0.055***	***1.92***	***18%***
3	155,952	Coach	0.77	2.47	0.053	2.67	-17%
450/T	26,385	Class 450 Trailer (2/unit)	0.85	2.30	0.041	2.26	-25%
159/M	14,359	Dies MU	0.63	2.30	0.041	2.3	-23%
158/M	49,801	Dies MU	0.66	2.23	0.041	2.23	-24%
357/M	17,727	Class 357 Motor Car (3/Unit)	0.87	2.22	0.041	2.2	-25%
165/M	15,830	Dies MU	0.68	2.13	0.041	2.12	-24%
375/T	14,997	Connx cl 375/3 Trailer (1/unit)	0.55	2.06	0.041	2.13	-27%
377/T	20,195	S.cl 377/1 Trailer (1/unit) (@70kg)	0.61	2.01	0.041	2.08	-24%
156/M	25,718	Dies MU	0.55	1.83	0.041	1.9	-20%
150/M	28,185	Dies MU	0.42	1.72	0.041	1.84	-18%
222/M	30,371	Class 222 (9 car unit)	2.4	2.69	0.04	2.52	-41%
450/M	26,385	Class 450 Motor (2/unit)	1.81	2.57	0.04	2.4	-30%
170/M	55,267	Dies MU	1.25	2.51	0.04	2.4	-28%
444/T	20,813	SWT cl.444 Trailer (3/unit)	0.99	2.35	0.04	2.27	-27%
375/M	43,889	Data ex Adtranz	0.99	2.26	0.04	2.21	-33%
377/M	57,280	S.cl 377/1 Motor (3/unit) (@70kg)	1.13	2.23	0.04	2.18	-27%
220/M	33,690	Class 220 DMU	1.34	2.13	0.04	2.06	-50%
321/T	34,239	Elec MU	0.31	1.91	0.04	2.11	-15%
319/T	36,105	Elec MU	0.28	1.83	0.04	2.04	-14%
142/M	18,198	Dies MU	1.26	2.04	0.026	2.09	-37%

16 Appendix G: Freight vehicle charge comparisons CP3/CP4

Changes in Freight vehicle track access charges proposed for CP4 with those current in CP3 for the 30 vehicle types with the highest annual mileages ranked by the new RSD factor

Vehicle class	Million Gross tonne Miles	Laden?	Commodity Type	Structures damage Factor	Vertical Track damage factor	Rail Surface Damage Factor	£/kgtm	Overall change
HTAB	1930	Y	Coal ESI	9.73	3.41	0.135	3.89	-18%
HTAA	1551	Y	Coal ESI	9.73	3.41	0.135	3.89	-18%
TEAK	**969**	**Y**	**Petroleum**	**11.32**	**2.94**	**0.126**	**3.99**	**23%**
HHAA	1053	Y	Coal ESI	9.73	3.14	0.025	3.02	-26%
HHAB	871	Y	Coal ESI	9.73	3.14	0.025	3.02	-26%
FSAO	**1618**	**Y**	**Domestic Intermodal**	**9.33**	**3.13**	**0.025**	**3.15**	**30%**
FTAI	**382**	**Y**	**Domestic Intermodal**	**9.33**	**3.13**	**0.025**	**3.16**	**30%**
KFAF	**311**	**Y**	**Domestic Intermodal**	**7.44**	**2.98**	**0.025**	**2.93**	**26%**
JNAA	257	Y	Construction Materials	11.32	2.77	0.025	2.85	-9%
JHAI	412	Y	Construction Materials	11.32	2.76	0.025	2.84	-10%
FAAA	**206**	**Y**	**Domestic Intermodal**	**3.84**	**2.74**	**0.025**	**2.53**	**18%**
TEAP	**245**	**Y**	**Petroleum**	**9.45**	**2.71**	**0.025**	**2.78**	**0%**
TDAD	**397**	**Y**	**Petroleum**	**7.01**	**2.62**	**0.025**	**2.58**	**23%**
JGAK	266	Y	Construction Materials	7.01	2.62	0.025	2.49	-16%
FEAB	1562	Y	Domestic Intermodal	0.96	2.32	0.025	2.05	-12%
KTAA	213	Y	Domestic Intermodal	0.39	2.15	0.025	1.95	-3%
IKAJ	573	Y	Domestic Intermodal	0.11	1.69	0.025	1.42	-23%
66/5	453	N	Domestic Intermodal	8.29	3.65	0.024	3.26	-24%
66/0	201	N	Steel	6.10	3.21	0.024	2.8	-25%
66/0	764	N	Coal ESI	5.74	3.13	0.024	2.72	-35%
66/5	280	N	Coal ESI	5.74	3.13	0.024	2.72	-35%
HTAB	578	N	Coal ESI	0.09	1.74	0.024	1.77	-14%
HTAA	458	N	Coal ESI	0.08	1.73	0.024	1.77	-25%
HAAV	1213	Y	Coal ESI	8.67	3.15	0.021	3.09	-28%
HMAA	552	Y	Coal ESI	8.67	3.09	0.021	3.05	-27%
PCAC	214	Y	Construction Materials	13.59	2.91	0.021	3.19	-19%
HHAA	303	N	Coal ESI	0.10	1.63	0.015	1.5	-27%
HHAB	248	N	Coal ESI	0.10	1.63	0.015	1.5	-27%
FSAO	**205**	**N**	**Domestic Intermodal**	**0.04**	**1.57**	**0.015**	**1.56**	**2%**
HAAV	418	N	Coal ESI	0.11	1.67	0.007	1.52	-29%

17 Appendix H: Top 10 Vehicles by Miles PA & Proposed VTAC for CP4

Comparison between VTAC per passenger vehicle mile based on 2007 data and that available in 2005, for the top ten most used fleets

				A			B
					Data from Booze Hamilton Report 2005		
Passenger vehicle classification in TTCI model	Total miles/annum	Vehicle Group in TTCI model	Vehicle Description	VTAC cost pence/mile for 2009/10 including RSD	Total miles per annum predicted in 2005	VTAC cost pence/mile 2005 excluding RSD	Cost per mile based on 2009/10 predicted usage and updated for inflation*
3	152,614	3	Mark 3 passenger coach design speed 125 mph	12.36	167,007	11.2	13.14
4	75,650	3	Mark 4 passenger coach design speed 140 mph	21.87	68,170	19.3	18.64
158/M	48,735	4	Dies MU	12.07	59,079	11.2	14.56
170/M	54,084	4	Dies MU	15.03	49,316	14.1	13.78
221/M	52,994	4	Class 221 DMU	21.43	52,867	19.2	20.53
375/M	42,949	4	Class 375 EMU	13.49	26,961	14.5	9.76
377/M	56,054	4	Class 377/1 Motor (3/unit)	13.85	28,953	14	7.75
390/M	79,307	4	Pendolino class 390 with motor	27.33	51,363	28.7	19.93
390/T	39,654	4	Pendolino class 390 without motor	25.54	23,882	26.7	17.24
Y	91,840	3	Eurostar coach	14.28	91,935	11.2	12.02
Total	693,881				619,533		

*Inflation indicies used in calculation: RPI April 2005 = 191.6
RPI April 2007 = 205.4

Columns A and B may be compared as they are based on the same (2009/10) annual mileage