Developing a Cost-Effective Renewal Strategy for Railway Track on Conventional Networks

A practical example of a policy revision at Netherlands Railways

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Summary
Due to increasing budget pressures, operational restrictions and the restructuring of the European railways, the ‘life cycle costing’ (LCC) concept gets more and more attention: the Infrastructure Manager (IM) can use LCC to systematically underpin and optimise budget needs and track possession time. Since tracks and switches consume the larger part of the maintenance and renewal budget, optimised strategies for track maintenance could contribute importantly to savings in the overall budget. However, examples of a successful revision of the maintenance and renewal strategy are scarce. This paper presents a revision of the track renewal strategy undertaken by Netherlands Railways in 2000 and 2001. The new maintenance strategy leads to at least a 10% reduction of the forecasted budget needs in the coming 25 years. The implementation of the strategy in the M&R planning cycle as well as further research on some issues is scheduled for the next year.

Keywords: Asset maintenance management, life cycle costs, railway track, renewal planning, decision support system

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1. The challenges of maintaining rail infrastructure

In the last decade the maintenance of railway infrastructure in Europe has become a different profession than what it was in the more than one hundred years before, due to a rapidly changing environment. In the first place EU directive 91/440 requires that a separate entity has to provide the railway infrastructure in order to stimulate profit-driven (trans-European) transport operations and transparent cost accounting of infrastructure and operations [1]. In most EU Member States as well as other European countries the restructuring of the railway is in progress, the split-up and privatisation of British Rail being the most radical example [2]. In the second place the operational conditions on many railway lines are increasingly tight in order to facilitate more diverse transport services (e.g. light rail and high-speed trains), more trains per hour, longer operating hours and an improved punctuality. These conditions conflict with the efficient scheduling and execution of maintenance works and can lead in the long run to an increase in maintenance and renewal as well. In the third place government regulations imply more and more restrictions, related to railway safety, labour safety and noise levels, while government grants for maintenance are not easily acquired anymore [see e.g. 3].

Besides the increasing performance requirements set by government and operators, the Infrastructure Manager (IM) is often confronted with worn-out assets, backlogs in maintenance and track possession claims for construction and upgrading (e.g. track quadrupling and improved utilisation technology such as 25 kV and ERTMS). In order to deal with the short-term cost and performance demands and to guarantee the RAMS (Reliability, Availability, Safety and Maintainability) systematic, transparent ‘asset maintenance management’ will be needed [4].

The following steps for developing maintenance management can be distinguished:

- **asset registration**: the first step in maintenance management is to establish a complete asset register that is able to link data of inspections, maintenance history and operations (e.g. tonnage) with the asset location and the specific asset;
- **maintenance concepts**: as for planning and forecasting, the (average) maintenance and inspection needs per type of asset should be available (e.g. Mean Times To Restore Services and Mean Time Between Failures). The introduction of new designs of components and maintenance technologies, such as Condition Monitoring and advanced renewal trains, can influence these parameters. Maintenance concepts are developed through Failure Mode Effects Analysis (FMEA) [5];
- **life cycle cost optimisation**: to realise an optimal trade-off between maintenance and renewal (M&R), life cycle cost analysis (LCCA) should be applied. As for LCCA, the information from maintenance concepts and additional expert judgements and inspection data can be used. LCCA can be applied at the level of individual projects or to develop a total maintenance and renewal strategy (also reflected in the maintenance concepts). A decision support system should facilitate the estimation of the life cycle costs under different operational conditions in order to test the robustness of the M&R solution chosen [6];
- **optimisation of work planning and scheduling**: in a following step it is possible to prioritise and cluster M&R works in the medium or long term and to optimally co-ordinate the planned works with the availability of resources, such as track possessions, labour and machines. An expert system like ECOTRACK assists the planning of major (track) overhaul and renewal [7], while small maintenance tasks can be clustered in regular, e.g. monthly, cycles;
- **performance based maintenance contracts**: finally the IM could choose to outsource the well-defined ongoing maintenance tasks and to develop maintenance contracts which are based on performance indicators (e.g. track quality and incident response times) [8].
Most European Infrastructure Managers make efforts to develop and implement the information systems, decision support tools and work procedures required for professional maintenance management, as described above. However, especially the steps related to life cycle cost optimization and computer-assisted work planning (ECOTRACK) are in an early phase. In some railways, such as Austrian Federal Railways and Netherlands Railways, decision support systems for calculating life cycle costs have been developed and applied for track maintenance decisions [9, 10]. Serious feasibility studies for ECOTRACK are currently in progress at for instance Railtrack and Netherlands Railways. In this paper the recent progress in relation to life cycle cost optimisation at the Dutch infrastructure manager, Railinfrabeheer (abbreviation: RIB), will be presented.

Life cycle cost analysis (LCCA) is performed at two levels at RIB, i.e.:

1) **Project-level**: proposals for large investments, such as new construction or renewals, have to include an LCCA, in which the different feasible design or M&R solutions, e.g. postponement of renewal, are investigated. The maintenance staff of RIB has been trained to use a simple computer model, which uses expert judgements to calculate the life cycle costs including costs of non-availability (11). The solution with the lowest life cycle costs is to be selected, unless the outcomes are not significantly different from each other and other aspects are to be considered. At the moment a database is being constructed to make the expert judgements from the individual projects available for all RIB-staff in order to improve transparency and consistency of estimates.

2) **Policy-level**: LCCA can also be performed on the ‘policy-level’ in order to revise generic maintenance and renewal rules. The first example of this kind of exercise is the Life Cycle Management Plus (LCM+) project, which focused on railway track and switch renewals. A more sophisticated approach and decision support tools are required. Note: it is possible that project-based choices lead to generic rules as well if they are considered widely applicable, but this will not cover a whole maintenance strategy.

In this paper a revision of a maintenance and renewal strategy (level 2 analysis) is presented, which was one of the major achievements of the Asset Management Programme of RIB in 2000 and 2001. The focus of this LCM+ project was directed towards renewal of track components (rails, fasteners, sleepers and ballast) and switches under all possible operational conditions (categorised according to the UIC classification, UIC leaflet 7.14). The reason to focus on track is that it consumes the larger part of the renewal budget and planned track possessions, and that a strong increase of the track renewal needs is foreseen in the years to come. A prioritisation in the track renewal projects is unavoidable, but should lead to optimal life cycle costs given the budget constraints.

In the next section the objectives of LCM+, the organisation and work process are drafted. In section 3 some of the outcomes of the performed analyses are shown. Section 4 contains the generic rules, which are deducted from the analyses. Finally, section 5 includes some remarks on the consequences for the renewal planning cycle as well as the overall conclusions.

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Railinfrabeheer (RIB) is the managing body responsible for construction and maintenance of the railway assets of the Dutch conventional network. This year (2001) it will be transferred from the Netherlands Railways Holding to the Ministry of Transport. The LCM+ project considered is a key element of the so-called Asset Management Programme, which contains all projects needed to develop professional maintenance management at RIB.
2. The LCM+ objectives, organisation and work process

Tracks and switches account for about 60% of the total maintenance and 80% of the renewal expenses on the Dutch rail network and, besides, track works need a lot of planned possessions (12). Not only are the expenses very high, but they can also vary largely each year due to the age distribution on the network and the realisation of maintenance and renewals in previous years. A timely insight into the costs and track possessions is crucial in order to:

- **level out the renewal volume**: insight into the life cycle costs of different M&R strategies makes it possible to develop an optimal prioritisation between the different renewal projects planned (e.g. using life-lengthening maintenance techniques). This can help to achieve a flat annual renewal volume with the lowest life cycle costs;
- **anticipate on developments related to upgrading**: upgrading projects can include, for instance, the replacement of older rail types, which may be very well usable in side-tracks or yards. The expected life cycle costs should determine whether instant re-use of materials is profitable;
- **acquire track possessions**: a timely insight into the renewal volume is necessary for negotiations on track possessions and for an optimal planning of possessions on the main transport corridors;
- **plan work capacity**: a timely insight into the M&R works is necessary for acquiring machines and labour with the lowest production costs, especially if works have to be tendered.

In 1999 a prognosis of the renewals for the period 2000-2020 was developed based on so-called ‘theoretical lifespans’ of the track and switch types on the Dutch network (13). For instance, for UIC54 continuously welded rails on a UIC class 3 railway line a theoretical lifespan of 45 years is applied. In practice, rail renewal is based on the actual quality deterioration and the tonnage carried. The theoretical lifespans are based on the past performance and updated according to the latest expert judgements.

The Renewals Prognosis 2000-2020 showed a strong increase in the renewal volume needed, especially in the years 2000-2010. Besides, in 2000 Railinfrabeheer and the Ministry of Transport decided to renew about 890 kilometres of so-called ‘Nefit-track’ during the years 2000-2007 due to the fact that the quality deterioration of the fasteners is hard to control, which can endanger the railway safety (gauge widening). This causes much more renewal than was forecasted in the prognosis made in 1999. Halfway the year 2000 this was an important trigger as well for the Maintenance and Renewal Department of Railinfrabeheer to start the Life Cycle Management Plus project.

The objectives of LCM+ were (14):

- **The development of 'policy rules' for decisions related to track and switch renewal on main tracks, side-tracks and yards, the cost-effectiveness of which can be demonstrated explicitly in terms of reduced Life Cycle Costs and number of track possessions.**
- **The policy rules should, in the short run, lead to an important reduction on the renewal volume required in the years 2002-2010 and they should be able to level out the peaks in the renewal volume in these years.**

Besides the staff from the Headquarters, a track specialist and a planning analyst of every Maintenance Region were participating to appraise feasible cost-saving measures and the analysis of life cycle costs. With this project team of about 20 persons the reliability of maintenance estimates was guaranteed. In the first project phase a top-30 of promising cost-saving measures was developed, including ‘lighter’ track designs for UIC class 6 lines, life-lengthening maintenance, and instant re-use of main-track components and switches on UIC class 6 lines.
Criteria for selecting the cost-saving measures were not only the cost-effectiveness (life cycle costs), but also the feasibility (short-term implementation with short-term impacts) and ‘market conformity’ (the measure should be acceptable for transport operators and the Ministry of Transport).

In the second project phase the regional teams (one track specialist and one planning analyst) had to perform the life cycle cost analysis with the help of a Data Checklist for a number of ‘pilot projects’. In total nine pilot projects were developed in order to represent the diversity of track structures and switch types on the network as well as the different operational features (main track, side-track and yards). Most projects were (preliminary) scheduled for a major renewal in 2002. The regional teams had to develop feasible maintenance and renewal solutions based on the top-30 of promising measures. The data was collected in a computer model named Life Cycle Cost Plan 2000. Subsequently the judgements and the results were discussed in a number of sessions with all the track experts, in order to improve the consistency of the estimates.

In the third phase an extensive sensitivity analysis was performed for each pilot with Life Cycle Cost Plan 2000, in order to test the robustness of the M&R solutions under different operational conditions (e.g. an increased or decreased tonnage, renewal cost rate, and interest rate). In this way it should be possible to deduct a generic policy rule for the track or switch type analysed from a pilot result. This phase was finished with a session, in which the results of the analyses were discussed with the experts. This finally resulted in sixteen rules being acceptable to all Maintenance Regions. In the fourth phase the impact of the new rules was quantified in an adapted Renewals Prognosis 2003-2020.

3. Two examples of the LCM+ regional pilots

One pilot focused on a track section with a length of about 5 kilometres in the southern part of the Netherlands, between the cities of Sittard and Heerlen. This UIC class 6 railway line is only used for passenger traffic with an annual tonnage of 1.3 million tons carried. During the night the tracks are available for maintenance. The rail type used is NP46, an old Dutch standard which can still be found on 45% (2500 km) of the rail network, especially on the class 5 and 6 lines (27% of the population is continuously welded, 18% is jointed rail). The NP46 rails are laid on soft- or hard-wooden sleepers. With respect to the section analysed 3250 metres is CWR with hard-wooden sleepers laid in 1970, 700 metres is CWR with soft-wooden sleepers, and 1000 metres is jointed rail on hard-wooden sleepers. The total section is worn-out and was scheduled for a renewal in 2002.

The feasible M&R solutions identified were:
- SOLUTIONS 1 and 2: Keep the NP46 rail type in tact by placing new hard-wooden sleepers and a new ballast bed; the whole track is made continuously welded. Solution 2 uses re-usable wooden sleepers with a shorter lifespan but with reduced acquisition costs.
- SOLUTION 3: Full track renewal and upgrade to UIC54 rails with concrete sleepers.
- SOLUTIONS 4, 5 and 6: Application of life-lengthening maintenance on the hard-wooden sleepers (improvement of all fasteners with coils) and a replacement of the soft-wooden sleepers. After five years solution 1, 2 or 3 is applied.

The life cycle cost analysis showed solution 6, that is the life-lengthening maintenance for the first five years and the full track renewal with UIC54 rails and concrete sleepers, to be the best solution. As figure 1 shows this leads to a saving of more than 5% with a real interest rate of 3%. Although relatively a lot of track possession hours is needed, this is not a major obstacle: there are no trains running during night. With sensitivity analysis the robustness of this outcome can be shown for other (worn-out) NP46 tracks on class 5 and 6 railway lines.
An important impact of life-lengthening maintenance is that the budget can be saved to realise more urgent renewal works. It is therefore an instrument to level out the renewal volume over the years in a controlled way, without endangering safety and reliability levels.

Another example is a pilot focused on the renewal of a switch on a railway yard near Amsterdam. About 50% of the switches can be found in side-tracks and railway yards and these side-track switches have a considerable contribution with respect to the total renewal volume. The situation on side-tracks can vary from very low used to quite intensely used, which is the case on the Amsterdam shunting yard. Switch nr. 1107A should be replaced within a few years (in 2003 at the latest). In 2000 a main-track switch nr. 237 became available from an upgrading project near Amsterdam Central Station. The switch had a residual life of 20 years for use on the yard, but would be transferred to a contractor for a minimal price (the railway restructuring has led to the closure of the stock depot for re-usable track components). Co-ordination with the upgrading project staff made it possible to instantly replace switch 1107A with switch 237. In the pilot the life cycle costs of the following M&R solutions were analysed:

- SOLUTION 2 and 3: A switch with a lifespan of 20 years would be placed in 2000 (transported during night from the main-track location), and in 2020 a new switch would be placed. In solution 2 it is assumed to continue the principle of re-using similar main-track switches.
- SOLUTION 4 and 5: Renewal of components in 2003 and 2011. In 2015 a new switch has to be placed after all. In solution 5 the ballast is already renewed in 2003 instead of in 2011, which results in a small reduction of ongoing maintenance.
Solution 2 proves to lead to a reduction of 16% in life cycle costs (figure 2), but also solution 3 is very attractive and deserves still the extra planning effort needed; in this case the number of track possessions is not a critical resource.

**Figure 2: Maintenance and renewal solutions for NP46 tracks (INDICATIVE)**

### 4. The LCM+ rules for maintenance and renewal

Based on the extensive analysis of life cycle costs of different switch and track types on the Dutch network, new policy rules were developed for planning renewals. These rules will be the reference for the Maintenance Regions in their decision-making: they can make a different decision than the rule would suggest, but this has to be motivated with (at least) a convincing life cycle cost analysis.

In the LCM+ project modifications of track designs have not been considered for the main lines (UIC class 1 to 5), except for the feasibility of a specific ballastless design. The track design applied for renewals on the Dutch network uses UIC54 rails, concrete monoblock sleepers (NS90) and a ballast bed with a height of at least 30 centimetres (to the bottom of the sleepers). The policy rules to be implemented are related to:

- **UIC54-track**, i.e. UIC54 rails with the above-mentioned track design (concrete monoblock sleeper), the duoblock concrete sleeper and the Nefit-track (UIC54 on hard-wooden sleeper);
- **NP46-track**, i.e. the standard track design applied during the post-World-War reconstruction phase starting in the 1950s up to the 1970s (NP46 on hard- and softwooden sleeper);
- **Switch Types** (not considered);
- **UIC Class 6-track**, i.e. the track structure on regional lines, side-tracks and yards. During LCM+ modifications to the UIC54 Concrete Sleeper design were considered with respect to these lines;
- **Track Renewal Methods** (not considered).
Below an overview of some important rules is discussed in order to give an impression of the results.

**UIC54-track**
- During LCM+ the current strategy to harmonise renewal cycles of the track components (rails, sleepers and ballast) was analysed. The extra costs and possession time of a separate renewal of rails (rerailing) prove to be relatively small. Therefore a **postponement of the rail renewal** is the most attractive solution if the rails have a residual life of more than 10 years considering the life cycle costs. It is also attractive for levelling out the renewal budgets required. 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 on all lines** due to the problems with geometry control except for some regional lines. In total it concerns some 750 kilometres of track. During LCM+ the impacts of controlled life-lengthening have been analysed. It proved to be feasible to lengthen the lifespan of the Nefit-track by five years through applying a large-scale replacement of the fastenings (with even a small reduction in life cycle costs). This is an instrument to prioritise the planned renewals of Nefit-track on the network.

**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 main problems of these tracks are the fastenings, but they can be improved temporarily by applying so-called ‘coils’. This is attractive from a life cycle cost perspective and also for levelling 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 optimised 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 therefore to be co-ordinated with renewals on Class 6 lines in order to instantly re-use the materials.** From the Nefit-renewals, for instance, materials become available that have a long residual life for side-tracks and some regional lines. Sometimes, modifications to the sleepers are needed.

Other policy rules relate to the instant re-use of main track switches and the realisation of more efficient renewal projects e.g. using renewal trains, longer track possessions and the clustering of renewals on adjacent track sections.

It is clear that the policy rules need a regular update. It can for instance be the case that assumed external conditions change, such as the costs of penalties for track possessions. Also, it is important to monitor the assumptions made, such as whether a life-lengthening maintenance method really has realized a 5-year postponement of renewal with the estimated costs.
5. CONCLUSIONS AND FURTHER RESEARCH

LCM+ has shown, at least at Netherlands Railways, 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 maintenance and renewal. Of course, it can also be the case that LCCA shows that with more budget (than available) the life cycle costs can be reduced further, but this still remains a decision of the infrastructure owner. The only thing an infrastructure manager can do in this case is to make the trade-off between short-term costs and long-term performance transparent, and LCCA can still show the M&R plan with the less damaging impact on costs of ownership.

LCM+ was finished in 2001: the final step was the development of a modified Renewals Prognosis 2003-2020. Based on cautious assumptions on the applicability of the rules a reduction of the (average) annual renewal budget by 10% is forecasted; the extra maintenance expenses are taken into account. A plan is being developed for the implementation of the proposed measures (policy rules), since LCM+ has its consequences for the organisation, procedures and information exchange within the Renewal Planning Cycle. For instance, an improved co-ordination between upgrading projects and renewal projects on main tracks and side-tracks is required. As for the instant re-use of materials, the renewal plans have to be co-ordinated a few years in advance. Also for clustering of renewals and for scheduling longer track possessions, plans have to be developed a few years in advance.

The Implementation Phase, which will start in the autumn, contains the following actions (14):
- The proposed rules for maintenance and renewal are to be included in a formal policy document that covers all rules and procedures related to the maintenance and renewal of tracks and turnouts.
- The procedures in the Renewal Planning Cycle will be adapted in order to maximize the cost-saving potential. This will include a modification of the procedures to collect information and an earlier co-ordination through ‘optimisation meetings’ between the Maintenance Regions. Further, the topicality of the LCM+ rules has to be monitored.
- The development and application of computer-based tools, which support the planning process especially for realising optimal maintenance and renewal plans for whole transport corridors (minimising costs of ownership and traffic disruption).

As LCM+ fits in the overall programme to develop ‘asset maintenance management’ at Railinfrabeheer, the LCM+ policy rules will also be used in follow-up projects, such as the ECOTRACK feasibility test. 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. The life cycle cost expectations have led to developing the rules, since guaranteeing the long-term infrastructure quality and costs of ownership is the key responsibility of Railinfrabeheer. The involvement of the regional track experts was essential for the development of robust rules. The chances of a successful Implementation Phase are multiplied as well by this way of working. This is crucial, since the potential benefits of LCM+ are only fully utilised if the organisation is able to develop a robust, timely Renewal Plan (the target is about two years prior to execution).

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