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INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

Deliverable 1.4.8 – Overall Cost Reduction

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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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Glossary

Abbreviation/acronym	Description
BB ERS	Balfour Beatty Embedded Rail System
DLD	Driving and locking device
IM	Infrastructure Manager
LCC	Life Cycle Cost
LICB	Lasting Infrastructure Costs Benchmarking study
NPV	Net Present Value
RAMS	Reliability, Availability, Maintainability, Safety
RCM	Remote condition monitoring
SCL	Surface Crack Length (for RCF defects)
TLT	Technical lifetime

1. Executive Summary

The INNOTRACK project set itself the goal of demonstrating that a 30% reduction in LCC of track infrastructure is achievable. Sub-project 1.4.8 has assessed the results of INNOTRACK research and development using a standardised LCC formulation developed within the project, with the objective of investigating the impact of INNOTRACK research on the track infrastructure costs of the four participating infrastructure managers:

IM	BV	DB	NR	SNCF
INNOTRACK innovations considered	S&C - New designs, hollow bearer, RCM (SP3)	Slab Track (SP2)	Premium Rail, Grinding & Lubrication (SP4)	Sub grade treatments, soil strengthening (SP2)
Method of analysis	SP6 LCC model combined with qualitative analysis of benefits	SP6 LCC model	NR RCF/Wear model and NR LCC analysis	Case study cost/benefit analysis using SP6 LCC model

With the exception of the premium rail/grinding/lubrication case, it has not been possible to evaluate the impact of the innovations on the overall LCC of the infrastructure managers. This was partly because a poor understanding and definition of infrastructure costs makes it very difficult to determine the existing costs and hence the base case to compare with innovations and partly because greater resources than were available to the project team are required to complete this level of analysis (however it should be possible).

Instead, a number of case studies have been analysed for each innovation, the results of which are as follows:

INNOTRACK Work Package	Innovation	LCC Impact (Discounted NPV)
SP2 – Support Conditions	Low bearing zone (drainage)	Reduced by 60% for the trial site, with a payback of <2 years
	Soil strengthening (inclined concrete piling)	Lower delays to traffic compared to the conventional track treatment
	Transition zone	Lower delays to traffic compared to the conventional track treatment
	BB ERS Slab Track	Reduced by up to 20% for traffic levels of 27-55MGT per year, for a nominal 100km of track, with potentially greater benefits for higher annual tonnages
SP3 – S&C	New design & materials	Reduced by 10% for a single S&C unit
	Enhanced DLD	Reduced by 12% for a single S&C unit
	Condition Monitoring	Reduced by 4% for a single S&C unit
SP4 - Rail	Premium rail	Reduced by up to 16% for the specific routes modelled Reduced by 11%-30% for all NR primary curves <2500m radius Estimated to equate to a 1.3-2.6% reduction in total annual track maintenance and renewal costs
	Rail grinding	
	Rail lubrication	

Key conclusions from the project are:

- The life cycle cost calculation favours low investment costs (due to the discounting factor).

- Poor understanding and definition of infrastructure costs makes it very difficult to determine the existing costs and hence the base case to compare with innovations.
- The work carried out in D1.4.8 has shown the difficulty with scaling up life cycle costs to whole networks using generic rules for LCC calculations. Instead, a comprehensive ‘bottom-up’ approach is recommended where every site that can potentially benefit from use of innovative technology is analysed separately and the results from individual analyses can be summed to calculate the total network-wide LCC reduction.
- The true LCC benefits of a number of the innovations developed by INNOTRACK will only emerge after several years of site trials. As well as closely monitoring the technical performance of new technology, it is recommended that a comprehensive record of interventions and costs is also maintained for trial sites so the economic impact of the innovations can be properly assessed.

2. Introduction

The INNOTRACK project aims to develop a Cost-Effective high performance track infrastructure for mixed traffic mainline rail systems. The objective of INNOTRACK is to reduce Life Cycle Costs (LCC), while improving the RAMS characteristics of a conventional line with a mixed traffic duty. The project set itself the goal of demonstrating a 30% reduction in LCC of track infrastructure.

In order to develop the range of solutions required to deliver a significant overall reduction in LCC, the INNOTRACK project has brought together infrastructure managers, the railway supply industry and academia to investigate and evaluate leading edge track system technologies, adopting a controlled methodology to assess life cycle cost benefits of track-technology.

The results of INNOTRACK research and development have been assessed using a standardised LCC formulation developed within the project, based on best LCC practices at EU level and independently assessed. To demonstrate the overall contribution of INNOTRACK innovations to LCC reduction the detailed analysis from each sub-project must be applied at full network level. The work on Deliverable 1.4.8 was initiated in July 2009 with the objective of investigating the impact of INNOTRACK research on the track infrastructure costs of four participating infrastructure managers:

- Banverket (BV)
- Deutsche Bahn (DB)
- Network Rail (NR)
- Société Nationale des Chemins de Fer Français (SNCF)

This report summarises the findings from the assessment of the potential overall reduction in LCC through implementation of a range of INNOTRACK developments.

2.1 Constraints of the economic study

When discussing a 30% cost reduction, it is important to clarify what reference to use. In SP1 the cost distributions for some infrastructure managers (IM) have been analysed. Such data often covers an overall cost of the whole infrastructure and not only the track. As an example, a typical cost distribution is presented in Figure 1 which is taken from the Swedish infrastructure manager Banverket for one of their lines. Out of the total maintenance cost, the track cost is roughly 69% and hence, the 30% cost reduction corresponds to a 21% cost reduction of the overall annual cumulated costs. It should be noted that this is an annual cost rather than a life cycle cost.

The cost distribution in Figure 1 is based on annual costs from the accounting system excluding reinvestment. A complete LCC analysis covers all costs over the total life time of a system or product including (re)investment and is strongly dependent on discount rates. Such a complete analysis of all the railway costs on all lines in the network is possible but requires sufficient relevant LCC data, which would require significant resources to obtain and would produce an extremely complex LCC model. So far, such a complete analysis of all detailed costs has not been produced for any of the participating IMs. Therefore, for the purpose of D1.4.8 a simpler approach is required of scaling up LCC from part studies of some innovations to the whole railway and comparing their expected impact on the full system to actual cost data.

Even though LCC is not fully accounted for, Figure 1 is still a useful reference when evaluating innovations. It reflects regular current costs per year for maintenance, so if that maintenance cost is reduced by 30% it will give a saving effect on LCC. However the effect of this maintenance saving on overall LCC will vary depending upon the investment costs and other economic parameters such as discount rate. When considering Figure 1, the (re)investment cost of introducing new innovations must be handled carefully because they are not current. They have to be converted to a net present value as is done in LCC analysis. A higher reinvestment cost of new innovations should be compensated for by lower maintenance costs and/or extended in-service life/durability.

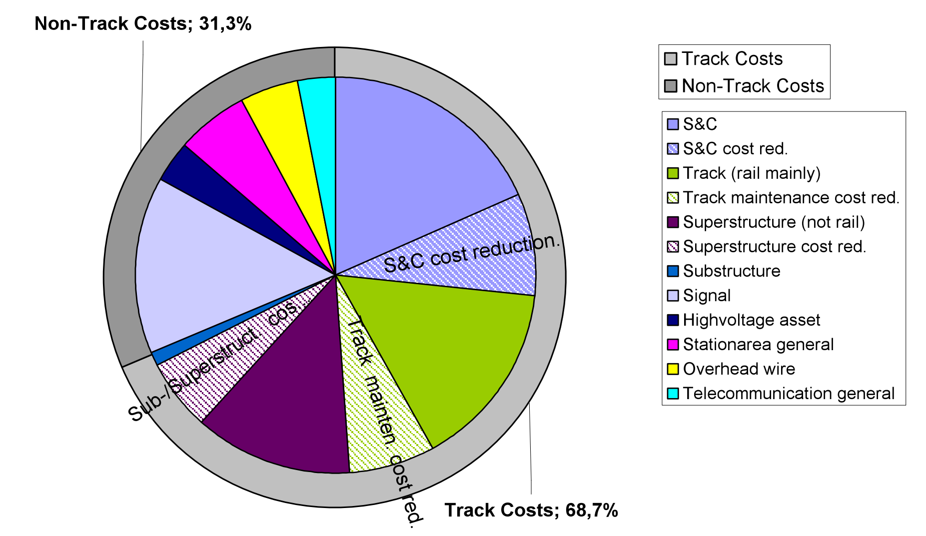


Figure 1. This is an example of a cost distribution for track maintenance. The data is taken from Banverket. Dashed areas illustrate the INNOTRACK objective of 30 % cost reduction on track. As track costs are only 2/3 of the overall maintenance cost, the areas cover 21% of the total chart.

Referring to Figure 1, if excluding reinvestments then a hypothetical cost reduction for track of 30% is assumed by making equal reductions in the 3 largest sectors (dashed areas). There is no analytic base for that assumption but the deliverables from INNOTRACK show great potential for cost reductions in all parts of the IM process. As conditions vary between different railways and lines due to different asset management policies and operating environments, the outcome from INNOTRACK should not be expected to be universally applied for every IM and every line. Instead, the potential savings will be relative to costs as compared by LICB and the innovations will provide a tool box of solutions to be chosen depending on the characteristics of each line to be optimised.

INNOTRACK has established an LCC and RAMS methodology with a focus on applications and the benefits of these methods in evaluating innovation. The LCC and RAMS framework, the common LCC tool and the standardised cost model is an excellent base for carrying out comparable LCC analysis, standardised at European level and feeding into future LICB and other benchmarking studies. Further work to understand costs and LCC, and increase the availability of LCC/RAMS data could provide further increased cost savings and performance in the future.

2.2 Benefits from innovations not LCC-analysed

Of all innovations and results generated in INNOTRACK, the SP5 results are the most difficult ones to evaluate with LCC, as available data is mainly subjective and most data was collected as a result of questionnaires and interviews. SP5 covers logistics and the interface between contractors and infrastructure managers. In spite of the LCC complexity, the delivery D5.1.4 with interviews of both IM and contractors indicates great potential for cost reductions. Contractor A with international experience refers to costs for reinvestment projects that are 3 times higher in one country compared to the others. This large difference was explained by the different safety rules and regulations and worksite logistics between the infrastructure managers.

Other conclusions made in D5.1.4 highlight the large potential cost savings to be made on key heavy equipment, which are perceived to be excessive priced and under utilised. Increased machine efficiency, better maintenance planning and plant utilisation and also increased competition in the heavy rail equipment market will also lead to large reductions in operational costs.

The SP5 results have highlighted the potential to produce a 30% cost reduction for certain infrastructure managers and lines, but due to the data gathered in SP5 being qualitative rather than quantitative, LCC calculations for SP5 have not been possible, so they have not been further evaluated in this report from WP1.4.

Based on the INNOTRACK deliverables and innovations, with the cost data available from the IMs and contractors, the working group of WP1.4 states that there is undoubtedly the capability to reduce costs in the European railway system and although this is difficult to quantify it is strongly recommended that further work is carried out at a European level to benchmark and understand costs.

With such a background, this report has deliberately focused on 3 technical innovations for which the LCC calculation is possible: modified S&C, Balfour Beatty Embedded Rail System and Premium Rail (including grinding and lubrication). The results of these will not sum up to a 30% cost reduction, but with support from all the other non-analysed ideas this target could be achieved for some infrastructure managers.

3. Overall LCC Reduction

3.1 Objectives

3.1.1 Initial approach

The deliverables D1.4.8 was established to investigate the problem outlined above. Initially D1.4.8 had the following main objectives:

- Create a model capable of demonstrating the potential reduction in total LCC achievable for a specific railway if the innovations developed in INNOTRACK are fully implemented.
- Collect baseline cost data from each project participant to demonstrate the potential improvements in LCC due to INNOTRACK research and development.
- Use of the model will also show which innovations give the greatest potential benefits to enable implementation of each new product or process to be prioritised.
- Participating IMs use the model to analyse their own cost data, calculate potential LCC reductions, compare results with other IMs and indicate how initiatives to deliver LCC reductions may be prioritised in future.

However, it quickly became clear in the early stages of the project that the objectives of D1.4.8 were too ambitious given the time and resources available. Collation of comprehensive cost data for track inspection, maintenance and renewals at full network level was, in some instances, an impossible task. LCC models for each Innotrack innovation were not available to the project team so it was necessary to prioritise which developments should be included in the assessment of overall LCC reduction. Constructing a generic model for demonstrating potential reductions in overall LCC for each participating IM was not feasible as each IM has track infrastructure and operations with its own set of characteristics, priorities and constraints. Therefore, a change of methodology was agreed.

3.1.2 Revised approach

Taking a typical annual track infrastructure inspection, maintenance and renewal cost distribution, the potential reduction in costs of S&C, Track and Superstructure were investigated (Figure 1).

Analysis of each of the three sectors was carried out by participating IMs as follows:

IM	BV	DB	NR	SNCF
INNOTRACK innovations considered	S&C - New designs, hollow bearer, RCM (SP3)	Slab Track (SP2)	Premium Rail, Grinding & Lubrication (SP4)	Sub grade treatments, soil strengthening (SP2)
Method of analysis	SP6 LCC model combined with qualitative analysis of benefits	SP6 LCC model	NR RCF/Wear model and NR LCC analysis	Case study cost/benefit analysis using SP6 LCC model

Table 1. Summary of D1.4.8 LCC analysis approach.

Each of the sectors analysed will now be looked at in turn. Sections 3.3 and 3.4 are extracts from the relevant INNOTRACK deliverable reports. In contrast, section 3.5 (LCC of premium rail/grinding by Network Rail) is first reported in this document.

3.2 Track support structure (SP2)

3.2.1 Subgrade improvement methods (WP2.2)

Within WP2.2 the following areas are identified as major problems and reference systems were established corresponding to these three zones for the LCC calculations:

- Low bearing zone (France)
- Soil strengthening under existing railway embankment (Sweden)
- Transition zone (Spain)

3.2.1.1 Low bearing zone

Reference system

The reference track is an existing double track section of the French National rail network (the Chambéry-Montmélian). The section is a ballasted track of 7 kilometres length inside the Alps, with mixed traffic and a constant tonnage of 14 MGT/year.

Huge maintenance activities and repeated track levelling needed to be undertaken because of subsoil problems.

Optimised system/innovation

The renewal of the superstructure did not have the expected effects, the problem still remained. The maintenance experts found out that the track could be improved by subsoil improvement in order to solve the problems encountered on this site. As no measurement tools had previously been used the subsoil problems couldn't be identified prior to renewal of the superstructure. The subsoil problem has been solved by a special drainage construction.

LCC In/Out Frame

The LCC In/Out Frame shown in Figure 2 below documents the boundary conditions used in the LCC calculation for the low bearing zone case study.

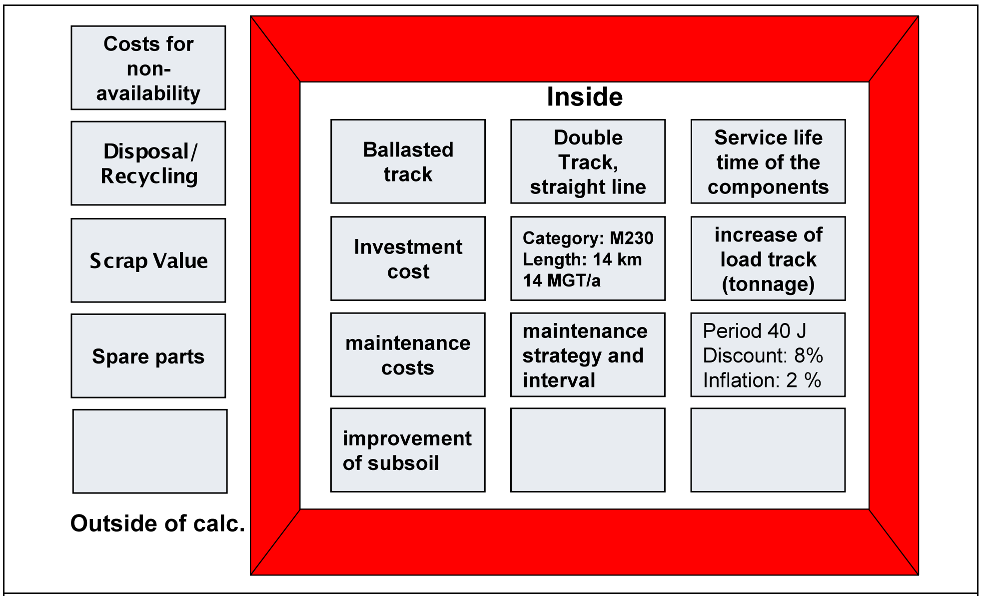


Figure 2. LCC In-Out frame for low bearing zone case study.

CBS (Cost Breakdown-Structure)

The cost breakdown structure applied to the low bearing zone case study is shown below in Figure 3.

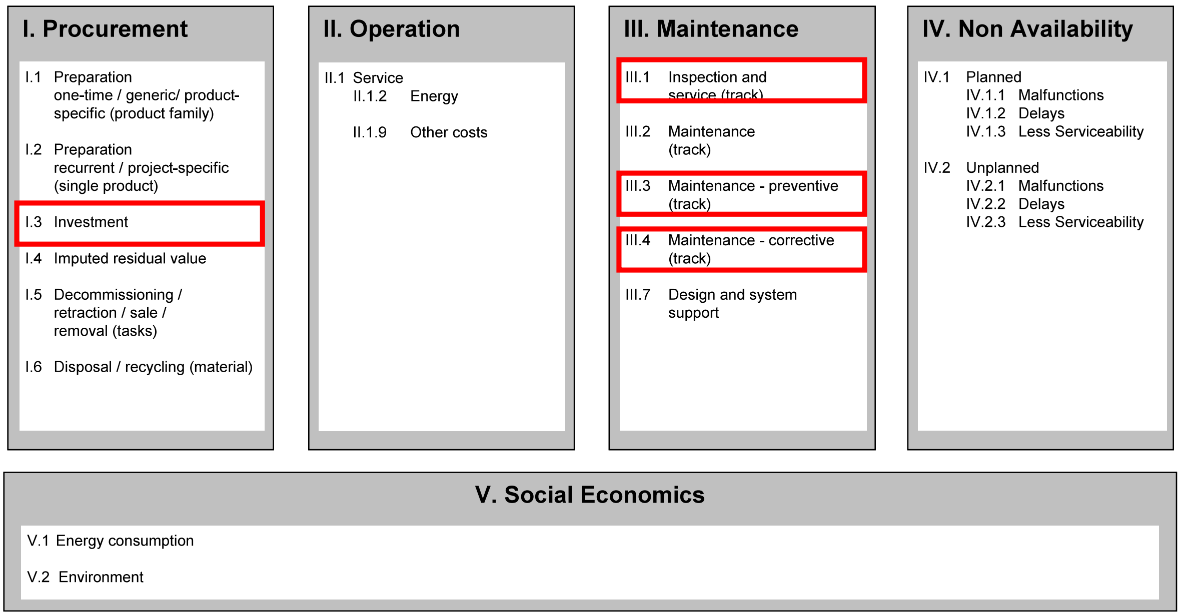


Figure 3. Cost breakdown structure for low bearing zone case study.

Results in terms of LCC

The LCC calculation consists of the comparison of the reference system – no drainage linked with huge maintenance costs – and the optimised system with a drainage construction. The costs of installing, maintaining and operating this system have been modelled in the software D-LCC. The LCC model includes all necessary track components and the LCC input data for the ballasted track has been verified. The evaluation of the solution in terms of LCC demonstrated that the optimised system is not just the best technical solution but also gives benefits in economic terms as the following Figure 4 shows. Without the drainage solution the cost over the life cycle of 40 years would be more than double mainly due to the annual maintenance costs.

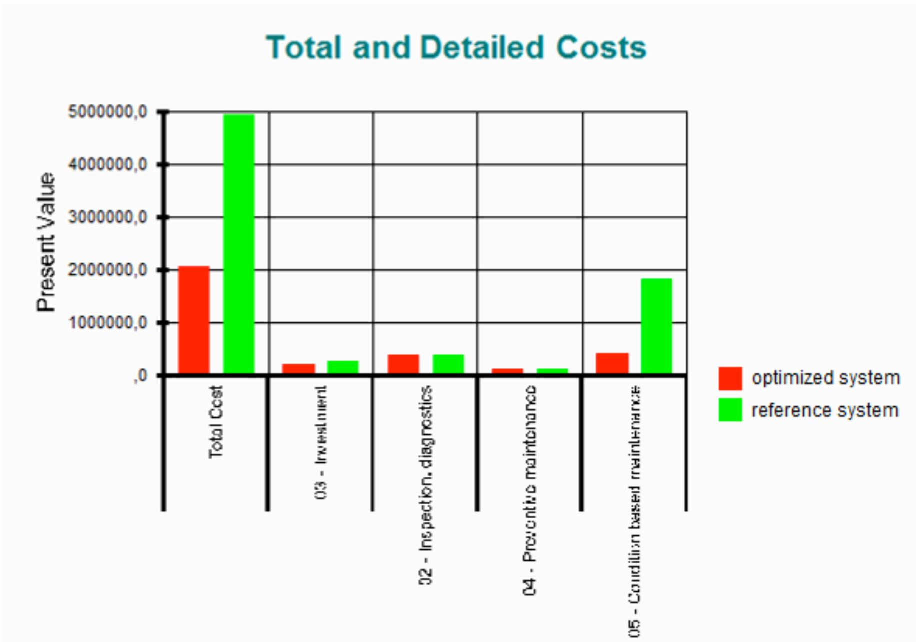


Figure 4. LCC comparison between reference case and optimised system for the low bearing zone in France.

3.2.1.2 Soil strengthening under existing railway embankment

Reference system / Optimised system

The LCC calculation requires the comparison between the reference system (which is not defined) and the optimised system. The latter is soil strengthening of the embankment with inclined lime cement columns. This innovative method has been carried out under existing track without track excavation and without traffic disturbances. A reference system has not been defined, but is required for comparison in the economic evaluation. Therefore, the reference system for the case of soil improvement has been taken to be the excavation of the whole track for ground and track works including catenaries.

LCC In/Out Frame

The appropriate boundary conditions are fixed and the question what is within the calculation and what is not are made clear by the In/Out Frame. Figure 5 shows there are some points to be clarified (see fields on the frame) which are required as essential input for the LCC calculation. An LCC calculation is not possible without the definition of a reference case with cost data to be compared with the innovation case.

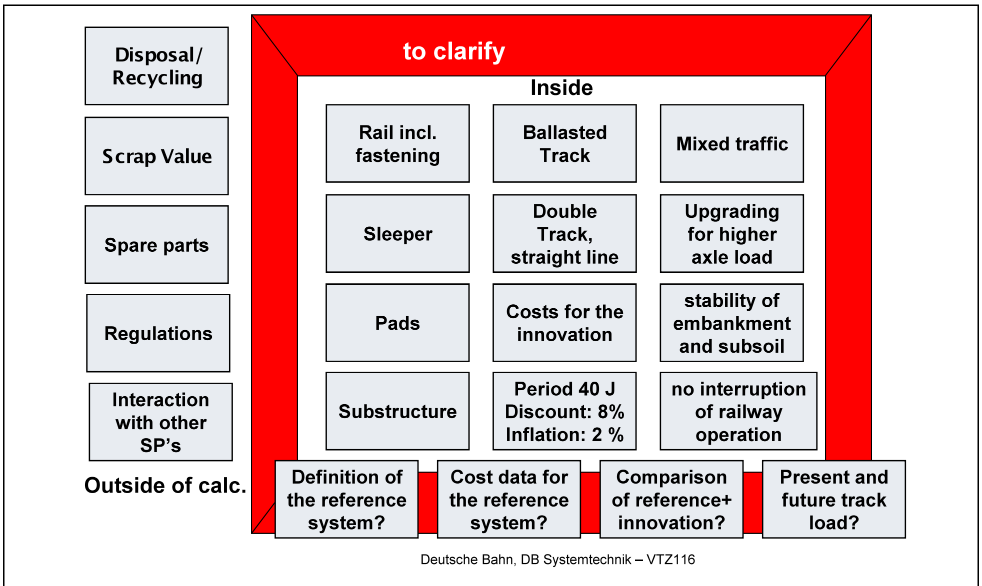


Figure 5. LCC In-Out frame for soil strengthening case study.

CBS (Cost Breakdown-Structure)

The cost breakdown structure applied to the low bearing zone case study is shown below in Figure 6.

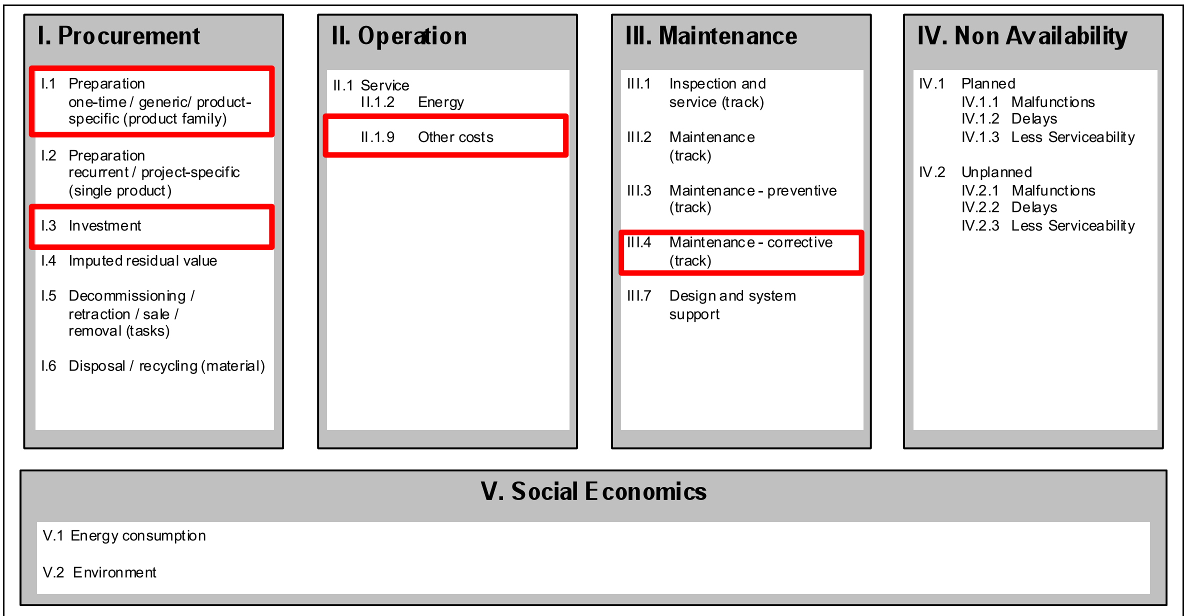


Figure 6. Cost breakdown structure for soil strengthening case study.

Results in terms of LCC

Regarding the optimised system the costs for investigations and design were 21% of the total costs and the installation of the lime cement columns 16% of the total costs. In contrast to the optimised system there are additional costs of 56% for the reference system due to the excavation of the whole track for ground and track works (including the catenaries) in order to perform strengthening.

In this regard three points should be emphasised.

1. The total cost of the innovation was low compared to other methods.
2. The costs for lime cement columns were only 16 % of the total costs.
3. No additional costs due to traffic disturbance had been taken into consideration because the remedial work was carried out under existing track and without restriction to train operation. Therefore it is obvious that there is a great economical and operational interest to use soil improvements methods that can be used without any, or very little, interference with existing railway track.

In this case investment for the innovation is easy to justify from an economic point of view, because the benefit of the optimised solution is clear and for this reason it was decided that there is no need for LCC calculations for this case study. In order to do an LCC calculation it is necessary to define a reference case containing detailed LCC input data (especially maintenance activities and related costs) to be compared with the innovation of the inclined lime cement columns. The following approaches were suggested by SP6:

- To find another track in Sweden with almost the same boundary conditions and soil problems where sufficient maintenance cost data are available or;
- An alternative case could be defined evaluating what happens if the track would have not been strengthened by the used columns but was just maintained. This requires all maintenance activities (e. g. measurements, monitoring, special retrofitting measures) and costs for these activities to be defined.

It has not been possible to complete the approach suggested by SP6 but this is recommended for further trial sites where soil strengthening is considered to be an appropriate track treatment.

3.2.1.3 Transition zone

Reference system / Optimised system

The optimised solution consists of the improvement of 32m of an embankment, at both sides of a concrete block, by replacing 2.5m of the material below the sleeper with well compacted sandy gravel of the QS3 type reinforced with two layers of geo-grid. Ballast at both sides and over the concrete block was replaced by a 35cm thick layer of high quality ballast.

Beside the fixed boundary conditions and the described technical structure the maintenance activities (described by frequency and the unit cost) have to be defined and established in the LCC analysis. This is a requirement if LCC for different systems or components are to be compared. As there was no detailed information for the reference system (especially costs for maintenance activities), the case without the optimised transition zone linked with speed restrictions and large Non-Availability costs has been taken as reference system.

In/Out Frame

The LCC In/Out Frame shown in Figure 7 below documents the boundary conditions used in the LCC calculation for the transition zone case study, highlighting a number of factors where clarification is required regarding the data inputs to the LCC calculation.

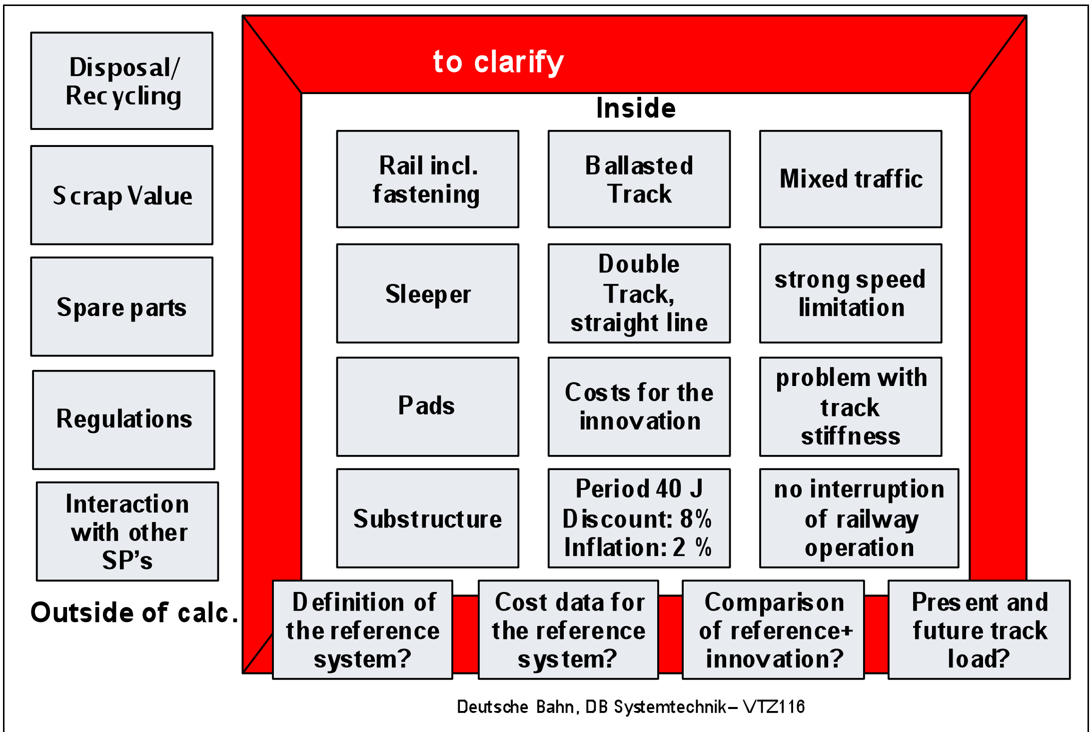


Figure 7. LCC In-Out frame for the transition zone case study.

CBS (Cost Breakdown-Structure)

The cost breakdown structure applied to the transition zone case study is shown below in Figure 8.

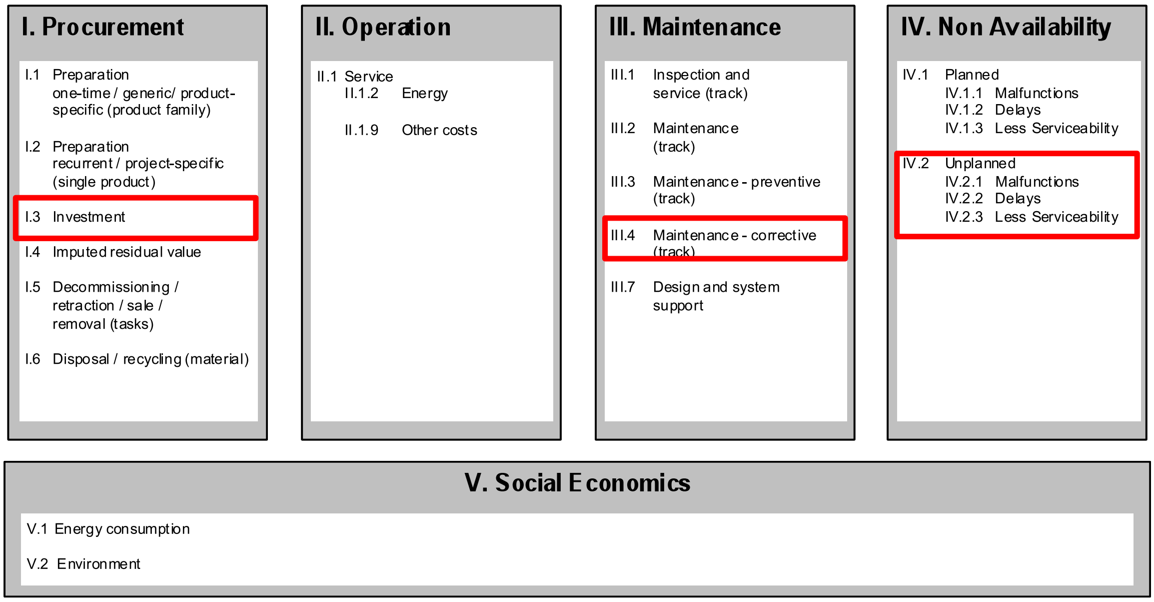


Figure 8. Cost breakdown structure for transition zone case study.

Results in terms of LCC

The costs for the optimised system consist of investment and maintenance. For the reference system only the cost due to speed limitation had to be taken into account as Non-Availability cost. The benefit of the optimised system is clear, because the investment is small compared to maintenance costs of the reference system distributed for the study period.

With the optimal solution for the transition zone problem, the high maintenance costs due the speed restrictions (reference system) could be removed and the economic benefit verified. The new method has been used to increase stability of subsoil before the railway will be opened for higher axle load condition; it has been successfully tested and can be applied with the benefit of achieving permanent subsoil improvement to mitigate the problems of stability, bearing capacity, settlement and track vibrations that can occur on existing railway lines.

3.2.2 Innovative slab track (WP2.3) – BB ERS

SP2 has also studied alternative track support systems with the aim of developing an alternative solution to ballasted track because increasing speeds, axle loads and traffic may impact on the cost effectiveness of traditional ballasted track. One solution evaluated by SP2 is the Balfour Beatty Embedded Rail System (BB ERS), where an existing concept and modified design to deliver low manufacturing and low installation costs have been analysed. The optimised components have been validated through comprehensive component and system testing.

Reference system

The reference system is a standard ballasted track with a service life of 40 years, CEN60 rail and concrete sleepers.

Optimised system/innovation

The Optimised system is the Embedded Rail System of Balfour Beatty (BB ERS) as an innovative slab track. Further details regarding the novel track system of BB ERS are described in deliverable D2.3.3.

In/Out Frame

The LCC In/Out Frame shown in Figure 9 below documents the boundary conditions used in the LCC calculation for the BB ERS.

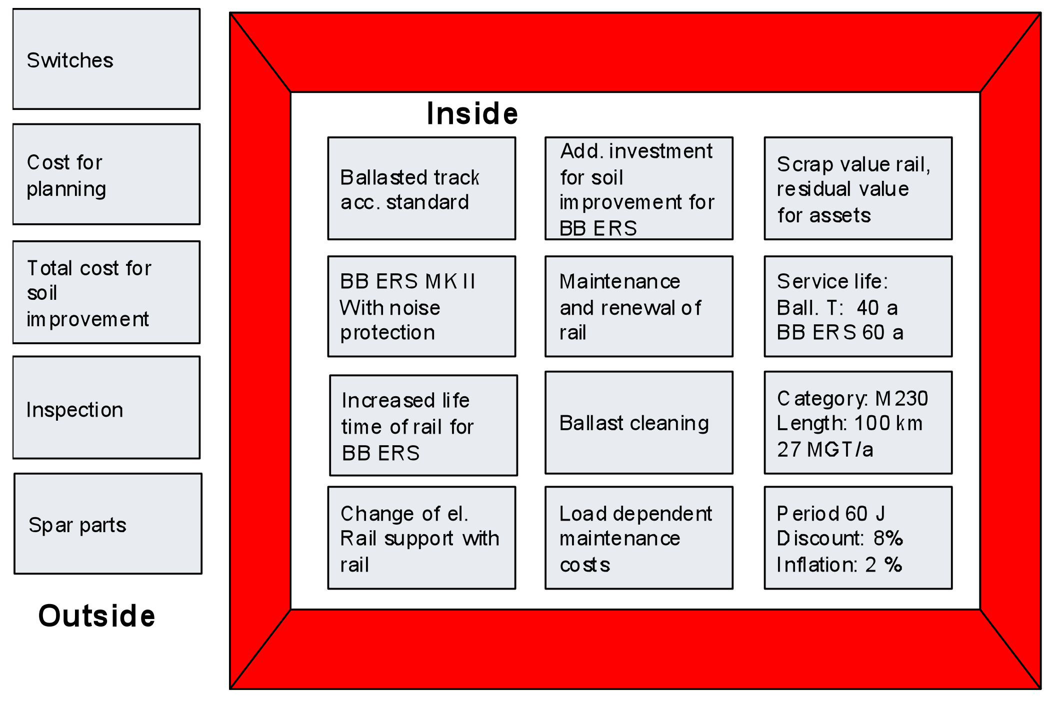


Figure 9. LCC In-Out frame for BB ERS case study.

CBS (Cost Breakdown-Structure)

The cost breakdown structure applied to the BB ERS case study is shown below in Figure 10.

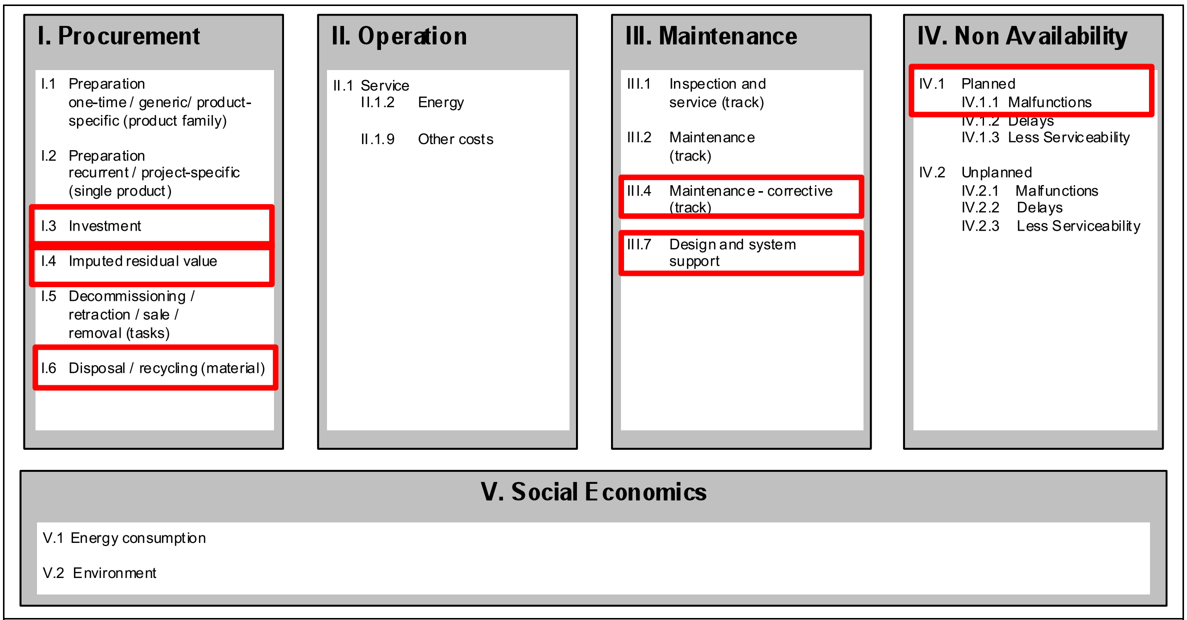


Figure 10. Cost breakdown structure for BB ERS case study.

LCC input data for the BB ERS case is shown below in Figure 11.

Cost block	Data structure	Reference case Ballasted track	Innovation BB ERS
Investment	Euro Cycle Source Quality	515 – 600 €/Tm*) load dependent, nom. 40 year DB intern Experts / Analysis	644 - 827 €/Tm load dependent, nom. 60 year BB Estimation / Experts
Operation	Euro Cycle Source Quality	N/a	N/a
Maintenance Rail renewal	Euro Cycle Source Quality	154 – 202 €/Tm load dependent, nom. 20 year DB Intern Experts / Analysis	168-207€/tm + 68 €/tm supp. load dependent, nom. 36 year BB, DB intern Estimation / Experts / Analysis
Maintenance Rail grinding	Euro Cycle Source Quality	Load dependent load-, radius dependent , 3 year DB Intern Experts / Analysis	Same like ballasted tracks
Maintenance Ballast tamping	Euro Cycle Source Quality	Load dependent load dependent , nom. 4 year DB Intern Experts / Analysis	Consideration of one weak point in soil

Figure 11. LCC input data for BB ERS case study.

Results in terms of LCC

Analysis has shown that a significant reduction in LCC is potentially possible with the BB ERS slab track system but that the benefits are dependent on the annual tonnage, Figure 12.

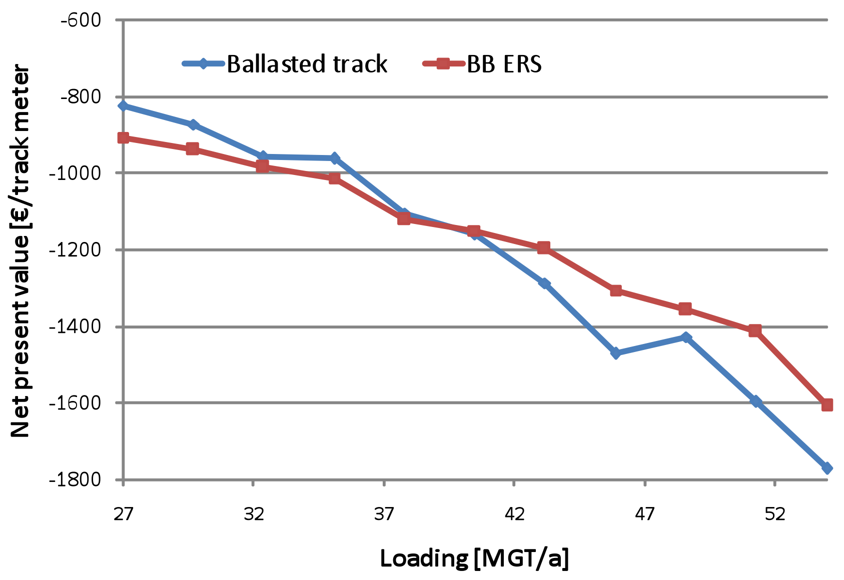


Figure 12. NPV of ballasted track compared to BB ERS slab track.

In this case identical LCC are reached at 38 MGT per year. For higher loading the LCC of BB ERS is lower than that of ballasted track. The Break-Even Point (Return of Investment) is between 10-20 years, governed by the reinvestment for rail renewal on the ballasted track system.

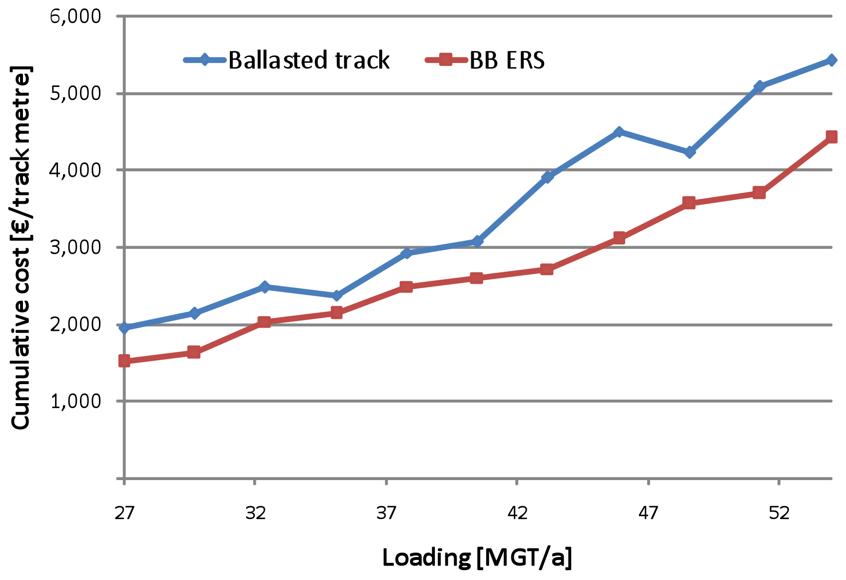


Figure 13. Cumulative lifetime cost (per track metre) for ballasted track compared to BB ERS slab track (not discounted).

Comparing the total costs over 60 years per track metre (without the consideration of the discount rate), there is a saving with BBERS over ballasted track of 20-30% for all annual tonnages modelled (see Figure 13). This is due to lower maintenance requirements and a longer service life for the BB ERS. It should be noted that this example includes the costs for the BB ERS associated with making soil improvements prior to installation of the concrete slabs.

3.3 S&C (SP3)

3.3.1 LCC input data – base case

Input for the S&C LCC model has been provided by the members of Sub-Project 3 (SP3), Switches and Crossings. Data for inputs are based on statistics from Banverket (Sweden), DB (Germany) and SNCF (France). These figures are approximate as they represent a mixture of experience from several countries and track conditions. The data shown in Table 2 represents the base case for S&C, i.e. no innovations implemented.

LCC-Input	Value		Source
General data			
Traffic data	20	MGT/year (Million Gross Tonnes/year)	1
Technical Life Time	500	MGT (25 years)	2
Maintenance activities			
Failure rate	1.5	failure/year	1
Preventive maintenance	20	maintenance actions/year	1
Mean time to repair (MTTR) for corrective maintenance	0.5	h	1
Mean time to repair (MTTR) for preventive maintenance	1	h	1
Mean Waiting Time (MWT) for corrective maintenance	1	h	1
Mean Logistic Delay Time (MLDT) for preventive maintenance	1	h	1
Replacement of crossing	240	MGT	3
Replacement of switch blades	160	MGT	3
Tamping interval	120	MGT	3
Grinding interval	80	MGT	3
Unavailability data			
Probability for train stop	33 %	per failure	1
Train delay cost	80	€/min	1
Cost data			
Investment material cost	125 000	€	1
Investment installation cost	53 000	€	1
Worker cost	50	€/h	
Net present calculation			
Discount rate	5	%	1
Calculation period	25	Years (See TLT)	

Table 2. S&C LCC input data (base case – no innovations implemented).

1) Agreed within SP3
2) Litterature: (Zwanenburg 2008)
3) Swedish data

3.3.2 LCC input data – innovations

Using data in Table 2, LCC models have been built for three different cases:

- WP3.1 Design and material
- WP3.2 Driving and locking device
- WP3.3 Condition monitoring

For modelling the three cases the assumptions in Table 3 have been proposed by SP3.

Innovation	Investment	TLT	Corrective Maintenance	Train delays	Preventive Maintenance	Operation	Inspection
WP3.1 Design and material	+ 6%	+20%	- 30%	-30%	-30%	-	0%
WP3.2 Driving and locking device	+ 9%	0%	- 80%[1]	-80%[1]	-60%[1]	-	0%
WP3.3 Condition monitoring	+ 4%	+ 20%	-20%	-50%	+20%[2] -15%[3]	+0.3k€/year	-49%

Table 3. Changes to LCC input data (base case) for each Innotrack innovation, as proposed by SP3.

1) Only control device and switch device
2) Small activity maintenance (adjustment and small repair)
3) Larger repair and replacements

3.3.2.1 WP3.1 Design and material – justification for changes in Table 3

Material test and development of new designs is evaluated in the INNOTRACK Demonstrator project which will be presented in 2011. Therefore only preliminary data can be used for assessment. In deliverable D3.1.5, “Recommendation of, and scientific basis for, optimisation of switches & crossings – part 1 and part 2” the following is highlighted:

- With a new switch blade design and lower stiffness the maximum wear index (at 10.7 m) is reduced by 50 % due to track gauge optimisation (at the first contact point).
- With a new frog design and reduced stiffness the contact force at the frog is reduced by 24-44% depending on the speed and axle load.

In the calculation a reduction of 30 % in frequency of maintenance has been used together with increased TLT.

3.3.2.2 WP3.2 Driving and locking device (DLD) – justification for changes in Table 3

Deliverable D3.2.1, “Definition of Acceptable Rams and LCC for DLD’s” has described the assumptions in detail.

From this report the following conclusions are highlighted:

- Banverket have a higher cost than DB for maintaining the DLD. The initial results of this study (not shown here, since they have been corrected) indicated differences are greater than expected and therefore a recalculation was done.

- Banverket has used a unit cost of 365 €/action. This unit cost is an average based on actual data, compensated for high cost actions such as replacement of switch blades and frogs as well as welding.
- The number of actions is higher for Banverket than for DB.
- The LCC for (only DLD over 30 years) the studied switch configuration at DB (BKZ93): 84.104 €.
- The LCC for a comparable Banverket switch configuration, JEA 73 (only DLD over 30 years): 133.436 €
- The LCC target can be achieved by investing in more reliable and less maintenance intensive equipment. For example the position detector – which has the lowest MTBF of all DLD components – could be a fully encapsulated solution integrated into a hollow sleeper. Position detectors with a similar approach are already available (VAE IE 2010).
- Cost for today's DLD is 8500 € (DB) compared to 15 000 € for the INNOTRACK innovation.

The following goals were set by the work package 3.2 project team:

- Modular design concept integrated into a hollow sleeper with
    - Drive unit
    - Locking unit
    - Detection unit
    - Control unit
- Each component individually replaceable within 30 minutes (reduced from at least 120 minutes)
- Maintenance interval 12 months, 1 h maintenance per year (actuator and locking device). (Interval increased from 3 month)
- 0,3 h maintenance per year (detection device) (Reduced maintenance time from 1 h per year)
- Cost for replaceable unit 2.000 € in average
- Detection unit replaceable within 30 minutes and maintenance interval 12 months, 0,5 h maintenance per year (Interval increased from 5 month , Reduced maintenance time from 1,5 h per year).
- Cost for replaceable drive unit 2.000 €
- Cost for replaceable locking unit 1.000 €
- MTBF of DLD components >= 250.000 h (Increased from today 11 000 h)
- Service interval = 12 months
- Service time regular 1 hour (2 workers)

These improvements have been used as input data for the re-designed DLD developed by INNOTRACK.

3.3.2.3 WP3.3 Condition monitoring – justification for changes in Table 3

SP3 have proposed that the implementation of reliable condition monitoring systems on S&C will lead to the following improvements:

- Reduced need to hold teams in readiness to react to failures
- Reduced time on site when attending a faulty asset
- Reduced or eliminated need for periodic inspection and maintenance tasks
- Eliminated need for staff to prioritise and schedule work

3.3.3 LCC outputs

Using the SP6 S&C LCC model with the changes to input data shown in Table 3 applied to a single S&C unit shows that the potential reduction in LCC due to each SP3 innovation is as follows:

Innovation	Reduction in LCC value compared to base case
WP3.1 Design & materials	-10.2%
WP3.2 DLD	-11.7%
WP3.3 Condition monitoring	-4.2%
TOTAL	-24.0%

Table 4. Summary of LCC reduction through implementation of INNOTRACK SP3 innovations.

All values refer to S&C total LCC, and because some of the LCC benefits overlap, the total savings of 24.0% is not an exact sum of the individual results. Further indirect savings are expected due to better logistics and service planning, for example 1 hour of net service time in track can often be preceded by a 4 hour waiting for the service teams.

3.4 Rail (SP4)

3.4.1 Approach

A model for rail LCC has been developed (using the principles defined by INNOTRACK) that combines the effects and interdependencies of:

- Rail grade selection
- Rail grinding
- Gauge face rail lubrication

Two pieces of analysis have been carried out using this tool.

Firstly, the whole life costs for 220 individual curves (~400 track km) on three main line routes in the UK have been analysed, investigating the impact of different combinations of rail steel, lubrication and rail grinding frequency on the LCC for different curve radii. For this case, the rail degradation rates (for rolling contact fatigue and rail wear) are modelled using Network Rail's TrackEx software which generates curve-specific predictions based on actual traffic data (frequency, vehicle type, linespeed) and track data (measured lateral geometry, rail grade). The TrackEx tool utilises RCF and rail wear damage accumulation theories based upon contact patch energy (the combination of creepages and creep forces) which have been developed and tested in the UK principally since 2001. The approach is the subject of ongoing validation but has been calibrated against major RCF studies on three NR routes and is accepted by the UK rail industry as an important tool in understanding how best to control RCF.

Secondly, the LCC for all curves <2500m radius in the UK has been examined, using average modelled rail degradation rates and the rail degradation algorithms created by SP4 in INNOTRACK.

The LCC In/Out Frame shown in Figure 14 below documents the boundary conditions used in the LCC calculation for premium rail steel, rail lubrication and rail grinding.

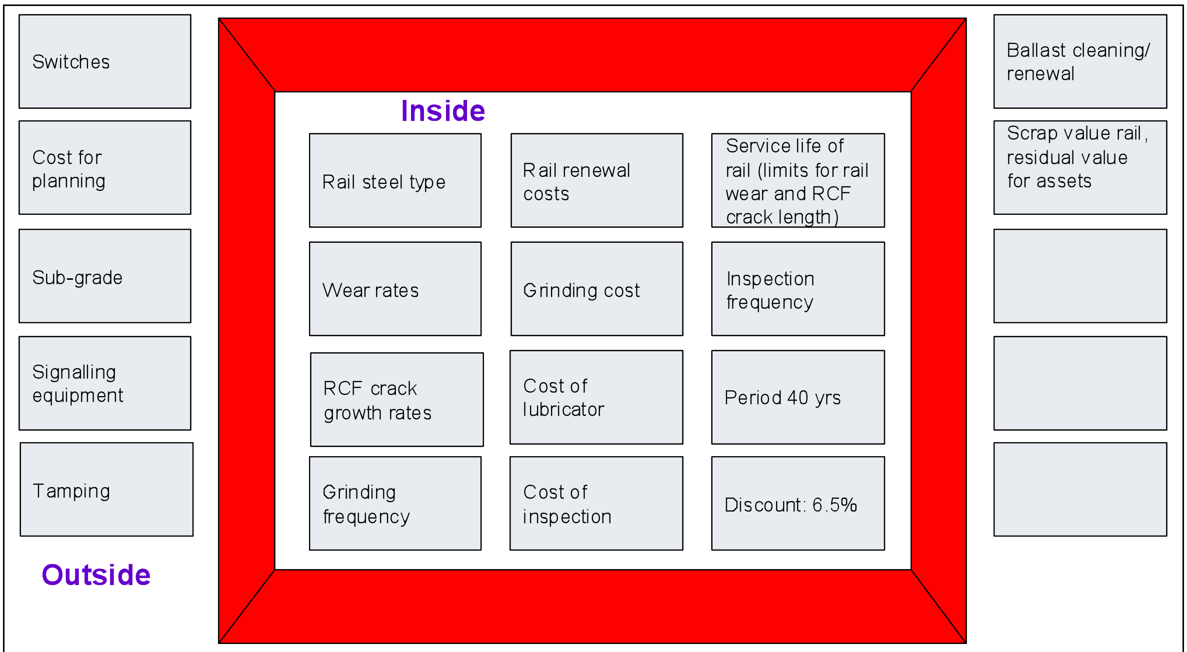


Figure 14. LCC In-Out frame for rail.

The data input form for the rail LCC model is shown in Figure 15.

Rail Grinding, Lubrication & Premium Rail Steel LCC Analysis

Data Input Form

Section 1 - Financial Data

Parameter	Units	Value	Comments/Source
Single rail renewal cost - grade 260 rail	£/Per Rail Metre		
Single rail renewal cost - grade 400MHH rail	£/Per Rail Metre		
60kg Grade 260 (108m)	£/Per Rail Metre		
60kg Grade 400MHH (108m)	£/Per Rail Metre		
NR Maintenance ABC calculation for replacement of a single 120' Grade 260 rail	£/Per Rail Metre		
NR Maintenance ABC calculation for replacement of a single 120' Grade 400MHH rail	£/Per Rail Metre		
Rail grinding cost - 64 stone timetabled grinding	£/Per Rail Metre		
Rail grinding cost - 16/32 stone possession grinding	£/Per Rail Metre		
Basic visual inspection	£/track km inspected		
Manual ultrasonic testing	£/track km inspected		
Train-based ultrasonic testing	£/track km inspected		
Train-based geometry inspection	£/track km inspected		
Cost of manual follow up UT inspection for an RCF defect	£/track km inspected		
Cost of Installation of a Rail Head Lubricator	£/lubricator		
Cost of Annual Rail Head Lubricator Maintenance / Consumables	£/lubricator		
No. of track lubricators per 500 track m	No./500m		
Inflation Rate	%		
Discount Rate	%		

Section 2 - Technical Data

Parameter	Units	Value	Comments/Source
Grinding metal removal rate (vertical axis)	mm per grinding treatment	0.20	
Grinding metal removal rate (gauge corner, 45deg.)	mm per grinding treatment	0.30	
Grinding reduces SCL by	mm	1.20	
Additional side wear required to eliminate wheel-rail gap created by grinding	mm	0.30	
Grinding frequency 1	MGT	15.00	
Grinding frequency 2	MGT	45.00	
Maximum permissible RCF SCL	mm	20	
Maximum permissible side wear - 60kg	mm	9	
Maximum permissible side wear - 56kg	mm	9	
Maximum permissible vertical wear - 60kg	mm	14-side wear	
Maximum permissible vertical wear - 56kg	mm	14-side wear	
RCF surface crack length for a reportable defect (manual follow up UT)	mm	20	

Inspection Frequencies (NR/L2/TRK/001/A01, B01, C01 Dec 09) - No./Month

Track Category	1A	1	2	3	4	5	6
Basic visual inspection	4.00	4.00	4.00	2.00	2.00	1.00	1.00
Manual ultrasonic testing	0.33	0.17	0.08	0.04	0.04	0.04	0.04
Additional routine manual UT of RCF sites	0.17	0.17	0.17	0.17	0.08	0.08	0.08
Train-based ultrasonic testing	0.50	0.50	0.25	0.17	0.17	0.17	0.08
Train-based geometry inspection	1.00	0.50	0.33	0.25	0.17	0.17	0.17

Section 3 - Curve Data

Parameter	Units	Comments/Source	Curve No. 61	62
NB - Yellow shading below = formula DO NOT OVER-WRITE				
ELR	ELR			
TID	TID			
Start Mileage (lowest mileage)	Miles			
Annual traffic	MGT			
Radius	m			
Curve length	m			
Grade 260 RCF SCL Growth Rate	mm/MGT			
Grade 260 Side Wear Rate - unlubricated	mm/MGT			
Grade 260 Vertical Wear Rate - unlubricated	mm/MGT			
Grade 260 Side Wear Rate - lubricated	mm/MGT			
Grade 260 Vertical Wear Rate - lubricated	mm/MGT			
Grade 260 MGT of Side Wear to Eliminate Ground Rail Profile Relief	MGT			
Grade 260 Total RCF Benefit (Reduction in SCL) due to Grinding Material Removal plus Rail Profile Relief	mm			
Grade 400MHH RCF SCL Growth Rate	mm/MGT			
Grade 400MHH Side Wear Rate - unlubricated	mm/MGT			
Grade 400MHH Vertical Wear Rate - unlubricated	mm/MGT			
Grade 400MHH Side Wear Rate - lubricated	mm/MGT			
Grade 400MHH Vertical Wear Rate - lubricated	mm/MGT			
Grade 400MHH MGT of Side Wear to Eliminate Ground Rail Profile Relief	MGT			
Grade 400MHH Total RCF Benefit (Reduction in SCL) due to Grinding Material Removal plus Rail Profile Relief	mm			
Material Selection Option (1=260, 2=400MHH)	1 or 2			
Track Category	1A-6			
Grinding Option (1=timetabled, 2=possession)	1 or 2			
Grinding Frequency	MGT			
Routine Ultrasonic Testing Option (1=manual, 2=train)	1 or 2			
Lubricated (1=Yes, 2=No)	1 or 2			

Figure 15. Rail LCC model input form.

3.4.2 Route-specific LCC

3.4.2.1 Input parameters and key assumptions

The input conditions and key assumptions used to conduct the route-specific analysis for rail LCC are as follows:

- Grade 370CrHT rail has been chosen as the premium steel grade to be modelled, as this has been on trial in the UK since 2007 and an initial relationship between wheel/rail contact energy and RCF damage has been developed for this grade based on known material properties and in-service performance to-date.
- Lubrication is assumed to reduce the rate of side wear by a factor of 4 (similar to what has been reported in Sweden and elsewhere).
- Network Rail's 2009/10 standard unit costs for installation, maintenance and inspection have been applied.
    - The material cost of the premium rail grade is 40% higher than the standard cost of Grade 260 rail.
    - Rail grinding unit costs are based on the slow timetabled train mode of operation, i.e. minimum cost per metre.
    - The fixed cost for installation of an electric track lubricator includes equipment and possession costs, based on two quotes received in October 2009. One track lubricator per 500m of track is specified, as per current Network Rail standards. Note – electric lubricators and grease delivery units (GDUs) are approximately five times as costly as a simpler mechanically-operated equipment but are known by experience in NR to be far more reliable with significantly lower maintenance costs. NR plans to follow up this initial analysis of gauge face lubrication LCC with a more comprehensive study of the relative costs, reliability and benefits of a range of track lubricators, GDUs and lubricants.
    - Ultrasonic inspection costs/track km for both train-based and manual inspections are included.
- Current Network Rail standards for the frequency of different inspection techniques have been applied – these are based on the linespeed and annual traffic tonnage carried by each section of track. Additional inspection requirements for RCF sites are also included in the cost analysis.
- Traffic levels are held constant through the 40 year period of analysis, for each curve modelled. However, traffic levels (both frequency and type of vehicle) can vary significantly from one curve to another and these differences are accurately included by using the actual monthly recorded traffic from July 2009 for each curve as (recorded in Network Rail's ACTRAFF database).
- A discount rate of 6.5% (as per UK Department for Transport guidelines) has been applied in NPV calculations.
- Rail replacement occurs when RCF surface crack length reaches 20mm.
- Rail replacement occurs when side wear reaches 9mm or vertical wear exceeds a value equal to (14 – current side wear value).
- Rail grinding removes 0.2mm of metal from the vertical rail axis and 0.3mm of material from the gauge corner but does not increase the rail side wear at the measurement position.
- Rail grinding has two effects on RCF:
    - Reduces surface crack length by 1.2mm (assuming cracks propagate into the rail head at 30^{o} to the rail running surface and that RCF cracks are approximately semi-circular throughout propagation).
    - Offloads existing RCF cracks by creating gauge corner profile relief. This relief must be worn away before cracks are allowed to propagate again. The relief is worn away at a rate directly proportional to the modelled rail vertical and side wear. This assumption has been included based on research in the UK which studied the effects of moving the lateral position of applied wheel load relative to existing RCF cracks using a mathematical model of wheel/rail contact[1].
- The LCC analysis has been carried out for high rail wear and RCF and excludes any consideration of low rail damage, for which premium rail has already demonstrated LCC benefits during UK trials.

3.4.2.2 Mainline 1 LCC results

The first case study looked at a mainline route with known problems with severe rail rolling contact fatigue (RCF). 39km of the 158km of track modelled has a curvature of less than 4000m, 11km is less than 1400m in radius. Typical traffic tonnage on the lines included in the analysis is 10-30MGTPA, made up primarily of passenger rolling stock. A majority of the rolling stock has stiffer suspension characteristics (primary yaw stiffness) known to contribute to increased wheel-rail lateral contact forces and RCF initiation/propagation rates. Modelled rail degradation rates are shown in Appendix 1.

The base case of Grade 260 rail without any lubrication or rail grinding was compared to a range of scenarios for different curve radii. Figure 16 below shows the effect of rail grinding on LCC (based on a 40 year analysis with a 6.5% discount rate).

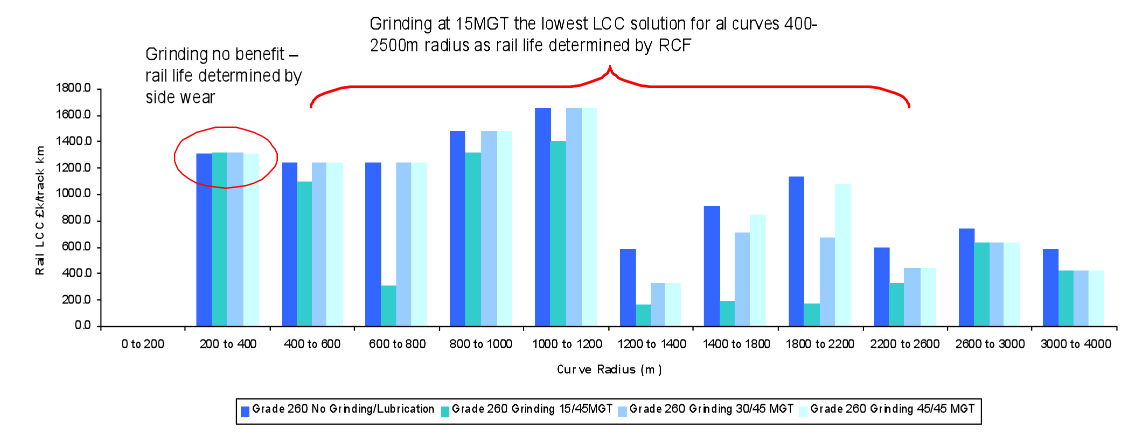


Figure 16. LCC output for curves on Mainline 1 – impact of rail grinding on LCC.

The analysis highlights how rail grinding at a frequency of every 15MGT on curves <2500m radius is the optimum solution for this route (within the constraints of existing NR policy of grinding at intervals which are a multiple of 15MGT), with the exception of curves <400m in radius where rail life is determined by side wear so grinding does not offer any additional LCC benefits. It should be noted that the analysis of rail grinding has assumed the most efficient method of delivery (timetabled grinding trains). The potential LCC reduction through use of grinding will decrease if a proportion of grinding was assumed to be higher cost possession-based grinding, and the optimum grinding frequency may also change to less frequent intervals.

The effect of lubrication and optimised rail grinding can be seen in Figure 17 below. The cost of installation of an electric gauge face rail lubricator is relatively high, so the analysis highlights how the technology only offers LCC benefits on tighter radius curves (up to 1200m) where side wear rates are high. In these cases rail lubrication reduces side wear to either extend rail life or extend the benefits offered by rail grinding (by reducing the rate at which the gauge corner profile relief is worn away on the rail). Figure 17 also shows that the LCC benefits of combining Grade 260 rail with rail grinding and lubrication for Mainline 1 are not universal – for example the LCC with rail grinding is higher for curves with radii between 600-800m. This is due to route and curve specific characteristics such as the curve length, annual tonnage and the relative modelled rates of side wear, vertical wear and RCF crack growth rate. The analysis highlights the importance of being able to carry out a site-by-site LCC analysis since the application of generic LCC input data may overestimate the potential benefits.

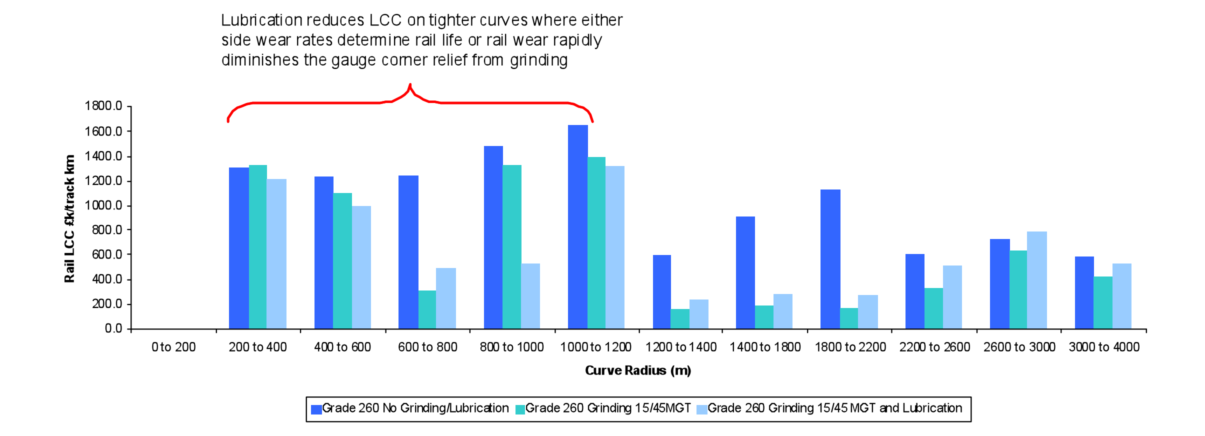


Figure 17. LCC output for curves on Mainline 1 – impact of rail lubrication and rail grinding on LCC.

Installing 370CrHT rail on the same section of track combined with rail grinding at different tonnage intervals results in the LCC summarised in Figure 18. There are three conclusions from this analysis:

- Curve radius <400m : installing premium rail steel without grinding offers the optimum solution (reducing LCC by >50%), as the rate of side wear is significantly reduced. Note, this conclusion is for high rail RCF/wear only since low rail degradation is not modelled (where grinding may be an effective remediation measure).
- Curve radius 400m - 1200m : a combination of premium rail and rail grinding every 15MGT results in the lowest LCC.
- Curve radius 1200m - 2600m : a combination of premium rail with rail grinding at extended intervals of every 30 or 45MGT appears to offer a marginal reduction in LCC, although a curve-by-curve analysis would be required to determine the appropriate treatments.

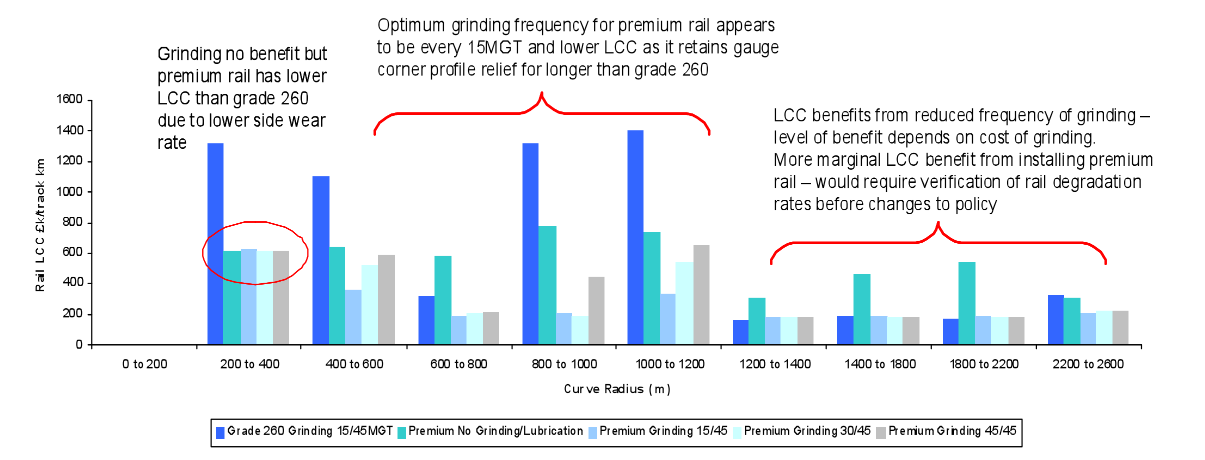


Figure 18. LCC output for curves on Mainline 1 – impact of premium rail and rail grinding on LCC.

Analysis has also been conducted combining premium rail and rail lubrication – results are summarised in Figure 19 below. The analysis indicates that due to the relatively high initial capital costs of the electric lubricator case modelled, this combination of technology does not reduce LCC further than the scenario when premium rail is installed without any lubrication. Reducing side wear rates further on tighter curves (for example a reduction by a factor of 10 has been reported for curves < 400m) and modelling the costs of lower cost alternative rail-mounted lubricators would result in a lower LCC result. However, the simpler lubrication technology is known to be less reliable and therefore is less likely to be as effective at reducing wear over a long period of time without more frequent, most costly maintenance. As described above, NR plans to conduct a more comprehensive review of track lubricator effectiveness, maintenance requirements and LCC to build on this initial work.

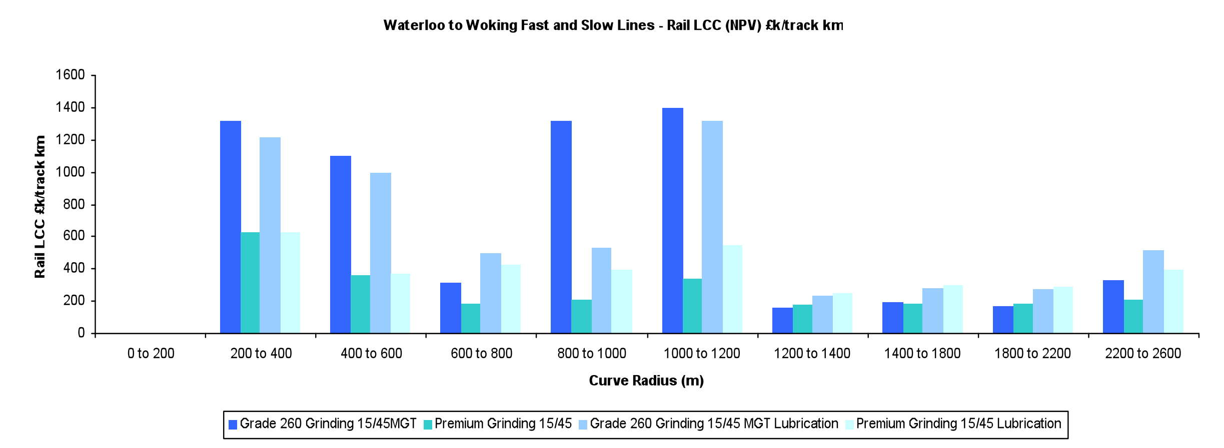


Figure 19. LCC output for curves on Mainline 1 – impact of premium rail, rail grinding and gauge face lubrication on LCC.

To summarise, LCC analysis for Mainline 1 has shown that the combination of premium rail and a modified standard rail grinding frequency could reduce total LCC for all of the curves modelled by up to 16%.

3.4.2.3 Mainline 2 LCC results

The second mainline track included in this analysis has a smaller proportion of tighter radius curves than Mainline 1 (28km of the 129km of track modelled has a curvature of less than 4000m but only 1km is less than 1400m in radius). Approximately 10% of the annual traffic is freight; a high proportion of the passenger coaching stock on the route is known to be relatively damaging in terms of RCF for tighter radius curves. Modelled rail degradation rates are shown in Appendix 1.

Repeating the analysis shown above indicates that the LCC offered by premium rail combined with grinding is actually slightly higher (by <2%) than the case with Grade 260 rail, see Figure 20 below. Reviewing the detailed calculations for Mainline 2 shows the LCC model predicts that using Grade 260 rail with grinding at every 15MGT results in RCF-free high rails on each of the curves included in this analysis. This is partly due to the low modelled vertical/side wear rates for each curve which results in the ground gauge corner profile relief (and subsequent off-loading of RCF cracks) being maintained for the full period between grinding operations.

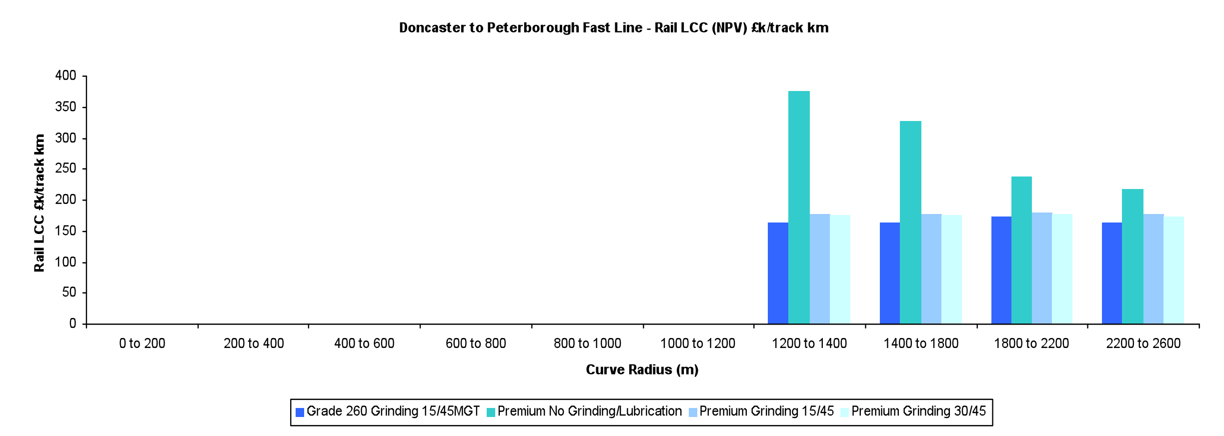


Figure 20. LCC output for curves on Mainline 2 – impact of premium rail and grinding on rail LCC.

3.4.2.4 Mainline 3 LCC results

The final mainline track included in this analysis has a range of curve radii between the first two cases modelled - 45km of the 132km of track modelled has a curvature of less than 4000m and 7km is less than 1400m in radius. 95% of the annual traffic is passenger rolling stock, the majority of which is high speed intercity trains with relatively high bogey suspension characteristics. Modelled rail degradation rates are shown in Appendix 1.

For Mainline 3, a combination of premium rail steel and rail grinding at extended frequencies does result in a reduction in LCC compared to using Grade 260 rail with rail grinding and lubrication, see Figure 21.

- Curve radius <1000m : installing premium rail steel and grinding every 15MGT reduces LCC by >70%.
- Curve radius 1000m - 2600m : a combination of premium rail and rail grinding every 45MGT results in the lowest LCC, reduced by approximately 4%.

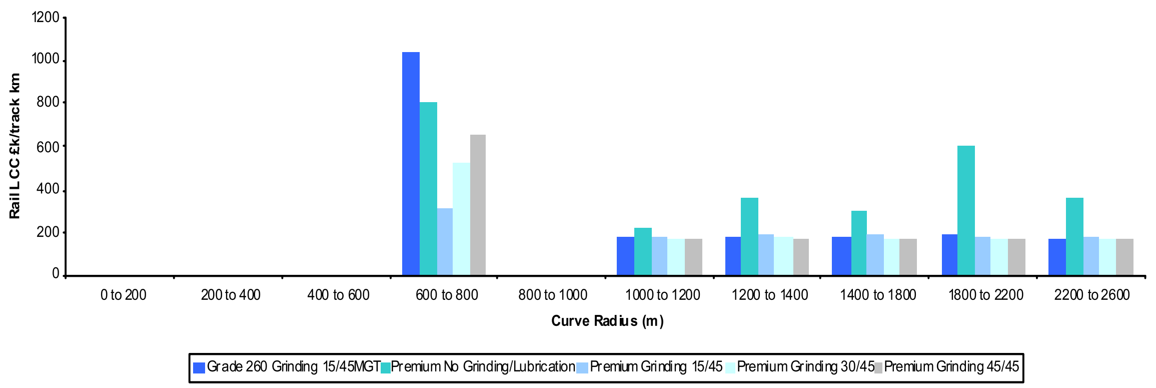


Figure 21. LCC output for curves on Mainline 3 – impact of premium rail and rail grinding on LCC.

The analysis for Mainline 2 and 3 route sections highlights how, for marginal LCC cases, the discounting rate applied has a significant effect on the results. For example, without discounting the LCC reduction for Mainline 3 curves 1000-2600m radius is >20%, compared to 4% with discounting. Alternatively, the analysis indicates that if the initial cost of premium rail grades can be reduced through development of alternative rail metallurgies and manufacturing processes, the economic case for the use of premium rail in curves with higher side wear and rolling contact fatigue crack growth rates is further strengthened.

3.4.3 Full network analysis

3.4.3.1 Curvature distribution on Network Rail network

Table 5 details the curvature distribution for Network Rail track, for each route type, and also indicates the typical annual tonnage experienced by the three route categories used to define Network Rail infrastructure.

The use of premium rail, rail grinding and rail lubrication is likely to have the greatest impact on LCC for the Primary route curves less than 2500m radius, which equates to around 8% of the Network Rail network. There will be benefits for some more highly utilised Secondary and Tertiary routes but these have not been included in this analysis as the issues are site-specific so a high level more generic LCC analysis is not appropriate.

Route Type	Track km <800m Radius	Track km 800m-1500m Radius	Track km 1500m-2500m Radius	Comments
PRIMARY	348	883	1253	Annual duty typically 15-20 EMGTPA, high criticality routes
SECONDARY	317	1910	1215	Annual duty typically 5-10 EMGTPA, although a small number of route sections with significantly higher tonnage
TERTIARY	535	415	277	Annual duty typically 1-2 EMGTPA, maximum rarely > 5 EMGTPA

Table 5. Network Rail curvature distribution by route type.

3.4.3.2 LCC results for full network analysis

Two scenarios have been modelled for all Network Rail primary curves <2500m radius:

- Scenario 1: Grade 260 rail, grinding every 15MGT and lubrication on curves <800m radius;
- Scenario 2: Premium rail, grinding every 15MGT up to 1500m radius and 45MGT for curves 1500-2500m radius, no lubrication.

Two sources of rail degradation rates have been applied in the analysis – (i) Network Rail average modelled side wear and RCF crack growth rates and (ii) INNOTRACK rail degradation algorithms derived from site data collected over several years of detailed monitoring. The degradation rates used in the modelling are as follows (Tables 6 and 7):

Curve Radius (m)	NR Modelled RCF Growth Rates (mm/MGT)				INNOTRACK D4.1.4 RCF SCL Growth Rates (mm/MGT) *[1]	
	260		370CrHT		260*[2]	370CrHT
	Average	Maximum	Average	Maximum	Average	Average
<800	0.382	0.458	0.127	0.153	0.400	0.020
800-1500	0.333	0.834	0.111	0.278	0.358	0.018
1500-2500	0.093	0.741	0.031	0.247	0.128	0.010

Table 6. NR modelled and INNOTRACK D4.1.4 rail RCF growth rates applied to full NR rail LCC analysis.

*[1] Calculated by applying INNOTRACK D4.1.4 algorithms for penetrated crack depth and multiplying these results by 2 (assumes RCF cracks are semi-circular defects).

*[2] RCF growth rate for Grade 220 rail used as no equation for Grade 260 is stated in the INNOTRACK deliverable D4.1.4.

Curve Radius (m)	NR Modelled Side Wear Rates (mm/MGT)				INNOTRACK D4.1.4 Side Wear Rates (mm/MGT) *[3]	
	260		370CrHT		260	370CrHT
	Average	Maximum	Average	Maximum	Average	Average
<800	0.117	0.233	0.039	0.078	0.023	0.016
800-1500	0.014	0.014	0.005	0.005	0.009	0.008
1500-2500	0.005	0.005	0.002	0.002	0.004	0.004

Table 7. NR modelled and INNOTRACK D4.1.4 rail side wear rates applied to full NR rail LCC analysis.

*[3] INNOTRACK D4.1.4 algorithms for 45^{o} wear have been used as no algorithms for side wear are provided.

Tables 8 and 9 summarise the results from the LCC calculations for both scenarios. Table 8 results are based on the use of AVERAGE modelled rail degradation rates. Table 9 shows data using MAXIMUM modelled degradation rates. Note, the two sources of rail degradation rates used in the full network analysis produce predicted overall LCC reductions within a similar range (INNOTRACK degradation algorithms produce LCC reductions at the higher end of the ranges shown in Tables 8 and 9).

Curve Radius (m)	Scenario 1 – Grade 260 + Lubrication on Curves<800m Radius + Grinding Every 15MGT	Scenario 2 – Grade 370CrHT + Grinding Every 15MGT (Curves <1500m Radius) or 45MGT (Curves 1500-2500m Radius)	% Reduction in LCC for Scenario 2
	LCC £k/Track km	LCC £k/Track km	%
<800	342	276	19
800-1500	229	176	23
1500-2500	165	174	-6

Table 8. LCC reduction for Scenario 2 compared to Scenario 1 – based on **AVERAGE** modelled rail degradation rates.

Curve Radius (m)	Scenario 1 – Grade 260 + Lubrication on Curves<800m Radius + Grinding Every 15MGT	Scenario 2 – Grade 370CrHT + Grinding Every 15MGT (Curves <1500m Radius) or 45MGT (Curves 1500-2500m Radius)	% Reduction in LCC for Scenario 2
	LCC £k/Track km	LCC £k/Track km	%
<800	576	416	28
800-1500	296	177	40
1500-2500	223	175	21

Table 9. LCC reduction for Scenario 2 compared to Scenario 1 – based on **MAXIMUM** modelled rail degradation rates.

The analysis highlights that in some cases premium rail, while extending rail life, may not reduce LCC. For example, as curve radius increases (1500-2500m category), the measured and modelled degradation rates for both Grade 260 and premium rail are low so the LCC of Grade 260 rail may, for some curves, be lower than the case when premium rail is installed. This illustrates that rail grade selection should be based on a knowledge of rail degradation rates at specific track sections rather than simply track curvature and traffic tonnage (which are two important variables but not the only variables).

A total LCC reduction of 11%-30% is predicted for the use of premium rail (discounted over 40 years), or 27%-54% if values are converted to 2009/10 prices.

The results above (at 2009/10 prices) have been converted to an assessment of the potential reduction in annual track costs as follows:

- The annual track maintenance and renewal budget is split approximately 46% for renewal and 54% for maintenance (including inspection).
- Rail-only costs for curves <2500m radius are approximately 4.8% of the annual track budget – this is made up of costs for rail-only replacement in curves, inspection, rail grinding and rail lubrication plus a proportion of indirect costs.

Therefore applying the potential LCC reduction of 27%-54% at 2009/10 prices to the 4.8% of annual rail-only related costs results in a potential annual reduction in the Network Rail track maintenance and renewal budget of 1.3%-2.6%, see Figure 22.

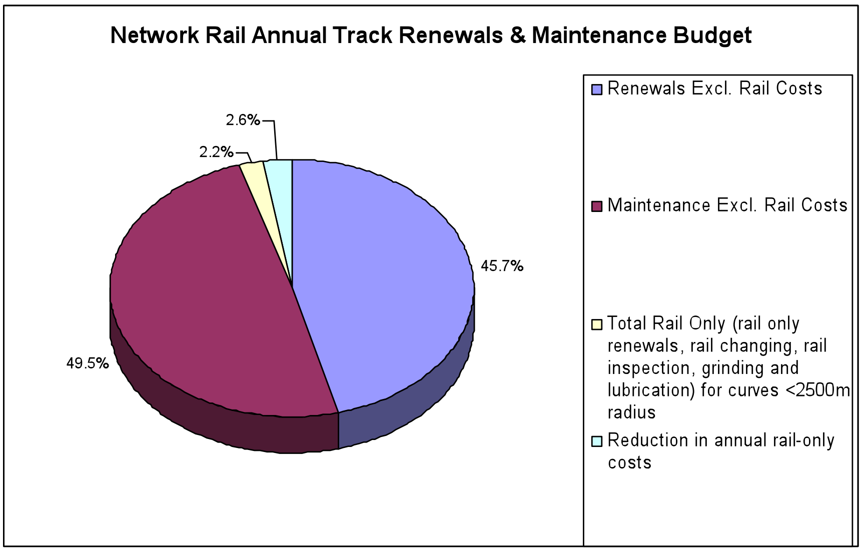


Figure 22. Maximum potential reduction in Network Rail annual track budget if premium rail steel is combined with a modified rail grinding strategy on all Primary route curves of < 2500m radius.

This reduction in the annual budget is the 'steady state' position once premium rail has been installed on all Primary route curves of <2500m radius and represents a significant annual cost saving for NR.

4. Conclusions

- The predicted cost savings from innovations can be estimated by various methods including:
    - Life cycle cost calculation;
    - Comparison of future operation costs with and without innovation.
- The results from the different calculations could also lead to different conclusions being made and hence the background and reasons behind the calculations must be known.
- The life cycle cost calculation favours low investment costs (due to the discounting factor).
- Poor understanding and definition of infrastructure costs makes it very difficult to determine the existing costs and hence the base case to compare with innovations.
- LCC calculations for a number of key innovations developed by INNOTRACK SP2, SP3 and SP4 indicate significant reductions in the NPV LCC compared to the base cases are achievable for specific sites/route sections:
    - Subgrade improvement (drainage) - 60% reduction for the case study analysed;
    - BB ERS slab track – 20% reduction for annual traffic of 55MGT with potential for greater reductions at higher annual tonnages;
    - New S&C designs, materials, components and monitoring – 20% reduction;
    - Premium rail and rail grinding – maximum 30% reduction for the sites modelled.
- Some innovations lead to savings which are difficult to quantify, for example transition zone optimisation investments or soil strengthening (SP2) are compared to savings of increased speed/reduced delay – difficult to estimate the number of sites across a network which could benefit from this modification and hence the future savings.
- The work carried out in D1.4.8 has shown the difficulty with scaling up life cycle costs to whole networks using generic rules for LCC calculations. Instead, a comprehensive ‘bottom-up’ approach is recommended where every site that can potentially benefit from use of innovative technology is analysed separately and the results from individual analyses can be summed to calculate the total network-wide LCC reduction.
- The true LCC benefits of a number of the innovations developed by INNOTRACK will only emerge after several years of site trials. As well as closely monitoring the technical performance of new technology, it is recommended that a comprehensive record of interventions and costs is also maintained for trial sites so the economic impact of the innovations can be properly assessed.

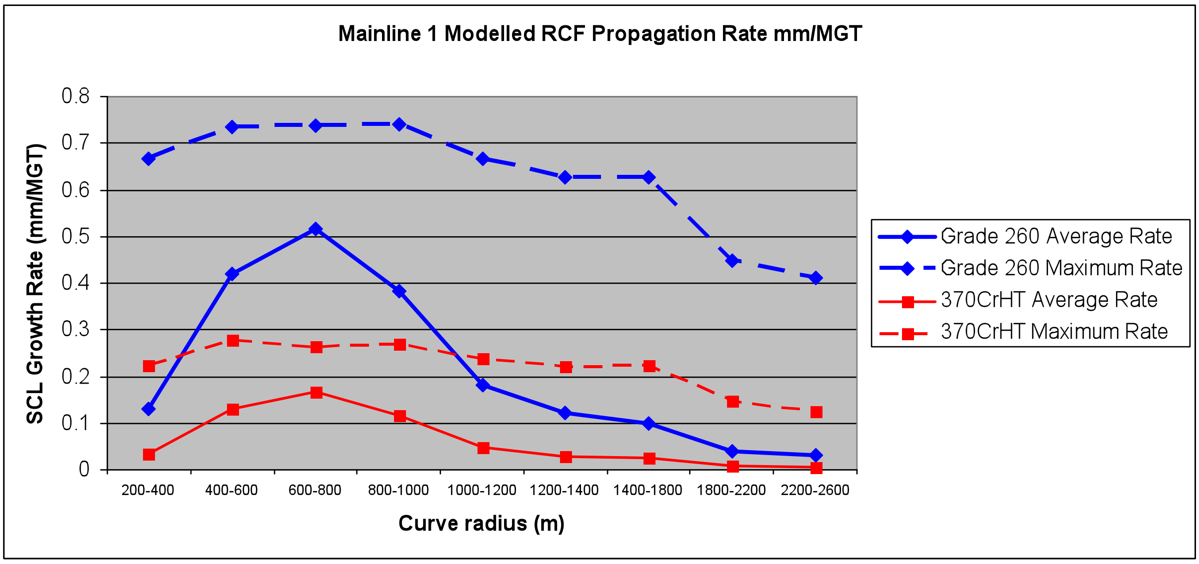
5. References

1. Kapoor, A., Fletcher, D.I., Franklin, F.J., and Alwahdi, F., Whole life rail model, interim report. *Technical Report* MEC/AK/AEA TECHNOLOGY RAIL/September02/, The University of Sheffield and AEA TECHNOLOGY RAIL, 2002.

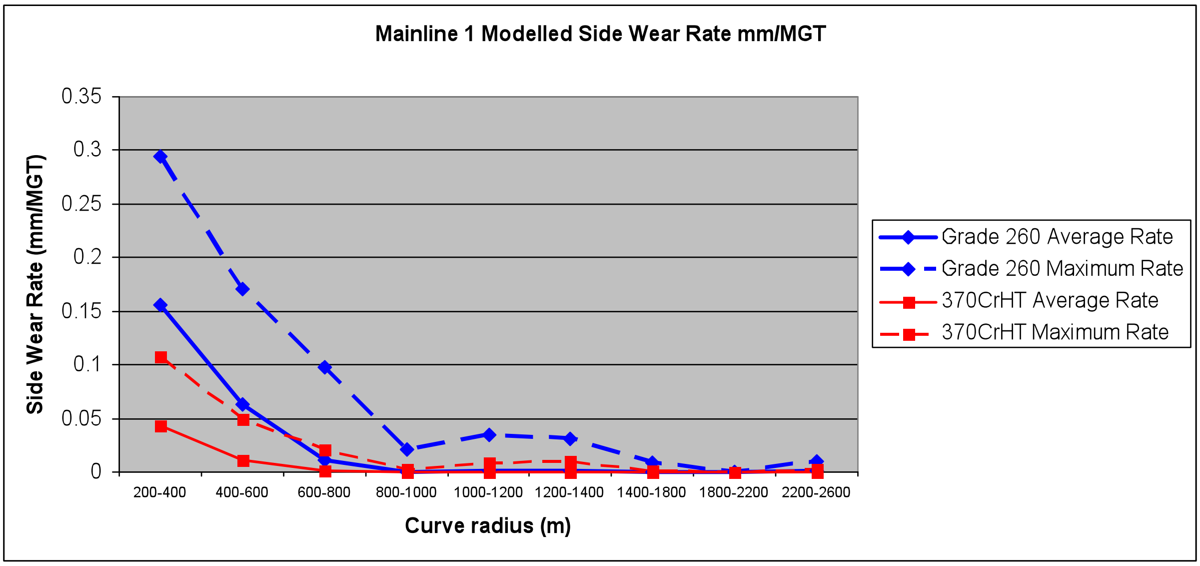
Appendix 1 – Modelled rail degradation rates

Mainline 1

RCF

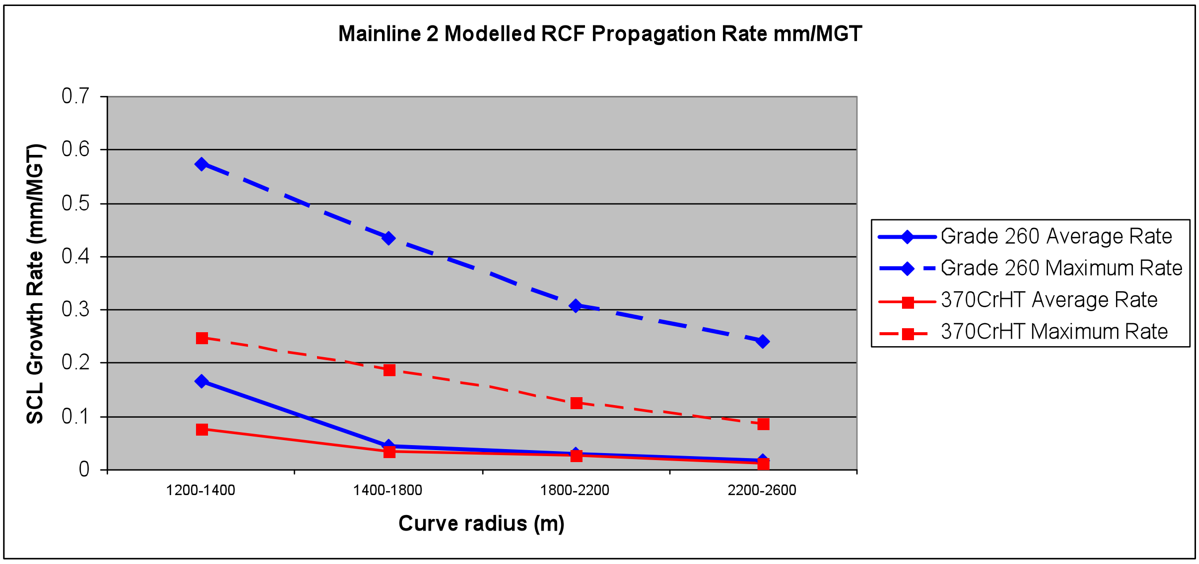


Side Wear



Mainline 2

RCF



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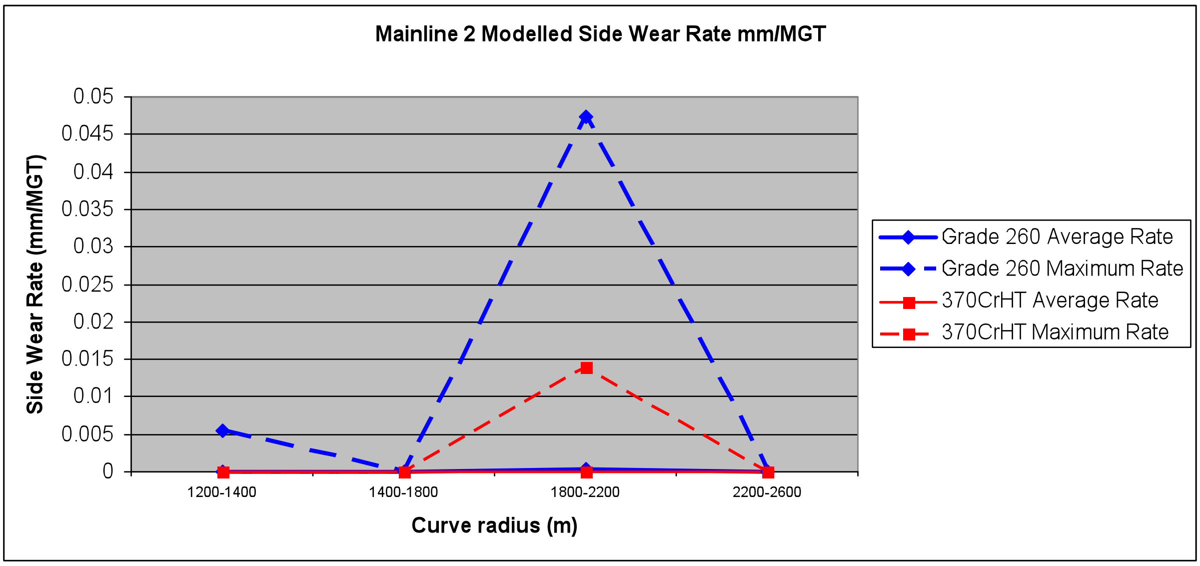
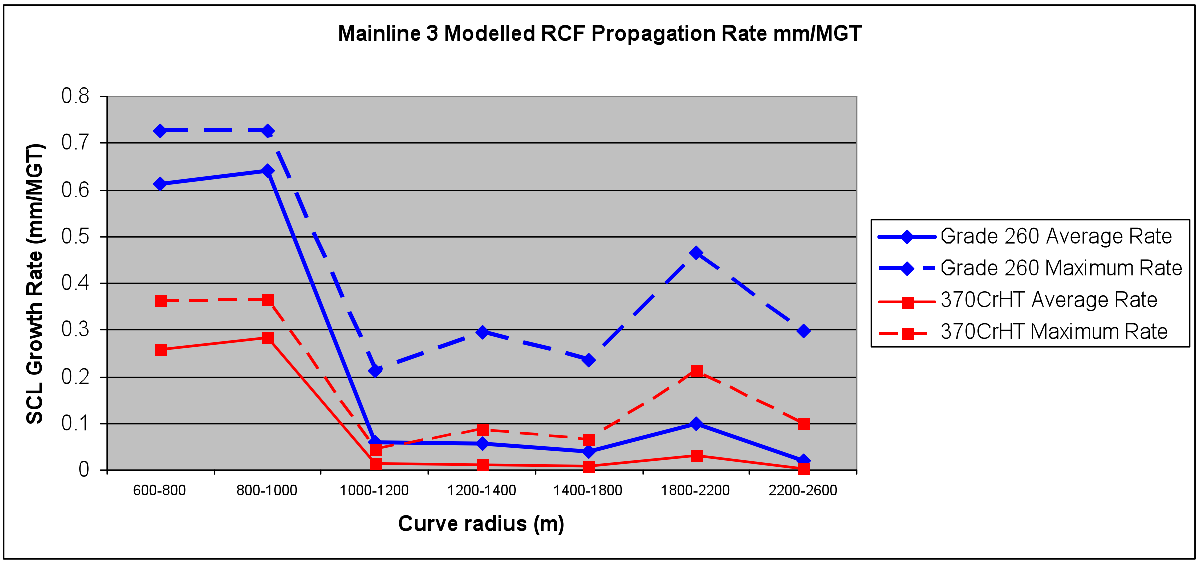


Mainline 3

RCF



Side Wear