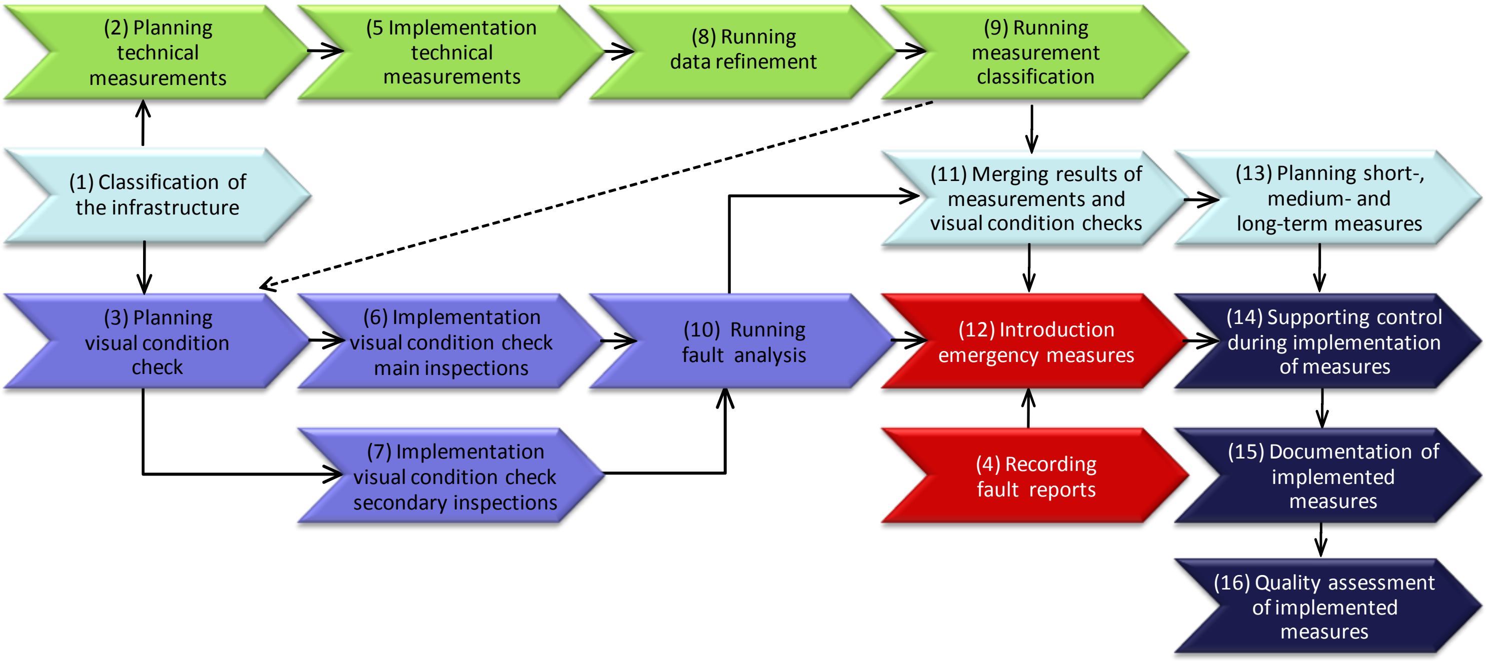
Maintenance Management

Basis for optimised management
of railway facilities

09.01.2010

The maintenance management process model



(Kochs, A. & Marx, A. 2009)

Maintenance Management -
Basis for the optimised management of railway facilities

I. Objectives

Background

The fixed infrastructure of a transportation company forms the foundation of the transportation system. The focus lies on providing a reliable and economic infrastructure service as well as ensuring the availability of the system according to requirements. Here the main processes are planning, construction, operation (Maintenance), and finally disposal – (this too is part of the life cycle) – and are the prime tasks of a transportation company.

The maintenance of transportation facilities, which constitutes approximately 65% of the life cycle costs (LCC) result in high economic costs (Figure 1).The result is that on the one hand efficient technical solutions and long-term direction for the maintenance are required, and on the other hand, maintenance costs are already determined by the initial planning and technical selection for the infrastructure.

Maintenance management is defined as the sum of all the actions required for the organisation, control and development of maintenance.
Operational maintenance management deals with the implementation of aims as defined by maintenance objectives. This requires the contribution of thorough planning, management, implementation and monitoring of necessary measures and resources, for the economic fulfillment of this task. Maintenance management is really a complex task which has to take into account a variety of different aspects.

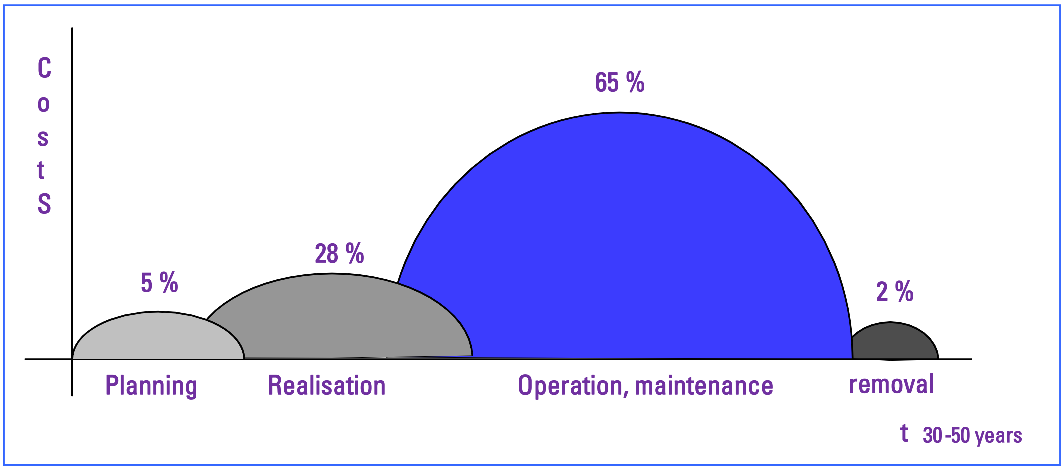


Figure 1: Typical distribution of costs of railway facilities in the life cycle

Studies in relation with the research aims of IDMVU[1] show that the daily business processes of transport organisations are significantly influenced by structured processes with qualified data retrieval and analysis of the transport infrastructure if these are to be efficient and economical.

[1] The research project Infrastructure-Data-Management (IDMVU) was commissioned by the German ministry for traffic, construction and urban development. The IDMVU-Standard forms the necessary data structure required for maintenance solutions in the form of a conceptual data model and an interface standard for data exchange for inventory and condition data. It has been published as VDV guideline 456 in Germany.

Information Technology (IT) in the maintenance environment

Maintenance processes in the field of rail infrastructure have particularly high relevance to data. There are a number of users who permanently rely on reliable and timely data. It is therefore important to optimise the processes by providing quality data. Process chains need to be optimised and implemented without interruption so that all parties share the same secure database. Of significance is the inventory data concerning the fixed infrastructure such as railway tracks and stations, and their relevant condition data, because the maintenance of the infrastructure results in significant costs (*Bickelhaupt R., Stüwe, H. "Urban transport" 10.2005*).

In the past no great significance was placed on structured data management, employees could create or delete data according to their own needs. Therefore the information would often be scattered and redundant, or would be conflicting or outdated. In addition undocumented knowledge was lost when employees left the company.

According to present standards, information should not be concentrated with a few employees only, but to be made available to every entitled person across the organisation for the use in evaluation, analysis and reporting.

The basis for this is provided by technical systems that can capture and monitor the site condition with minimum effort and can provide reliable forecasts for the development concerning wear and tear. These electronic systems support the planning process especially for operators who are maintaining large areas, through the provision of operating-, inventory-, status- and history-data. The point as from where these systems become viable in terms of a cost-benefit analysis is dependent on the nature and extent of the site, as well as the information and documentation required by the owners and operators. Above 20-30 turnouts the limits of static solutions such as spreadsheets are normally reached. In this event relational database systems offer significant advantages in terms of parallel processing, management, maintenance and analysis of data.

Modern information systems actively support the management of rail networks. This allows, for example, for the qualified data capture of sites and inventory. These systems also document and evaluate as well as actively support the processes of inspection, maintenance and repair. Monitoring and control of scheduled jobs, such as revisions, inspections, and warranty durations also form part of modern information systems. The scalability of the data presentation is a key requirement of software systems destined for infrastructure data management. Depending on the analysis to be conducted, it has to be possible to present a condensed visual overview of the complete site through to single sections and down to single measurements and the status of development of a site.

Due to the diversity of requirements a number of different software types and systems evolved around infrastructure maintenance (Figure 2). As a result each data system has its own software for the control of the measuring hardware. Most of these systems also allow for an initial condition analysis in the form of a simple comparison of the actual and nominal values in combination with positive and/or negative tolerance limits. For the visual checking of point objects like turnouts, crossings, stations, etc., and line elements, such as tracks, there exist few practical solutions since software development and practical applications are far apart in terms of content. The same applies for the combination of measurements and visual checks - which have successfully established themselves as the standard for efficient and practical condition assessment and analysis.

A variety of software systems can meet the information needs of management. Significant synergies result from the interaction of the individual applications if a continuous use of captured data can be ensured right from the measurement through to the planning and control of maintenance.

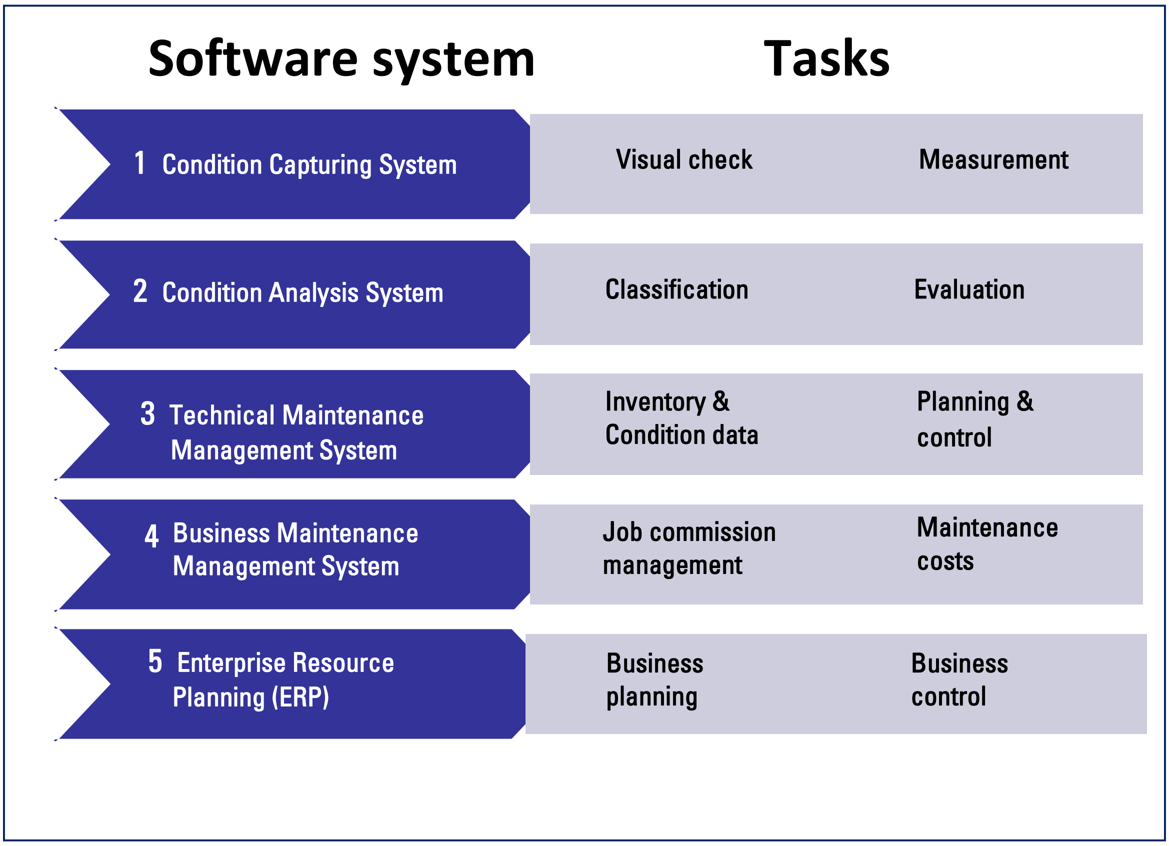


Figure 2: Overview of the software systems and their main application in maintenance.

Requirements of a functioning Infrastructure-Data-Management system
In general, large amounts of data are collected, but it is not always the correct data, further the assessment of the quality of the infrastructure without the matching of the requirements with the current infrastructure is not possible. Many infrastructure managers share the concern that the quality level of their sites continue to deteriorate – this however is not sufficiently transparent and therefore it is not possible to react appropriately.

The establishment of an infrastructure data management system should not trigger new waves of data capturing and "data swamps". This is best achieved if as much as possible of the already collected data can be utilised. For this reason, the use of prescribed (statutory) inspections is ideal for the collection of supplementary data.

With a focused rework of the collected data it is possible to generate suitable information, which represents a good compromise between cost and benefit. This "output-oriented" data processing differs from the "input-oriented" culmination of facts, through

- a manageable effort for data collection,
- concentrated information refinement (categorisation / classification) and
- a valuable information base for comprehensible and sustainable decisions.

Or in other words: more transparency for an optimised use of assets.

II. An integrated system for holistic solutions

Schreck-Mieves has since 1994 successfully been developing concepts and practical components and services for site managers, aimed at the overall optimisation of maintenance of wheel and track. These include data capture and diagnostic systems, evaluation methods for the assessment of infrastructure quality, technical track inspections, as well as the training of specialists and managers of rail freight, local and long distance traffic. The Department 'inspection-analysis' has for 10 years been working with the inhouse-developed software MR.pro ®, which has since 2004 also been offered to rail operators for their own use.

In 2008 Schreck-Mieves became part of the Balfour Beatty Group. Balfour Beatty Rail GmbH is one of the world's leading suppliers of railway electrification, power supply and track systems, with its headquarters located in Munich. The company belongs to the Rail group of the international construction and services company Balfour Beatty plc, London. Balfour Beatty Rail develops designs and installs railway infrastructure all over the world.

Developed by users for users

MR.pro ® is a technical information and maintenance management system.
It evolved out of the "everyday business" of inspecting of track and turnouts. The software which was initially developed exclusively for own use, served to quickly and reliably evaluate the collected data of the digital turnout and track measurement tools of Vogel & Plötscher. These together with the visual condition checks where combined into an overall evaluation of the infrastructure.
The automated creation of easily understandable and visually supported documentation was an essential aspect. The documentation could easily be interpreted even without special technical knowledge and technical means, due to the classification of faults.
Reasons for the continuous digital data capture of an inspection (without a media break) were primarily the minimisation of errors through plausibility checks, the elimination of transcription errors and not least, the completeness of the information through the integrated control of dialog which requires an on site proposal of the measures to be taken for each detected deviation from the nominal. Based on an ergonomic condition check, an automated condition analysis, evaluation and documentation, the software besides the already mentioned improvements of quality, also unlocked additional cost saving advantages through continuous optimisation of the process.

Since the program version 2.0 (2006), MR.pro ® has also been directly available for end-users in the transport organisations. This was made possible by a new, user-friendly interface with many additional features that provide a practical combination of inventory and condition data (inventory, monitoring and visual inspection) and condition assessment (analysis, classification). Since then processed and categorised information have been available for the user in a central infrastructure database, ready for planning, control and realization of the maintenance tasks.

With the upgrade to version 3.0 released in 2008 the areas of application of MR.pro ® have increased substantially with functions in technical management for the maintenance of railway networks:

- RailMap, an interactive schematic plan for the representation of all, or part of a network with bi-directional database connectivity,
- GoogleMaps™ [2]- has been integrated as an orientation and positioning tool,
- warranty and lifespan management,
- measurement of the wear margin (Kennziffer Abnutzungsvorrat KAV),
- Maintenance and inspection management,
- Fault management,
- maintenance calendar for the overview of schedules,

[2] Google Maps™ and Google™ are registerd trademarks of Google Inc.

- Order management with interface to SAP / PM,
- Specifications module (GAEB format)
- etc.

The RailMap commands the presentation of dynamic segmentation as required by the IDMVU norm, with which line elements can be attributed more than once without influencing the xy coordinates of the corresponding line elements. The designs and condition information of the track can be mapped exactly to proportion (Figure 17). With the help of warranty management, claims can be identified and secured timely. Even the lifespan management offers decisive advantages in the estimation, prognosis and monitoring of the economic lifespan – in other words, the memory of the system.
With the integrated GoogleMaps ™ function, the user has access to extensive geographic information. MR.pro ® supports the user in determining the exact location and position. With the "Get Distance" function the exact lengths and distances in GoogleMaps™ can be determined because the distance between two arbitrary points can directly be measured and displayed.

The developers have placed specific emphasis on an "output-oriented" software product which is both economic and ergonomic. With mobile data collection all relevant data can be recorded directly where it is collected (Figure 10). Since the collected data is directly processed, no further processing is required between the on-site data capture and the transfer to central IT – transfer errors and transfer times are reduced to zero.
A user-oriented menu and the practical visualisation of status and inventory information actively support the decision making, while accountability is also maintained without an additional documentation effort. This convinces users, owners and rail authorities likewise.

As from version 4.0 (2010) the mapping of adjacent components of the track, such as supervisory and safety equipment, power supply, catenary and other structures, will be improved by the implementation of own object classes. Through a consistent further development together with the end-users, MR.pro ® will cover the entire infrastructure of transport companies and thus secure the future viability of the investment.

MR.pro ® offers a combination of all necessary technical tasks required for maintenance management, and thereby significantly reduces the number of software products required.
In combination with a business management software ERP (Figure ***3***) the entire spectrum of functions of a modern maintenance management system is ensured in a continuous workflow.

More than a 1000 words – Visualised Maintenance Planning with MR.pro

MR.pro® by means of distributed software on PC, server and mobile units, supports the management of network infrastructure right from the initial assessment through to the running control, as well as the planning, allocation and control of maintenance and repair contracts under economic and value-maintaining aspects. In addition, the software provides extensive numerical and graphical analysis tools for analysis and visualisation of status and substance of the track infrastructure to generate comprehensible and meaningful decisions for necessary repair and maintenance actions. Bi-directional interfaces ensure the connectivity to business management maintenance and planning systems - ERP systems such as SAP/PM.
The two systems can be supplemented by graphical or geographic information systems (GIS) as a global information platform and basis for planning.

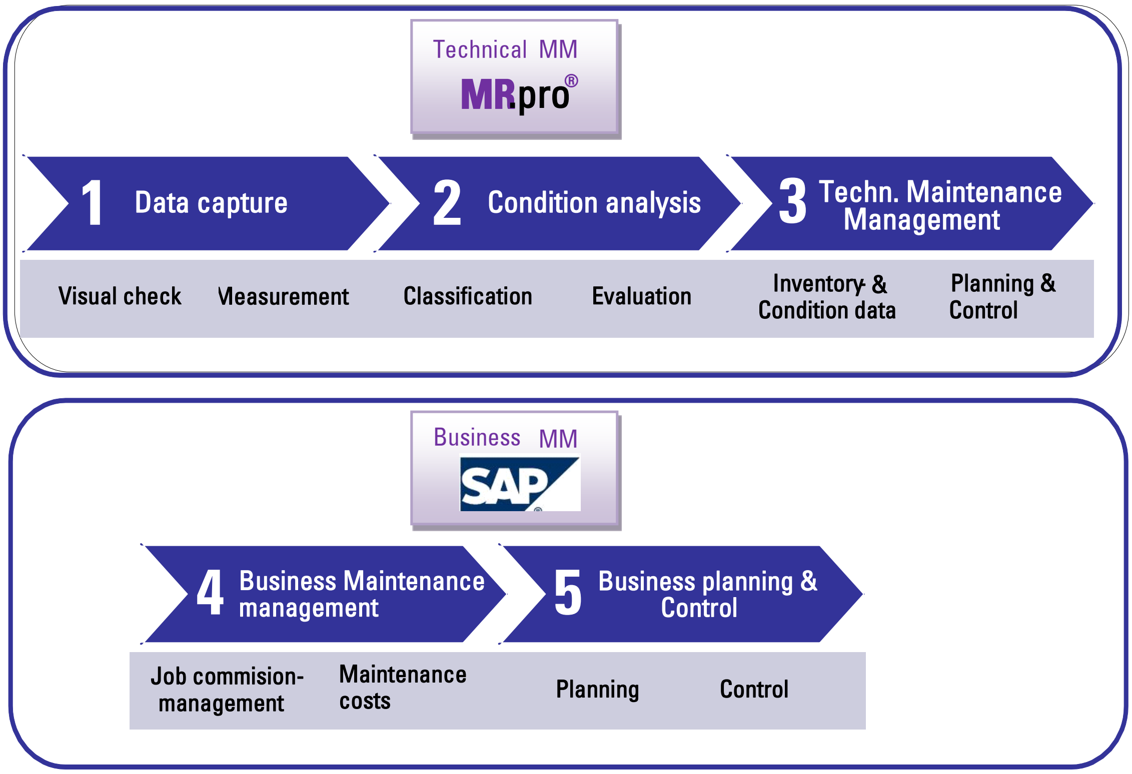


Figure 3: Two software systems for all functions of maintenance management: Technical = MR.pro® Business management = SAP/PM. Further, geographic information systems (GIS) offer a useful supplement.

<u>Background: Interfacing with ERP-Software</u>

A bi-directional interface between SAP/PM[3] and MR.pro® allows for a separation of tasks: It makes sense to use MR.pro ® as a technical information system and SAP as a commercial system. For this a more or less accurate, complete or abstract representation of the track infrastructure is presented in MR.pro ® - corrective measures have to be generated from faults, these have to be prioritized, and decisions have to be derived. Finally all the individual measures of MR.pro ® are transferred to SAP/PM.

The monetary valuation of the measures and the packaging from the transferred activities will take place in SAP/PM. A bi-directional interface between MR.pro ® and SAP/PM not only provides cost information but also ensures the updating of the life cycle concerning the object. Information relating to induced actions is available for follow-up inspections – this brings an additional gain of knowledge in the evaluation of the quality of actions undertaken and the safeguarding of warranty claims (Figure 4).

[3] SAP ERP is the main product of the German Software-company SAP AG. SAP/PM (Plant Maintenance) is a module for maintenance. SAP, SAP/PM and the SAP Logo are registered trademarks of SAP AG in Germany.

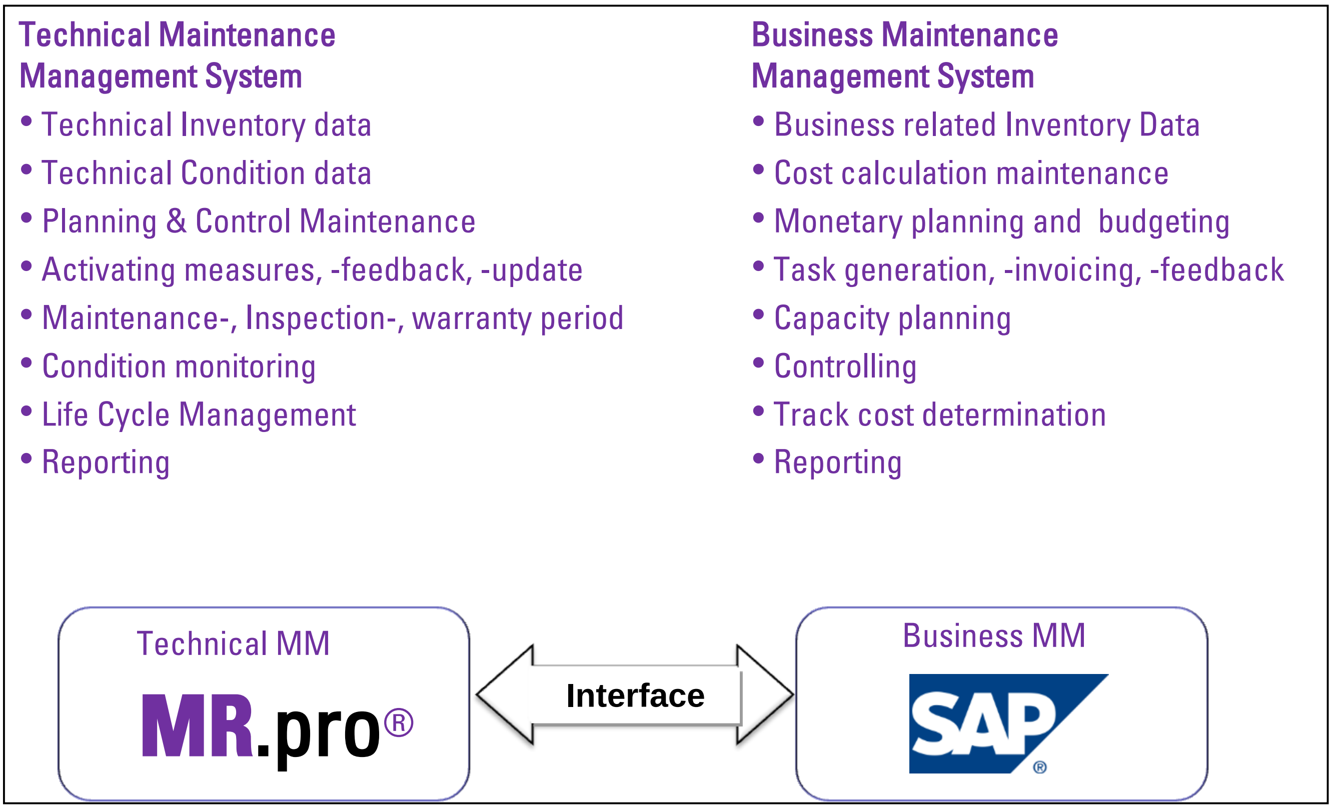


Figure 4: Overview of the technical and business management tasks of maintenance management.

III. Sub-processes of modern maintenance management

The overall process of maintenance management has been divided into 16 sub-processes for a better overview (Figure 5). These 16 operational sub-processes in turn consist of single process steps. Based on these sub-processes it can be demonstrated how a modern maintenance management system - supported by the IDMVU standard – is implemented in transportation companies.
The planning and control of maintenance is also depicted on the example of the rail infrastructure (track and turnouts) based on the IDMVU data model, and especially the condition data model. This basic methodology can be readily transferred to other property types of infrastructure such as control and safety systems, structures, catenary systems, power supply, etc., since these are also point objects and line items.
A precondition for the processes of asset management is the availability of rail inventory data, which is used as input data.
The individual sub-processes require different data as a basis. MR.pro® supports these processes by providing the necessary data (Input). The following describes the various sub-processes in terms of purpose, method and implementation. (for example with MR.pro®)

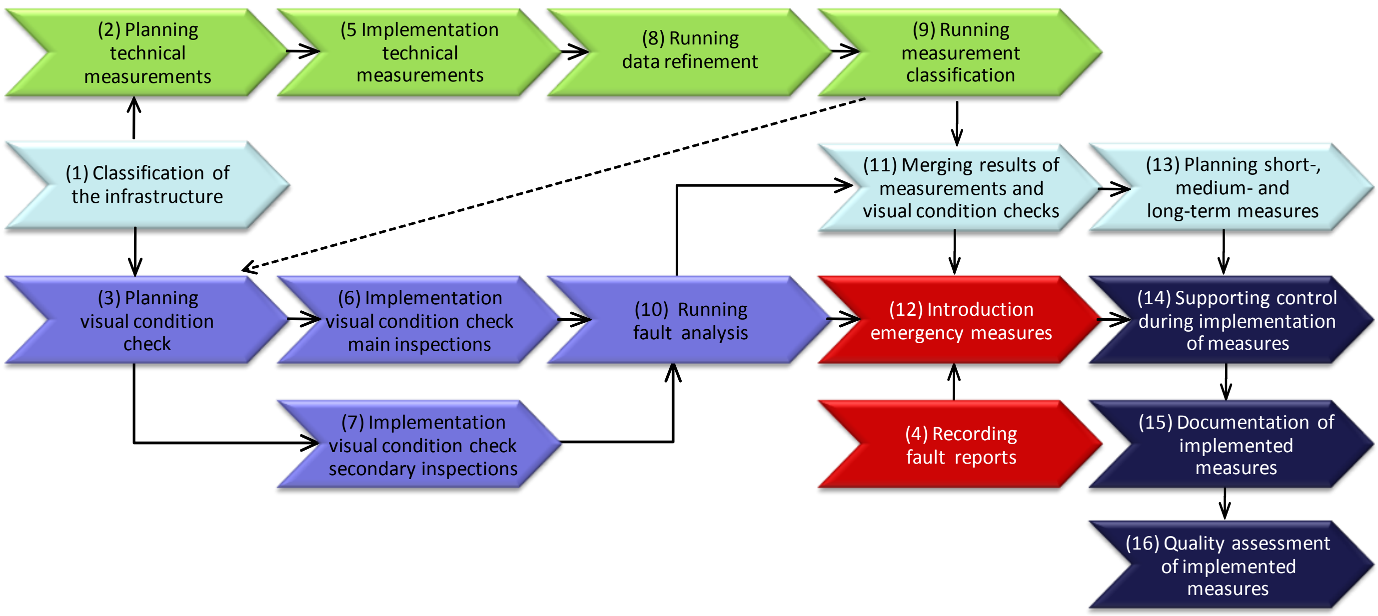


Figure 5: The process model maintenance management explains the order, dependencies and linking of the 16 sub-processes among each other. (Kochs, A. & Marx, A. 2009)

<u>The sub-processes of maintenance management:</u>

1. Classification of the infrastructure - differentiation through different load classes
2. Planning the technical measurements (of the current condition)
3. Planning the visual condition check
4. Recording fault reports
5. Implementation of the technical measurements
6. Implementation of the visual condition check for main inspections
7. Implementation of the visual condition check for secondary inspections
8. Running the data refinement
9. Running the measurement classification

10. Running the fault analysis
11. Merging the results of measurements and visual condition checks
12. Introduction of emergency measures
13. Planning of short-, medium- and long-term measures
14. Supporting the control during the implementation of the measures
15. Documentation of the implemented measures
16. Quality assessment of the implemented measures

<u>The 16 sub-processes of maintenance management in detail:</u>

1. Classification of the infrastructure - differentiation through different load classes

Purpose: The differentiation of the infrastructure according to its importance to the infrastructure owner allows for focus to be placed on the essentials. Critical and heavily used rail facilities/site objects need to be maintained more intensively than less important and hardly used installations. Further criteria are downtime costs in the event of a disruption or the complete failure of the installations, or in how far a site can be bypassed by using alternative modes of transport.

Method: The ABC analysis has proven itself as a viable method for the identification of asset classes. It represents the practical application of the Pareto distribution[4] within the context of business management analysis. Therefore class A facilities are subject to intensive use and high load and have high significance – facilities of the class C are subjected to the lowest use and have low significance.

The asset class also serves as an indicator of the average economic life of a railway facility and can be used to estimate the theoretical replacement date in the context of long-term planning. A differentiation into more than 3 classes may be appropriate depending on the site structure.

Classification systems allow:

- to separate the essential from the trivial,
- to set priorities for rationalisation,
- to avoid uneconomical efforts,

and thus to increase in total, the safety as well as the economics of maintenance.

Realisation in MR.pro®: All system objects (point objects and line elements) can be assigned asset classes and can be evaluated numerically and graphically (Figure 6). Besides the differentiating ability for maintenance deadlines (inspection and maintenance cycles, etc.) the integrated software module "life cycle management" is also based on the stress-associated classes to predict the remaining life span and projection of the anticipated replacement date.

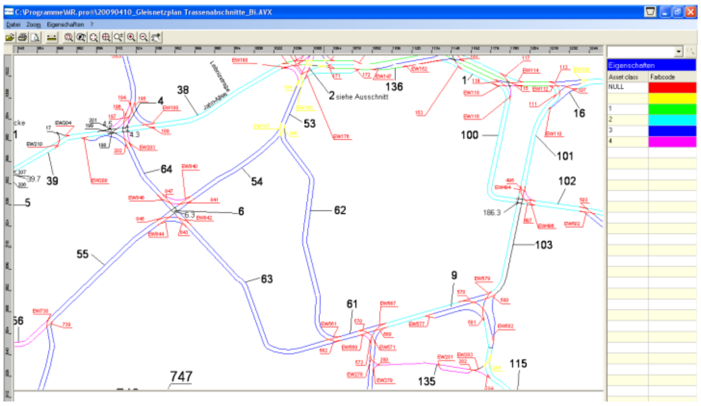


Figure 6: MR.pro® shows 5 asset classes of a big network (LVB Leipzig) in different colours.

[4] The Pareto distribution model, named after the Italian Engineer & Economist Vilfredo Frederico Pareto, describes the fact that a small number of elements are of high value to the system, whereas the majority of the elements contribute very little to the total. This describes the Pareto Principle, also known as the 80:20-rule: 80% of the success is achieved by 20% of the investment.

Masks serve to differentiate between the maintenance volumes. Different intervals can be allocated to these modularly designed maintenance masks according to facility type and class, so that responsibility, scope, timing and required qualifications are unambiguous.

2. Planning the technical measurements (of the current condition)

Purpose: Prior to the running of the data capture it has to be planned. Relevant, are the selection of the installations or network sections to be measured, as well as the type of measurement technology to be used (whereby a measuring system is to be selected, which can then be used for all future measurement runs).
Criteria for the choice of measurement technology are demands on the nature, extent and timing of measurements, whereby also here combinations of execution are considered in conjunction with the visual condition check.
Planning has the purpose of scheduling the personnel and equipment as well as the integration of the measurements with the normal railway operations.

Method: Fundamentals for the planning process are the infrastructure classes (e.g. for the planning of measuring cycles), technical and legal requirements of the track and turnouts to be measured in order to determine the work volume (main or secondary inspection), the demands on the measurement parameters and measurement accuracy as well as the size of the facility, for the selection of the measurement method (track measurement vehicles, track-laying machine, lightweight mobile measuring equipment and hand instruments).

Implementation MR.pro®: The system allows different levels of inspection and measurement, and manages check lists for each facility. An integrated calendar function helps to comply with the requirements (Figure 7).

3. Planning the visual condition check

Purpose: As with the technical measurements, the visual check also has to be planned in advance in terms of which network areas and which facilities are to be checked when and by what method. Besides the choice of the installations to be inspected visually, the demands on the nature, extent and timing of the measurements, it is also here important to consider the inspection schedules in conjunction with the technical measurements, and to integrate the scheduling of personnel and equipment with the normal railway operation.

Method: When doing the visual checking it is distinguished between the main and secondary inspection:

- Secondary inspection: proof of operational safety, usually in the form of visual inspections on foot.
- Main inspection: same as secondary inspection, however extensive additional condition data is captured for the planning of maintenance.

As a result of this sub-process the selection of the track sections and objects to be tested, as well as the time schedule and circumference of the visual inspection are fixed.

Implementation MR.pro®: Condition checks with varying levels of detail can be planned and prepared in view of the personnel and equipment capacity. An integrated calendar function helps in complying with the requirements (Figure 7).

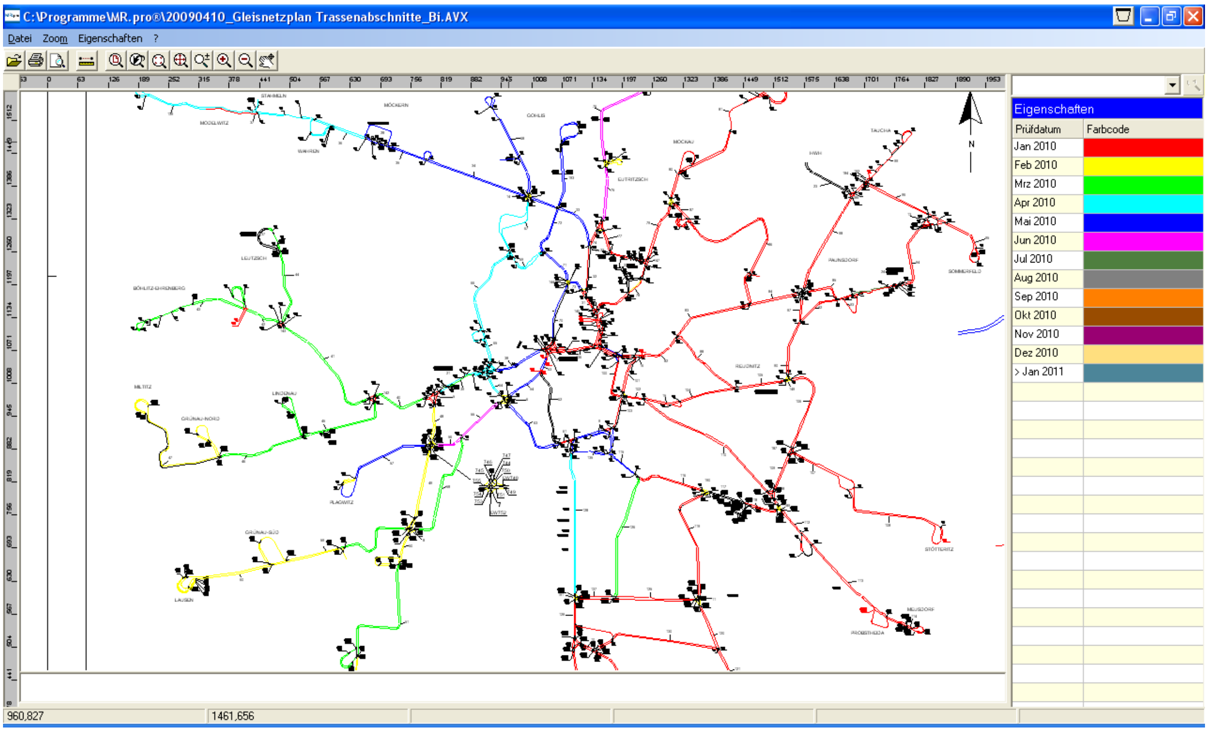


Figure 7: The data capture schedules can be displayed visually in the rail map

4. Recording fault reports

Purpose: In addition to the results from measurements and visual inspections, automatically captured or manually reported fault data is also available relating to the condition of the infrastructure. This part of the process concerns the documentation of the report and the correct allocation of the fault to its source, for the timely implementation of fault correction procedures which maintain or reinstall the functionality and operational safety of the installation.
This prioritisation and the following measures to create an information base should be undertaken for a vulnerability assessment. At the same time a prioritising of corrective measures and the creation of an information basis for a weak spot analysis should be conducted. The origin of the fault messages can stem from various sources, for example from the current rail traffic, from service and maintenance crews, and from inspection teams.

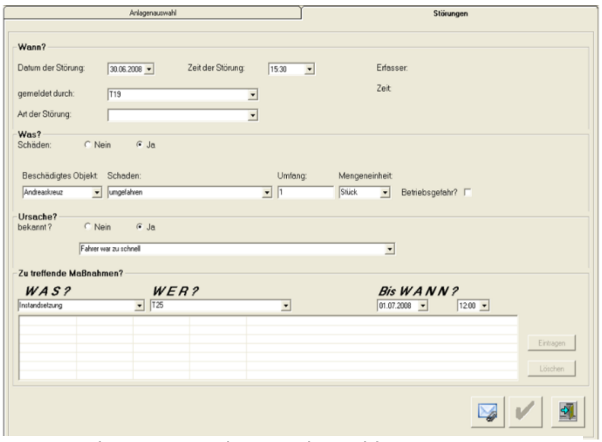


Figure 8: Fault reporting with MR.pro®

Method: The basis for the management of fault data is all track data and inventory data of the facility which must be available as a basis of reference for the fault data.

Implementation MR.pro®: The software has its own fault management, which allows for fault allocation based on the detection and mapping, impact assessment and prioritisation of measures (Figure 8). Also partial- or complete closures of turnouts and tracks can be administrated and displayed with MR.pro.

5. Implementation of the technical measurements

Purpose: The technical measurement is conducted according to schedule. Thereby typically parameters such as geometric diagonal measures and track and turnout properties are captured. The aim is to capture the condition so that it is repeatable, reproducible, comparable and clearly locatable.

Method: The results of the planning (sub-process 2) are used as a basis for the implementation. Network and inventory data of the section of facility to be measured are transferred to the measuring system.

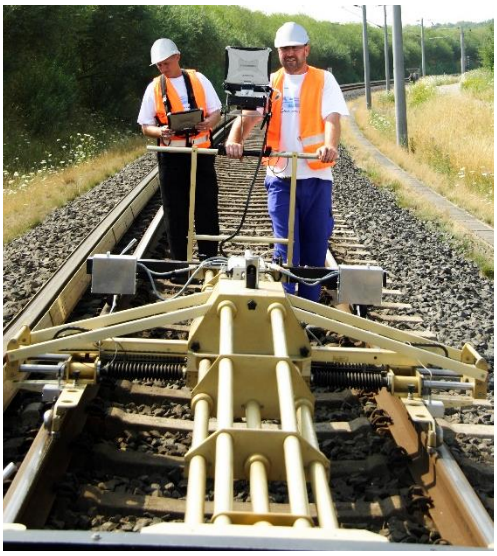


Figure 9: EMA for the measurement of track geometry and track scanning.

Implementation MR.pro®: The system 100% supports the measurement of track structures, i.e., turnouts, crossings and crossings with slips.
With an interface to the digital measurement tools from Vogel & Plötscher (MessReg, CDM, PTP, EMA, etc.) the digitally recorded primary data can be copied 1:1 into the database of MR.pro ® and can automatically be processed and categorised into audit reports.
In addition, it is also possible, by the pressing of a button, to present the combined results of all inspected turnouts, which allows for quick analysis through search-, sort- and filter functions.

The system supports track measurements (Figure 9) through the ability to incorporate categorized measurement data and to link these to the results of visual condition checks. Moreover track measurement results in the form of measurement diagrams are also made available as supplementary information for the visual data capture (Figure 13).

6. Implementation of the visual condition check for main inspections

Purpose: According to the planning (sub-process 3) a visual check of the actual condition of the tracks and turnouts is conducted for this sub-process, as supplement to the technical measurements of a main inspection. The aim is to identify causes of errors, to evaluate identified deficiencies with regard to their safety relevance, as well as the recognition and recommendation of relevant maintenance tasks.

Method: Visual condition checking of tracks and turnouts, in which the visible defects, the nature, the extent and the cause are described by a code. For certain items such as turnouts, the visual condition check is conducted as a positive evaluation (point-by-point examination according to checklist. Result: "OK" / "not OK") – and the line elements such as rails, in the form of a negative evaluation (capture of faults. Result: "not in order").

Implementation MR.pro®: The software has an ergonomic data capture module that is designed to meet the specific needs of rail infrastructure, and supports the user by a dialog driven inspection and with pre-defined checklists (Figure 10). Pre-defined and coded levels of wear (fault code) and their maintenance recommendations drastically reduce the effort of data capture (repair code), since the inspector can make his choice directly from the drop-down menu via touch screen on the computer. The direct relation to the object to be inspected (context) limits the selectable options in so far, that no searching is necessary. Therefore only a minimum of time is required for the data capture. A sophisticated dialog management system ensures that nothing is overseen, while the integrated plausibility check prevents any possible operator errors. Despite the structural and content specifications there still exists a fair amount of flexibility with the data input – it is always possible to enter arbitrary text and no additional handling of paper is necessary. The fault catalogue is updated by continuous backups, whereby new manually captured deviations, are evaluated according to their safety relevance and their level of wear, and are edited into the database offline.

Figure 10: Main inspection of the Basel network suported by MR.pro®.
Photo: Peter Binetti (BVB Basel)

Because the results of the previous inspection represent important information, these are stored in the database – they can not be confused because the old results are high lighted in colour. The visual inspections are always complete because the entry can only be closed once all compulsory fields have been completed. If faults are recorded for which a maintenance request has already been generated because of a defined warranty period, the system points this out to the inspector so that he can follow up on any possible claims.

7. Implementation of the visual condition check for secondary inspections

Purpose: Contrary to the main inspection, the aim of the secondary inspection is to inspect the infrastructure safety and functioning in a number of short term intervals between two main inspections. The circumferences of these inspections, which are usually conducted either on foot or by driving through, are as a rule markedly smaller than the main inspection.

Method: For the secondary inspections (safety check) checklists are used which, compared to the main inspection, present a reduced circumference and level of detail, because the results of secondary inspections mainly serves the current evaluation and confirmation of the operating safety, and are thus only marginally suitable for input for medium- and long-term maintenance planning.

Implementation MR.pro®: The system supports user-definable checklists for visual inspections of varying scope and intensity (Figure 11). The system is ideal for the data capture right from on-foot inspections through to mobile inspections. The aim of all activities on the track is the reduction of the inspection effort and the minimisation of operating infringements through a marked acceleration of the inspection procedure.

Figure 11: Secondary inspection of track with MR.pro®

8. Running the data refinement

Purpose: during the technical measurement of the line elements, e.g. tracks, a compression of data, with the aim of reducing the data quantity of the primary measurement data, is conducted. The aim is also to improve the handling during data exchange as well as the creation of a basis for further analysis and inspection documentation.

Method: There is no standardised method of compression. It stands in direct relation to the data capture and is, as a rule, conducted by the data capturing system.

Implementation MR.pro®: For the compression of track measurements, the system offers support in the form of a length dependant band pass filter, which allows measurement peaks to be smoothened. For imported turnout measurement results, a plausibility check is conducted in addition to the mandatory nominal versus actual comparison.

9. Running the measurement classification

The purpose of this sub-process is to undertake an assessment and classification based on the compressed measurement data by the comparison of tolerances and limits (FR_A, FR_{100}, FR_{lim}, FR_G). The aim is to categorise, to detect of extreme values and faults, as well as to derive and prioritize the measures to be taken.

Method: Here the tolerance limits FR_A, FR_{100}, FR_{lim}, FR_G are used for the classification of the measurement data into individual condition classes (Figure 12).
The definition of tolerance limits is usually based on defined rules and regulations.
The target and tolerance specifications (differentiated by track radius) valid in BOStrab[5] (Ordinance on the Construction and Operation of Tramways) and Technical Rules on Track Guidance (TRSp), e.g. gauge enlargement in a curve, must be displayed graphically and must be numerically evaluable.

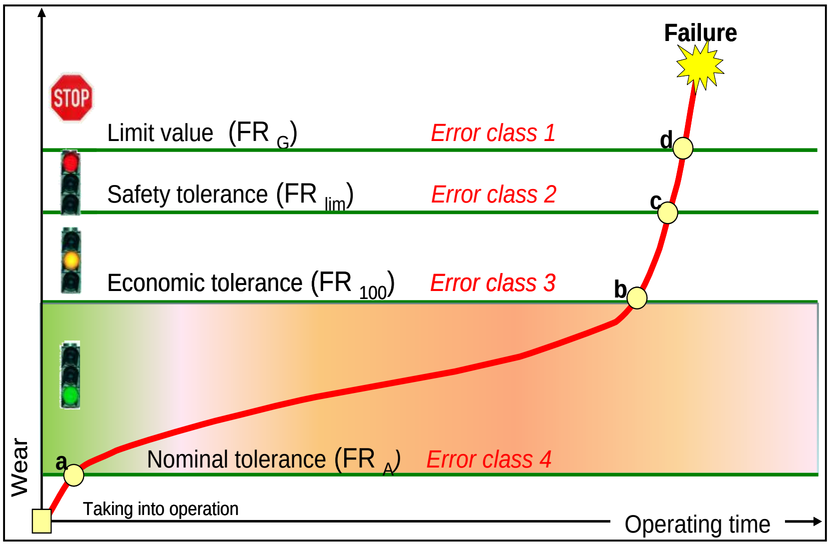


Figure 12: Schematically evaluation of measurements and visual inspections.(FR = Fault-Reaction)

Implementation MR.pro®: For track and turnout measurement data, the program by default offers the verification of measurement failures based on tolerance limits - whereby multi-level tolerances according to FR-Scheme or DIN EN 13848-5:2008-06[6] is used for classification.
The system also handles radius-differentiated target and tolerance values.

[5] BOStrab = German Ordinance on the Construction and Operation of Tramways
[6] DIN EN 13848-5 as an EU standard defines the minimum requirements for the quality of track geometry and defines safety limits.

10. Running the fault analysis

Purpose: This sub-process serves to classify pre-defined deficiencies, which may stem from a visual inspection, a fault report or from any other source. The application of the fault catalogue can again be found within the framework of this error classification, which besides coded fault descriptions and maintenance measures also provides allocated error classes and classification of faults.

Method: Whether this part of the sub-process takes place during the visual inspection or in a following separate step primarily depends on the technical requirements of the inspectors. The fault evaluation may take place during the visual condition checking (sub-process 6 and 7) if this takes place under the support of IT. If no IT is available during the data capture the allocation of error classes to each found fault (Fault classification) is possible in a separate subsequent step.

Implementation MR.pro®: The software provides a central catalogue for the classification and categorisation by using coded fault descriptions and descriptions of maintenance measures to be taken. Both evaluation methods are supported: online while in the track or offline in a subsequent step. Offline means that the data inspection is done with paper checklists and is later transferred into the inspection module of MR.pro® by hand.

The generation of maintenance proposals for maintenance planning on the basis of a defined catalogue is supported as a direct result out of the findings. The classification of measured values which violate tolerances and faults detected by visual inspection is based on a unitary 4-level evaluation scale (Figure 12).

11. Merging the results of measurements and visual condition checks

Purpose: To provide a solid foundation for predictable maintenance measures, the inter-dependence of technical inspections and visual checks have to be identified.
As even classified and evaluated test results usually do not allow for a direct hint as to the source of the fault, the suitable maintenance relative to the cause of the fault is only partially possible without any additional information. Therefore it is important to bring together the results of the technical measurements and visual checks. At the same time visually observed faults which have an affect on geometrical measurements are confirmed. Measurement results, besides their confirmation in the fault description, also find a concrete reference to the source of the fault.

Method: The culmination of classified condition results out of the technical measurements and visual condition checks result in a summarised inspection report. Measurement results that breach the tolerance limits are allocated and supplemented to the detected and evaluated faults of this infrastructure element.

Besides the plausibility of technical and visual inspection data, which could even have been conducted on different dates, this summary provides a gain of information in terms of interdependence and relationship, and therefore an important decision making tool for object oriented maintenance.

Implementation MR.pro®: The system is based on a holistic view of condition assessment and measurement, and hence is specialised for this task.
For the complete presentation of the logical relationships one possibility of output which has been implemented, is a standard infrastructure document (Turnouts: Wi-Dok and for tracks: Gi-Dok) in the form of a Microsoft Excel[7] file for tracks and turnouts.

[7] Microsoft, Microsoft Excel, Microsoft Office and Microsoft Windows are registered trademarks of Microsoft Corporation in the United States and/or other countries.

Individual work files are created for all installations consisting of one page for the measurement results as well as a number of work sheets for the documentation of each inspection. For line elements like track, the standard documentation consists of one measurement diagram with the information from a number of years being overlaid as well as documentation and measurement values (Figure 13).

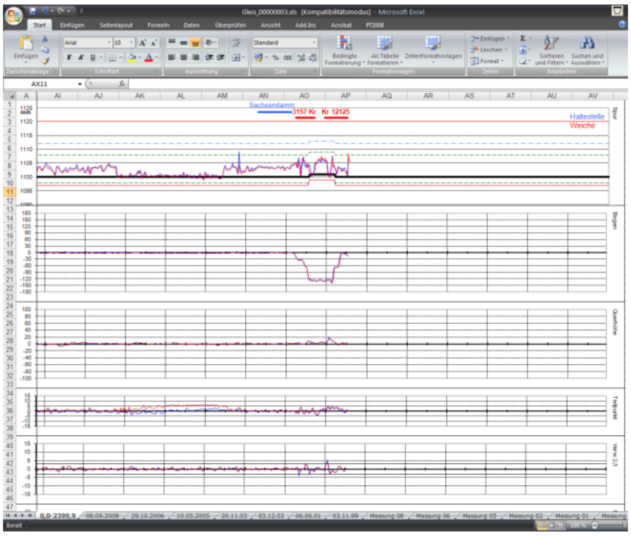


Figure 13: Overlay of a multiple of measurements of a track

Already existing files are automatically stored by MR.pro® and the current data is imported and appended (Figure 14). Program independent evaluations can at any time be generated by a standard Excel export function.
The seamless transfer and integration of new data into the existing data ensures that nothing is lost and that the data is promptly made available for further processing.

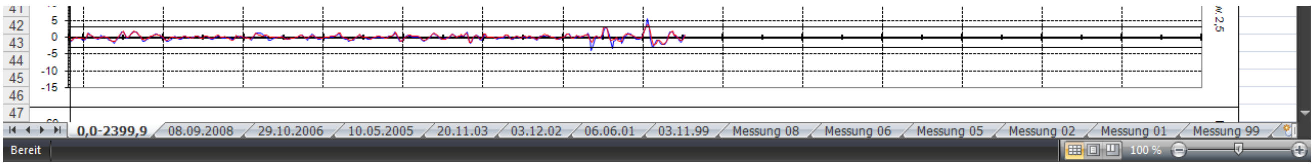


Figure 14: Buildup of a file for track inspection – consisting of a number of measurements and visual inspections.

12. Introduction of emergency measures

Purpose: The introduction of emergency measures serves to safeguard and/or restoration of operational safety and functionality of the railway. Emergency measures are executed as an immediate reaction to fault reports.

Method: The measurement results (Sub-process 9) captured in the framework of a fault report (Sub-process 4) and valued with a high priority (Error class 1 or FR_G) and faults (sub-process 10) are assigned as immediate actions, whereby maintenance tasks are ideally transferred to an ERP[8] system. Also the closure of sites or parts thereof is an emergency measure – as well as the creation of speed restricted sections.

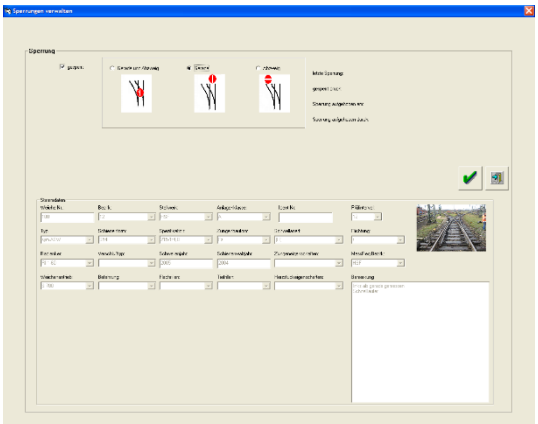


Figure 15: With MR.pro® turnouts can be closed separately under any condition of operation

Implementation MR.pro®: a data capture module for all kinds of incidents makes it easier to evaluate damage and faults, and through the object mapping provides a good interpretability (Figure 15). The commissioning of the maintenance can be carried out directly from the findings and will be documented, according to source and traceability, in the history Appendix (History file, Weak-point analysis). Tracks and turnouts can be individually closed under any situation. Closed infrastructure elements are also displayed in the RailMap.

[8] Enterprise-Resource-Planning (ERP) describes the task of planning available resources (Capital, Resources and Personnel) as efficiently as possible for the running of the infrastructure.

13. Planning of short-, medium- and long-term measures

Purpose: The purpose of short, medium and long-term planning is to optimise resources, taking full advantage of the wear margins through planable and condition-based maintenance of the facilities. This part of the process supports technically and economically sound planning - whereby short-term plans usually covering a 1-2 year span and medium- and long-term planning cover a period of >2 years.
Preventative maintenance also counts to the medium- and long-term actions besides the actions based on inspection and condition data. These may be triggered either time dependant or load dependant, like for example regular maintenance and service actions.

Method: The criteria for determining prioritisation, planning, management and budgeting are the previously defined infrastructure classes from sub-process 1, inventory data (track formations, railway objects, estimated lifespan), the evaluated and combined inspection results (only main inspection) and the subsequently derived and prioritised corrective maintenance out of sub-process 11. A monetary evaluation in manual form of the planned activities for each year is possible even without a direct ERP connection.
Supplementing this, findings of lifecycle management and evaluation of remaining hardware (wear margins of the infrastructure) of the transport infrastructure are of importance in the determination and planning of optimal renewal schedules. The results of maintenance planning are measures of different scope and time horizons.
Without visual support line elements can only be estimated with difficulty, therefore a clear graphic processing of results is of great importance. The representation of the relationships between several variables, such as gauge, cant and the direction of the track, is as important for the interpretation of the measurement results as it is to know the location of track structures and buildings as well as information relating to design (track specifications). These requirements are achieved by a tiered display of a number of parameters of the track section.

Implementation MR.pro®: For inventory and condition analysis, the software provides unique visualisations of relationships and dependencies, of the condition, age and type. An integrated statistics module allows for an evaluation of the current wear margin, the inspections and maintenance standards. The fault management allows an object-specific vulnerability assessment. All data can also be managed for each object in the form of digital history files for each object (Figure 17).
The track measurement results of a number of years are presented in sequence for a section of track and can be superimposed on a diagram. This clearly displays any trends in development of state (Figure 13).
Even multi-level tolerances (FR_{100}, FR_{lim}, FR_{G}) as well as nominal and tolerance specifications differentiated by track radius, e.g. track widening in a curve, are displayed graphically, and can be numerically evaluated.

The RailMap (Figure 17) is an interactive schematic track plan of the complete or partial network with bi-directional database interfacing which is used for the visualisation of state and inventory data (dynamic maps related to topic).
The RailMap presents all the infrastructure elements in a schematic expression and in a form related to the data base information (inventory maps and site inspection maps). For this existing CAD drawings can be imported and linked 1:1 with the database. Both complex and to-scale railway network plans, as used by tram, metro and light rail (Figure 20, Figure 22), as well as simple, schematic representations used for industrial railways (Figure 16) can be displayed.

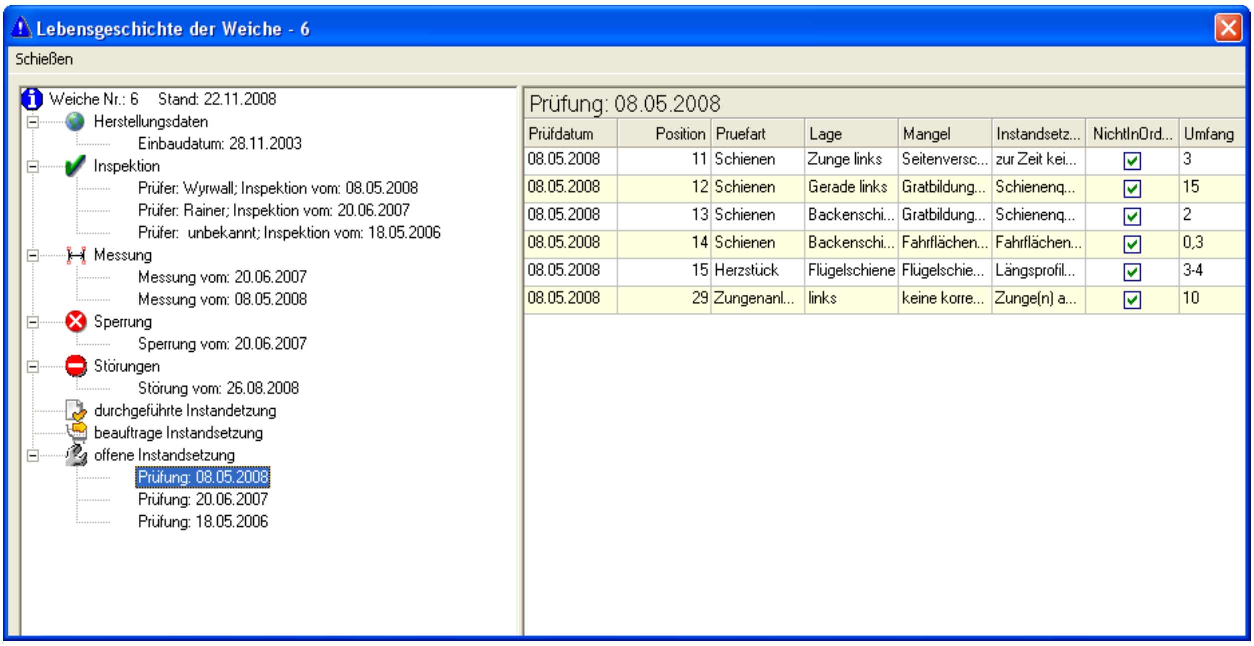


Figure 16: MR.pro® continuously gathers information about the entire life cycle - here for example of a switch. Due to the continuity of the system, all data will be collected once only - there where they arise. This minimizes the maintenance effort and increases the timeliness of data.

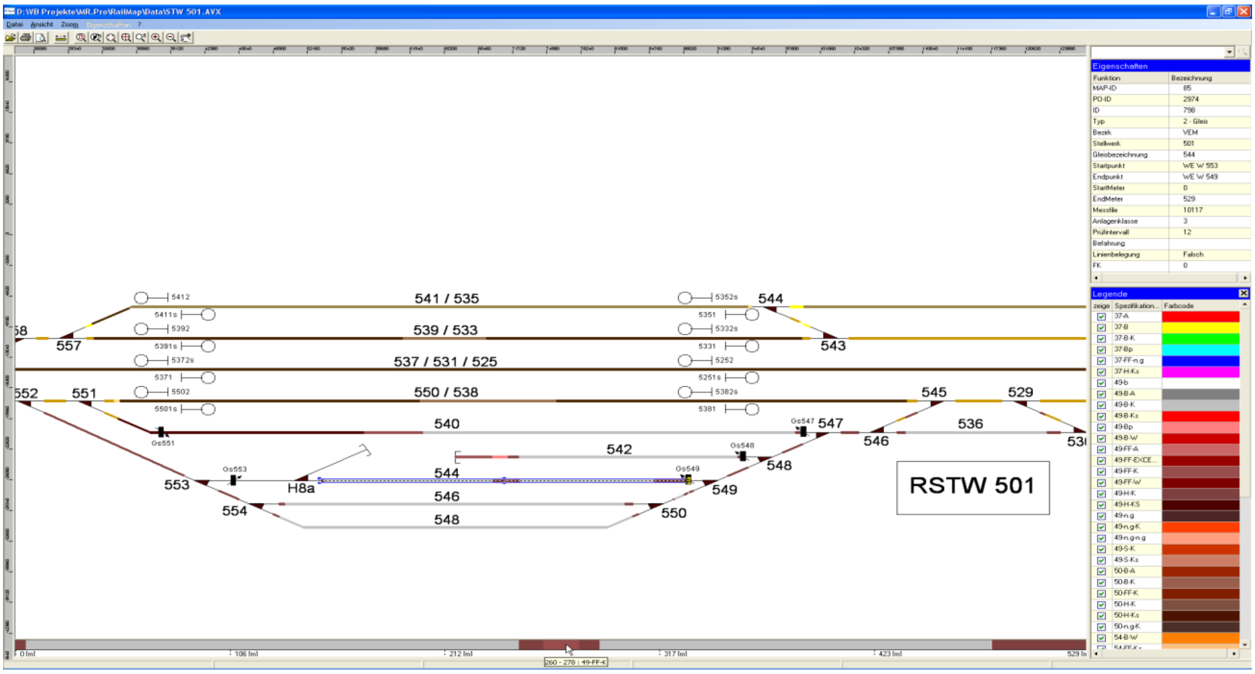


Figure 17: RailMap supports the presentation of dynamically generated track segments (dyn. Segmentation) and can thus present complex properties very realistically. Besides the construction forms which change over time, this applies to all condition data of the track. This example illustrates an industrial railway siding dissolved according to the superstructure types of tracks and turnouts.

14. Supporting the control during the implementation of the measures

Purpose: Maintenance measures serve to restore the infrastructure to its original condition by renewal, repair or maintenance.
In addition to the introduction of emergency procedures which resort to the unscheduled maintenance actions as described in sub-process 11, this sub-process is concerned with the implementation of predictable short-term maintenance measures as described in the short term planning of sub-process 13, i.e., the execution of predictable and non predictable maintenance measures in an agreed upon time, nature, scope and quality.

Method: The result of this sub-process is either a repaired (functional) or a renewed infrastructure element.

Implementation MR.pro®:
The software is ideally suited for the assignment and monitoring of orders. Proposed measures may result in self-directed jobs or may be outsourced (Figure 18). Requests for quotations may be generated and incoming offers can be compared. Contracts may be awarded, and then settled. The confirmation of a job assigns all related actions with the status “done”. Through the integration of Microsoft-Office[7] it is possible to compile query, analysis results and topic maps into Office documents and files. The integrated document management facility can accept and make available all project documents, right from the specifications through to the final acceptance, so that everybody concerned with the process remains up to date.

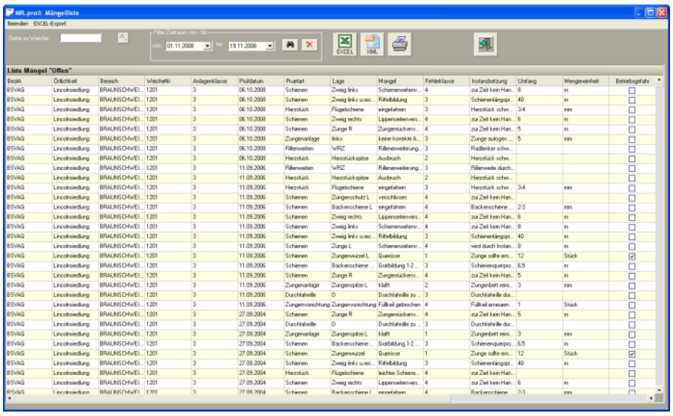


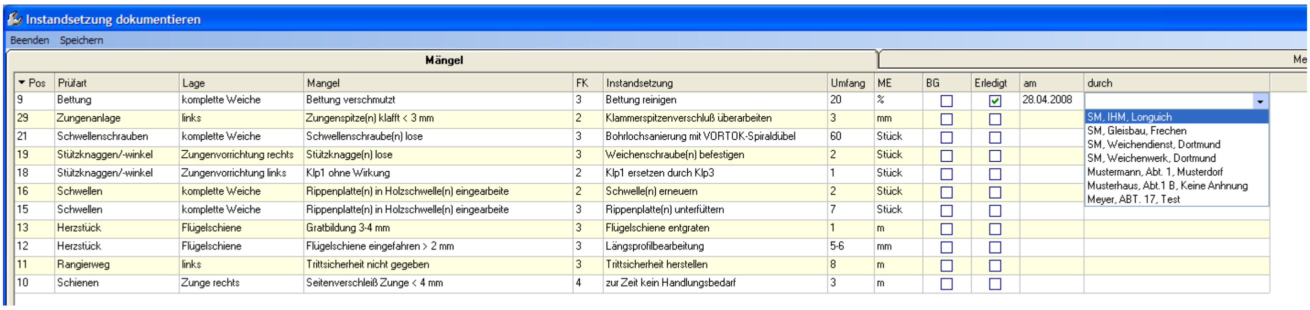
Figure 18: The result of the data capture - seen here as a compressed list of faults with a prioritised list of proposals, serves as a basis for costing and commissioning of maintenance tasks.

15. Documentation of the implemented measures

Purpose: In addition to the information concerning changes of condition, the completed maintenance measures as part of the infrastructure history, provide important information for maintenance decisions to be taken in the future. Furthermore it enhances the knowledge concerning the progression of wear and the success of maintenance measures.
Therefore the documentation of the conducted actions of sub-process 14, serve as both feedback for project management as well as to update the inventory and changes in condition data. The unambiguous assignment of the project documents to the respective infrastructure is therefore imperative.

Method: An important part of the project documentation is the acceptance, which at the same time marks the beginning of the warranty period and also has financial implications. Also here it is sensible to interface to an ERP system for audit and release of funds (Figure 3).
Completed emergency actions, as well as middle and long term maintenance measures and their relating inventory changes are updated by „job completed“ reports and the editing of relevant inventory and condition data. The result is an updated job status as well as updated inventory and condition data of the serviced infrastructure.
Implementation MR.pro®: The integrated tool triggers the ‘job completed’ report and allows the modifications of the infrastructure status based on the completed actions (Figure 19). The information system supports the project management in monitoring the job progress and the acceptance – whereby the documentation resulting during all phases can directly be allocated to the respective objects. Through the centralised data management all authorised users can access the current data. Changes in inventory data based on deviating construction types can be updated as easily as

changed measurement results due to maintenance and repair, without the necessity of conducting a full inspection. The integrated document management system allows fast access to any kind of centrally stored data.
The RailMap theme card „completed maintenance“ graphically displays the completed measures on the track map. Due to dynamic segmentation even smaller sections can be displayed proportionally (Figure 20).



Pos	Prüfart	Lage	Mangel	FK	Instandsetzung	Umfang	ME	BG	Erledigt	am	durch
9	Bettung	komplette Weiche	Bettung verschmutzt	3	Bettung reinigen	20	%	☐	☑	28.04.2008	
29	Zungenanlage	links	Zungenspitze(n) klafft < 3 mm	2	Klammerspitzenverschluß überarbeiten	3	mm	☐	☐		
21	Schwellenschrauben	komplette Weiche	Schwellenschraube(n) lose	3	Bohrlochsanierung mit VORTOK-Spiraldübel	60	Stück	☐	☐		
19	Stützknaggen/-winkel	Zungenvorrichtung rechts	Stützknagge(n) lose	3	Weichenschraube(n) befestigen	2	Stück	☐	☐		
18	Stützknaggen/-winkel	Zungenvorrichtung links	Klp1 ohne Wirkung	2	Klp1 ersetzen durch Klp3	1	Stück	☐	☐		
16	Schwellen	komplette Weiche	Rippenplatte(n) in Holzschwelle(n) eingearbeite	2	Schwelle(n) erneuern	2	Stück	☐	☐		
15	Schwellen	komplette Weiche	Rippenplatte(n) in Holzschwelle(n) eingearbeite	3	Rippenplatte(n) unterfüttern	7	Stück	☐	☐		
13	Herzstück	Flügelschiene	Gratbildung 3-4 mm	3	Flügelschiene entgraten	1	m	☐	☐		
12	Herzstück	Flügelschiene	Flügelschiene eingefahren > 2 mm	3	Längsprofilbearbeitung	5-6	mm	☐	☐		
11	Rangierweg	links	Trittsicherheit nicht gegeben	3	Trittsicherheit herstellen	8	m	☐	☐		
10	Schienen	Zunge rechts	Seitenverschleiß Zunge < 4 mm	4	zur Zeit kein Handlungsbedarf	3	m	☐	☐		

Figure 19: Documentation of the implemented measures with MR.pro®

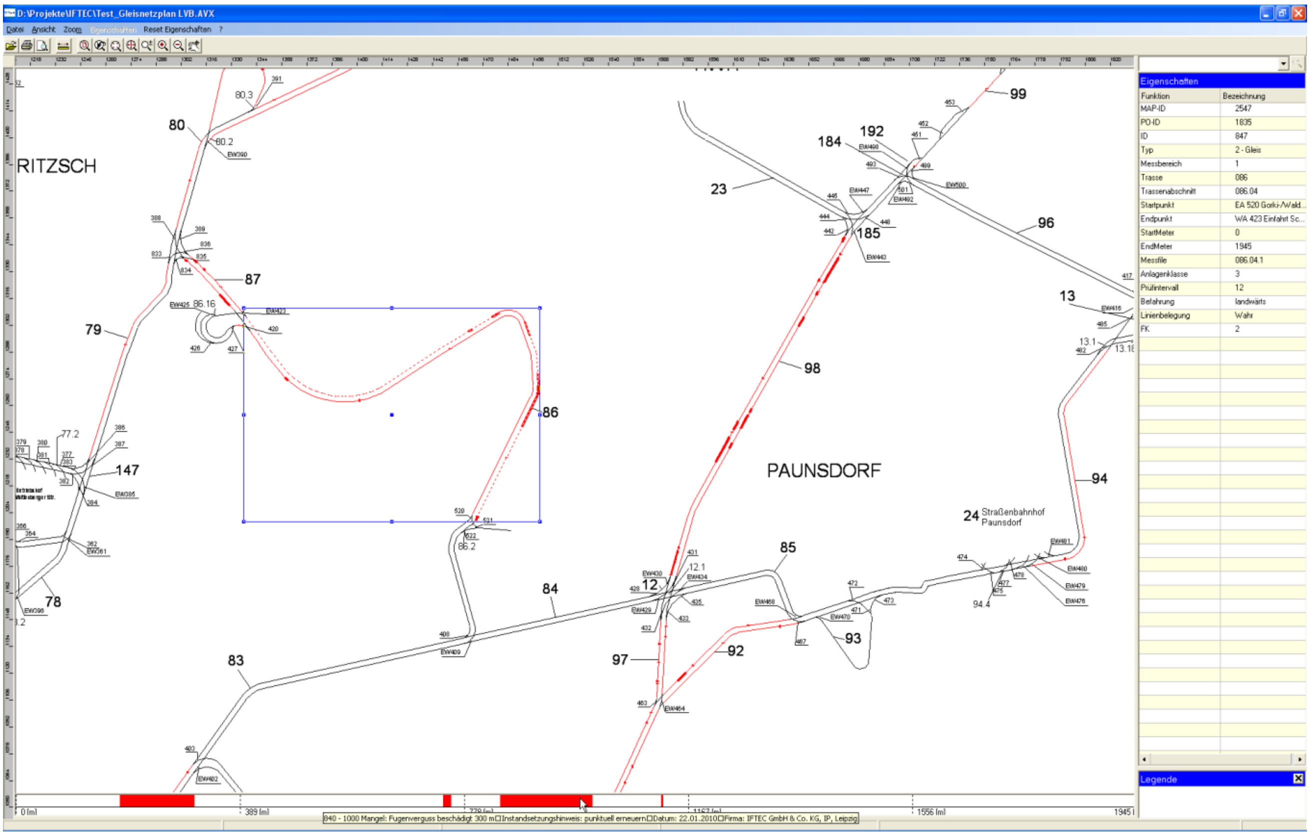


Figure 20: The completed maintenance measures can also be displayed visually by RailMap. The above image displays the maintenance carried out during 2009. With the help of dynamic segmentation tracks can be subdivided into and realistically displayed in an arbitrary number of subsections.

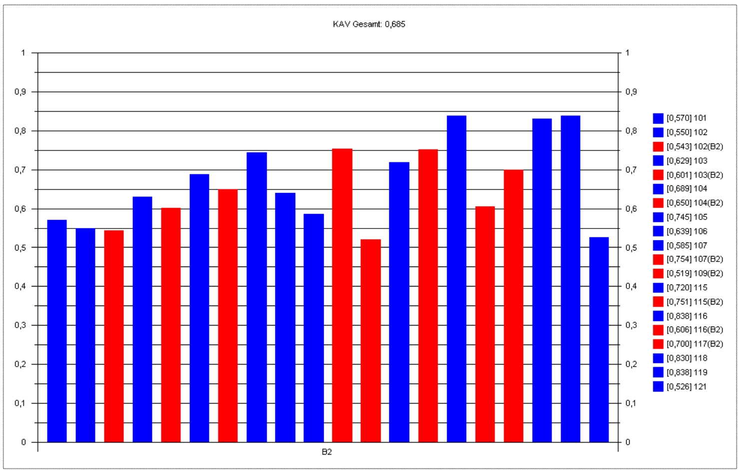
16. Quality assessment of the implemented measures

Purpose: To evaluate the success of the actions conducted in sub-process 14 and the documentation of sub-process 15, a comparison between the newly repaired condition and the infrastructure specifications takes place. Respectively also the technical maintenance specifications are compared under consideration of the previous condition data which triggered the maintenance measure.

Method: This is done either in the context of project management, immediately during the acceptance inspection or within the framework of an inspection following the maintenance. In addition, the monitoring of warranty periods and the timely execution of quality checks (before the expiry of the warranty) is a subject of maintenance management. For continuous quality monitoring it is suitable to use an automated warranty monitoring system to, on the one hand, identify recurring faults or faults of the same class within a track network or track object, and to separately check for claims, and on the other hand to be used as input for weak-point assessments.
Completed and documented measures resulting out of emergency measures and midium- or long-term planning - compared with the results of subsequent inspections represent the major input for this sub-process.

Figure 21: Overview of the rail infrastructure wear margin.
The evaluation results of the wear margin (Kennziffer Abnutzungsvorrat KAV®) are displayed, whereby both the values of the individual track districts consisting of tracks, turnouts and crossings, as well as the combined value of the track infrastructure (KAV 0,885 = 88,5 %) are clearly visible.
The comparison of the KAV over a couple of years clearly shows the development of the wear margin of the track infrastructure.

1 = 100 % wear margin (in new condition)
0,5 = 50 %
0 = 0 %



Implementation MR.pro®: The software already during the capture of a new fault of a specific category compares the data with the historical data of the past and reliably shows any possible warranty claims, in case a similar type of fault has already been recorded and issued for this warranty period of this object. Thus, for example, the system warns when during the recording of a fault in the area of the heart of a turnout, if a similar repair has already been conducted on this object during the last two years.

Similar as during the planning, the question also arises in connection with the evaluation of the system quality as to the correct point of renewal. Hereby the remaining wear margin of the infrastructure is of particular significance. MR.pro® assists the user in determining the current residual wear margin (the remaining substance in %) of infrastructure objects with the technical reference wear margin KAV®[9] (Figure 21).
Further MR.pro® also has a practical module "life cycle management" that supports the medium-and long-term maintenance planning to determine the optimal timing for renewal. The entire system history is available for fault analysis and the determination of weak points. Also here evaluations can clearly and understandably be visualised by means of the integrated RailMap viewer.

IV. Successful implementation - guaranteed

[9] Empirical method for the calculation of the current residual wear margin of the infrastructure (Remaining substance of objects, areas, networks) to determine the current level of wear and the reproducible remaining duration of usage.

The establishment of an infrastructure data management system is a complex task that requires a structured and strict results-oriented approach. Detail and structure of the data should be based on IDMVU standards and should be adapted to the requirements of the users, as the maintenance effort associated with each data base field can be quite substantial.

To create a reliable data base, consistent and up-to-date inventory information of the network infrastructure is a basic prerequisite. Due to the heterogeneous and changing construction types within the track network this is an important and necessary task. If the inventory of an infrastructure takes a longer period of time the validity of the objects inspected first, might already be questionable. It is therefore recommended to execute a concentrated data capture of the complete railway network or sub-sections thereof. The successive inspection of sub-networks and/or the network equipment can be useful, if the inspection takes place within a closed period of time during which no significant changes in the inventory and condition of the facility occurs. The data base "track" should in terms of the order of data capture always form the beginning.

Some railway network operators manage the transition into the digital infrastructure data management (IDM) at first go, because they use a combination of service as well as software and hardware – in other words a "ready to work" solution.

Schreck-Mieves calls this combination solution **„Simplify Database for tracks“** which in the shortest possible time provides a reliable data overview of the inventory and condition information. First of all the meaningful information required for maintenance planning and control is pre-configured in co-operation with the operator.
These are details of assessment and classification procedures which have already been determined in advance, interfaces and processing of state information in planning and/or Geographical Information Systems (GIS). In the further implementation the specialists of Schreck-Mieves – generally in co-operation with the professional staff of the transportation company - create a complete data base of the tracks and turnouts while conducting the inventory.
MR.pro® is installed, tailor made for the customer with all inventory and condition data. The inspection equipment is handed over to the operator after intensive training, and finally the „flying start“ is professionally supported and supervised.

Also the evaluation of the infrastructure wear margin – as a technical reference of the wear margin KAV®, can in this relation be fine tuned to the operational specifics of the site and can be practically realised.

The underlying data structure allows for a transfer of data into corresponding planning and control systems as well as corporate information systems. Both the data model and the interface format of the IDMVU are supported by MR.pro ®.

For more information see: www.mr-pro.de

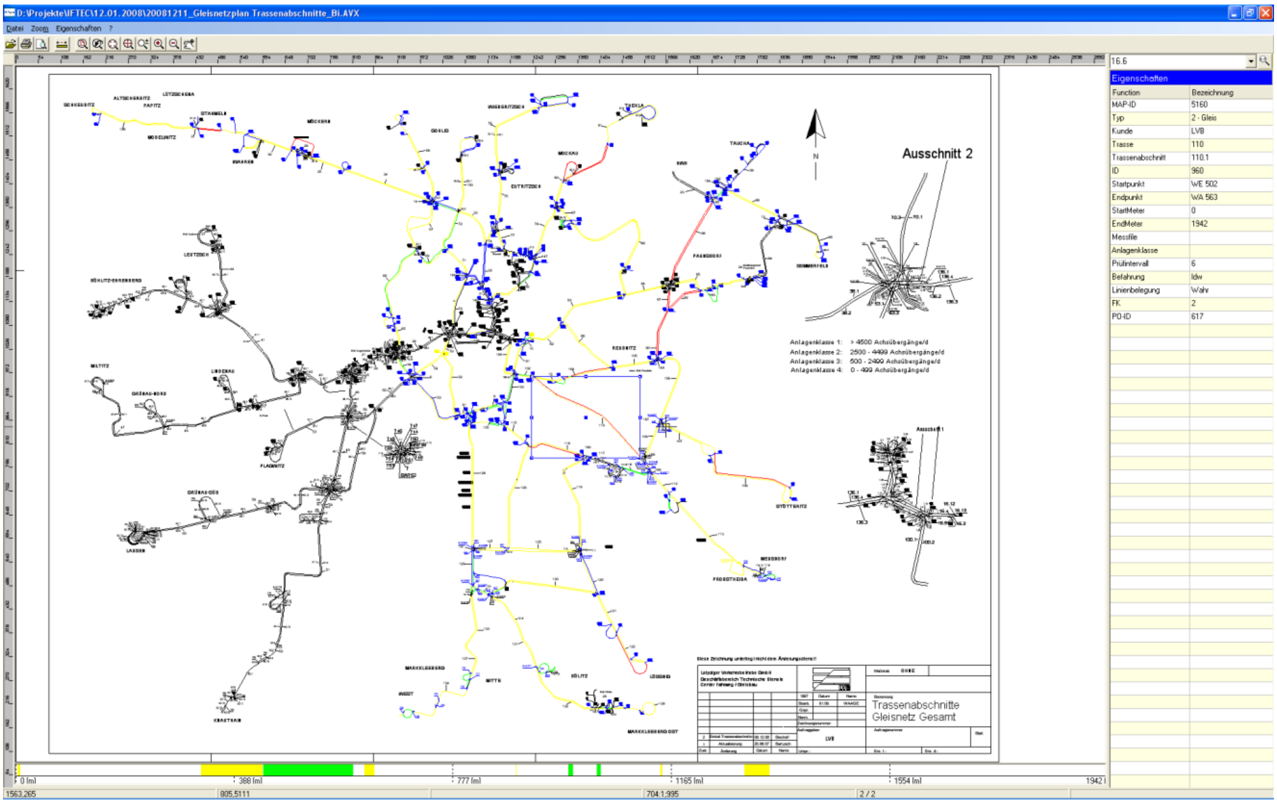


Figure 22: The integrated RailMap of MR.pro® besides offering a good overview of condition, also offers direct access to inventory and condition data as well as all associated documents - even for large networks. Shown is the track related fault distribution (error class) within the activated track section 16.6.
(Source: IFTEC, Network of the Leipzig transportation company)

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