

**Developing Life Cycle Based Strategies for Track
Maintenance and Renewal**
Tools and Rules from the *Life Cycle Management Plus* Project

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Abstract

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Demands from the government, shareholders and transport operating companies (TOCs) can lead to a short-term focus, as all of them have a natural preference for short payback times on investments and a focus on quick performance improvements. Although this is a completely justifiable request, it is the professional task of the Infrastructure Manager to analyze long-term impacts of decision alternatives and to balance short-term pressures to increase availability and reduce expenditure with the impacts on the quality of the infrastructure on the long run. Strategic design and maintenance choices have a high degree of *irreversibility*: costs of modifying a design during the operational phase of a railway line are huge, while backlogs in maintenance can – after reaching certain quality levels – lead to progressive degradation and thus capital destruction. Under the current conditions maintenance and renewal (M&R) plans based on tacit, implicit knowledge of skilled line supervisors are no longer acceptable, as the necessity for those plans cannot be demonstrated explicitly and the plans cannot be optimized based on performance targets for the rail system as a whole.

A *systematic, transparent, and objective approach* to identify maintenance needs, plan maintenance and renewals, and schedule the works within the timetable is thus needed (5). This strategic management level, where agreed levels of *reliability, availability, safety and costs of ownership* are translated into actual M&R strategies and works, is to a great extent an uncultivated area, although many IMs state asset life-cycle management (LCM) to be a leading principle. The increasing attention for LCM is for instance demonstrated by the implementation of European Standard 50126 on Railway Applications (6). LCM is focused on maximization of the return on investment in the production assets owned by a company, considering the whole asset life cycle. In order to be able to realize LCM, maintenance data and analysis methods and tools are required. During the last couple of years progress is being made in the development of professional asset management tools (such as ERP systems) respect, but most tools are still in an early phase of development, and successful implementations are practically absent, at least in Europe. Most railways put a lot of effort in developing a comprehensive 'asset register', which is able to link infrastructure quality measurements, maintenance work history and traffic data (tonnage) to the specific asset. The Dutch IM, *Railinfrabeheer*, needed a couple of years to develop such an SAP system, and still many issues have to be resolved (7). Implementation of computer-assisted maintenance planning systems, such as ECOTRACK, an expert system developed by the International Union of Railways, is now being considered by a number of railways in Europe and abroad (8).

Due to the increasing pressures it is however essential to increase the quality and transparency of design and maintenance decisions already in absence of the above-mentioned planning tools. In this paper the concept and actual use of a decision support system (DSS) is discussed, which can assist decision makers quickly in identifying long-term costs of ownership and operation (life cycle costs). Advice on the implementation of LCM within a real-life situation where different actors interact with varying problem perceptions and interests, such as can be found in the railways, is absent in the literature. The concept of using a DSS can provide a new opportunity to be more responsive to their (rapidly) changing information needs. In section 2 the DSS structure is discussed. Section 3 provides an example of its use during a revision of the track renewal policy of the Dutch Infrastructure Manager. Section 4 contains a

‘Approved logic’ to balance costs and revenues on the short and long term can be found in the Life Cycle Costing (LCC) concept. LCC is defined as an economic assessment of an item, system, or facility and competing design alternatives considering all significant costs over the economic life, expressed in terms of equivalent currency units (9). It will however be shown that it can also function for maintenance or renewal strategies, although especially renewal strategies are in some way “end-of-the-pipeline solutions”: possible savings to be expected are smaller than during the design stage.

Life cycle costs are the result of a complicated set of (partly) uncertain conditions. An analysis of the sensitivity of the life-cycle costs to a wide range of operational conditions is required to enable decision-makers in selecting a decision alternative with the best guarantee to be cost-effective and robust. The concept of a decision support system (DSS) can eminently contribute in this respect. A DSS can be defined as a computer-based data processing system developed and used to improve the effectiveness and efficiency of decision makers in performing semi-structured tasks, partly having a ‘judgmental’ character (10). It usually consists of a database, a model-base, and a user-interface. Models from the model-base can be used in a flexible way in order to respond to management information requests. A DSS with the capability to estimate infrastructure life-cycle costs should be able to assist in several tasks:

- evaluating different physical designs or maintenance strategies quantitatively;
- analyzing the impacts of (restrictive) operational and financial conditions for infrastructure maintenance;
- supporting the development of maintenance plans that aim at optimizing the life cycle costs of the system;
- training engineers and managers in recognizing system-wide impacts of design and maintenance decisions.

Such a DSS proved not to be available off-the-shelf in 1997, although there were some developments in other railways as well. With these goals of application in mind, Delft University of Technology and partners from the European rail industry decided to develop such a DSS named *LifeCycleCostPlan (LCCP)*. As responsiveness of the DSS was considered of more importance than direct interactivity, ‘chauffeur system use’ was deemed satisfactory: a skilled ‘DSS chauffeur’ functions as an intermediary between the computer model and the decision maker. Only a few other railways in Europe and North America have developed such types of DSSs (5, 11, 12). Examples are the TRACS system of the North-American railways and the DSS of TU Graz and Austrian Federal Railways. Often contents of the tools have been developed for a very specific goal, and applications are still limited or have been considered as confidential and proprietary to the railway company.

The final outputs of LCCP are the estimated life cycle costs, reliability and availability, delivered by each of the analyzed design and maintenance alternatives during the predefined time period. Budget limits are not used as an input: the decision maker has to select those alternatives to be assessed, which are also feasible considering the required initial expenditure. In order to obtain this output, a number of calculation steps is required, according to figure 2. The calculation processes are shown as rectangulars. On the left and right side data input tables processes are shown. The dotted arrows indicate the use of data from a data table for the calculation, while the other arrows indicate the sequence in the calculation.

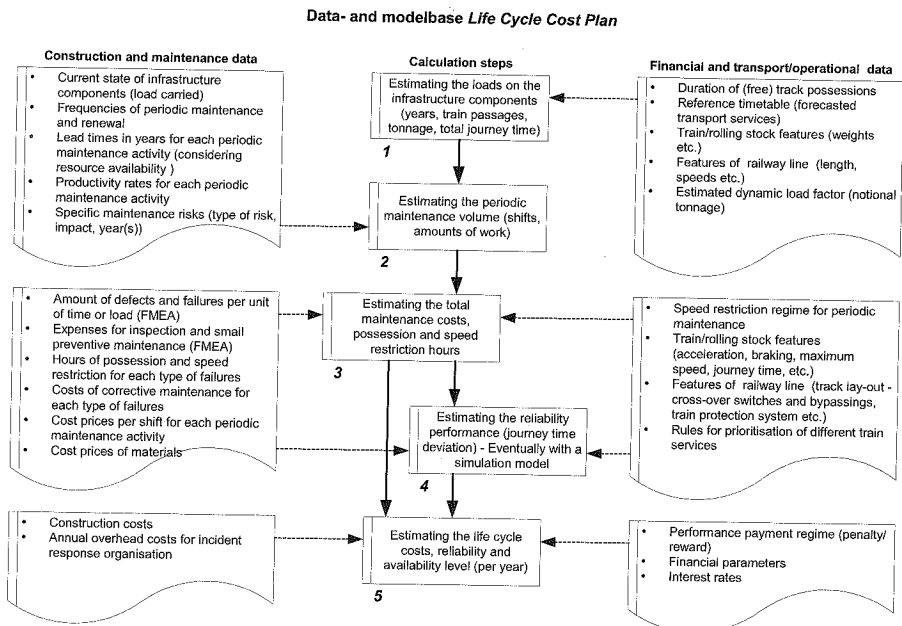


Figure 2: Structure of the *LifeCycleCostPlan* DSS

Below the calculation processes are described. Some graphical output screens are added to give an impression of the intermediate results; data in the figures are for illustration purposes only. For each calculation process a model is used that consists of a set of equations.

Calculation Process 1: Estimating the loads on the infrastructure

Quality degradation is a function of time (in years) and load on the track (in cumulative gross tons or number of train passages). A gross notional tonnage can be calculated according to UIC leaflet 7.14. The formula takes the impact of different speeds, axle-loads and wheel diameters into account. A lot of factors influence the degradation *rate* (loss of quality per unit of time or load), which is reflected in a tonnage- or calendar-based threshold for maintenance.

growth or decline and contains the expected number of trains and train-sets for the different services (specified to e.g. axle-loads and train weights) as well as the number of operational hours per day (per direction). Beside the tonnage, this timetable can also be used for calculating the (annual) scheduled journey time. This is the sum of the journey times for all trains on the particular track section. Some 'Performance Regimes' use this for the calculation of the reliability level. The Reference Timetable also reveals the available time for possessions that do not disrupt the transport operations.

Calculation Process 2: Estimating the periodic maintenance volume

Major M&R works have intervals of more than a year: based on the forecasted load on the infrastructure and expert judgments on the residual life spans (tonnage that can be carried), the amount of periodic M&R is estimated. Expert judgments are unavoidable as many factors determining track behavior, such as subsoil quality, maintenance history, and initial construction quality, are usually not known. These residual life spans (or: M&R thresholds) have to be specified for each major infrastructure component. The input can differ for different parts of the analyzed infrastructure segment, due to the presence of different materials, years of installation and traffic loads. These thresholds can be defined directly in a tonnage limit (cumulative tons) or indirectly via an infrastructure quality indicator. The decline of the quality indicator, again, has a relation with the cumulative time or load. Thus the residual life spans, and the intervals for major overhaul or renewal, are derived for each component (for the distinguished homogenous parts of the analyzed infrastructure segment). Thresholds for major M&R can be interdependent: renewals can be harmonized in time and place (clustering of renewals on adjacent track sections) and components (clustering renewal of different infrastructure components). Based on the estimated M&R intervals, the required number of work shifts can be calculated for each of the activities. Once M&R is initiated for a particular component and infrastructure segment, it can be realized in a single year or in a couple of years. The user can define the number of years, in which a type of M&R activity has to be finished. Finally, the required amount of work shifts in a single year is calculated. Input data are the productivity rates for each activity, specified in a net productivity rate (or production speed) and duration of set-up and finishing tasks, and the available duration of track possessions. In figure 3 the graphical output of the second calculation step is shown.

Calculation Process 3: Estimating maintenance costs and possession hours

Based on the number of work shifts per year, the costs per kilometer (materials) and the costs per work shift (labor and machines), the total costs for periodic maintenance can be calculated. A number of days with speed restrictions (possibly with different, gradually increasing speed limits) can be set as well. The total hours of possession and speed restriction can thus be calculated directly from the number of work shifts, in which the clustering of activities has already been taken care of (see calculation process 2). Moreover, in this step the impacts of small maintenance and failures are added: amounts of small maintenance and failure time are partly related to the cumulative tonnage or years in service of the infrastructure components and partly independent from loads (e.g. inspection intervals).

The user can set the costs, possession and speed restriction hours involved in the inspection, small maintenance and failure repair *per ton carried* or *per year*. Small maintenance and failure repair consists of a variety of tasks and failure types, which is why summarized estimates are used. The impact on the life cycle costs is small, compared to the investments in new construction and periodic M&R. The Failure Mode Effects Analysis (FMEA) technique can be used to produce estimates on the amount of small maintenance and failures (13). Figure 4 gives an impression of the intermediate output after step 3.

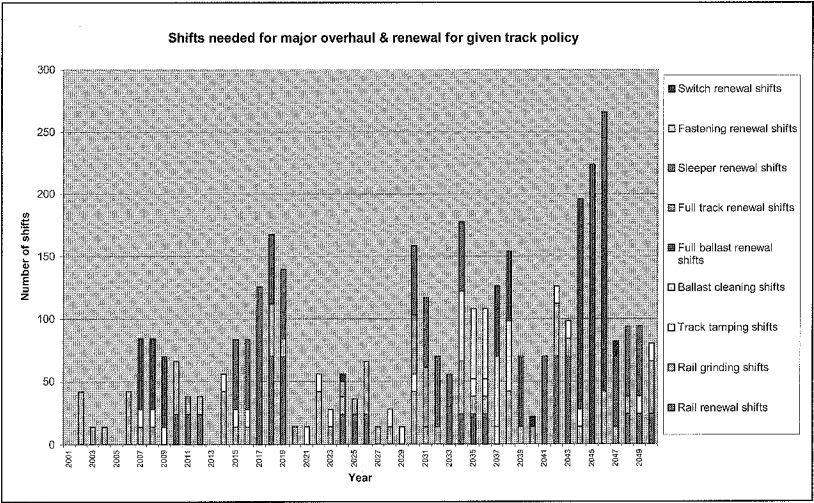


Figure 3: Planned work shifts, intermediate result after step 2

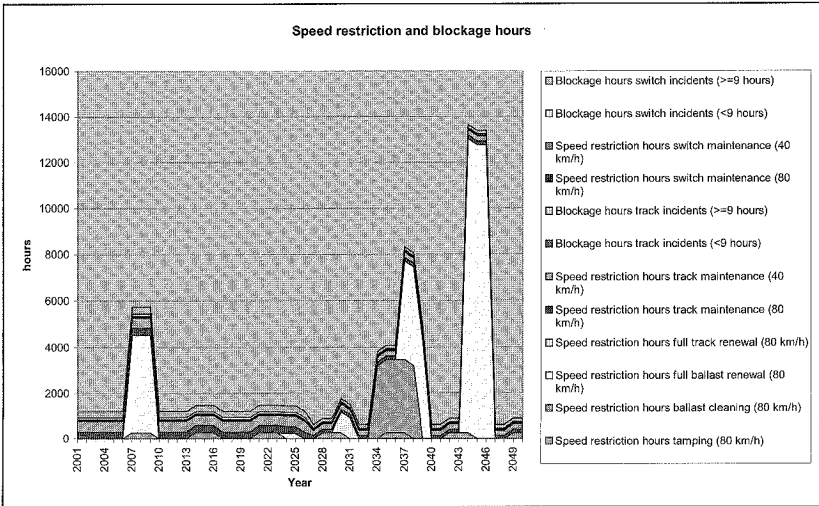


Figure 4: Expected traffic disruption, intermediate result after step 3

planned and unplanned track possessions and speed restrictions, for each of the analyzed decision alternatives. A valuation of the impaired availability and reliability is however an inevitable next step: a possession or speed restriction on a regional, low-density line will have less severe consequences in terms of higher operating costs and lost revenue than on an international high-speed line. Insight into the impacts of the infrastructure performance on operating costs and revenues is essential for the assessment of the life cycle costs.

LCCP can take care of the valuation of possessions and speed restrictions. With the use of the Reference Timetable the average amount of affected trains can be estimated. This disruption leads to a rise in operating costs and a loss in revenues; average figures on the impact of a train delay minute and a train cancellation have to be available. The total amount of train delay minutes is also influenced by the availability of passing tracks or rerouting options, and the braking and acceleration performance of the trains. The costs of the delay are related to the transport value, and thus the traffic types.

A model has been included, which estimates the cumulative train delay minutes and cancellations, based on the acceleration and braking performance of the trains and a number of assumptions. The main assumptions are that a speed restriction does not result in train cancellations and knock-on impacts on later scheduled trains and that an unplanned track blockage leads to a cancellation of the trains scheduled during those hours. Validity of the assumptions under the specific conditions should be verified. A more advanced analysis of the ‘knock-on impacts’ of delayed trains on later scheduled trains can be done with for instance Simple++, a dedicated simulation model such as RailSys (14), or by using MaxPlus algebra (15). For instance the location of crossover switches and the number of train services can influence the cumulative delay minutes. In conclusion, the result of this step is that speed restrictions and possession hours are converted into figures, which can function as input for the applicable Performance Regime, such as train delay minutes. In (16) an example can be found where LCCP is used in combination with a dynamic queuing model.

Calculation Process 5: Estimating the infrastructure life cycle costs

Based on the earlier calculation steps, the total running infrastructure costs during the analyzed period can be calculated, needed for maintenance, renewal and performance penalties. Based on the Performance Regime the estimated performance of the infrastructure is converted into actual penalties, and eventually rewards, which reflect the impacts on the transport operating process. In case that the decision concerns the construction or upgrading of infrastructure, initial investments have to be included as well. Design alternatives vary in their designed quality and maintainability (e.g. M&R thresholds). Together with the maintenance strategy the initial quality determines future maintenance needs. On the other hand this quality is also reflected in a “price tag”. Construction costs can be put into LCCP as a lump-sum cash flow during the first couple of years or in a more detailed specification, if this assists in the comparison of decision alternatives. Once the cash flows for initial investments and running costs are available, the financing costs can be calculated based on the (real) interest rate. First, all future costs are discounted to their *present value*, which is their value in the Base Year that the choice for one of the decision alternatives is being made.

Next, based on the total present value of the life cycle costs, the annuity is calculated for each of the alternatives. This is the so-called *annual (flat) performance fee*, which has to be paid every year to cover interest, depreciation, and running costs. Also the possibility is included to label particular, unlikely, maintenance activities as ‘specific risks’, which are depicted separately as risk margins on top of the annuity bar.

The main feature of LCCP, in contrast to for instance *ECOTRACK*, is that it does in principle not contain, and not need, track quality degradation models. LCCP is therefore not designed as an expert system with predicting capabilities, but as a “sophisticated calculator” for the key relations between transport loads, maintenance thresholds and life cycle costs. Such models, in which a high level of uncertainty is involved, can however be integrated into LCCP, or used separately to deliver some of the input data. This has been a principal design choice, which transfers the responsibility for estimating maintenance frequencies almost entirely to the engineering and maintenance staff. The strength of LCCP is that the assumptions of the maintenance staff, which usually remain unspoken, become available for a detailed validation and analysis. The crux in the analysis becomes thus the facilitation of an adequate data collection and validation process. A Data Collection Checklist, which describes required input data and data formats, is used for the collection of input data. Many data sources can be used, such as empirical data (e.g. laboratory tests, computer simulation, supplier information, maintenance history and cost rates) and ‘expert judgments’. Aggregated figures on failures, track degradation and work history are in many European railways hardly available or reliable (8).

Reliability of the data is taken care of in two ways. First, Chauffeured Sessions are organized, where the experts meet each other directly. In the Chauffeured Sessions a process of data validation takes place. Depending on the progress, the input data itself is discussed or the DSS is used for ‘real-time’ analysis and validation of the assumptions (‘face validity of outcomes’). Participation of experts from, at least, different organizational units is a prerequisite for the quality of the process. Each of the participants has to elaborate feasible alternatives and make his judgments on the input parameters prior to the session and has to show references to underpin his judgments. This creates a kind of “creative competition” between the experts to show their skills and expertise. During the sessions these assumptions are discussed and the participants get the opportunity to adjust their judgment or to come up with new information. In most cases one judgment results after discussion; however a range of input data can be tested as well. Secondly, the robustness of the outcomes can be assessed with the DSS itself using sensitivity and scenario analysis. Automatically the deviations in the output for the defined scenarios are calculated; the ranking of the alternatives is summarized in a single table, which provide the decision makers an insight into the robustness of alternatives and the sensitivity to specific conditions. In the studies performed with LCCP also a detailed check of the model parameters by technical railway staff has been organized besides the face validation of the output. Moreover, in the case study described in this paper the LCM Calculation Model of *Railinfraabeheer*, the Dutch IM, has been used to check the outcomes step by step.

A process of involving engineering and maintenance staff is expected not only to contribute to a more reliable, valid analysis, but also to a greater commitment within the maintenance department to the outcomes. This was one of the reasons not to

Total Maintenance and Renewal expenditures on the Dutch rail network have been both about 200 million Euros in the year 2002. The Tracks Subsystem consumes about 60% of maintenance and 80% of renewal expenses. Not only are the expenditures very high, they also vary in time due to the age distribution on the network and the realization of projects in previous years. A timely insight into the costs and track possessions is crucial in order to level out the renewal volume over the years. Insight into the life cycle costs of different renewal strategies is in this respect a method to realize an optimal prioritization between proposed renewal projects on the railway network (15). In 1999 a prognosis showed a strong increase in the renewal volume required between 2000 and 2010. This was an important trigger for the Dutch IM, *Railinfrabeheer*, to start the LCM+ project.

Objective of LCM+ was to develop policy rules for tracks and switches that lead to an important reduction and leveling out of the renewal volume without reducing the quality of the network. A prerequisite for new policy rules to be accredited was that the cost-effectiveness had to be demonstrated explicitly for a wide range of (future) conditions, which is why it was decided to support the process with the *LifeCycleCostPlan* DSS. Besides staff from Headquarters, four sub-teams of technical track specialists and planning analysts from each of the four Maintenance Regions were participating to develop and assess cost-reducing strategies. In the first project phase a top-30 of promising measures was composed. In the second project phase the regional teams assisted in the life cycle cost analysis by performing a number of pilots. In total ten pilots were selected in order to represent the diversity of track and switch types as well as the different operational features (main track, side-track and yards). Most pilots were preliminary scheduled for renewal in 2002; the regional teams were requested to develop feasible maintenance and renewal strategies. A special management module was developed for LCCP, where overall data on operating conditions could be stored (e.g. interest rates, M&R production speeds and unit costs) and which could steer the estimation processes of the individual pilots.

LifeCycleCostPlan was first used during a number of Chauffeured Sessions in order to show the outcomes from the regional pilots and to perform validity tests. The central staff, the (other) Regions as well as external experts, reviewed critically the solutions and assumptions of each regional pilot. In the third phase central staff assisted in an extensive sensitivity and scenario analysis, performed for each pilot. This also contributed to deriving policy rules, applicable to a wide range of situations on the network. The phase was finished with a Policy Session, in which the results of the analyses were discussed with the experts, and the agreement on sixteen rules being acceptable to all Maintenance Regions. In the fourth phase the financial impact of the new rules was quantified in an adapted Renewals Prognosis for the years 2003-2020. The drafted process will be illustrated for one of the pilots, the *Baarn-Amersfoort Pilot*, in detail.

The tracks between the cities of Baarn and Amersfoort are part of the main rail network, and are quite intensively used (UIC class 3¹), with especially a lot of passenger traffic). On these tracks so-called 'Nefit-track' has been used, which has been used on a large scale in the 1970s when the Dutch network needed a rapid upgrading to accommodate higher axle-loads (22.5 tons). Its advantage was a rather inexpensive and quick installation. However, the disadvantage showed to be that the quality deterioration of the fasteners is hard to monitor, and considering the current state of the tracks the risk of gauge widening due to broken fastening clips has become a realistic risk. *Railinfrabeheer* and the Ministry of Transport have decided to renew a huge amount of about 890 kilometers of 'Nefit-track' during the years 2000-2007. According to the standard policy the tracks are completely renewed with a renewal train, and possibly some materials can be sold as scrap to railway contractors. Since the railway restructuring the stock depot of Dutch Railways, where used materials were stored and renovated, has been closed. In this pilot however a proactive approach was chosen: at the nearby yard of Amersfoort a sleeper renewal for more than 6 kilometers of track was planned. A quality check confirmed that both sleepers and rails from the main track could be re-used, although there were problems to be overcome. Enough Nefit-sleepers in good shape could be obtained, but they were designed for the UIC54 rail profile, whereas at the yard UIC45 rails are in use.

A number of options for re-use in the yard renewal were envisioned, further referred to as Z-variants:

1. the Nefit-sleepers could be renovated with new fastening plates for UIC45;
2. the UIC45 rails could be attached to the Nefit-sleepers with the use of so-called 'chocolates' (cast iron strips to fill the gaps);
3. both UIC54 rails and Nefit-sleepers could be re-used.

The "chocolates solution" was in first instance being debated, but a field test on an operational line showed the safety and durability of the solution for branch lines with some small corrective maintenance once per year. The applicability of the Z-variants is also depending on the chosen renewal variant on the main track (H-variant). The outcomes for the pilot under normal operating conditions are shown in figure 5. In these outcomes also the costs of track possessions for main line and yard have been included.

A remarkable and promising result of this pilot proved to be that the ranking of the different alternatives (combinations of H- and Z-variants) proved to be rather stable to changing operating conditions and changes in the assumptions. Figure 7 shows some of the tests, where also different working methods were elaborated, such as renewal during a full single-track possession in a weekend or working week (100 hours).

A partial renewal of the main track in combination with the "chocolates solution" is expected to lead to a life cycle cost reduction of at least 13%, and an immediate reduction of the required investment. A joint tender of the works on main track and yard has started in 2002; execution of the works takes place in 2003. Considering the large renewal quantities, many sleepers in good shape will be available for a great number of yards and branch lines. Although instant re-use of components requires more project planning and co-ordination, all Regions agreed that the inexpensive renewal of branch lines was worth the efforts.

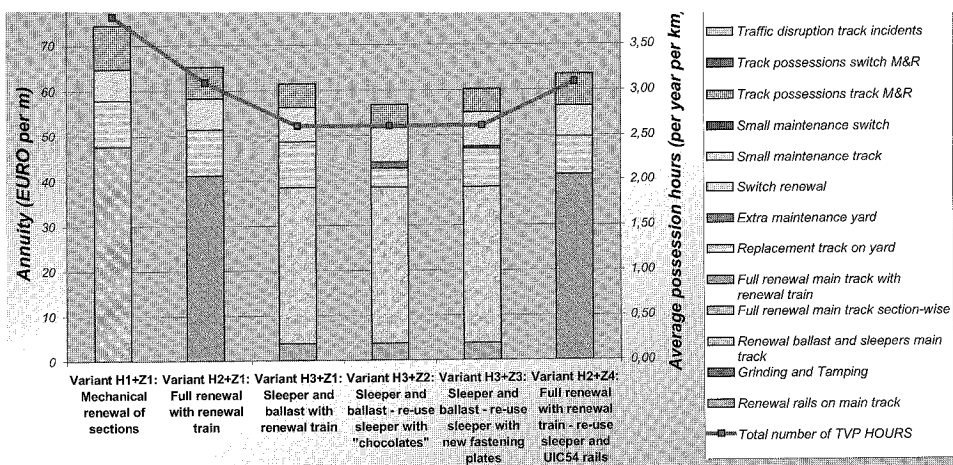


Figure 5: Indicative outcomes for Baarn-Amersfoort pilot including yard

A number of planning rules on *partial renewal* and *instant-re use of Nefit-sleepers* were distilled, also confirmed by the outcomes of other pilots. Instead of applying the usual renewal policy (solution H2+Z1) these 'smart rules', which take the local required functionality into close consideration, prove to be able to reduce both short-term investment and total life cycle costs. In box 1, included at the end of section 4, a number of new, LCM+ based, rules are shown in order to give an impression of the advice delivered to RIB.

4 Discussion and conclusions

Based on the extensive analysis of life cycle costs of different track and switch types on the Dutch network, the LCM+ project was able to deliver renewal planning rules, which were acceptable to both the Maintenance Regions and the central management. The set of rules provides a certain amount of flexibility for the Maintenance Regions to plan renewal projects according to their own priorities and to consider (unusual) local operating conditions such as noise and safety regulations. However, convincing motives have to be delivered in order to make a different decision than the rules would suggest. A commitment made by the participants is to review the policy rules regularly, since operating conditions can change and expectations from the LCM+ project need to be monitored. In this respect Maintenance Regions can come up with new life cycle cost analyses, which lead to modification of existing rules or new rules.

LCM+ was finished in 2001; the new prognosis for the years 2003-2020 showed an annual reduction of the renewal budget by 10% or about 20 million Euros, based on cautious assumptions on the applicability of the rules and including costs of extra (large-scale) maintenance. Implementation of the rules, which have been accredited by the Central Management, is in progress: LCM+ has its consequences for the organization of the maintenance and renewal work planning. The realization of for instance rules, related to re-using components, life-lengthening maintenance, and clustering renewals on adjacent track sections require a more smart planning of renewal projects in the coming years and a timely coordination between different departments of RIB. In order to facilitate a timely co-ordination and discussion periodic "Optimization Meetings", in which the technical and economic experts of the Regions take part, have become part of the planning process since 2002.

LCM+ was the first project in which the joint Maintenance Regions presented 'smart' policy rules, which were able to save direct renewal costs as well as total life cycle costs. It has shown that life cycle cost analysis (LCCA) is not in conflict with current budgeting practice as is often thought. It is an additional tool to select justifiable investments and to make the right prioritization in planning M&R. Of course, it can also be the case that LCCA shows that more budget (than available) can reduce the life cycle costs even further, but this remains a decision for the infrastructure owner. The only thing an analyst can do in this case is to make the trade-off between *short-* and *long-term* costs and performance transparent: LCCA can still show the decision alternative with the least "damaging impact" on the life cycle costs.

A clear direction for further optimization can be distilled from the planning rules as well. Instead of using a standard renewal solution, the "LCM+ philosophy" is focused on the functionality to be delivered on a particular line. In order to realize this functionality more cost-effectively, a set of solutions can be applied. The set consists of methods of *controlled* life-lengthening maintenance, instant re-use of components, and up-scaled work methods (clustered renewals, renewal trains, and weekend possessions). Possibly cost-savings and performance improvements can be further enhanced within coherent and optimized renewal strategies.

provide a framework for systematic, sound discussion and the development of transparent M&R planning rules. Further development of the DSS could focus on methods to manage and improve the process of participation. 'Probability analysis' techniques (e.g. Monte Carlo simulation), benchmarking with other railways and the consultation of external experts could improve the quality of analyses further.

Acknowledgement

Herewith I express my gratitude to the management and technical experts of the Maintenance and Renewal Department of NS Railinfrabeheer B.V. for providing the opportunity to present the research work. More information on the project and the Sponsors can be obtained from <http://go.to/LCC-project>.

Box 0.1: A number of LCM+ rules (straight track)

UIC54-track

- A postponement of the rail renewal should be considered if the rails have a residual life of more than 10 years. The additional costs and possession time of a separate renewal of rails prove to be relatively small. In principle, the ballast is cleaned/renewed simultaneously with the sleeper renewal.
- Before 2007 the so-called 'Nefit-track' (UIC54 on Wooden Sleeper with Nefit-fastening) has to be replaced due to the problems with geometry control, except for some regional lines. It proves to be feasible to lengthen the lifespan of the Nefit-track with five years by applying a large-scale replacement of the fastenings. This can be used as an instrument to prioritize the planned renewals of Nefit-track.

NP46-track

- All NP46-tracks have to be replaced by the UIC54-track with concrete sleepers if a renewal of sleepers has become unavoidable: this will result in the lowest life cycle costs. Ballast is renewed simultaneously.
- The lifespan of worn-out NP46-tracks (hard-wooden sleeper) is to be extended by five years: the fastenings can be improved temporarily by applying so-called 'coils'. This is attractive from a life cycle cost perspective and also for leveling out the annual renewal budgets. Soft-wooden sleepers are to be removed completely and the rails have to be made continuously welded (CWR).

UIC Class 6-track

- In case of a worn-out track on a regional line (and side-track) the Maintenance Region elaborates two M&R scenarios: (1) renewal and (2) 'controlled life-lengthening' with five years, at least.
- In case of renewal (1) an optimized track design is used: UIC54 with concrete sleepers, but with a longer sleeper distance and less ballast (20 cm).
- Re-usable sleepers and rails from upgrading projects on main tracks are used for the Class 6 lines as much as possible. Main-track renewals have to be coordinated with renewals on Class 6 lines in order to instantly re-use the materials.

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