MAIN LINE

"MAINTENANCE, RENEWAL AND IMPROVEMENT OF RAIL TRANSPORT INFRASTRUCTURE TO REDUCE ECONOMIC AND ENVIRONMENTAL IMPACTS"

PROJECT RESULTS

A SUMMARY



This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 285121

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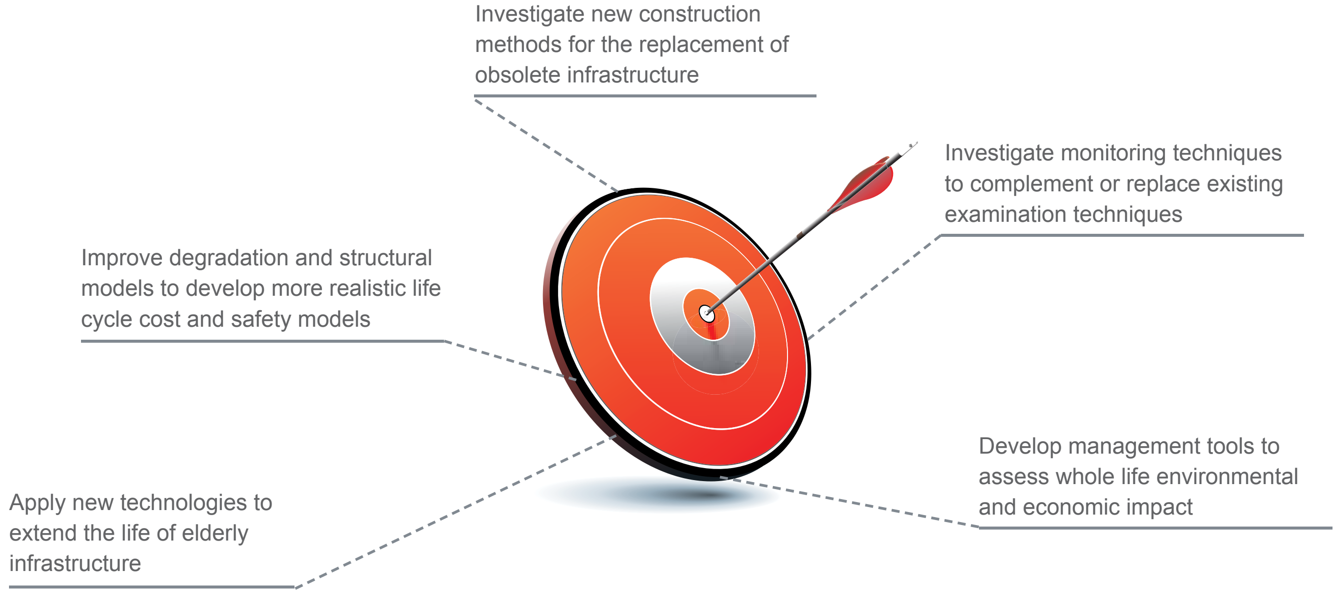
1 INTRODUCTION - A BRIEF SUMMARY OF MAINLINE AND HIGHLIGHTS

ABSTRACT

GROWTH IN DEMAND FOR RAIL TRANSPORTATION ACROSS EUROPE IS PREDICTED TO CONTINUE. MUCH OF THIS GROWTH WILL HAVE TO BE ACCOMMODATED ON EXISTING LINES THAT CONTAIN OLD INFRASTRUCTURE. THIS DEMAND WILL INCREASE BOTH THE RATE OF DETERIORATION OF THESE ELDERLY ASSETS AND THE NEED FOR SHORTER LINE CLOSURES FOR MAINTENANCE OR RENEWAL INTERVENTIONS. HOWEVER, INTERVENTIONS ON ELDERLY INFRASTRUCTURE WILL ALSO NEED TO TAKE ACCOUNT OF THE NEED FOR LOWER ECONOMIC AND ENVIRONMENTAL IMPACTS. THIS MEANS THAT NEW INTERVENTIONS WILL NEED TO BE INTRODUCED. IN ADDITION TOOLS WILL NEED TO BE DEVELOPED TO INFORM DECISION MAKERS ABOUT THE ECONOMIC AND ENVIRONMENTAL CONSEQUENCES OF THE DIFFERENT INTERVENTION OPTIONS BEING CONSIDERED.

OBJECTIVES

MAINLINE proposed to address all these issues through a series of correlated work packages to target savings of at least €300m per year across Europe with a reduced environmental footprint in terms of embodied carbon, and other environmental benefits. The overall objectives of MAINLINE were to:



Project benefits have also been derived from keeping existing infrastructure safely in service through the application of technologies and interventions based on life cycle considerations. Although MAINLINE has focused on certain asset types, the management tools developed are also applicable across a broader asset base.

The consortium

The consortium consisted of nineteen partners, including leading railway infrastructure managers, contractors, consultants and researchers from across Europe with a wide geographical representation, including both Eastern Europe and the emerging economies. These partners have also brought experience on approaches used in other industry sectors which have relevance to the rail sector.

It is also a global project through the involvement of both the Turkish Railways and the International Union of Railways. Many of our partners also have significant International rail experience outside the EU. MAINLINE has been co-ordinated by UIC with management support from ARTTIC.

Below you can see the project structure. It also shows how the different Work Packages are linked together and coordinated.

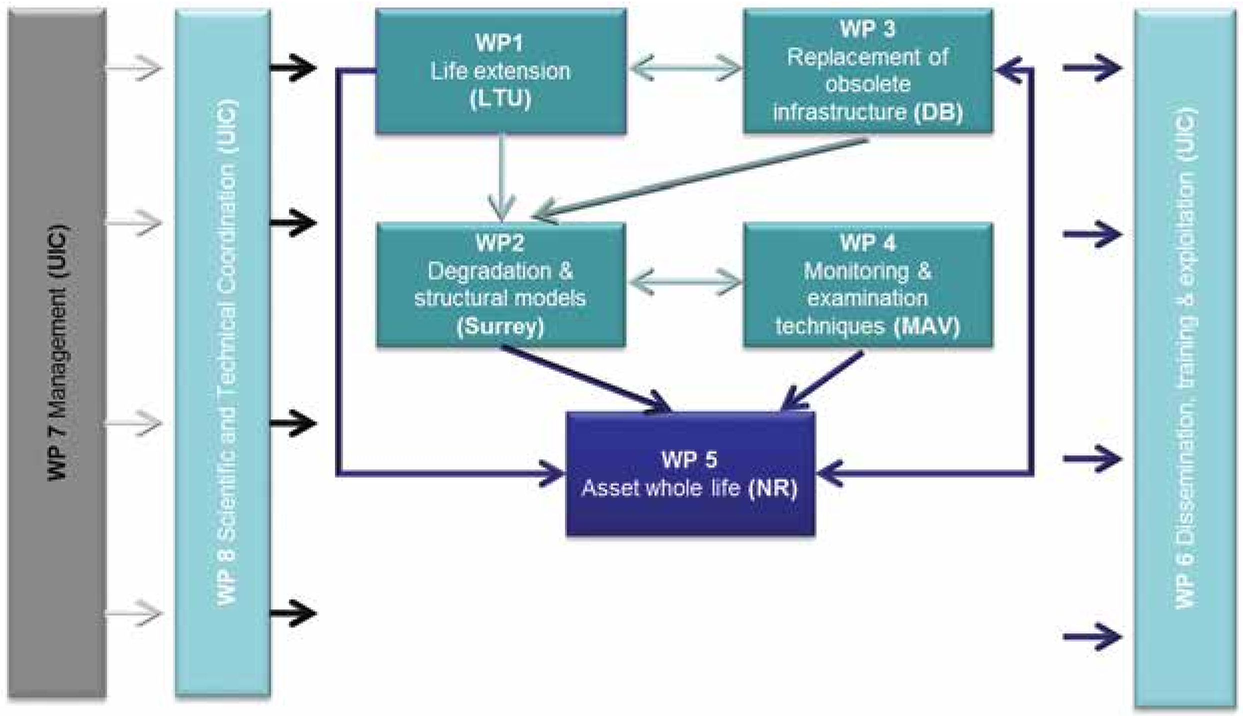


Figure 1.1 MAINLINE project structure

Highlights

In the work package 2 dealing with asset degradation & intervention strategies, methodologies for the derivation of deterioration and time profile for selected asset types were developed as a function of operational and environmental parameters. They were based on up-to-date research and the increasing availability of field data from infrastructure managers. They were directly fed into the Life Cycle Assessment Tool (LCAT), and offer the opportunity to study explicitly the implications of alternative maintenance strategies based on predicted asset performance.

Work package 4 that deals with degradation monitoring has Case Studies in deliverable D4.3 showing the application of appropriate monitoring and examination techniques to monitor assets.

Work package 1, dealing with extending the life of assets, produced the deliverable D1.4 “Guideline for application of new technologies to extend life of elderly rail infrastructure”, and work package 3, addressing the replacement of assets, produced the deliverable D3.4 “Guideline for Replacement of elderly rail infrastructure”. Both guidelines give Infrastructure Managers advice on intervention strategies for life extension and/or replacement of elderly infrastructure.

From work package 5 in charge of producing the MAINLINE Life Cycle Assessment Tool (LCAT), the principal deliverable D5.7 “LCAT User Manual” is a manual how to use the LCAT in real life situations.

EU-projects linked to MAINLINE

The INNOTRACK project (2006-2010) contributed the analysis of major track cost drivers to reduce maintenance costs for sub-structure, track, S&C including LCC and logistics aspects.

The Sustainable Bridges project (2003-2007) contributed knowledge about bridge inspection, assessment, monitoring, strengthening, and measurement methods.

In MAINLINE an active co-operation and a lot of fruitful exchanges of information with SMARTRAIL (2011-2014) have taken place.

2

The role of Life Cycle Assessment Tool (LCAT) in asset management

What is asset management?

Asset Management is defined in ISO55000 as:

"The coordinated activities of an organisation to realise value from physical assets"

The whole idea behind asset management is to have better control over the asset in order to enhance cost efficiency and robustness, and today also, to do this in a more environmentally friendly way.

Why is asset management important?

In the future, less funding may be available for railways and there is always a demand from the society to decrease costs and enhance robustness. Hence Asset Management will help Infrastructure Managers to:

- Prioritise and justify works so that available resources are used and spent more efficiently;
- Coordinate access/possession time in a more optimised way and also define levels of safety and service.

Figure 2.1 Collapse of Stewarton bridge in Scotland and earthwork cutting failure. ® MAINLINE Consortium

What is the LCAT?

The Life Cycle Assessment Tool (LCAT) can compare different maintenance/ replacement strategies for track and infrastructure based on a life cycle evaluation.

The evaluation quantifies:

- Direct economic costs;
- Availability (delay costs / user cost);
- Environmental impact costs.

The LCAT:

- Uses Microsoft Excel as this is familiar software;
- It is flexible to suit different users across Europe;
- It can be adapted to suit different working practices.

How will the LCAT help me?

Financial Savings:

- If a 5% reduction of the total life cost could be achieved through better decision making by using the LCAT; for bridges alone, a benefit of 250M€ could be realised across Europe.

Gives evidence / justification to decisions as the LCAT:

- Uses degradation data gathered from across Europe;
- Clearly displays trade-off between condition and financial costs;
- Shows environmental impact of a scheme.

How does the LCAT work?

The LCAT uses the outputs from the other MAINLINE work packages and data from Infrastructure Managers

This is essential to validate:

- Degradation rates;
- Disruption costs;
- Techniques for life extension and monitoring;
- Methods for replacement;
- Environmental impact.

The LCAT will be described more in detail and with examples in chapter 7. The input and how the different Work Packages feed in to LCAT is described in the picture below. All these Work Packages are also described in chapter 3, 4, 5 and 6.

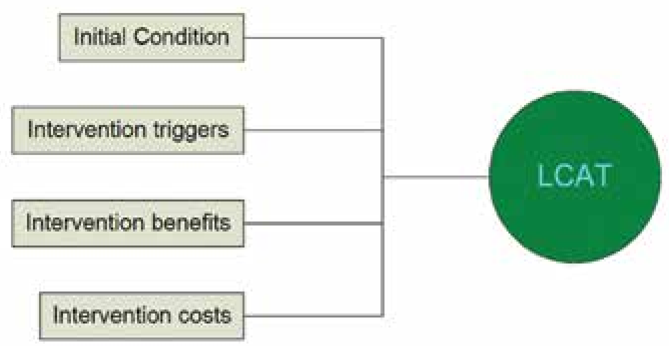


Figure 2.2 Life Cycle Assessment Tool - Inputs. ® MAINLINE Consortium

Figure 2.3 Life Cycle Assessment Tool - Processing. ® MAINLINE Consortium

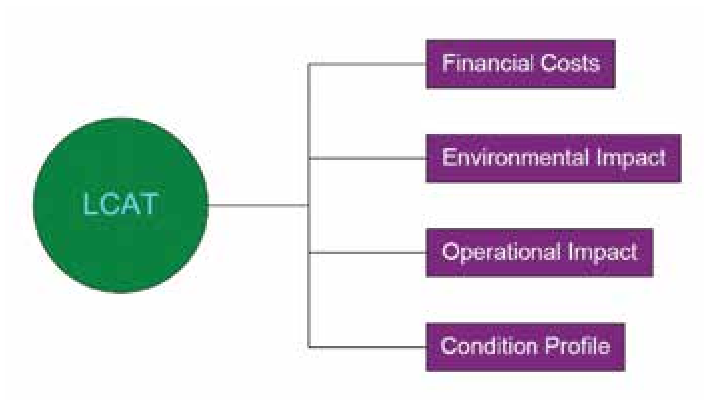


Figure 2.4 Life Cycle Assessment Tool - Outputs. ® MAINLINE Consortium

The LCAT will be described more in detail and with examples in chapter 7. The input and how the different Work Packages feed in to LCAT is described in the picture below. All these Work Packages are also described in chapter 3, 4, 5 and 6.

3 Asset degradation & intervention strategies

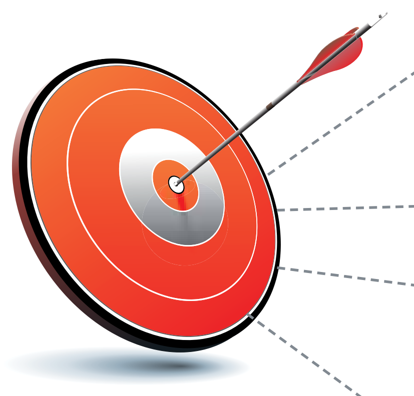
Background

The majority of existing railway civil engineering infrastructure was designed and built long before the modern concept of "design life" was developed in connection with limit state and reliability based codes; earthworks in particular are largely required to have a virtually infinite life, as replacement without massive disruption is extremely difficult, if not impossible.

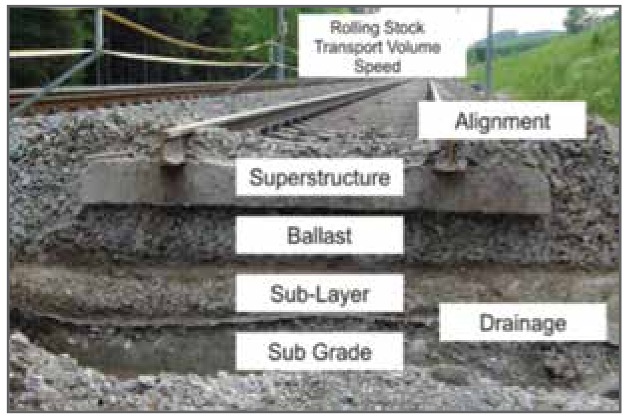
It is a tribute to 19th century engineers that a large proportion of this old infrastructure is still giving satisfactory performance, despite sometimes unsympathetic maintenance interventions. However, as the age of railway assets is advancing, critical performance milestones are being reached, especially in the light of predicted increases in both freight and passenger traffic and worsening of environmental exposure conditions due to climate change effects.

Objectives

The objectives of work package 2 were:



- To identify and model important degradation phenomena and processes for selected railway assets for the purpose of LCC and LCA analysis.
- To quantify the influence of intervention strategies on degradation time profiles.
- To develop performance time profiles for selected asset types.
- To validate the developed degradation and performance models through case studies.



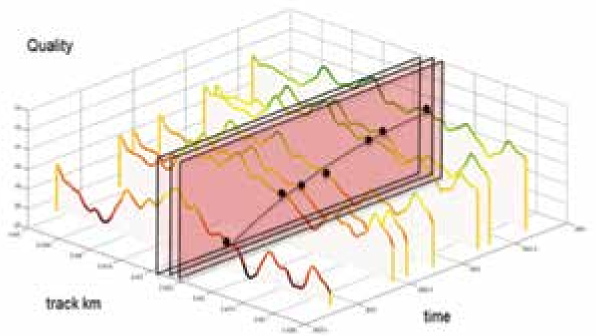


Figure 3.1 Generation of track deterioration profiles. ® MAINLINE Consortium

Achievements

At the start of the MAINLINE project, the available asset management tools for transport networks were largely deficient in the treatment of deterioration and how it impacts Life Cycle Cost and Environmental Impact analysis. In particular, available models were hampered by simplifying assumptions made in deterioration models, which had been developed from limited laboratory (rather than field) data or simply transferred from allied, yet distinct, industry sectors (e.g. corrosion models from the marine/offshore sector). This work package was aimed at the development and validation of deterioration models within a railway environment, in order to increase confidence in their predictions, which in turn would improve the capability of LCC estimates for alternative maintenance options.

The work first identified groups of railway assets, based on a ranking strategy that considered the potential to increase knowledge within the project's lifetime and the availability of field data for validation purposes. Additional considerations included the desire to cover asset types managed on the basis of their condition as well as those managed on a capacity basis, and the opportunity to demonstrate the development of deterioration models either from empirical data/observations or from physical laws and mechanical relationships (see Deliverable D2.1). Thus, the focus areas which were studied in detail were:

- Soil Cuttings;
- Track (plain line);
- Metallic bridges;
- Concrete tunnels.

For all four asset types, available deterioration models were analysed and compared, and specific recommendations were made as to how they could be adapted for use in a railway context. Moreover, a number of improvements and insights were introduced in order to create complete and robust deterioration models (see Deliverable D2.2) that are compatible with the Life Cycle Cost methodology described in Chapter 7. Specific examples of typical railway assets from each of the above four groups were presented in full, quantifying the influence of deterioration on the basis of changes in performance over time (see Deliverable D2.3). For the first two asset types, the adopted approach was based on the analysis of large historical datasets pertaining to asset performance over a period of more than ten years. On the other hand, for the last two asset types, analytical modelling was preferred, partly based on test and field data but also relying to a considerable extent on physical understanding of the underlying deterioration mechanisms and structural behaviour. Finally, significant effort was directed towards scrutinising all the proposed models through comparisons with real data and targeted sensitivity analyses (see Deliverable D2.4).

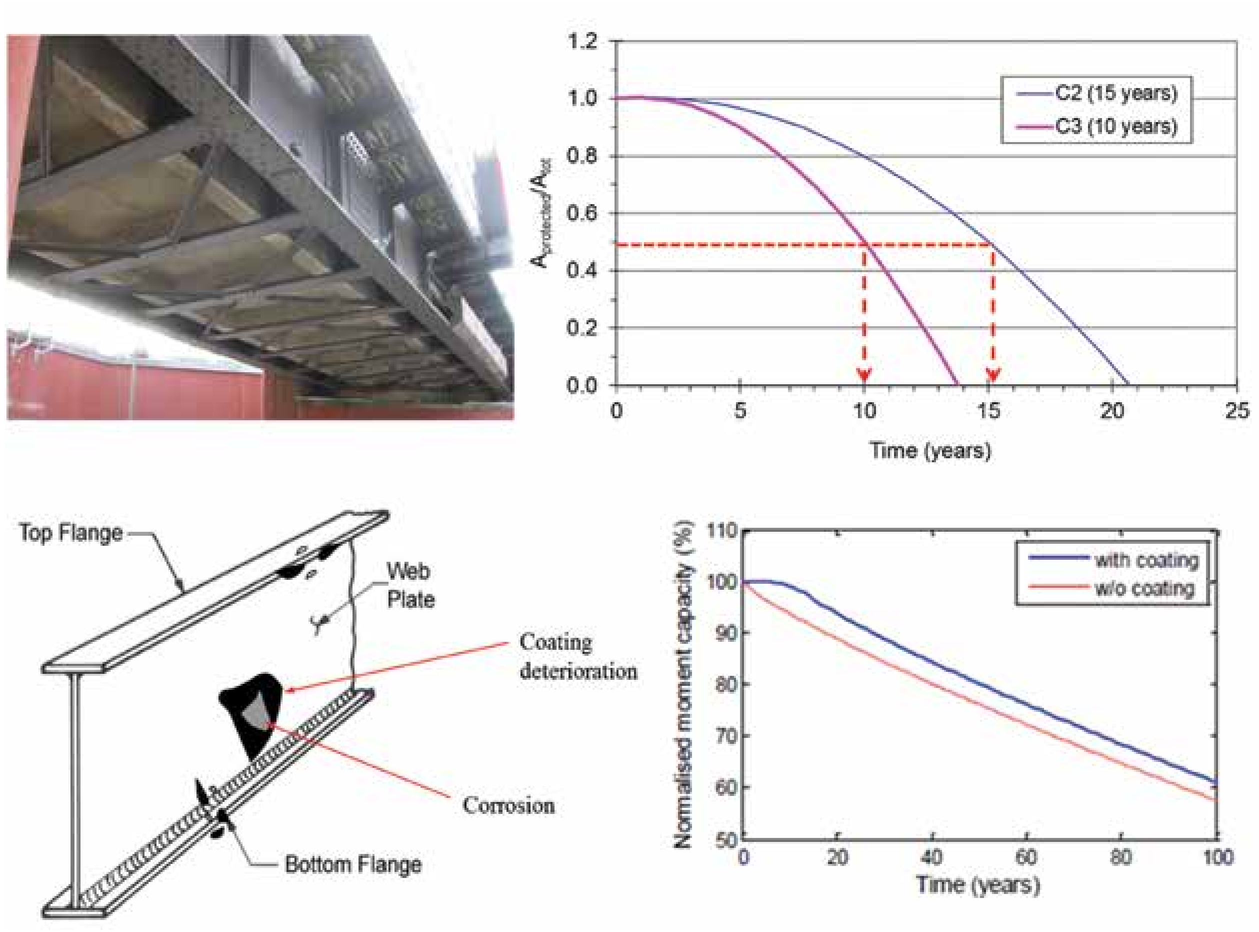
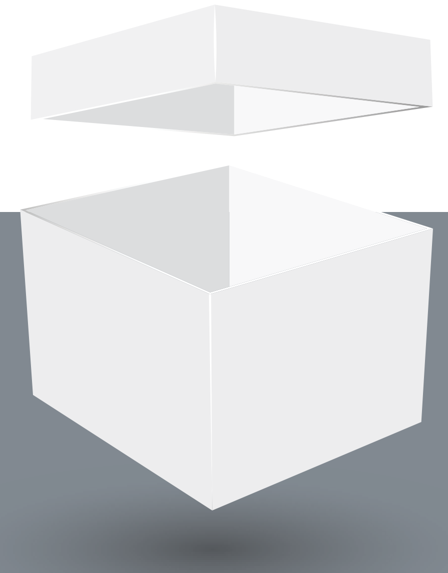


Figure 3.2 Generation of metallic bridge deterioration profiles. ® MAINLINE Consortium

To summarise, the main achievements are as follows:

- A deterioration model for Soil Cuttings which considers a number of time-invariant (such as soil type) and time-variant (such as vegetation and drainage) factors that predicts on the basis of historical trends captured through inspection cycles;
- A deterioration model for Track (Plain Line) that explicitly quantifies track quality as a function of time on the basis of initial conditions and a deterioration rate estimated considering line-specific factors (such as sleeper types, transport loads and track alignment);
- A deterioration model for metallic bridges susceptible to atmospheric pollution and corrosion, focusing first on the degradation of any available coating and the ensuing evolution of corrosion as coating becomes ineffective; the change of performance with time is captured under both condition criteria (such as percentage of unprotected area or fraction of thickness lost) and strength criteria (such as bending, shear or buckling capacity);
- A deterioration model for tunnels with concrete linings subject to chemical attack on reinforcing steel by carbon dioxide or by chloride ions, bearing in mind the specificities of tunnel geometry and availability of aggressive substances in a railway environment.



Open questions

In order to move to the next generation of deterioration models, and the next level of confidence in their predictions, further research will be needed. The MAINLINE performance-time methodology with explicit consideration of deterioration mechanisms and the effect of selected intervention actions is one of the first attempts to move from 'fixed life' asset management algorithms to a refined and adaptive tool that attempts to evaluate asset performance as a function of time.

There are open questions with respect to the following:

- How do these models perform across a very wide spectrum of countries, climates and management strategies?
- How can these models be improved to capture important deterioration attributes related to micro-climates, construction detailing and workmanship?
- How can these models be linked to the increasing availability of field inspections and, more recently, monitoring data?
- How can we combine the holistic understanding captured by field data with the analytical knowledge offered by scaling up laboratory experiments and numerical simulations?

4 Degradation monitoring: gaps & opportunities

Background

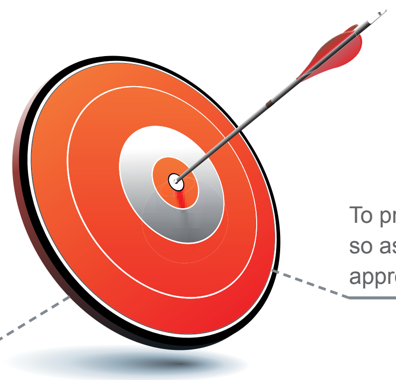
Monitoring and Examination (M&E) techniques are applied to assets so that timely action can be taken for these assets to remain fit for service. M&E systems thus form a crucial part of asset integrity management. They also provide valuable support in life cycle management decision making by enabling asset managers to assess the remaining life of their assets and plan for life extension or decommissioning.

M&E systems range from the very basic visual inspection by trained personnel to the remotely operated real-time continuous monitoring systems employing electronics for sensing and wireless communication. The M&E techniques used must be compatible with other parts of the asset management system, particularly the degradation assessment models that necessarily require appropriate inputs from such techniques. The issues that MAINLINE has sought to investigate include state of the art M&E techniques and the interface between such techniques and degradation assessments.

Objectives

The main objectives of work package 4 were:

To clarify what inputs the degradation models require from advanced monitoring techniques and examination systems, investigate their use and identify how these can operate in the most cost-effective and reliable way to complement or replace existing examination techniques for elderly infrastructure. Such monitoring and examination systems, together with the degradation models, are crucial for the effective and efficient integrated whole life asset management system described in Chapter 7.



To provide case study/validation evidence so as to promote take-up of the proposed approaches by infrastructure managers.

Achievements

The work package includes: assessment of currently used and promising M&E techniques, given the information provided regarding the degradation models in use; identification of gaps and recommendations to address the gaps between M&E and degradation assessment procedures; and, reports from Case Study applications.

Deliverable D4.1 provides an overview of currently available M&E techniques in relation to modelling degradation processes in a selection of railway assets – Cuttings, Metallic Bridges, Tunnels, Plain line, and Retaining Walls. This Deliverable summarises the pros and cons of each technique, draws on the suitability of these methods according to the degradation mechanism and the railway asset they apply to, and identifies gaps and issues to be addressed in the next stage in this work package.

Track monitoring is normally undertaken using track recording cars and the outputs are presented in deliverables D3.3 and D3.4.

Deliverable D4.2 is a report on the range of potential solutions to address the gaps identified in an efficient and cost-effective way. A suitable geographical coverage across Europe was ensured through the involvement of experts from both Western and Eastern European countries in the preparation of the document. A comparison of European methods has been carried out to offer reliable conclusions in regard to solutions to compatibility gaps between monitoring and examination systems and degradation models.

Deliverable D4.3 is a report on Case Studies showing the application of appropriate M&E techniques in the management of assets.

Figure 4.1 Retszilas bridge case study, Hungary. ® MAINLINE Consortium

Bridge Case Studies:

The Retszilas Bridge Case Study in Hungary illustrates how monitoring can be used to follow fatigue cracking and strengthening in a full scale test on a real bridge.

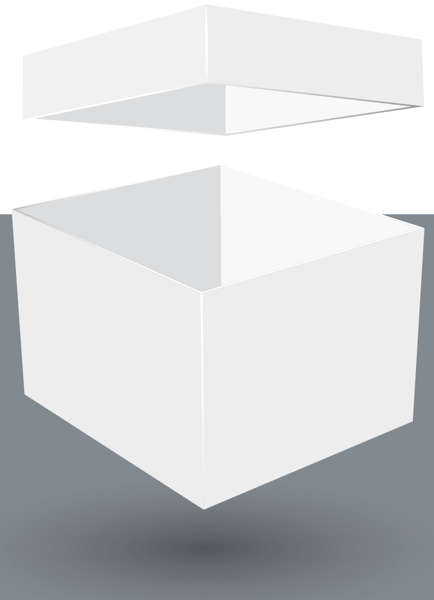
The Åby Bridge Case Study in Sweden illustrates how a photographic strain measurement system can be used. Results from the measurements are compared against traditional assessment of the remaining fatigue life of the bridge and finite element modelling.

These Case Studies have used information from the previous deliverables. In particular regarding fatigue in metallic bridges, optical sensors, photographic strain monitoring and full-scale testing are the proposed solutions to enable the measurement at points with maximum damage and calibrate fatigue models to improve their reliability.

Figure 4.2 Aby bridge case study. ® MAINLINE Consortium

Earthworks Case Study:

Another Case Study is the Sligo Line Cutting in Ireland which is a SMARTRAIL test site too. The cutting is a live railway cutting on the Sligo line in North West Ireland, owned by Irish Rail. State-of-the-art M&E techniques and assessment procedures are used and results compare to the existing approach. This Case Study gained from the results from both MAINLINE and SMARTRAIL projects.



Open questions

Any future developments of non-destructive techniques need to be evaluated, and any non-destructive evaluation (NDE) development projects need to take account of the requirements of degradation modelling and assessment calculations.

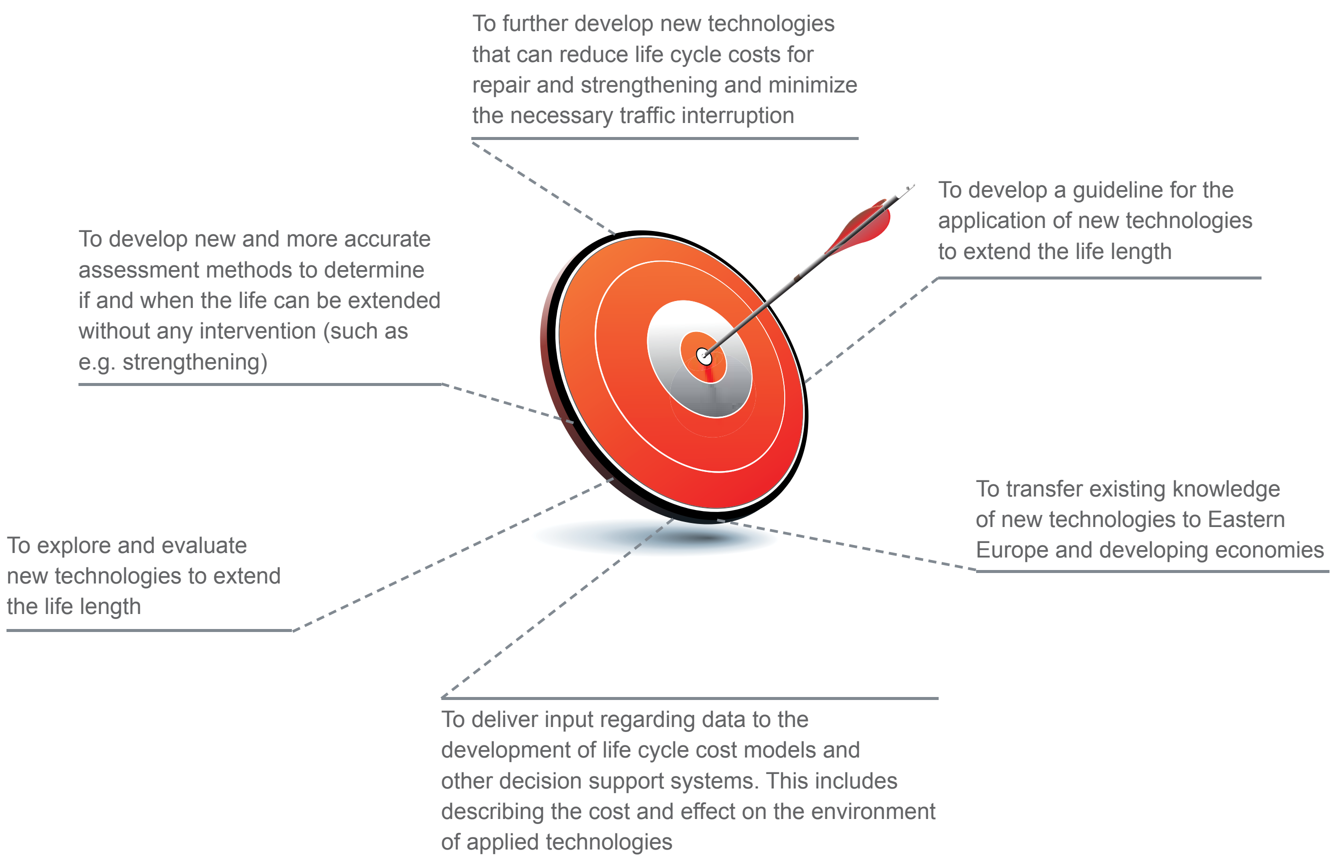
5 Methods to extend the life of assets

Background

Today a great proportion of existing rail infrastructure is old and has passed its theoretical lifetime. However, replacement is seldom an option so it is necessary to seek to extend its useful life as economically as possible.

Objectives

The main objective of work package 1 - dealing with life extension - is to apply new technologies to extend the life of elderly infrastructure. This can be subdivided as follows:



Achievements

In line with the objectives, the following results have been achieved:

New technologies to extend the life of rail infrastructure have been explored and developed. One example is strengthening bridges by post-tensioning to increase their load-carrying capacity (see Figure 4.1), saving 75 to 85% of the cost of replacement, which would have been the only feasible alternative.

Figure 5.1.1 A railway concrete trough bridge in Haparanda, Sweden, was strengthened by post-tension of bars placed in holes drilled transversely through the bridge slab. The allowable axle load could be increased from 250 to 300 kN. ® MAINLINE Consortium

Figure 5.1.2 Closer view of the works undertaken. ® MAINLINE Consortium

More accurate assessment methods have been developed to study if and when the life can be extended without the need for physical interventions. One example is the study of the Åby River metal truss bridge in northern Sweden, (see Figures 5.2 – 5.4), where direct reliability, redundancy and robustness were studied. This has enabled a number of similar bridges to be kept in service carrying higher axle loads.

A guideline has been developed for the application of new technologies to extend the life length of existing rail infrastructure. The guideline is based on three earlier deliverables and concentrates on assessment and strengthening, and will help infrastructure managers to decide on the best methods of life extension.

Existing knowledge of new technologies has been transferred to Eastern Europe and developing economies. One example is the workshop that took place in Budapest in May 2014.

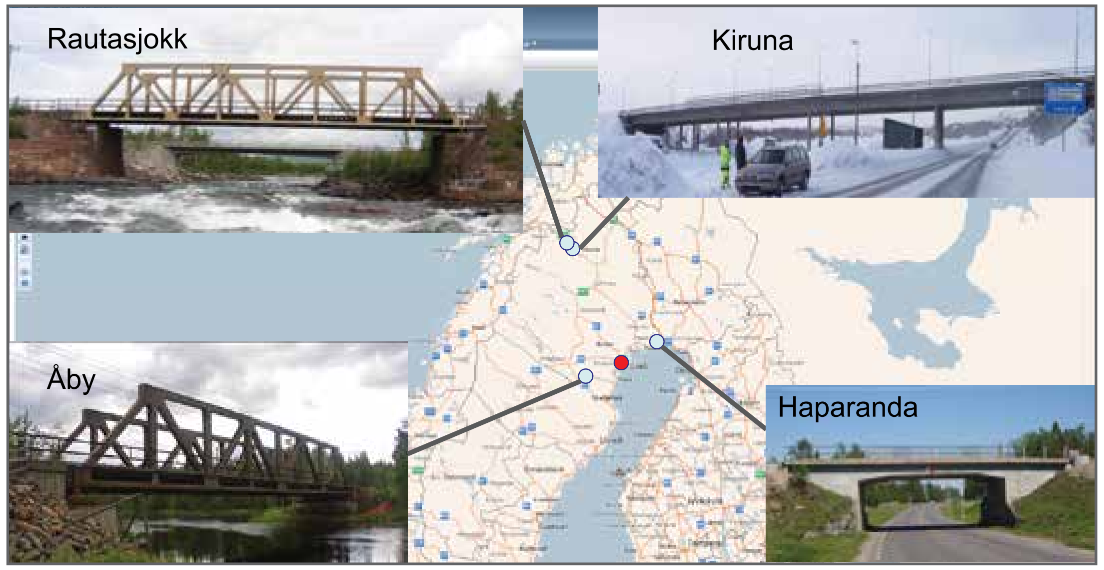


Figure 5 2 - Four 50 year old bridges in northern Sweden were assessed and strengthened to increase their load-carrying capacity. The metal truss bridges over the Rautasjokk and Åby rivers are twins built according to the same drawings. The Åby bridge was tested to failure and the very positive results were used to update the capacity of the Rautasjokk bridge. The pre-stressed concrete bridge in Kiruna was tested to failure to study its ductility and the influence of corrosion. The Haparanda concrete trough bridge was strengthened by post-tensioning. ® MAINLINE Consortium

Figure 5.3 Results from an advanced assessment of the Åby bridge shown in figure 5.2. It can be seen that an applied static load corresponding to four axles of 250 kN only represents a small part of the capacity of the bridge. ® MAINLINE Consortium

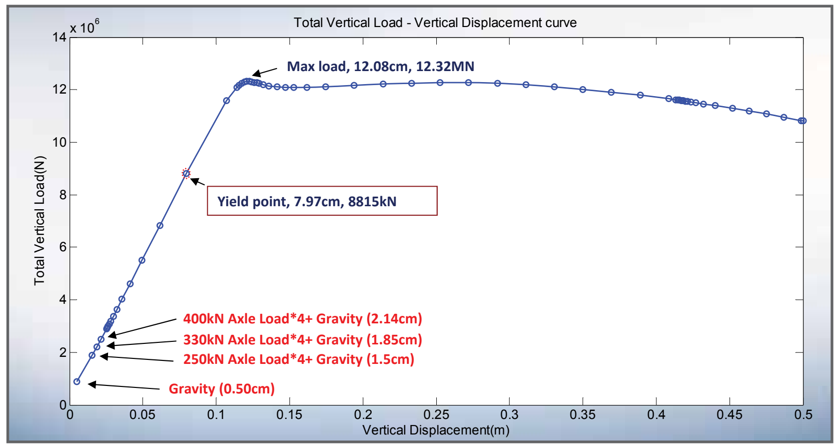


Figure 5 4 The Åby bridge after failure. It was caused by buckling of the top right girder. The failure was quite ductile and the bridge could carry a high load also after the maximum load as predicted by the model in Figure 5-3. A part of the FEM model of the failure is shown in the insert. ® MAINLINE Consortium

Open questions

The following questions are open:

- How to apply life extension techniques to structures in the light of increased demands caused by climate change?
- How to develop assessment methods that can be more easily used by infrastructure managers?
- How to better understand the functioning of structures in order to be able to strengthen them in a more effective and standardised way?
- How to use monitoring to secure a longer life length of structures that do not pass initial assessment?

6 Replacement of assets

Background

Replacement is an important part when infrastructure assets have reached the end of their service life or are functionally obsolete. It should be carried out with minimum traffic disruption. Traffic disruption can be minimised through the clustering of different work items between the same closure points together, provided that there is no logistical clash between work sites. This can be achieved through careful preplanning.

Work has been focussed on bridge structures and track systems as these are the infrastructure assets within the overall MAINLINE work plan that are most frequently replaced.

Objectives

The objectives of work package 3 were:

To investigate new construction methods and logistics for transport that minimize the time and cost required for the replacement of obsolete infrastructure. The focus here is on cost effective and environmentally sound methods that are easy to implement with low impact on the rail traffic and a short down time of the network.

To plan and optimise the construction processes on existing lines where replacement of existing infrastructure is an alternative. Here the systematic approach is extremely important and should always be connected to Life Cycle Cost Analysis (LCCA). The results will help the infrastructure manager to decide for the most favourable measure from technical, social, environmental or cost demands.

To deliver input regarding data to the development of life cycle cost models and other decision support systems for infrastructure managers. This includes taking into account construction time and logistics, short- and long-term impact on the network, future maintenance issues but also environmental aspects such as emissions of greenhouse gases from temporary transport services.

Achievements

Planning

A survey of railway infrastructure managers across Europe showed that, in those countries where there is a regime for compensating train operators when lines are not available to them, the longer notice of disruptive activities that is given the lower the compensation payment. In some cases, lead times of several years are necessary when very long disruptive possessions are needed, even when these are usually only made available over the Easter and Christmas holiday periods. As a result, advice has been given on how to undertake long term planning by comparing the strategies and methods used across Europe. This could lead to a reduction of up to 60% in disruption costs.

Since not all countries have established regimes for charging disruption costs, a number of regimes were studied and a simplified method devised to assist those countries without a method. This will allow such countries to populate the relevant parts of the LCAT models with consistent data.

The survey also showed that the clustering of maintenance and renewal activities within disruptive possessions would lead to cost savings for individual projects as the disruption costs could be shared and productivity was likely to increase due to a higher efficiency of machinery use. An example quoted showed a productivity increase of 15% following the introduction of clustering.

Another important part of the planning process is the consideration of the environmental impact of the work proposed. The MAINLINE LCAT tool will be of assistance to this when looking in detail at individual construction activities but it is designed to deliver the impact in terms of CO_2 output or Euro equivalent. This means that other less easily quantified environmental impacts such as noise, which is becoming a more important issue in parts of Europe, are not addressed by the tool. Hence advice is given in D3.4 about how to reduce both the generation of noise and its export to neighbouring communities, with different solutions being offered for both bridgeworks and track works.

Bridges

Most railway administrations across Europe have their own standard designs of bridges. A selection of these have been described and compared so that good or novel solutions from one railway can be adopted by others.

A Eurocode compliant design for a relatively simple concrete bridge, which could be considered as a future standard pan-European design, has been undertaken to compare the requirements of the Swedish and Spanish National Annexes. This has shown that there are only minor differences between the two designs and hence little practical difficulty in developing standardised products that could be offered commercially to the whole of Europe, with the potential for savings based on a larger scale of production.

Installation methods also vary across Europe. The most popular method is by the use of either road or rail mounted cranes but this can lead to additional time and cost where lines are electrified as overhead equipment may need to be removed. To counteract this, some countries possess special rail mounted bridge carriers and others rely more on multi wheel road based bridge carriers. In other cases, replacement bridges are built alongside the existing bridge and then slid (or launched) laterally into position during a relatively short track closure. For long bridges, particularly over water, this method can be combined with the sequential longitudinal launching of individual spans constructed on dry land onto temporary supports prior to lateral movement. A table has been produced to compare the merits of each solution to assist infrastructure mangers in the selection of the best option.

++ = yes + = may work — = no	Mobile Cranes	Rail Mounted Crane	Rail Mounted Bridge Carrier	Longitudinal Launching	Horizontal Launching	Deck Replacement
1. Bridge length						
1.1 Less than 5 m	++	++	++	++	++	++
1.2 5-20 m	++	++	++	++	++	++
1.3 More than 20 m	+	+	+	+	++	++
2. Bridge type to be exchanged						
2.1 Reinforced concrete beam bridge	+	+	++	++	++	++
2.2 Steel truss	++	++	+	++	++	++
2.3 Steel beam	++	++	++	++	++	++
2.4 Arch	+	+	+	+	+	+
2.5 Other	+	+	+	+	+	+
3. Track possession time						
3.1 Between 6-12 h	+	+	+	-	+	+
3.2 Between 12-24 h	++	++	++	+	++	+
3.3 Between 24-60 h	++	++	++	++	++	++
3.4 More than 60 h	++	++	++	++	++	++
4. Available funding						
4.1 Very restricted funding	+	+	+	+	++	++
4.2 Normal funding	++	++	++	++	++	++
4.3 Money is not the problem	++	++	++	++	++	++
6. The bridge runs over						
6.1 Water	++	++	++	++	+	++
6.2 A rural route	++	++	++	++	++	++
6.3 A highway	++	++	++	++	++	++
6.4 A street in a city	++	++	++	++	++	++
6.5 Agricultural land	+	++	++	++	++	++
7. Available working site						
7.1 Small	++	++	++	+	+	+
7.2 Normal	++	++	++	++	++	++
8. Electrified line						
8.1 Electrified line	+	++	++	+	++	+
8.2 No electricity	++	++	++	++	++	++

Figure 6.1: Recommendations for methods for replacement of the superstructure of short span bridges. ®MAINLINE Consortium

Finally, the use of novel materials for bridge construction, principally high performance concrete and fibre reinforced polymers (FRP), also known as advanced composites, has been investigated. This has shown that both materials have seen limited use worldwide in railway bridge applications and that they offer considerable promise in the future.

Two notional designs have been produced:

- A replacement FRP deck on pre-existing metallic main girders which could produce weight savings of up to 50% when compared with the more traditional concrete alternative.
- A fully FRP composite railway bridge with a span capability of up to 50m which are expected to offer cost savings on both initial construction (due to their relative lightness) and through life (due to lower maintenance requirements).

Nevertheless the absence of a Eurocode covering the use of FRP material is likely to inhibit the take up of these solutions in the short term, although design guidance, without the formal status of codes, is available in a number of European countries.

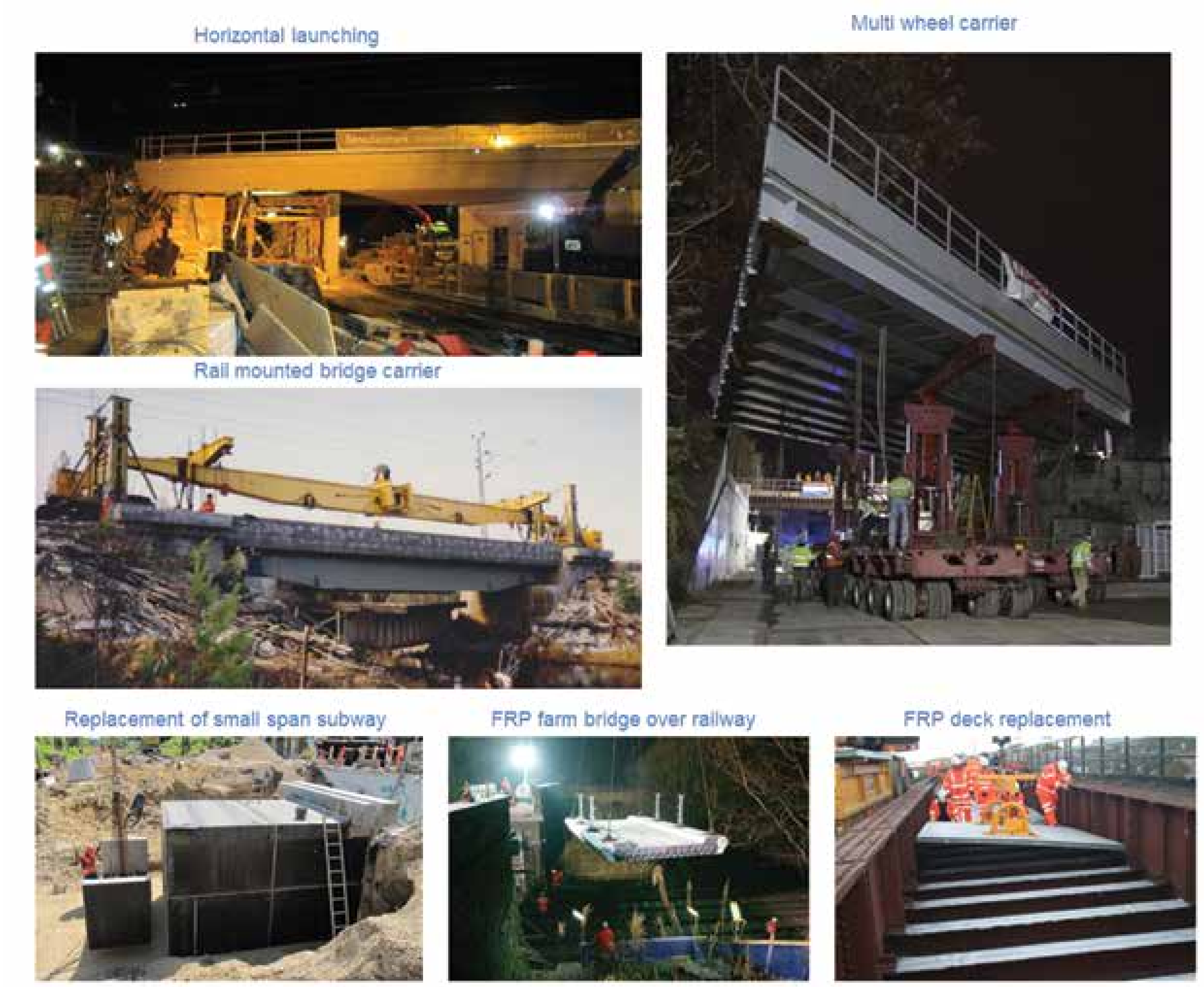


Figure 6.2 Examples of bridge replacement methods © MAINLINE Consortium

Track

Track replacement falls into two distinct categories, plain line and switches and crossings (S&C), each of which has different logistical and engineering requirements. The total replacement of a complicated junction can take several days. Plain line can be done in short track possessions in order not to affect train operation but with very low output and high costs or on the contrary, the line can be closed during several weekends -or even weeks- depending on the line, available alternative routes and the country. The latter enables higher output and lower costs (see also LCAT). Therefore the length of track possession for track activities depends strongly on the requirements/demands of the IMs, which affects directly cost and output of the works.

Plain line renewal can vary from the use of manual labour with minimal assistance from plant such as cranes or excavators

Figure 6.3 Different techniques for track renewal. ®MAINLINE Consortium

to the deployment of a modern fully automatic track relaying machine with the choice of system being dictated in part by the length of line to be replaced and the time available for the work. The manual method can be made less weather dependent by the use of mobile workshops (which can also be used when routine maintenance is undertaken) in which case the adjacent line can be kept open without restriction. The merits of each approach are discussed so that infrastructure managers can decide on the best approach for their own specific requirements. Major cost savings can usually only be achieved through the use of modern high output machines which have a high capital cost and thus need to be used intensively to justify the initial outlay.

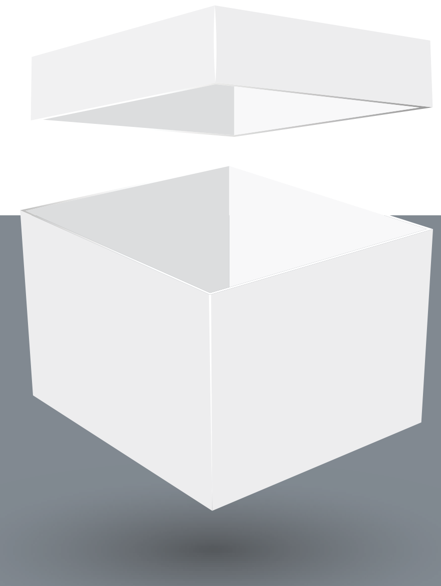
Switch & crossing renewal, as outlined above, can vary from the replacement of a single lead turnout to the total replacement of a complicated junction. There are many methods available, ranging from hand build up on site to the transportation and installation of large components fabricated offsite. There are also a number of commercially available machines to assist the installation of S&C, such as the Automated Ballast Collector which efficiently removes the old ballast and compacts the subgrade to avoid future differential settlements.

Additionally the use of modular S&C is becoming more popular as it can give time savings of up to 80% and a 33% reduction in work force on site. All these options are discussed in detail in terms of required machinery, output and labour and compared in specially produced tables so that the most appropriate system can be chosen for each particular site. Moreover, additional recommendations are provided in order to achieve higher initial quality after the renewal (such as avoiding provisional clamping in favour of welding or always removing the complete layer of old ballast layer), which is essential to minimize future track degradation.

Comparisons have been undertaken between the use of under rail pads, under sleeper pads and under ballast mats for homogenising track stiffness through S&C, which is now believed to be an important factor in long term track behaviour. The results are presented in a series of graphs and the following conclusions drawn:

- soft rail pads are the most efficient system to minimize track stiffness variation and hence, impact load on the crossing, while under ballast mats have very little effect.
- the combined use of rail pads and under sleeper pads can bring additional benefits, and should be considered. However, the stiffness of rail pads and under sleeper pads should be revised if used together.
- further studies should be carried out on under sleeper pads.

It is well known that the use of wood sleepers in S&C improve the dynamic behaviour to a similar degree as the use of under sleeper pads. The disadvantage of wooden sleepers is that they need to be preserved to prevent rot using creosote, which is no longer environmentally acceptable. Hence the use of synthetic sleepers manufactured from fibre-reinforced foamed urethane (FFU) has been investigated. These are extensively used in Japan and have been used in a number of European countries. Whilst more expensive than comparative wooden sleepers, FFU sleepers should have a longer life (up to 50 years is suggested) so are likely to prove to be cheaper on a whole life cost basis.



Open questions

From the previous sections the following questions remain open:

- Comparative calculations for the design of bridges using different National Annexes to the Eurocodes should be undertaken to reinforce the view that standard design(s) could be produced.
- Investigations into the use of FRP materials for new railway bridges should be undertaken. These investigations should particularly concentrate on the dynamic response of lightweight bridges under the action of both high speed trains (up to 300km/h) and heavy axle loads (up to 35 tonnes) and lead to the production of rail specific guidance on designing with FRPs.
- Research into the benefits of under sleeper pads in S&C should be undertaken.
- Methods for the replacement of soil cuttings and tunnels should be researched as it has not been possible to do this within the MAINLINE project since it is not a regular task for railway infrastructure managers.

7 Description of the Life Cycle Assessment Tool

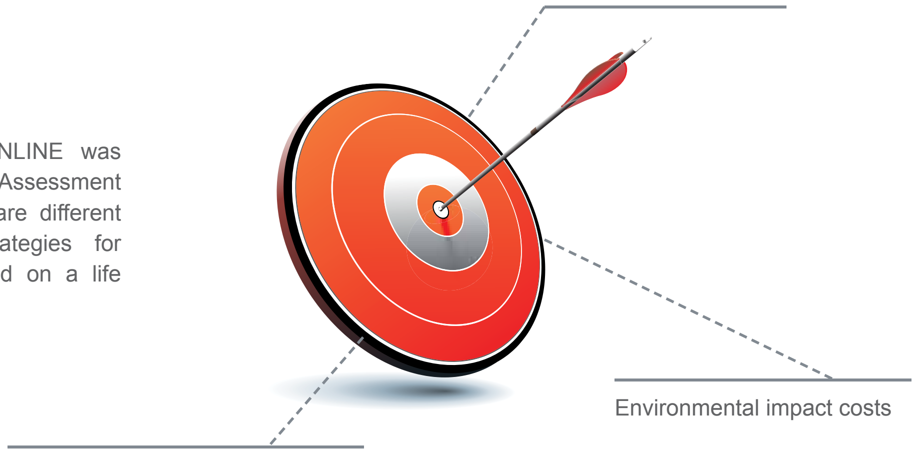
Background

The continued growth in rail traffic across Europe will increase both the rate of deterioration of these railway assets and the need for shorter line closures for maintenance or renewal interventions.

The impact of these interventions will need to take into account the financial constraints and enhanced environmental requirements as a result of new legislation. Tools to inform decision makers about the economic and environmental consequences of different intervention options are becoming essential to provide confidence and assurance.

Objectives

The main objective of MAINLINE was to create a tool (Life Cycle Assessment Tool - LCAT) that can compare different maintenance/replacement strategies for track and infrastructure based on a life cycle evaluation quantifying:



Achievements

The initial work was to establish which existing asset management tools could be used for railway assets and whether they provide both life-cycle and environmental outputs. This analysis highlighted positive and negative features of existing software and also found that combining life-cycle and environmental outputs was uncommon.

Questionnaires were issued to Infrastructure Managers to confirm the extent and nature of any life-cycle assessment that was carried out within their organisations. The results varied across Europe, although some activity was carried out within all countries; and that environmental outputs were performed less frequently than life-cycle costing. The respondents recognised the growing importance of both environmental and life-cycle costing.

The LCAT models have been designed to bring together both the improved deterioration rates described in chapter 3 and the ability to use monitoring intervention and replacement techniques, described in chapters 4, 5 and 6 or from user experience.

LCAT models have been created for plain line track, metallic bridges and soil cuttings. These assets were selected due to interest from the infrastructure managers and availability of sufficient data to calculate deterioration rates. These three models have been written in Microsoft Excel to provide transparency and allow users to amend the models as they need in the future. A consistent layout and style has been used to give a common identity to the models.

Figure 7.1 Examples of areas where LCAT is developed today. ®MAINLINE Consortium

The outputs from the LCAT are intended to assist the justification of interventions, to optimise spending of maintenance budgets, to compare different interventions and to predict the timing of future works and expenditure.

Training workshops have been organised to discuss, explain and demonstrate the LCAT models to infrastructure managers and other users. This has also allowed the models to be refined, based on feedback from these sessions.

The following examples show the application of the LCAT for a metallic bridge and plain track.

The metallic bridge in Figure 7.2 is a single span structure with half-through girders and is a typical railway asset. The inputs to the LCAT describe the properties of an individual element of the bridge, its dimensions and acceptable limits for both condition and loss of section which determines the strength in terms of shear and bending. The LCAT uses these limits, together with any defined maximum intervals for specific interventions.

Figure 7.2 Bridge over Ermelundsvej, Denmark ®MAINLINE Consortium

These limits are applied to the degradation rates within the LCAT and a life-cycle plan is generated, as shown in Figure 7.3. It shows the financial and environmental costs relating to the physical works, and coating and section loss over time.

The track example is for a length of route with good drainage and formation that is used by freight. Acceptable quality limits (Q) have been defined by the user to trigger interventions for tamping of the ballast and also relaying the track. Again, the degradation rates within the LCAT create the life-cycle plan shown in Figure 7.4.

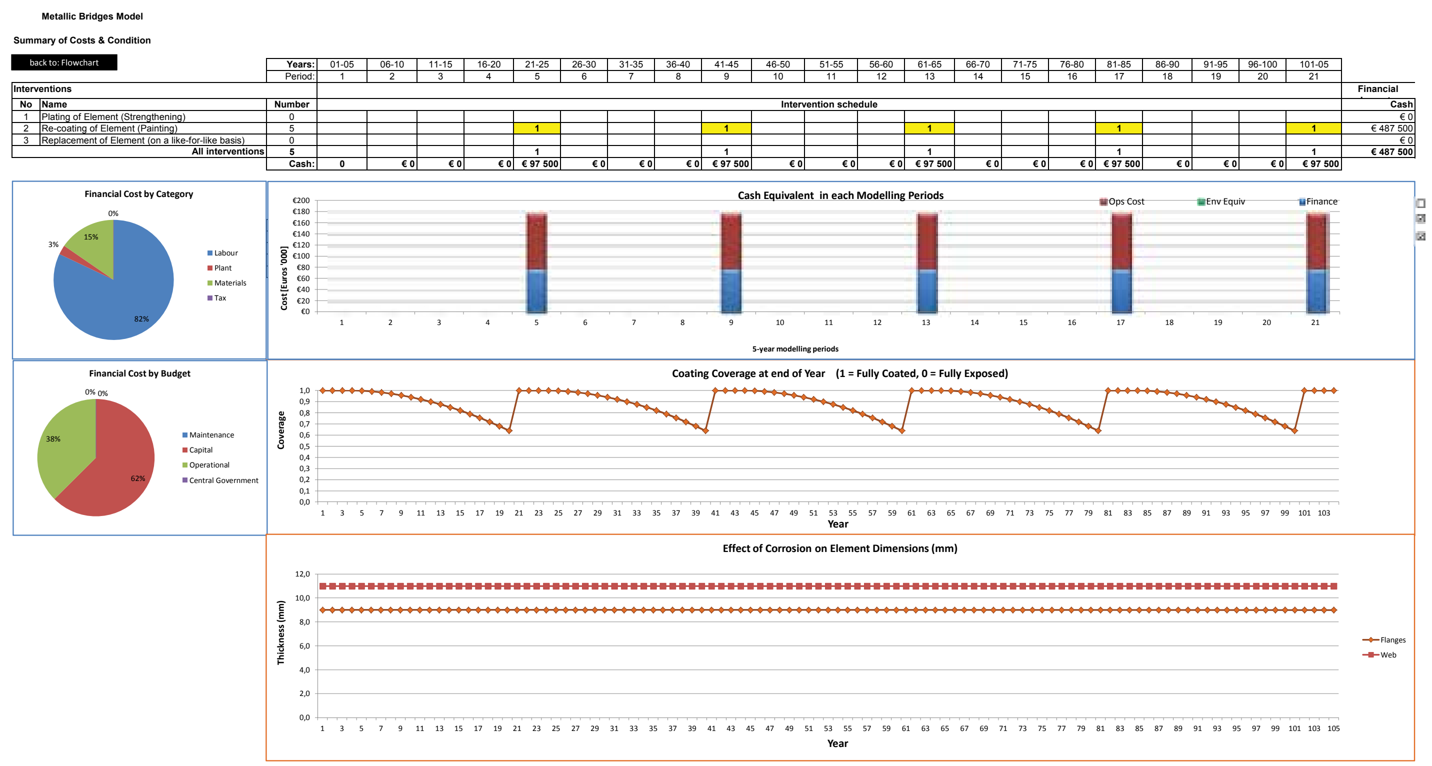


Figure 7.3 Example of LCAT output screen

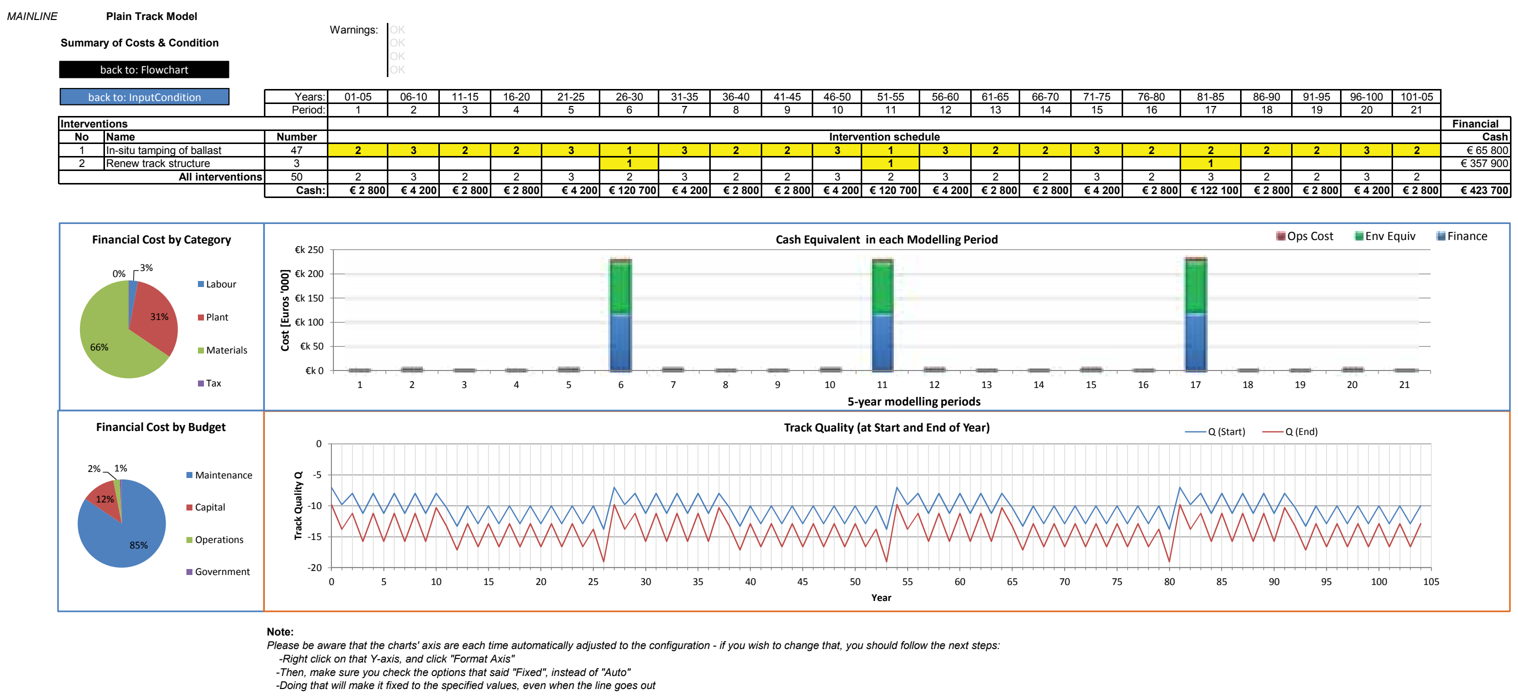
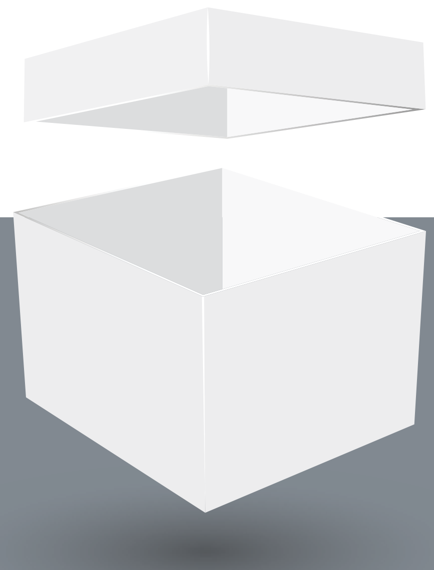


Figure 7.4: Life Cycle Plan generated based on the degradation rates within the LCAT



Open questions

Further research and development work could be carried out by others in the following areas:

- Collation of further data for the existing LCAT models to give greater validation of deterioration rates;
- Collation of data from other asset types to allow for the creation of degradation rates of other materials and assets;
- Creation of LCAT models for different assets based on the new data;
- Investigate the incorporation of fatigue modelling within the Metallic Bridges LCAT;
- Continuous updates to the existing LCAT models based on new data and user feedback;
- Creation of a 'combined LCAT' to consider holistic risk and whole life costing for a system approach rather than by individual assets;
- Greater number of environmental factors within the LCAT models including 'noise';
- Investigate the feasibility of adding a probabilistic approach into the LCAT models;
- Create an optimisation tool within the LCAT.

8 Technical, environmental and economic assessment

Background

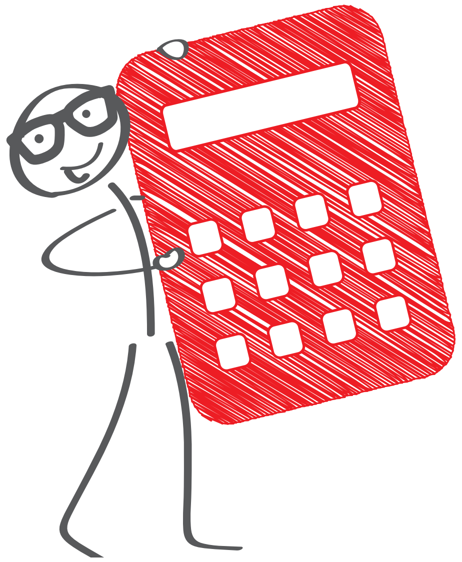
The MAINLINE project has targeted a reduced environmental footprint for selected items of rail infrastructure in terms of embodied carbon and other environmental benefits.

The project has:

- Improved degradation and structural models to develop more realistic life cycle cost and safety models) (chapter 3);
- Investigated monitoring techniques to complement or replace existing examination techniques (chapter 4);
- Applied new technologies to extend the life of elderly infrastructure (Chapter 5);
- Investigated new construction methods for the replacement of obsolete infrastructure (chapter 6);
- Developed decision support tools to assess whole life environmental and economic impact (chapter 7).

Technical assessment

Technical assessment methods are a main outcome from the work on new technologies for extending the life of existing elderly rail infrastructure (chapter 5) and the replacement of assets (chapter 6).



Economic Assessment

Many Infrastructure Managers do not yet use Life Cycle Costing (i.e. financial) and/or Life Cycle Assessment (i.e. environmental) in the planning of maintenance and renewal of their rail infrastructure. There is a lack of data and methods and this is where the MAINLINE project provides useful guidance (chapter 7).

There is often a lack of economic resources for maintenance which may lead to a shorter life length and less sustainability than would otherwise be the case; results from the MAINLINE project provide useful advice aimed at improving this situation. The Life Cycle Assessment Tools (LCAT) have been developed which allow users to demonstrate optimum interventions and reduce capital expenditure.

Europe has a railway network of some 230,000 km with an asset value of more than 1500 billion € and is spending – with large variations - less than 1% of it for yearly maintenance. A large proportion of the civil engineering structures and tracks are old; of the 500,000 bridges, 35 % are over 100 years old and earthworks and tunnels are often older. Nonetheless they can, with the help of the results from MAINLINE, remain in service for longer periods, improving the ability of the railways to deliver increased mobility across Europe and play an increasingly important role in the development of integrated, safer, “greener” and “smarter” pan- European transport systems.

The results from MAINLINE will facilitate longer service lives for existing railway infrastructure, which will bring about great savings for Infrastructure Managers in Europe. They provide methods to optimize replacement of obsolete assets which will further reduce costs.

A modest 10 year increase in the service life of 2% of the bridges due to the results of MAINLINE means that the replacement of 10,000 bridges could be postponed for 10 years with notional cost savings calculated below.

- The average construction cost (K) of a new railway bridges is about 1M €
- With a low interest rate (p) of 2% the present value of the cost for rebuilding a bridge in 10 years will be K/(1+p)10 = 0.820 K
- Compared to rebuilding the bridge now the saving will then be K – 0.820 K = 0.180 K.
- Not replacing 1,000 bridges per year gives a saving of 1,000 x 0.180 x 1 M€ = 180 M€.

Similar savings will be available for other kinds of infrastructure; for instance significant performance enhancements for Switches and Crossings (S&C) have been developed. There is potential to enhance replacement methods of S&C by reducing replacement time, ensuring good track alignment and reducing varying track stiffness. This has been one of the principal focus areas for MAINLINE and the potential benefit is outlined below.

- There are approximately 150,000 switches in mainline track in Europe.
- Switches are changed about every 20 to 30 years
- The cost to change a switch is of the order of 0.15 M€
- This gives a yearly cost of some (150,000/30) x 0.15 M€ = 750 M€.
- If the quality of the switches could be improved so that they would last some 25 % longer this would lower replacement costs and thus save 750 – (150,000/37.5) x 0.15 M€ = 150 M€ per year.

So, just from savings on bridges and switches and crossings we may reduce costs by more than 300 M€ per year. Additional savings will arise from the MAINLINE results for plain line track and soil cuttings, which have not been quantified here.

Environmental Assessment

Traditionally the main environmental consideration associated with railway operation has been related to reducing noise and vibration, but with the main environmental focus now turning to climate change and the associated carbon agenda, new considerations are becoming important.

In common with many other parts of the built environment, the carbon impact of railway infrastructure is dominated by usage rather than initial construction or ongoing maintenance. However if the railway industry is to play its part in meeting the carbon reduction targets set within Europe, then the carbon impact of infrastructure maintenance and renewal activities will have to decrease.

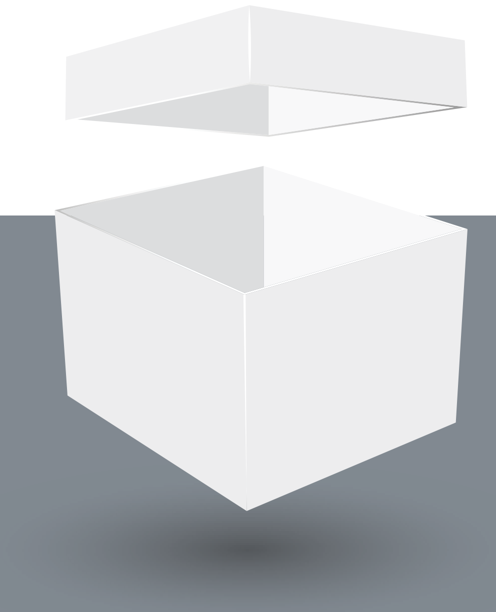
Within the MAINLINE project a tool has been developed that enables Infrastructure Managers to assess the environmental (carbon) impact of various maintenance or renewal interventions under consideration and hence have the opportunity to select the one with the least impact. Unfortunately the current state of knowledge about the carbon impact of typical interventions is limited and largely confined to academia, which means that it is virtually impossible to quantify the benefits from the project; however the example below will give an indication of the kind of benefits that could be realized.

The emission of carbon dioxide from the building of a concrete bridge containing 160 m^3 of concrete can be calculated in the following way:

- 1 m^3 of concrete weighs approximately 2.3 tonnes.
- Concrete contains about 400 kg of cement per tonne
- Cement production creates approximately 700 kg CO_2/tonne
- This gives 160 x 2.3 x 0.4 x 0.7 ton = 103 tonnes CO_2.
- To this we add 150 kg reinforcement steel per m^3 of concrete.
- Steel production is responsible for some 1,2 kg CO_2/kg steel
- This gives 160 x 0.15 x 1.2 tonne = 29 tonnes CO_2.
- In total we will emit about 103 + 29 >> 130 tonnes CO_2 per new bridge.

Research projects developing a new generation of lightweight, low energy, self-compacting concretes for structural applications have shown that it is possible to replace substantial quantities of cement with PFA (pulverized fuel ash) or GGBS (ground granulated blast furnace slag) without affecting structural performance. This can save around 40% of the embedded energy in concrete, which would mean a reduction of 40 tonnes CO_2 from the concrete – equivalent to a 30% reduction in overall carbon footprint for such a bridge.

The potential for savings in a new build scenario can be demonstrated by reference to the Environment Product Declaration prepared for 190 km of a new single track railway with 90 bridges of a total length of 11 km and with 25 km of tunnels, Bothniabanan (2010). Per km the bridges were calculated to emit 8 050 ton CO_2 equivalents and use 22 GWh (80 TJ) during construction and 60 years of maintenance. The energy use per km of tunnel was of the same magnitude and the emission was about half of that of the bridges. Per bridge this gives in average an emission of 1020 ton CO_2 equivalents and a use of energy of 2,65 GWh (9,5 TJ). So, the savings in extending the life of existing structures instead of replacing them are large.



Open questions

To achieve sustainable transportation and low carbon emissions there is a need for:

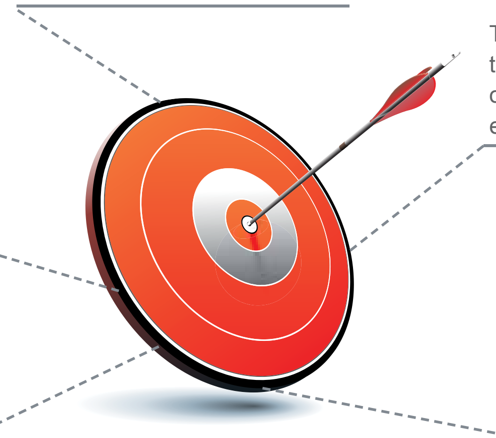
- Efficient utilization and maintenance of the rail infrastructure. Rail utilization will increase in the future if the carbon dioxide emissions from airborne traffic are subject to the same taxation as surface transportation.
- Increased use of strengthening to extend the life of existing structures. Full scale tests to failure of obsolete structures may give guidance on which strengthening methods that have the best function and sustainability
- Increased use of efficient assessment methods. Infrastructure Managers should be encouraged to learn to use and familiarize themselves with these methods. As an example a new method for estimating reinforcement corrosion degradation saved 3 M€ on two bridges in Stockholm
- Maintenance efficiency can be improved by better methods and data for RAMS (Reliability-Availability-Maintainability-Safety/Supportability)
- Better LCAT methods with more data and more options for different alternatives than the first important steps which are taken in the MAINLINE Project.

9 CONCLUDING REMARKS

MAINLINE HAS BEEN SUCCESSFULLY COMPLETED IN A PLANNED WAY BY VERY COMMITTED PARTICIPANTS AND GOOD RESULTS FOR THE MAIN OBJECTIVES HAVE BEEN ACHIEVED. TEAMBUILDING ACTIVITIES AT THE START ALSO CREATED AN OPEN AND COOPERATIVE ATMOSPHERE AND A PRODUCTIVE TEAM.

FIGURE 9.1 MAINLINE PARTNERS GOING TO A GENERAL MEETING IN LULEA, SWEDEN

In chapter 1 "introduction" the following objectives were listed:



All these objectives have been addressed in a good way. To assist Infrastructure Managers to implement the results some are presented in the form of guidelines and others as a manual.

The dissemination activities in MAINLINE have been extensive. They are described in a separate deliverable named “D6.3 Dissemination and Implementation of MAINLINE results”. Four activities are important to mention, namely:

» Good support from the UIC groups where MAINLINE has been spread to most European railway infrastructure managers.

» A special workshop targeted at Central and Eastern Europe was held in Budapest 15 May 2014. All presentations are also available on the project web page **www.mainline-project.eu**.

A special MAINLINE seminar with 8 presentations was hosted during the IABMAS2014 conference in Shanghai. The presentations are available on **www.mainline-project.eu** and give a short and comprehensive overview of MAINLINE.

» The LCAT training seminar (London, 11-12 June 2014 and Paris, 11-12 September 2014) was fully booked and 11 infrastructure managers participated. A continuation will be proposed under the UIC umbrella.

Regarding these activities, the dissemination of MAINLINE can be seen as successful.

All deliverables are also public and available on **www.mainline-project.eu** under result. They will be available at least until 2021.

Appendix I List of MAINLINE Public Deliverables

NB: The documents in this list are all available on the website for download.

Life Extension - Application of new technologies to elderly infrastructure

D1.1 Benchmark of new technologies to extend the life of elderly rail infrastructure
Overview of some of the most promising new or updated technologies in the fields of strengthening, inspection, water proofing, anti-corrosion, joints and bearing

D1.2 Assessment methods for elderly rail infrastructure
Description of the latest developments for advanced infrastructure assessment and their possible incorporation in life cycle assessment

D1.3 New technologies to extend the life of elderly infrastructure
Description of the potential and use of new or updated assessment and strengthening technologies for bridges, track and earthworks

D1.4 Guideline for application of new technologies to extend life of elderly rail infrastructure
Guideline for owners, consultants and contractors to support them in the use of new technologies

Degradation and structural models to develop realistic life cycle cost and safety models

D2.1 Degradation and performance specification for selected assets
Report containing the construction, geometric, material and functional characteristics for selected assets – earthworks, bridges, tunnels and track – and their relevance to LCC/LCA calculations

D2.2 Degradation and intervention modelling techniques
Degradation time profiles and effect of intervention strategies under a range of operational scenarios for track, metallic bridges, cuttings, corrosion and coatings, tunnels with masonry or concrete linings

D2.3 Time-variant performance profiles for LCC and LCA
Development of performance-time profiles, together with sensitivity analyses for track, metallic bridges, soil cuttings and concrete lined tunnels

D2.4 Field-validated performance profiles
Summary of comparisons between predicted performance profiles and actual profiles based on field data for the 3 assets for which an LCAT model was developed: track, metallic bridges and soil cuttings

Replacement of obsolete infrastructure – New construction methods and logistics

D3.1 Benchmark of production and replacement of railway infrastructure
Overview of existing techniques to replace railway infrastructure (civil engineering structures and track) and presentation of European practice for replacement methods

D3.2 Bridges: Methods for replacement
Comparison of the different methods for bridge replacement presented in the benchmark (D3.1) and description of improvement in terms of logistics, material use and production methods

D3.3 Rail switches and crossings: Development of new technologies for replacement
Review of different replacement methods for switches and crossings and introduction of potential improvements on logistics and design of S&C renewals

D3.4 Guideline for Replacement of elderly rail infrastructure
Guideline to help infrastructure managers in their decision making on infrastructure management (bridges, track, switches and crossings), considering cost effectiveness and environmental aspects

Monitoring and examination techniques

D4.1 Report on assessment of current monitoring and examination practices in relation to the degradation models
Summary of pros and cons and cost effectiveness of different approaches in use in the rail assets considered in MAINLINE

D4.2 Solutions to gaps in compatibility between monitoring and examination systems and degradation models
Identification of gaps and compatibility issues between output from monitoring and examination techniques and inputs to assessment models and solutions to address these

D4.3 Report on case studies
Presentation of two bridge case studies and one cuttings case study designed to validate new approaches to monitoring and examination for improved asset management

Whole life environmental and economic asset management

D5.1 Assessment of asset management tools
Presentation of questionnaires sent to infrastructure managers regarding management of bridges, tunnels, cuttings and track

D5.2 Assessment of environmental performance tools and methods
Benchmarking of current environmental performance measurement approaches and conclusions on the best features to be used in MAINLINE Life Cycle Assessment Tool (LCAT)

D5.3 Recommendations for Format of a Life Cycle Assessment Tool (LCAT)
Analysis leading to the choice of converting life cycle assessment results into environmental cost for life cycle cost evaluation

D5.4 Proposed methodology for a Life Cycle Assessment Tool (LCAT)
Identification of key parameters required for the LCAT and introduction of a system description

D5.7 Manual for a Life Cycle Assessment Tool (LCAT) for Railway Infrastructure - Metallic Bridges, Track and Soil Cuttings
Demonstration of MAINLINE LCAT tools for metallic bridges, plain track and soil cuttings with guidance on how to use them

Dissemination, training and exploitation

D6.2 Setup of a dissemination platform for MAINLINE
Presentation of objectives and strategy for dissemination and communication around the project

D6.3 Dissemination and implementation of MAINLINE results
Overview of performed dissemination activities and plans for the future

Scientific and technical coordination

D8.1 First report on advisory committee recommendations
Summary of recommendations provided by the advisory committee at mid-term of the project

D8.2 First analysis and identification of potential guidelines from MAINLINE R&D
Reflection on deliverables that may be turned into guidelines

D8.3 Second report on advisory committee recommendations
Summary of recommendations provided by the advisory committee following the workshop targeted to Central and Eastern Europe that took place on 15 May 2014 in Budapest, Hungary

D8.4 Second analysis and identification of potential guidelines from MAINLINE R&D
Presentation of the three major deliverables of MAINLINE that will be published as guidelines

APPENDIX II MAINLINE RELATED PUBLICATIONS AND PRESENTATIONS

A list of the main events MAINLINE partners have attended or hosted is included in deliverable D6.3 - Dissemination and implementation of MAINLINE results. Major events are presented below.

Organisation of workshops

Midterm workshop at UIC in Paris, 14-15 May 2013

AIM: identify common fields of interest with the SMARTRAIL project, funded by FP7 under the same theme "Cost-effective improvement of rail transport infrastructure"

Workshop targeted to Central and Eastern Europe, Budapest, 15 May 2014

AIM: disseminate knowledge and results to Central and Eastern Europe

Presentations available on the public website: **http://www.mainline-project.eu**

Final workshop at UIC in Paris, 30 September 2014

AIM: present and distribute final project results: LCAT tools, guidelines and other reports

Presentations available on the public website: **http://www.mainline-project.eu**

Training on the use of the Life Cycle Assessment Tool (LCAT)

AIM: to present and distribute the LCAT tools developed in MAINLINE, together with a user manual

First session, 11-12 June, Jacobs/SKM, London: presentation of the tools features, gathering of feedback for further improvements, distribution of homework to be presented in the second session

Second session, 11-12 September, UIC, Paris: models run through, presentation of worked examples, distribution of the tools and testing by the attendees

Participation in events

MAINLINE partners have done presentations in many national and international events.

The most extensive presentation was a Mini Symposium in the framework of the IABMAS 2014 Conference, in Shanghai, 7-10 July 2014, which included 8 papers:

» Paper 1: MAINLINE – MAINtenance, renewaL and Improvement of rail transport iNfrastructure to reduce Economic and environmental impacts – J.S. Jensen (COWI) et al

» Paper 2: Extending the life of elderly infrastructure by strengthening – J. Nilimaa et al. (LTU)

» Paper 3: Influence of advanced assessment methods on the LCA of Elderly Bridges – M. Soriano and J.R Casas (UPC)

» Paper 4: Performance profiles of ageing steel railway bridges affected by atmospheric corrosion – A.N Kallias, M.K. Chryssanthopoulos (UoS)

» Paper 5:. Life-Cycle Assessment tool for railway infrastructure – D. Castlo (NR) et al.

» Paper 6: Lifetime analysis of infrastructures – P. Cruz (UoM) et al.

» Paper 7: Challenges within Life Cycle Cost (LCC) studies and Life Cycle Assessment (LCA) – P. Linneberg et al (COWI)

» Paper 8: Test to failure of a steel truss bridge – Calibration of assessment methods – A. Carolin, B. Paulsson (TRV) and Th. Blanksvärd et al (LTU)

Publications

MAINLINE has published several press releases through UIC, all available on the public website:
http://www.mainline-project.eu/What-s-new.html

Some partners have also published articles in national journals, notably in Sweden, Denmark and Hungary.

APPENDIX III LIST OF MAINLINE PARTNERS

UIC: International Union of Railways

NR: Network Rail Infrastructure Limited (UK)

COWI: COWI (DK)

SURREY: University of Surrey (UK)

TWI: TWI (UK)

UMINHO: University of Minho (PT)

LTU: Luleå tekniska universitet (SE)

DB AG: Deutsche Bahn AG (DE)

MAV: MÁV Magyar Államvasutak Zrt (HU)

UPC: Universitat Politècnica de Catalunya (ES)

TUGraz: Graz University of Technology (AT)

TCDD: TCDD (TR)

DAMILL AB: DAMILL AB (SE)

COMSA: COMSA EMTE (ES)

TRV: TRAFIKVERKET (SE)

CEREMA: CEREMA (FR)

ARTTIC: ARTTIC (FR)

SKANSKA: Skanska a.s (CZ)

Jacobs/SKM : Jacobs/SKM (UK)

The 19 partners of MAINLINE have been chosen to bring a mix of competences and experiences into the consortium as well as to ensure a suitable geographical coverage across Europe (11 countries are represented):

Infrastructure Managers:

- The International Union of Railways (UIC), France;
- Network Rail Infrastructure Limited, United Kingdom;
- Deutsche Bahn, Germany;
- MÁV Magyar Államvasutak, Hungary;
- TCDD, Turkey;
- TRAFIKVERKET, Sweden

Industry partners:

- COWI, Denmark;
- TWI, United Kingdom;
- COMSA, Spain;
- SKANSKA, Czech Republic;
- Jacobs/Sinclair Knight Merz (SKM), United Kingdom

Universities:

- University of Surrey, United Kingdom;
- University of Minho, Portugal;
- University of Luleå, Sweden;
- Polytechnic University of Catalonia, Spain;
- Graz University of Technology, Austria

SMEs:

- ARTTIC, France;
- DAMILL, Sweden

A governmental organisation:

- Cerema, France.

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