Consistent Maintenance Tools Based on the Rail Track Data Base of German Rail

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SUMMARY

German Rail maintains a global data base where all rail track information is managed in a consistent way. The data base is used as a reference frame for all facilities.

However, rail maintenance work leads to geometrical changes in the situation. The same is true for rail track improvements with respect to a higher design speed. Both activities require updating concepts and procedures for the rail track data base which have to guarantee consistency and a high degree of up-to-date-ness.

This is of special importance as all emergency management can only be based on such a valid rail track data base, and the ongoing building activities have to be synchronized with the maintenance activities resulting from the measurements.

In this paper the concepts of the maintenance tools are described and maintenance examples are demonstrated.

ZUSAMMENFASSUNG

Die Deutsche Bahn AG unterhält zentral eine konsistente Streckendatenbank. Der Datenbankinhalt wird als Bezugsystem für die gesamten Anlagen verwendet.
Eine der Hauptaufgaben der Instandhaltung ist die periodische Überprüfung und Korrektur der Lage- und Höhenveränderungen.
Beide Aufgaben erfordern Aktualisierungskonzepte und Prozeduren für die Gleisnetzdatenbank die einen hohen Grad an Konsistenz und Aktualität gewährleisten soll.

Dies ist von besonderer Bedeutung unter dem Gesichtspunkt dass ein funktionierendes Sicherheitsmanagement nur auf der Basis einer ständig aktuellen Gleisnetzdatenbank funktionieren kann. Zukünftigen Bauvorhaben sind mit den Instandhaltungsaktivitäten als Ergebnis von Messungen abzustimmen.
In den vorliegenden Beitrag werden die Konzepte der Instandhaltungstools sowie dazu passende Beispiele präsentiert.

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1. INTRODUCTION

The main railway tracks as a typical linear object have individual lengths of several hundreds of kilometers by passing more than one reference systems. The different coordinate systems used nation-wide lead to inhomogeneous and inconsistent data bases and documentation. The inhomogeneity of the reference frames has historical reasons. These frames have different orientation and scale. This leads to serious difficulties in the alignment which can be regarded as a connection to the corresponding state reference systems in their overlapping regions. Therefore it is necessary to establish a unique reference frame.

2. PARTS OF DATA MODELLING

The particular track data possess a higher degree of abstraction in comparison to the pure topology. They contain selected railroads: the tracks which can be single or double for opposite directions. The tracks of a definite railroad are defined sequences of edges. Each track of a railroad can be identified uniquely through its track ID and direction ID.
In order to address a definite edge a mileage is associated with each railroad. The mileage line is a virtual line, i.e. it has no local mark. Discrete points of a railroad can be calculated from the mileage line and acquire a mileage value.

A record of the track data table contains:

- Track ID
- Direction ID
- Sequence of nodes and edges
- Sequence of chainage values

This permits an access to the geometrical elements using the node ID or the mileage corresponding to the specific track.

The kernel data of the logical data base are distributed in two levels:

- Geometrical data
- Topological data

The geometrical data include:

Information about representative track points
- Coordinates

Information about the track elements
- Start and end point

- Heights
- Benchmark type
- Element type
- Element parameter

The topological data include:

- Track junctions
- Logical information about the driving properties (switches)
- Selected lines (aggregation of alignment elements to railroad lines)
- Technical work flow information (Line ID, Track ID, switch ID, etc.)

In respect to the track maintenance there are two types of defects.

- Matched geometry and force defects
- Geometry defect without a corresponding force defect

3. TOOLS

It is of special importance to make the process of data acquisition efficient and at the same time to guarantee consistency. This can be achieved by strict definitions of points and elements, and by efficient tools for alignment calculations and transformations.

3.1 Reference Frame

The objective of the German Rail is to use its own homogenous reference frame **DBREF** for its surveying tasks. DBREF has been computed from about 6000 GPS obervation sites along the DB railway tracks. (Schmitz, M. et all. 2004). The homogeneous transition between DBREF, ETRF89 and the reference frames of all 16 German states (DHDN/STN) has been realized using the Geo++®GNTRANS transformation tool which includes also the height transformation (DHHN) and a geoid model.
The information about the coordinates from the previous, but still used official coordinate systems and coordinates derived from satellite surveying must be transformed into DB_REF and vice versa.
It is important for a transformation to maintain the local relationships in the vicinity of the coordinates. The adjacent metric properties can be changed while mapping the coordinates into another coordinate system (Fig. 2).

3.2 Georeferenced Track Maps

The drawing data from the last 10 years are collected in vector formats like DGN, DWG, DXF etc. There are no problems to import them into the GIS environment. If the drawings are older, only a paper or a folio print is available. Scans of these drawings in M 1:1000 TIFF format are loaded in a georeferenced manner and presented in a union view for a digitizing process in the module RASTRAN in Fig. 1.

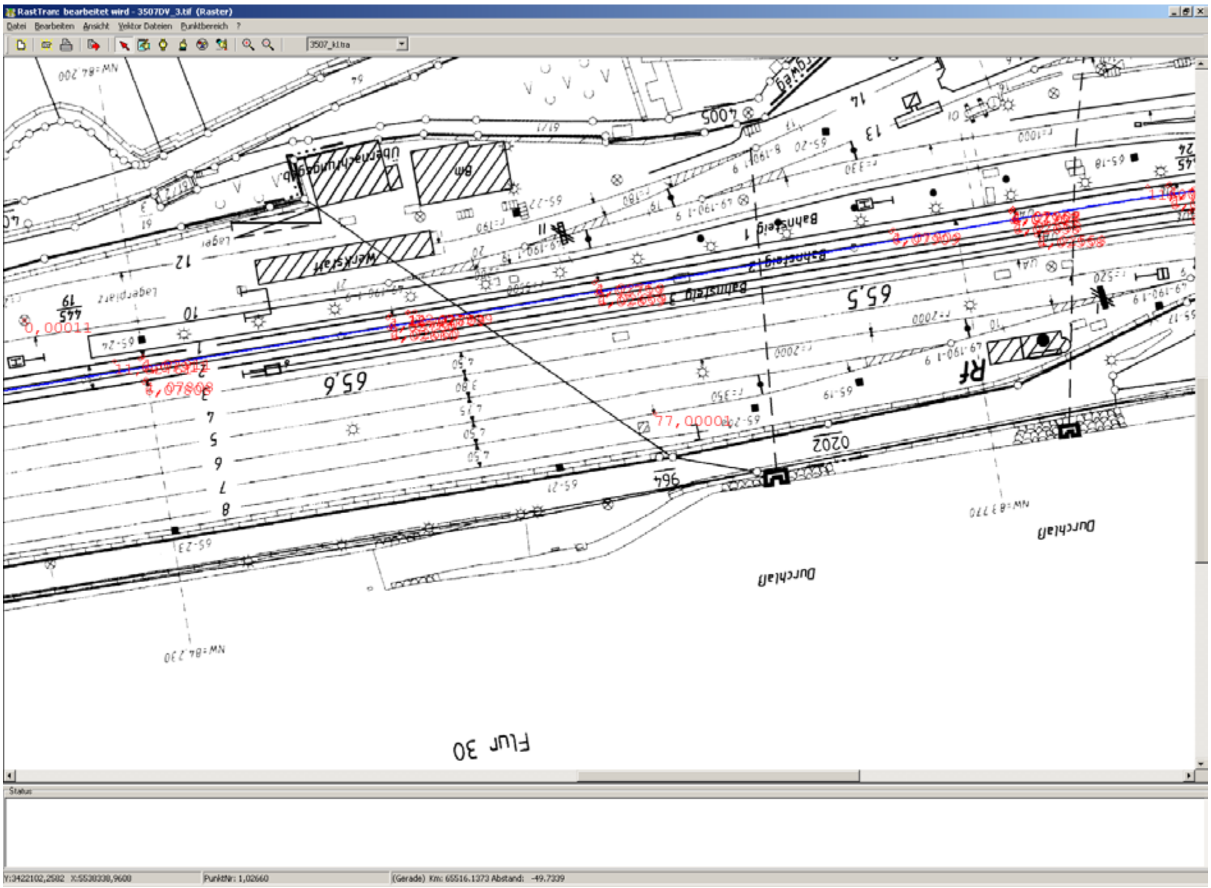


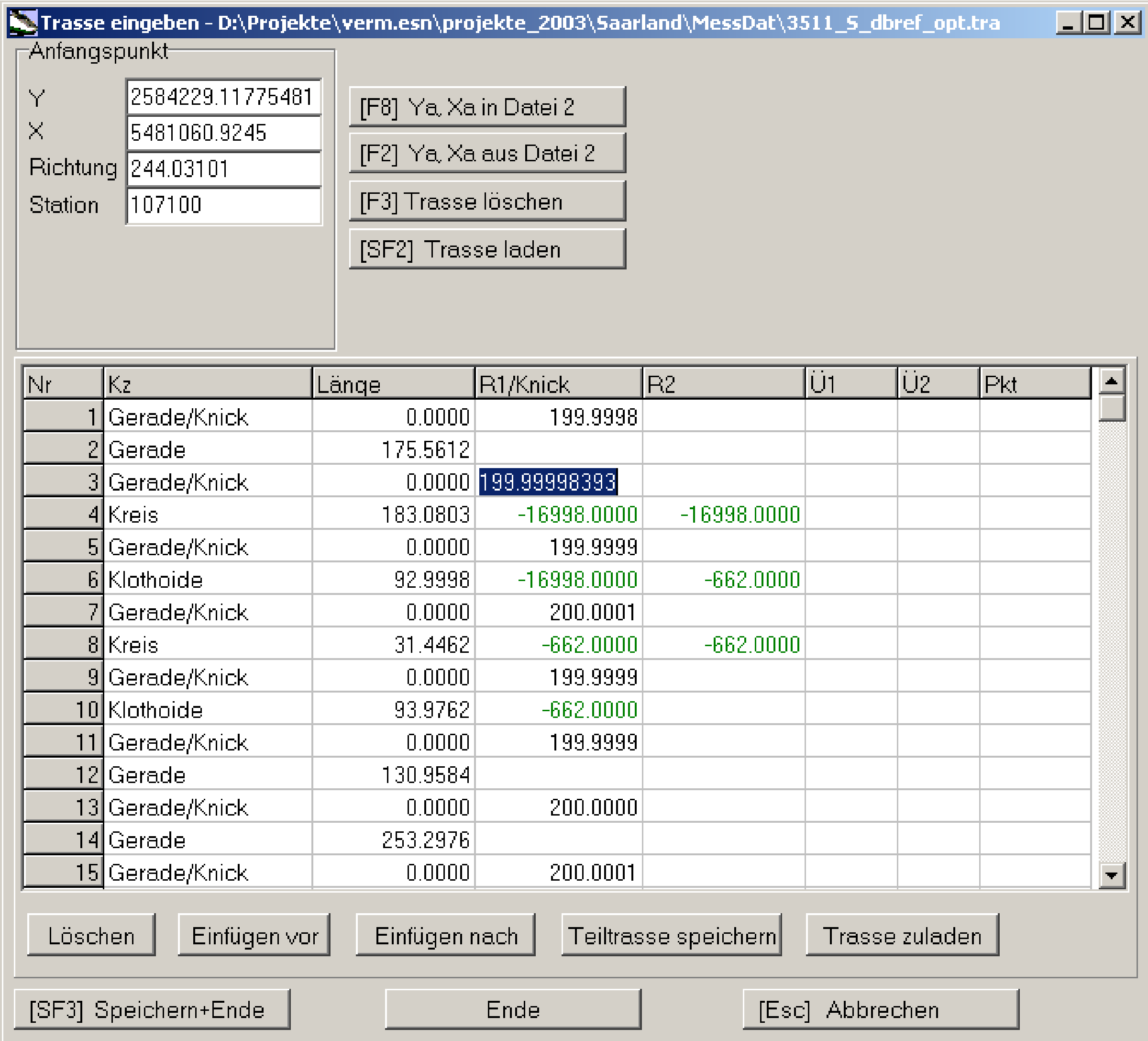
Figure 1 : Georeferenced track maps

3.3 Handling of Special Elements

For special tasks two kinds of additional elements are defined: the one in the plane and the other in the height.

3.3.1 Break Angle, Insufficient Length and Excess Length

The verification of the following consistency condition is included. The transition between the elements for one reference system with respect to the tolerance should be free of breaks. The start direction of an element coincides with the end direction of the previous element.
Insufficient or excess lengths result primarily from reconstruction activities and the condition not to change the chainage of the whole track.
The value of the break angle in the transition between the elements will be calculated. This value will be compared to the boundary value. Usually this boundary value is 0.0636619773 gon, which corresponds to a change in the direction 1:1000 (Winter 2003). As an exception the special element break has to fulfil this condition with less than 0.00001 gon with respect to the subsequent element.
If the elements are the result of a digitizing procedure it is necessary to consider the graphical accuracy by qualifying the break.



Nr	Kz	Länge	R1/Knick	R2	Ü1	Ü2	Pkt
1	Gerade/Knick	0.0000	199.9998				
2	Gerade	175.5612					
3	Gerade/Knick	0.0000	199.99998393				
4	Kreis	183.0803	-16998.0000	-16998.0000			
5	Gerade/Knick	0.0000	199.9999				
6	Klothoide	92.9998	-16998.0000	-662.0000			
7	Gerade/Knick	0.0000	200.0001				
8	Kreis	31.4462	-662.0000	-662.0000			
9	Gerade/Knick	0.0000	199.9999				
10	Klothoide	93.9762	-662.0000				
11	Gerade/Knick	0.0000	199.9999				
12	Gerade	130.9584					
13	Gerade/Knick	0.0000	200.0000				
14	Gerade	253.2976					
15	Gerade/Knick	0.0000	200.0001				

Figure 2: Geometry adaptation after transformation

These breaks can also be used for a consistent transition of the elements between the reference systems within an adaptation process. The degrees of freedom of this adaptation process are:

– Length of lines
– Transition conditions between the elements (breaks)

The following remain unchanged:
– Length and radius of the transition curves

3.3.2 Turnout Systems in Super Elevation

A special definition is necessary because of the difficult determination of the height for turnout systems in super elevation. The description using the standard elements height line and height parabola is not applicable.

3.4 Data Transfer

Typical tasks which have to be supported are reconstruction of certain rail lines, the change of alignment as a result of the rail maintenance or the construction of a new line which has to fit into existing parts. All these tasks require the complex modification of the data base of rail objects. In order to avoid inconsistencies the data needed for the modification have to be extracted from the data base (Fig. 3), modified according to the requirements of the specific task, and then transferred to the data base. For modification, specific independent programs will be used, and then a data base transfer table will be prepared to ensure consistency via suitable checks. In order to avoid any loss of information during the data base exchange procedure, each data set of the transfer file corresponds to a data set of the data base relational tables.

This concept has been realized in the program system VERM.ESN (Adelt, Milev, 2002) .The system has a modular structure. A specific advantage of the program system are its features for highly precise calculations. In order to satisfy the consistency requirements, the accuracy of the coordinates of the points should be better than 10^{-6}m and the precision limit for the tangent directions should amount to 10^{-7}gon.

The aim of the alignment is to find the curvature parameter in each point of the track. This can only be achieved in a stepwise manner, namely by introducing elements, because of the the numerous geometrical constraints the alignment has to fulfil. Due to the specific maintenance requirements the definition of rail alignments is based on the chainage alignment and the actual alignment of the right or left rail. Due to the complexity of the maintenance tasks of alignment the actual task can only be carried out in sub-tasks. Afterwards the result has to be merged in a consistent way. This approach requires a specific structural information. For a number of tasks a three line alignment model – chainage and right and left rail - will be sufficient, for complex data, however, a seven line model is necessary. There, the vertical alignment and the super elevation is additionally required.
Based on this measured track geometry and vehicle accelerations, the force predictions are more than adequate to provide the basis of a performance measuring regime. Real time data can already be obtained readily from recording equipment mounted on service vehicles. This approach of data processing has a potential for an overall reduction of track maintenance and renewal costs.

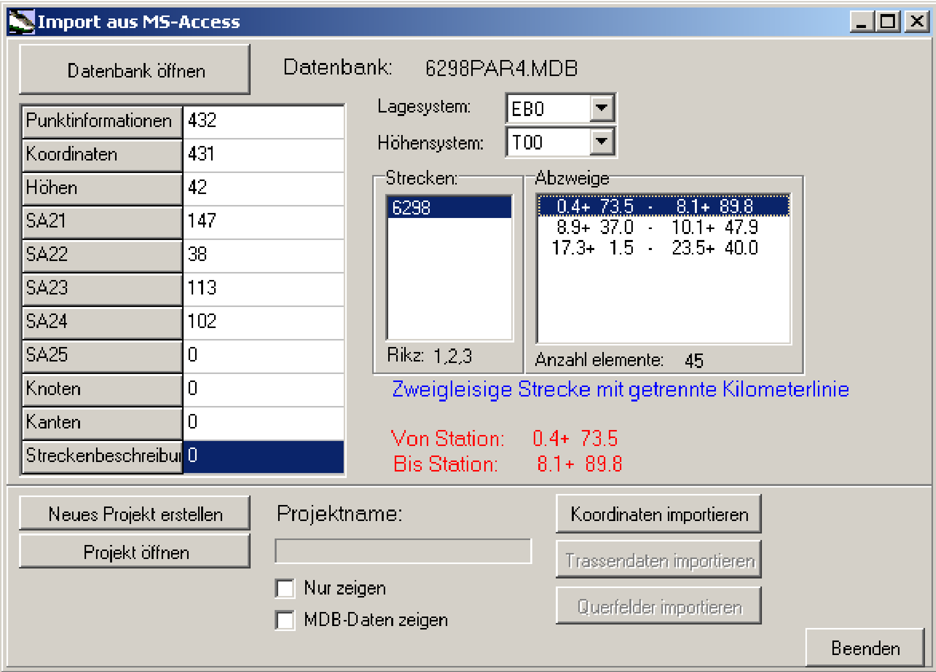


Figure 3: Structure of a data base import tool

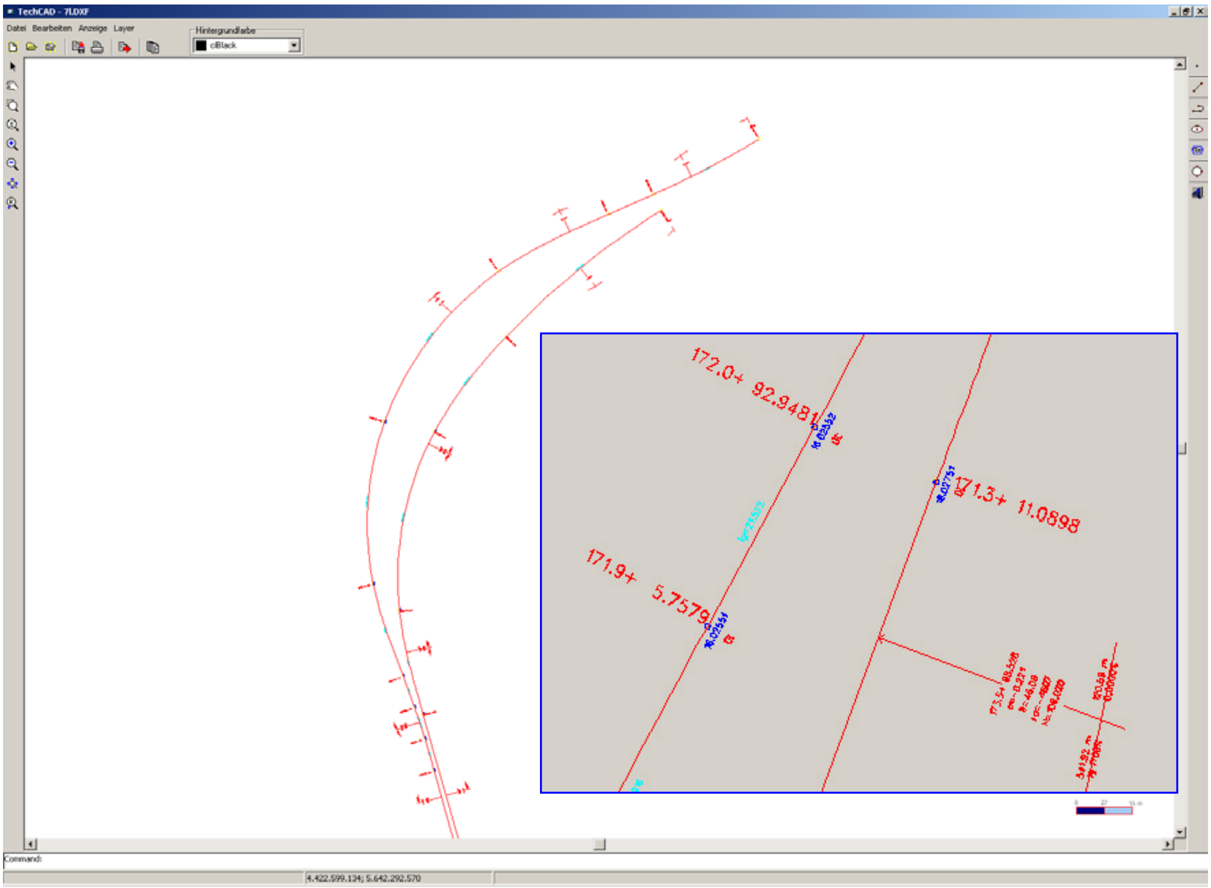


Figure 4 : A result of the geometrical import

3.5 Benchmark Drawings

For the construction companies the benchmark drawings are of primary importance. Fig. 5 shows a typical benchmark drawing.

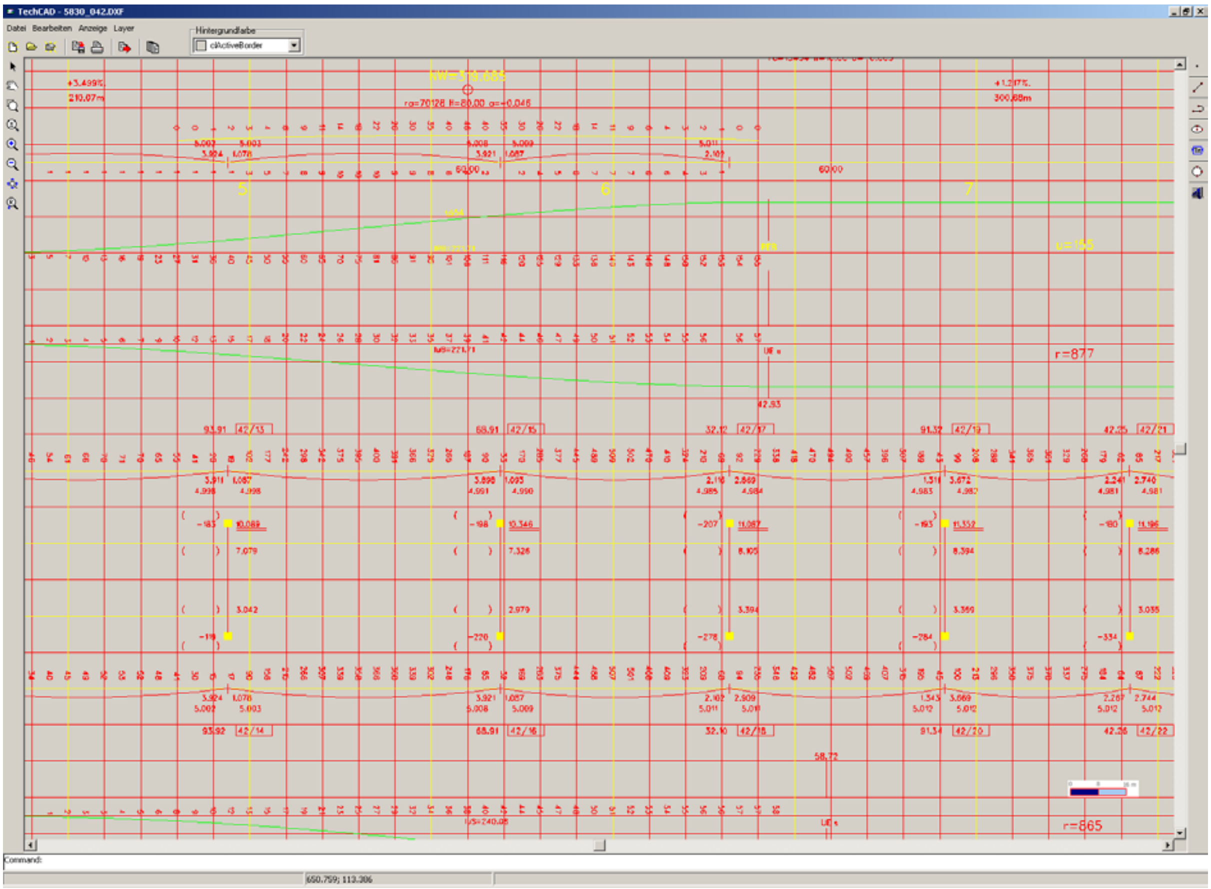


Figure 5:A track benchmark drawing

4 GIS CONNECTION

In order to ensure the consistency of the track net data base the exchange of optimised lines is crucial. Only the chainage line carries global information. The other lines are stored in the data base in accordance with their relative position to the chainage line. By storing the relative position the controlled redundancy and the integrity of the geometric information is enforced in the data model. Whenever global data has to be retrieved from the data base it has to be calculated on the basis of the relative position with respect to the chainage line.

The assignment of lines relative to the separate chainage line for the left and right track is shown in Figure 4.

5 CONCLUSIONS

When maintaining complex geometric situations with long transactions and strict consistency requirements like in a rail network data base it becomes necessary to reduce the absolute geometrical information to a minimum and reference the objects in a relative way. This approach proves to be powerful and reliable.

It makes a sense to substitute the homogeneous reference frame for linear objects, especially for rail tracks, and use the new reference frame for their GIS solutions.
It is strongly recommended not to make this change before the handling guidelines, tools and the technological work flow are developed.

The only straightforward approach is to develop an adequate model for cost attribution based on a proper understanding of the interaction between vehicle and track, the site specific engineering data and the development of verifiable algorithms which relate track geometry deterioration to the properties of the track subgrade and the vehicles passing over the track.

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BIOGRAPHICAL NOTES

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