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Track Innovations by Austrian Railways (OEBB)

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ABSTRACT:

As in any railway in the world, Austrian Railways Infrastructure is under constant pressure to provide optimum availability of their tracks at a minimum of cost. Key element to achieve this task is ongoing research of track technologies, analysis of economic and technical dependencies and implementation of innovative track maintenance and track components.

The paper will describe innovative methods of OEBB:

On Austrian Railways infrastructure strategies are based on life cycle cost analysis, for which a model was developed jointly by the Technical University of Graz and OEBB.

For Monitoring of track condition a comprehensive data base was implemented, which allows prognosis of track and track component degradation, based on long term history.

Basis of track condition analysis is the “NATAS” system which uses the “gliding standard deviation” for track geometry condition and integrates ground penetration radar measurement into the track report.

Another newly developed important information tool is the geotechnical database, the so called “extended structure” where each 200 meter section of the whole main line network is classified according to the condition of ballast, substructure, drainage and adjacent structures. This allows optimal planning of the sequence of rehabilitation projects.

The exact survey into the cause of track failures led to the improvement of track components, such as rails, fastenings and rail pads. This increases the service life of the components and reduces the occurrence of rail defects. A helpful tool is the measurement and analysis of rail inclination.

It also turned out that the right elasticity of the whole track system is of basic importance for a cost effective track strategy. OEBB therefore now installs concrete sleepers with under sleeper pads and pays utmost attention to the condition of ballast and formation. Formation rehabilitation always includes the application of a gravel-sand layer above a geo-synthetic. Another new strategy is the “integrated maintenance” where tamping and rail grinding is done in one common track occupation, the results are longer lasting track quality and reduced development of rail defects.

For track work Austrian Railways apply high capacity machines which are contracted on a long term base (three to five year contracts). Machine systems which are used are:

- Track geometry maintenance machine groups with four sleeper tampers, stabilisers and ballast distribution systems
- Continuous action turnout tamping machines with integrated ballast distribution
- Ballast cleaning machines
- Formation rehabilitation systems combined with drainage maintenance systems
- Combined track relaying and ballast cleaning systems
- Transport and laying systems for preassembled “plug in” turnouts
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1. Introduction

One important part of the system railway is the permanent way. The purpose of the track is to lead and to carry trains. From an economic view the track is a means of production to render possible train rides. On one hand engineers have to design the infrastructure adequate in a commercial sense but infrastructure has to be in the same time sustainable. OEBB started more than 15 years ago with cooperation with Technical University of Graz in life cycle cost analysis and a new model was developed. Main maintenance works were analysed and at the same time OEBB started to launch a data store with significant data, like track quality, maintenance works and basic track data like rail section and installation date, fastening type, sleeper type and installation date and others. Later on we combined specific surroundings, turnouts, level crossings, bridges, stations, platforms, geotechnics….

In the meantime many billions of network and track data is stored to use it for statistic manners as well for directly acting of hand tailored actions of maintenance.

2. Life-Cycle-Cost (LCC)

OEBB railway system: Mixed traffic on almost 10,000 km tracks, 84 % electrified and 76 % LWR. 14,600 turnouts, max. speed 250 kph; max. axle load 22.5 t

2.1 Economic evaluation - Cost Optimisation

The focus of the provider is production optimisation to be competitive on the market with adequate products. The focus of customer is to get a benefit of use, favourable overall costs. As return on railway infrastructure investment is long-term, maintenance costs are of critical importance.

Theory says: "Economic evaluations need to take account all cost consequences of an investment, independently from the point of time and place of the payment caused by the investment".

So LCC have to deal the whole product span, that means the whole service life and the system railway must be taken into concern, not only one organisation unit. For LCC following costs taken into account, the direct costs of the life cycle like:

- Investment until next re-investment, inspection, maintenance and additionally costs of operational hindrances (COH).

The OEBB model for COH evaluation is a linear cost model which is based on average costs for standard trains including positions for:

- Train delay costs, increasing energy consumption due to braking and re- acceleration, additional train-kilometres caused by deviations and costs for buses substituting passenger trains

- All other like

  - Follow up delays, train failure, connecting problems, shunting problems, fee-repayments and others are not included.

Infrastructure assets and particular railway infrastructure shows two specifics:

1. extreme long service life, 40 years and more are a standard
2. no direct revenues
Therefore an adoption of economic evaluation required in the way that only a comparison of two possible technical options leads to a different payment flow. Additional costs are treated as “costs” while savings occur as “revenues”. That means:
- the differences in the annuities show annual savings
- the internal rate is the interest rate of the additional investment
- the amortisation means the time of refinancing of the additional investment

2.2 Standard Elements

A standard element e.g. one kilometre of track or one turnout is describing a typical situation in the respective railway net. The different significant track conditions are described by different parameters defining the different standard elements. That leads to “Standard Kilometres” which are describing the whole network. Parameters
- traffic load
- speed
- single or double track
- superstructure (ballasted track)
  - rail profile, steel grade, CWR or jointed,
  - sleeper type,
  - ballast
- alignment
  - radius
  - gradient
- subsoil condition

A typical acquisition format for standard kilometres is in figure 1 (fig.1).

![Standard Kilometres](image)

2.3 Strategies

After analysing the cost drivers you’ll get the input for defining strategies. The parameters for track behaviour are from loading side rolling stock type, traffic volume, speed and from track side alignment, rail, sleeper, ballast and formation (sub layer, subsoil).
As a result of our evaluation a prolongation of service life of tracks and turnouts of 20% higher by using high ballast quality can be managed (fig. 3).

### Fig. 3 LCC evaluation for different ballast qualities

**2.4 Analysis of Cost Composition**

The composition of average annual costs shows the core part is in depreciation costs (see fig.4).
The main effect for cost optimisation is in extension of service life to reduce depreciation costs. The reduction of COH can be found in changing of strategy, working length or (what we don’t want) less traffic. Reduction of maintenance costs as a result of “better” components and optimised maintenance regime. Higher initial quality with more expensive track components is economical reasonable if higher quality is resulting in longer service life. Analysing all the data we spotted the following cost drivers for track maintenance (speed ≤ 200 km/h):

1. Initial track quality defines life-maintenance
2. Subsoil quality & functional drainage: 1 to 9 times
3. Turnout-density: 1 unit equals 450 m track
4. Alignment (Radii…): 1 to 3
5. Cost of operational hindrances (COH): up to 30%
6. Traffic density: ~ linear (if superstructure and formation (substructure) fits to the traffic requirements)
7. Quality of RST (motor power units): ± 10%

But as mentioned before if the subsoil (formation) quality and/or drainage demands do not meet the requirements optimisation of track is not possible. Permanent slow orders in general for main lines are not economic (see also fig. 10)

2.5 Track Quality

Within the EC regulations (EN 13848-5) the longitudinal level (isolated defects and standard deviation) and many other values like gauge (isolated defects and mean gauge) cross level (isolated defects), alignment (isolated defects and standard deviation) and twist are proposed to describe track quality.

Within optimising track and its maintenance track quality is relevant. Quality levels cannot be defined by safety limits. Safety limits don’t give any space for optimisation and planning, therefore economically justified quality levels must be stricter than safety limits. By analysing all deterioration data we tried to find an algebraic coherence. We had to mention a very simple observation:

Fig. 4 Cost composition, annual costs versus number of trains per day and track
A good track behaves well, a poor one declines faster. So quality must be a function of (from) time and the degradation depends on actual quality level.

\[ Q(t) = Q_0 \times e^{-bt} \]

\( Q(t) \) = actual quality level  
\( Q_0 \) = initial quality  
\( b \) = degradation

This equation can be interpreted in an economic way also:  
\( Q_0 \) as a result of investment, investment delivers initial quality and \( e^{-bt} \) as a result of maintenance, maintenance transforms this initial quality into service life.

If we follow this interpretation the separation if investment and maintenance caused by organisational reasons cannot separate the technical interrelations, thus does not reflect reality and so needs to lead to sub-optimisation.

OEBB has stored since the year 2000 with many millions of e-functions with all relevant information and history, so the whole net is covered (see fig.5). This source of data gives OEBB the possibility to analyse interrelations of degradation from superstructure, the influence of homogeneous section’s length, points of unsteadiness, etc. All this is necessary to get a functional knowledge of track quality behaviour to predict quality behaviour and thus optimising the point of track work. Furthermore this allows increasing service life of track.

Due to the state of art of the LCC tool the following parameters are included within the prognoses:
- traffic volume
- alignment (radii)
- sub-layer
- sub-soil
- ballast quality
- type of superstructure

For long term prognosis further behaviour must be analysed:
- behaviour of all sets of parameters
- quality increase due to maintenance action
- possible initial quality depending on formation

Fig. 5 Typical e function for quality behaviour
We analysed many reasons for different track quality behaviour but there are still some question marks kept. However prognosis is already possible if one deterioration function on the specific track section is known. (see fig. 6)

4. Examples evaluated by Life Cycle Management (supported by LCC tool)

4.1 Evaluation of innovation within investment:

Under Sleeper Pads (USP) in track and turnouts

USP is an elastic layer on the sleeper bottom. The aim of USP is to achieve advantageous properties of the ballast superstructure. In that way the load-distributing areas between the sleeper and the ballast are increased since the elastic layer enables an embedding of the ballast stones (see fig. 7). The elastic layer between the concrete sleeper and the ballast reduces the ballast pressure and consequently reduces the costs for track maintenance – with a simultaneously moderate capital expenditure. In addition to this economic effect the USP also protects against vibrations, structure-borne noise, and reduces damage of the rail surface.
Fig. 7 Comparison contact areas sleeper-ballast

Economic Efficiency of USP Turnout

Fig. 8 USP in turnouts

4.2 Examples of evaluation of innovative maintenance:

- design tamping (see fig. 9)

Design Tamping

Levelling-Lining-Tamping (LLT) only delays the onset of track deterioration. It seems track has a memory. The failure generally occurs again at the same place. The idea of design tamping is to over-lift the failure in order to increase the time until it occurs again. If the amount of over-lifting is equal to the initial settlements after LLT, at the starting point of normal operation the track is close to be plane.
Normal tamping action is to get the theoretical longitudinal level, but it can be observed the track deteriorates always, at the same positions. Yellow line: 1 month after tamping, red line: before tamping, blue line: after tamping.

Design tamping increases the time between two necessary maintenance actions at not any additional costs.

5. Expert System for Infrastructure Facilities

In 2011 based on all the works we did since more than 15 years we started the “Expert System for Infrastructure Facilities”. This system is a combination of many different tools and at least the track engineer in the region get a hand tailored proposal for his facilities.
The core is an exact documentation of the status, prognosis of the degradation, preparation of recommendations and the LCC evaluation of maintenance actions or renewal. With this system we reach a before never known quality, transparency and objectivity for track works. All data is stored in a generally open access data base for all technicians and regional engineers.

5.1 Single Defect Report

The track recording car shows all exceeding of intervention levels. This data will immediately transferred to the regional engineers on board of the track recording car and the railway officials. All data will be stored in a data base too.

5.2 Track Analysing system NATAS

NATAS (New Austrian Track Analysing System) have been introduced in the year 2003 for supporting the planning procedure of maintenance. All the data gained from track recording car will be linked with other information and graphically edited (see fig. 12). With NATAS it is possible to prognosticate the degradation of the infrastructure status. NATAS gives an overview normally on 5 km analysing distance, but also 50 km for generally remarks and several details can be seen in special windows to subtle the analysing of degradation for shorter (100m) distance.

In the 50 km report you will find all the details of sleepers, machinery works, speed (theoretical speed), superstructure, station situation, curvature and gradients. With the possibility to (over)lap track documentations from different years, sections displayed with different deterioration.
NATAS

On 4 basic sheets happens the status documentation of the sections.

Fig. 12 NATAS basic sheets

Unique is the documentation of the wear of the rail pads by rail inclination (see fig. 13). Also new is the measurement of the rail foot distance for the quality analysing of the fastening system mainly in sharp curves (see fig. 14).

NATAS - Example

Unique is the rail pad wear evaluation by rail inclination.
To late maintenance reduce the service life of tracks significantly.

Fig. 13 wear of rail pads due to rail inclination

NATAS - Example

The signal rail foot distance allows to evaluate the dysfunction of fasteners in curves.

Fig. 14 dysfunction of fasteners due to rail foot distance
The entire machinery works are documented from 1998, to get an instruction of the maintenance density for long stretches. For 100m sections detailed deterioration and power density can be shown. The power density is an indicator for ballast quality. The analysing of the longitudinal level help to rate the quality of maintenance actions as well.

**NATAS**

Integration of machinery work documentation help to evaluate the intensity of maintenance due to sections.

**NATAS**

Power density analysis allow to detect sections with malfunction of ballast.

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**Fig. 15** Machinery work implementation

**Fig. 16** Power density analysis allows objection of ballast malfunction
5.3 Photo documentation

The track recording car take pictures on the run with the exact positions by GPS and all this current pictures are stored to get helpful information, e.g. vegetation status, correct position of sleeper caps, passages of different sleeper types, mud spots,…

5.4 Rail Status

All rail defects and the results of ultra-sonic and eddy current tests are stored to get a support for rail maintenance actions.
5.5 Geotechnics

All results from ground penetration radar (GPR) from the year 2003 are stored and linked with the NATAS documentation directly, additionally all data from ground surveys, results from excavations, drop weight tests too. All this helps to gather information of potential weak spots in formation.

5.6 Statistical Analysis of sections

The change of the track quality for all tracks will be analysed statistically. The extension of quality change after maintenance is a statement of the evaluation of the actual status and the functionality of the ballast. So it’s possible to predict the right time for tamping and to make target-performance comparison. Combining many quality values with empirically data will allow forecasts for remaining operating life of components.

Parallel to all OEBB measurements the Life Cycle Team of TU Graz analyses with additional quality indicators like MDZ to describe the riding quality. We get extra recommendations for predictions.
6. Machinery Equipment for Track Works

Now it has to be mentioned all efforts to optimise track quality and to gain benefits are the one hand on the other hand you need to bring it on the track. Therefore it is necessary to work with the proper machinery.

For track work OEBB apply high capacity machines like track geometry maintenance machine groups with four sleeper tampers, stabilisers and ballast distribution systems, formation rehabilitation systems combined with drainage maintenance systems, combined track relaying and ballast cleaning systems and transport and laying systems for preassembled “plug in” turnouts which are contracted on a long term base (three to five year contracts).

Fig. 21 a modern tamping machine UNIMAT 09-475 4S

Fig. 22 formation rehabilitation AHM 800R
7. Summary

Austrian Railways Infrastructure installed a new infrastructure strategy model which is based on life cycle cost analysis, developed jointly by the Technical University of Graz and OEBB. This model is linked with new track monitoring equipment and analysing tools. For monitoring of track condition a comprehensive data base was implemented, which allows prognosis of track and track component degradation, based on long term history data since the year 2000. Basis of track condition analysis is the “NATAS” system (New Austrian Track Analysing System) which uses the “gliding standard deviation” for track geometry condition and integrates ground penetration radar measurement into the track report.

Another newly developed important information tool is the geotechnical database, the so called “extended structure” where each 200 meter section of the whole main line network is classified according to the condition of ballast, substructure, drainage and adjacent structures. This allows optimal planning of the sequence of rehabilitation projects.

The exact survey into the cause of track failures led to the improvement of track components, such as rails, fastenings and rail pads. This increases the service life of the components and reduces the occurrence of rail defects. A helpful tool is the measurement and analysis of rail inclination. To get the right track elasticity OEBB installs concrete sleepers with under sleeper pads and pays utmost attention to the condition of ballast and formation.

New working processes for LLT like “Design Tamping” and formation rehabilitation always includes the application of a gravel-sand layer above a geo-synthetic are introduced. For track work Austrian Railways apply high capacity machines which are contracted on a long term base (three to five year contracts). High performance equipment like track geometry maintenance machine groups with four sleeper tampers, stabilisers and ballast distribution systems, continuous action turnout tamping machines with integrated ballast distribution, ballast cleaning machines, formation rehabilitation systems combined with drainage maintenance systems, combined track relaying and ballast cleaning systems, transport and laying systems for preassembled “plug in” turnouts. As a result a longer lasting track quality and at least the best economic result can be performed.