Track Management Solution MR.pro® for the Milan Tram network

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Abstract: German
Einer der größten Straßenbahnbetriebe der Welt, ATM Milano, hat die Balfour Beatty Tochter Schreck-Mieves im Sommer 2010 mit der Implementierung einer „ready-to-work" Lösung zum Aufbau eines Informationssystems für das Management der Gleisnetzinstandhaltung beauftragt.
Die von Schreck-Mieves entwickelte standardisierte Fehlerklassifizierung und Digitalisierung des Gleisnetzes konnte innerhalb kürzester Zeit (3 Monate) im Rahmen einer sog. Inventurinspektion, die zur Erfassung und Bewertung der Bestands- und Zustandsdaten, und der Ableitung priorisierter Instandsetzungsmaßnahmen dient, unter Anwendung der Software MR.pro® erfolgreich umgesetzt werden. MR.pro® stellt darüber hinaus alle, für die Planung und Steuerung der Instandhaltung erforderlichen technischen Informationen zur Verfügung, die neben der Prozessoptimierung ein echtes Lifecycle Management ermöglichen.
Mit den vielfältigen Visualisierungsmöglichkeiten von MR.pro® erhält ATM Milano wertvolle Entscheidungs- und Planungshilfen und ein hohes Maß an Transparenz für eine praktikable und wirtschaftliche Anlageninstandhaltung.

Abstract English
One of the world's largest tram network operators, ATM Milano, has during summer 2010 tasked Schreck-Mieves, a Balfour Beatty company, for the implementation of a ready-to-work solution of an information system for the management and maintenance of their tram network.
The standardised system of fault classification and digitisation of the tram network could be implemented within a short period of 3 months as a so called inventory inspection. This serves to capture and evaluate the inventory and condition data of the network as well as the determination of prioritised maintenance measures through the use of the MR.pro® software. Further MR.pro® provides all necessary technical information required for the planning and control of maintenance. Besides the optimisation of processes this also allows for real lifecycle management.
Along with the numerous display functions of MR.pro®, Milano has aquired a valuable planning and decision tool with a high level of transparency for practical and economic maintenance management

1. Initial situation

Azienda Trasporti Milanesi also known as ATM Milano, is the communal light rail operator of the north Italian city of Milano. ATM is reponsible for the operation of the underground-, tram-, trolleybus- and bus-networks. The Milano tram network is one of the most traditional tram networks of Italy with a vast network. The network comprises of 19 lines with a total length of approx. 300 kilometers. This makes it one of the largest tram networks of the world.

Fig 1: With it's 1,4 million inhabitants, the industrial metropolis of Milano still has in operation a number of pre-war trams of U.S. construction.

Besides the daily operation ATM Milano is also responsible for the maintenance of tracks as well as vehicles, and thus opted for a mix of condition based and preventative maintenance.
In view of the 2015 Expo, numerous improvements and modifications of the infrastructure are envisaged - which require additional information for decision making

To date a daughter company of ATM conducted the inspection of the Milano network. The collected data was managed de-centrally at the respective operator and not corelated with each other. Due to the distributed data location it was not possible to combine the measurement results with the visual inspection results. This fulfilled the safety aspects of the inspection, but did however not support condition-based planning and feedback for effective maintenance.

Fig 2: Mechanical as well as visual data capture in front of the historical backdrop of the dome of Milano

Further ATM was searching for a practical possibility of checking the maintenance strategy of individual sites or elements in order to optimise their strategy mix. Up-to-date information relating to the condition development and availability of the site should actively support decision making on maintenance.

Decisive factors for the ATM decision were:

- Holistic overview through visual assessment and mechanical measurements as a whole
- Ergonomic data capture with categorisation of the faults by pre-defined fault classes and prioritised maintenance measures
- Condition assessment of individual track elements that are grouped into track segemnts as well as overall networks with their history
- Generation of proposals of action (budget plans) based on a catalog of measures defined directly out of the findings
- Interactive site plan with bi-directional database interfacing to visualise conditional and inventory information
- Visualisation of correlation and dependancies of condition,age and construction type
- Standard reporting of inspection results and compulsory documentation, fast access to data for further evaluation and proof
- Control of scheduled work, such as audits, inspections, warranties, etc.
- Datastructure which allows interfacing with other planning and control systems.

2. Data aquisition

Out of experience the Italians know that in order to establish a reliable database it is a prerequisite to have consistant and up-to-date inventory information. They also know that this is a task not to be underestimated, given the diversity and variety of designs within the tram network.
During the year 2010 ATM decided to implement the maintenance management system of Schreck-Mieves (S-M) for a systematic development of a well structured infrastructure data management system. To capture the required data within the shortest period of time, an "inventory-inspection" of the whole tram network was selected. Simultaneous the data was implemented into a technical information system as a complete solution.

The condition data capture (inspection) generally takes place in the form of a visual track inspection along with mechanical measuring. The combination of inventory- and condition data capture, a so called "inventory inspection" has proven to be very efficient when inventory data is not available or incomplete. In this way all required inventory and condition data can be captured and made available very timely. Railway sites can be linearly referenced and segmented within the framework of a continuous measurement and visual inspection. Parallel to the measuring of geometry, length, coordinates and rail profiles a visual inspection of design, configuration, age, manufacturer, etc. takes place. At the same time all deviations from the specified values which are not measured are visually captured by qualified technicians and are avaluated with regard to their maintenance needs. In this context suitable correction measures for each detected fault can be deducted on-site with respect to scope and priority. Further the aim of the visual inspection is to detect the source of a fault and to propose appropriate corrections. Typical faults are transverse and logitudinal profile errors and track surface irregularities such as corrugation and weld defects which can be the source for noise and vibration. The visual inspection as a rule also includes checking the condition of the track cover (paving) and joints (joint sealant) as well as noting the age and condition of sleepers and tracks. All this information is fed directly into the IT-system. The IDMVU-condition data model (Infrastruktur Daten Management für Verkehrsunternehmen[1]) determines the required data structure as well as a normed interface format for the data transfer.

Inspections deliver the required information required for the planning and control of maintenance – whereby deviations from the technical norm condition are determined as faults[2]. In order to assess their effect on the safe operation of the system and thus to prioritise their removal, the categorisation into four fault classes has proven itself in practice. The same classification is also used for the management of the considerable amounts of data (on average about 15 Megabyte of primary measurement data is collected per km of track) which are generated by the continuously recording electronic measuring instruments. In order not to loose the overview of these masses of data, it is summarised into 4 condition categories. Such categorisation considerably contributes towards focusing on the essential.

The track quality and the boarder values of individual faults are important parameters for the infrastructure which are required for the definition of the interface between vehicle and track. The track quality stands in direct correlation to:

- the safety preventing derailment
- the economical life-spann and the progress of wear and tear
- the valuation of a vehicle on acceptance testing
- the durability of wheelsets and bogies.

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[1] The research project Ifrastructure data management for transport operators (Infrastruktur-Daten-Management für Verkehrsunternehmen (IDMVU)) has developed a data model, which allows the system neutral imaging of the infrastructure. It describes a qualified foundation, clear definitions and object descriptions as well as an interface standard.
[2] Fault always refers to the negative deviation from a defined norm, whilst a damage is a negative change on the grounds of a fault.

Within a geometric track bed it is differentiated between the outer and inner geometry of the track bed. The outer geometry describes the track bed with reference to geographically measured fixed points. The inner geometry describes the form of the track superstructure[3].
Schreck-Mieves measures the inner geometry of the tracks in a continuous unloaded method with the universal digital EMA measurement machine from the German manufacturer Vogel & Plötscher.

Digital measurement machines for the inspection of tracks and turnouts represent state-of-the-art technology. Tracks are measured in a continuous fashion while turnouts are inspected non-continuous. Because the inspection effort requires overall overview of the condition evaluation and the measurements this is realised as one unit. The faults are weighted according to predefined fault classes as well as the application of multi-level tolerance limits. This is supported by the on-site electronic data capture. The generation of maintenance suggestions is on the one hand generated directly out of the inspection results on the basis of a fault-class-maintenance-catalogue, and on the other hand it is coupled to the vast experience in determining the optimum point of replacement.

The beginning of this process started with the structured inventorisation of the complete Milano tram network, which Schreck-Mieves conducted with the aid of their own software MR.pro® within the shortest period of time. Under the contract and with the local support of Balfour Beatty Rail Italy (Milano), the inventory data and the condition of the tracks were captured, evaluated and transferred into a new database in one process step. Although work was only possible at night during the operational breaks (1-5 o'clock), the assessment of the complete network only took 10 weeks. An investment which paid off for ATM – because a timely all-round inventory guarantees the relevance of the data – which is rather questionable with a successive approach[4].

<u>The data collection in detail:</u>

* Organisation of measurement sections
  - Segmenting the network into sections of a min. of 50 and a max. of 1.500 m lengths
  - Local allocation by numbering and marking in site maps

* Measurement and registration by the EMA UNI precision machine
  Chord: 5.000 mm, Sample frequency: 10 mm
  capturing the following parameters:
  - Gauge (1445 +35/-10mm)
  - Cant (+/-200mm)
  - Twist/Warp (+/- 25mm)
  - Versed sine (+/- 180mm) Rmin = 17,5m
  - Gradient (+/- 10mm)
  - Distance (m)

* Rail scan (See figure 6)
  Continuous scan and quantification of the rail condition by means of
  Laser technology with a sampling rate of 50 cm – comprising of 4 rail profiles
  per meter of track (2 x left, 2 x right rail).
  Capture, quantification and documentation of:
  - side wear of rail head (Delta s1)
  - side wear of guide rail (Delta s2) with groved rails
  - vertical wear of rail head Wear in height (Delta h)

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[3] Roesch, M.: Moderne Gleismessfahrzeuge für den Nachweis der qualitätsgerechten Bauausführung. Eisenbahn Ingenieur (55) 9/2004, S. 48.
[4] Vergleichbare Verkehrsunternehmen benötigen im Durchschnitt 1,5 bis 2 Jahre für eine derartige Netzdigitalisierung.

* Visual inspection and inventory data capture
Visual inspection using the checklist ’track inspection’ of condition, wear and completeness of the superstructure and immediate surroundings. Assessment and prioritisation of the identified faults according to fault classes (according to a standard fault class – maintenance - catalogue). Determining the cause for operational limit exceedances and allocating the identified faults to the mileage. Linking the track specifications to the mileage (type of surface cover, structures and if available the fastenning type, sleeper type and rail form).

Fig 3: The data capture modules of MR.pro® are designed to the specific needs of track, and present the user with a comprehensive view of condition assessment and measurements as an entity

3. Maintenance concept

If tracks are inspected by different persons this in general results in a mix of subjective opinions. According to the background knowledge and experience of the involved persons, the assessed faults and their need for maintenance will be interpreted differently.

With the implementation of a catalogue of maintenance measures independant of assessment (a so called fault catalogue) a uniform procedure of classification and prioritisation of faults has been created in Milano. Each Fault is already evaluated withn its assigned class during its assessment (See **Fehler! Verweisquelle konnte nicht gefunden werden.**).
Digital terminals are used which support a menu driven "online collection" and all inspection results are ready and available immediately after the condition assessment. This results in a significant time saving because duplication is avoided and only complete inspection reports are generated.

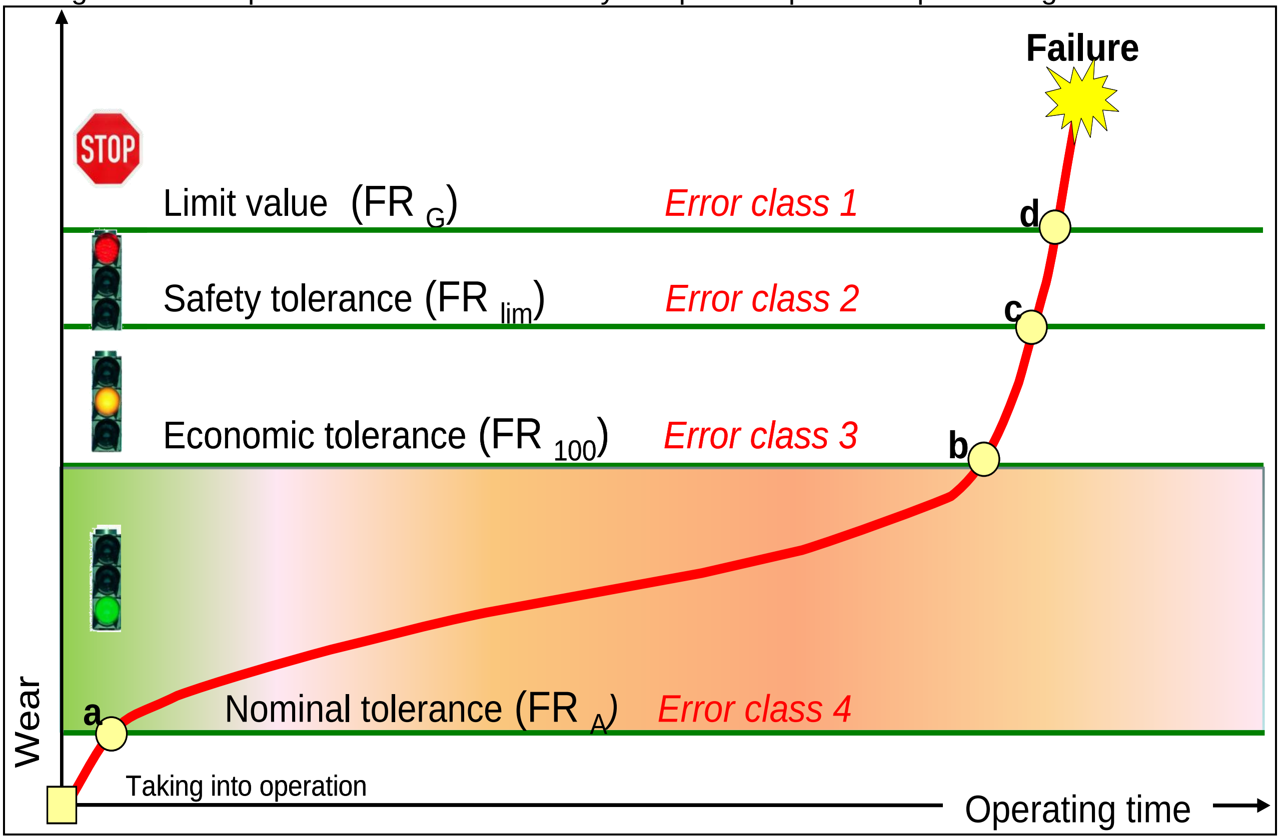

Fig 4: Schematic development of wear with evaluation limits: Tolerances (for the classification of measurement results) und fault classes (for classification of results out of visual inspections).

In order to support the ease of interpretation of the results, multi-level tolerances, SR_A, SR_{100}, SR_{lim}, SR_G were introduced. These allow for differentiated "fault-maintenance-schedules" to be made, contrary to the knock out-criterium of the single-level tolerance. In the event of breaching a tolerance it is necessary to react within a time limit as specified between user and maintainer.

The TSI[5] and DIN EN 13848-5:2008-06[6] define the following:

1. Immediate Action Limit — IAL (Grenzwert): refers to the value obove which the track operator has to take measures to reduce the risk of derailment to an acceptable level. This can be achieved by either closing the section, reducing the speed limit or by correcting the track geometry.

2. Intervention Limit — IL (Sicherheitstoleranz): refers to the value obove which corrective maintenance has to be undertaken to prevent reaching the “Immediate Action Limit” before the next inspection. The level of maintenance depends on the correct maintenance policy, the inspection intervals and the frequency of fault occurences.

3. Alert Limit — AL (Wirtschaftliche Toleranz): refers to the value above which the condition of the track geometry needs to be analysed and considered within the framework of the scheduled maintenance work.

4. Nominal tolerance: may be used as a further level of quality for the acceptance after maintenance, e. g. FR_A.

As a rule 4 categories are used for the evaluation of measurement data (graded tolerance levels) which are defined in a so called fault class - maintenance measure - catalogue specified for each site. This contributes considerably to a unified language ruling:

Mesurement		DIN EN[10]/TSI[11]	Visual inspection
a = FR_A	Nominal tolerance	optional	Fault class 4
b = FR_{100}	Economic tolerance	AL	Fault class 3
c = FR_{lim}	Safety tolerance	IL	Fault class 2
d = FR_G	Limit value	IAL	Fault class 1

Without visual support it is difficult to assess line elements therefore great importace is assigned to the clear graphic processing of the track inspection results. The presentation of the relationship between several variables such as gauge, cant and allignment is equally important for the interpretation of the results as is the position of track elements and structures as well as track specifications. These requirements are met by a scaled representation of a multiple of measurements

[5] TSI = Technische Spezifikationen für die Interoperabilität des transeuropäischen Hochgeschwindigkeitsbahnsystems
[6] DIN EN 13848-5 legt als EU-Norm die Mindestanforderungen für die Qualitätsstufen der Gleisgeometrie fest und definiert Sicherheitsgrenzen.

on the measured section.

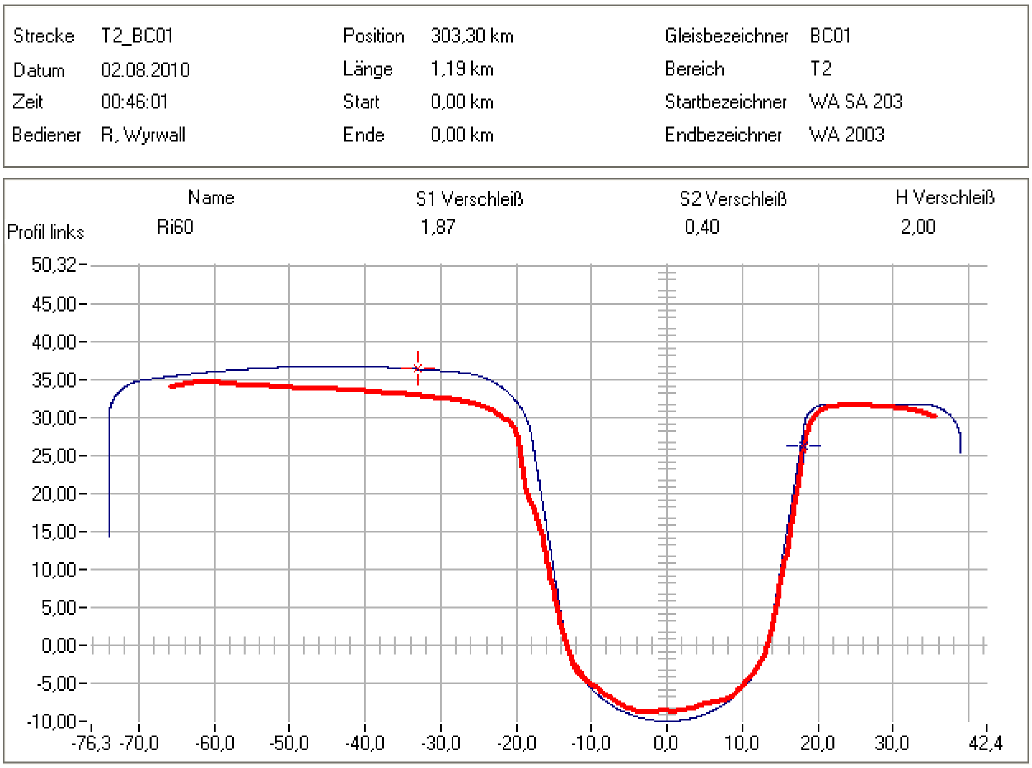

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Fig 6: The scan technology used by S-M delivers the actual rail wear besides the static cross-sectional profile (compared to a new profile) and continuously quantifies these values.

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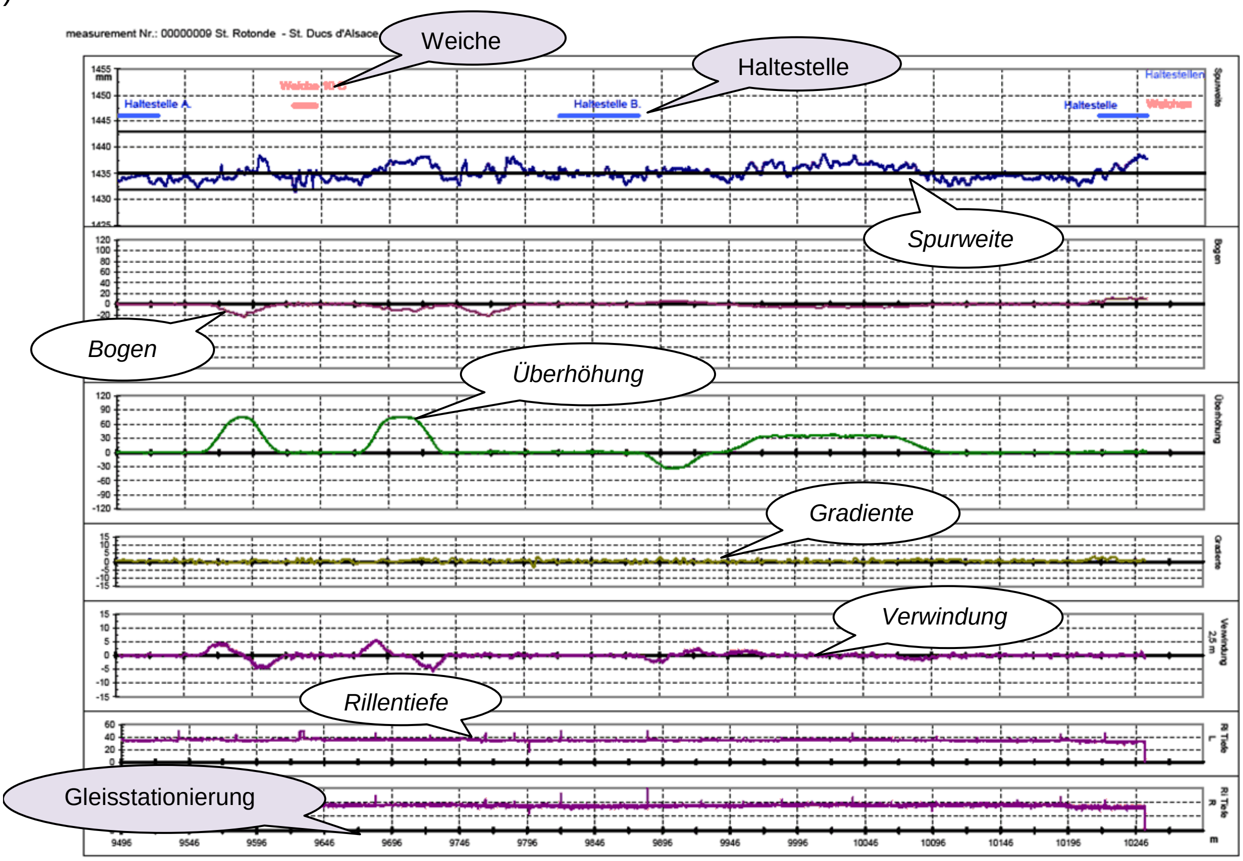

Fig 5: The results of a digital track geometry measurement show the different parameters along the distance on the common x-axis. Several years of measurements are superimposed to illustrate the rate of change.

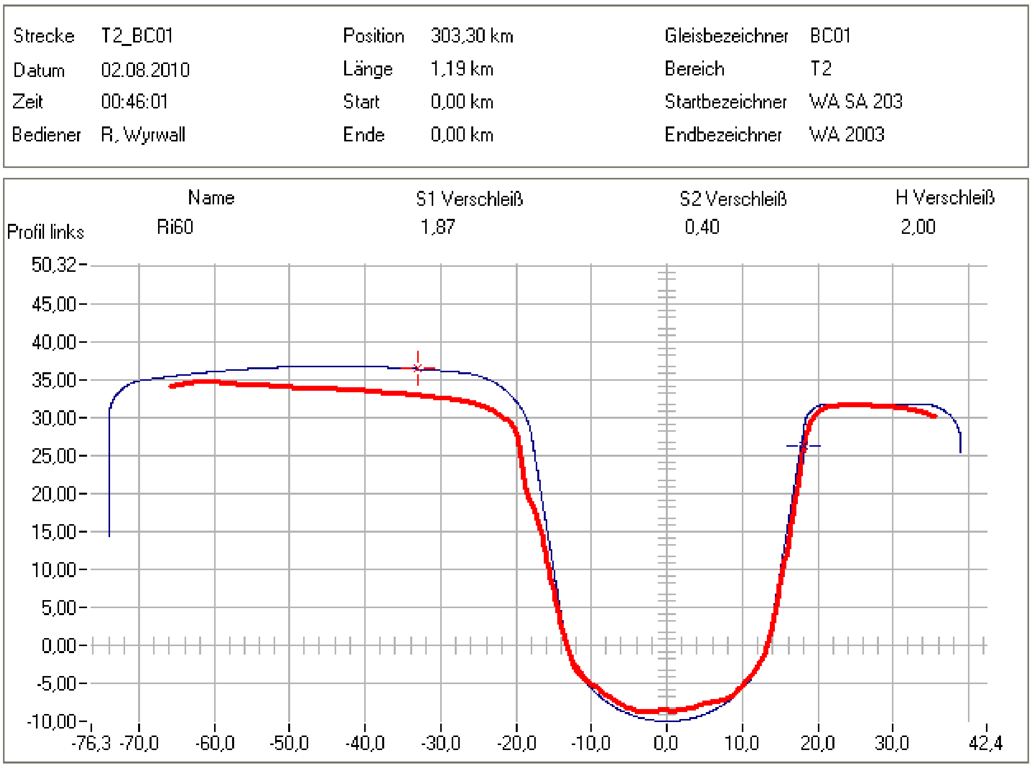

Fig 6: The scan technology used by S-M delivers the actual rail wear besides the static cross-sectional profile (compared to a new profile) and continuously quantifies these values.

4 Infrastructure Data Management

As with all light rail operators the predominantly manual maintenance work is significantly dependant on the operational line schedules – therefore the planning, preparation and control of maintenance within ever shorter time slots is becoming more and more significant.

For precise maintenance planning it is a prerequisite to have a reliable overview of the condition and development of wear of a site. Because a site can only be maintained economically to a certain degree (economic life span), it is also necessary to have the knowledge of type and specification of the objects as well as their operational loads to determine the optimal point of renewal. The complexities of the planning tasks increase since a number of different aspects have to be considered.
The technical information systems which, with little effort, capture, monitor and deliver precise forecasts for the development of wear, are indispensable for these process steps. Particularly operators with larger networks can't manage without the practical IT support for the provision of up-to-date operational, inventory, condition and history data as input to their decision making.

With MR.pro® ATM Milano has aquired a combined system which besides the capture and evaluation of track networks also provides a database of processed and categorised information of the network condition and inventory for the planning and control of maintenance.
Because MR.pro® has been tailored for the specific requirements of tracks, it allows comprehensive analysees, right from a compressed overview of the complete network, down to the conditional development of single component.
This includes comprehensive alphanumeric and graphic analysis tools for the evaluation and visualisation of track infrastructure (including necessary maintenance and service measures).

Optional interfaces ensure the connection to upstream or downstream information systems such as SAP or GIS-systems

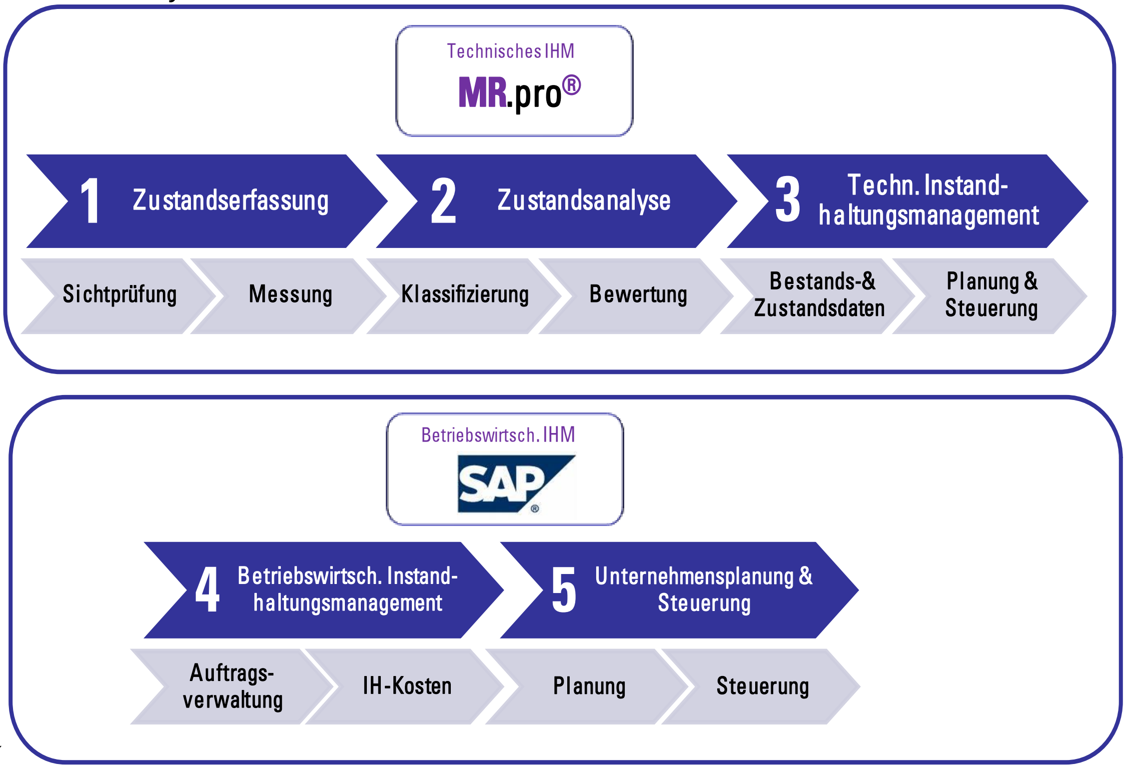

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Fig 7: Two software systems for all tasks of maintenance management: Technical = MR.pro® Comercial = SAP PM. The underlying data structure allows data transfer to corresponding enterprise information systems.

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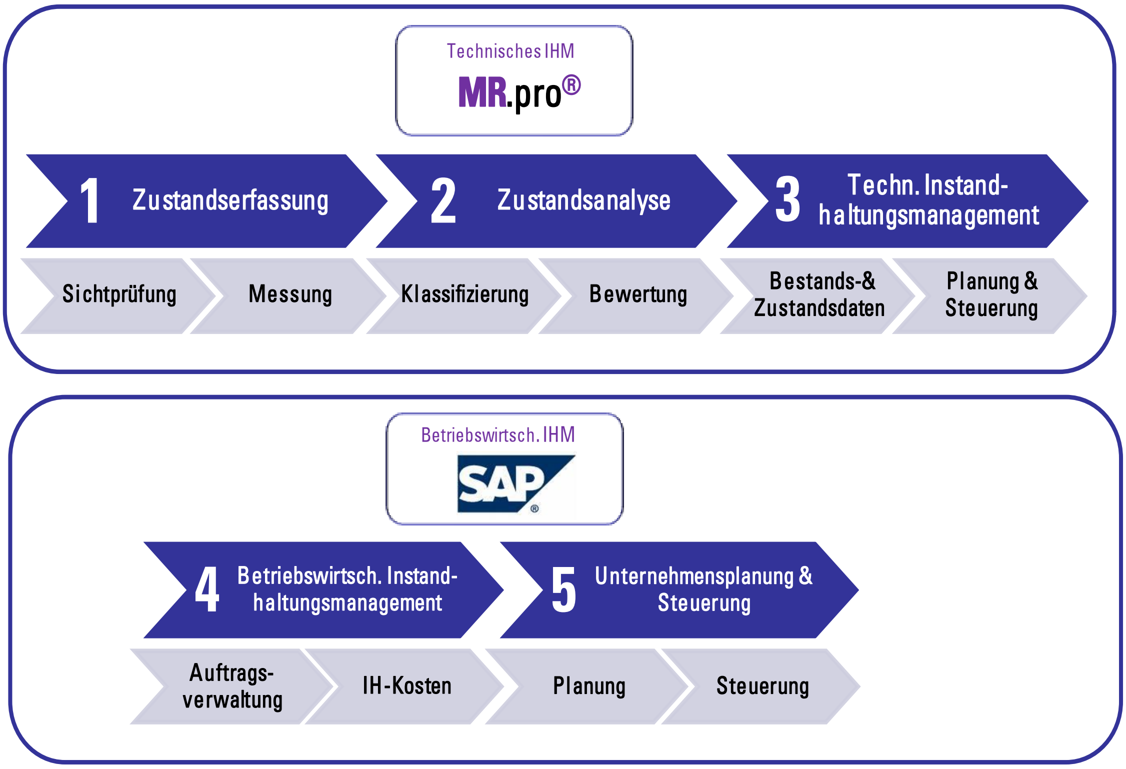


Fig 7: Two software systems for all tasks of maintenance management: Technical = MR.pro® Comercial = SAP PM. The underlying data structure allows data transfer to corresponding enterprise information systems.

The complete Milano tram network is displayed in a scematic track map (RailMap), the basis of which is an existing CAD-drawing which has been imported into MR.pro® (Fig. 8). An employee of ATM could in a short period of time link all imported vector drawing objects to the database. Since then each user could not only call up the inventory and condition data of each infrastructure object, but could also initiate topic related evaluations because all elements can be displayed in colour. Database queries such as construction type, age or condition of objects allow a unique visualisation of relations and dependabilities. Also very useful is the integrated statistics module which allows for timely evaluation of inventory, inspections and maintenance standards.

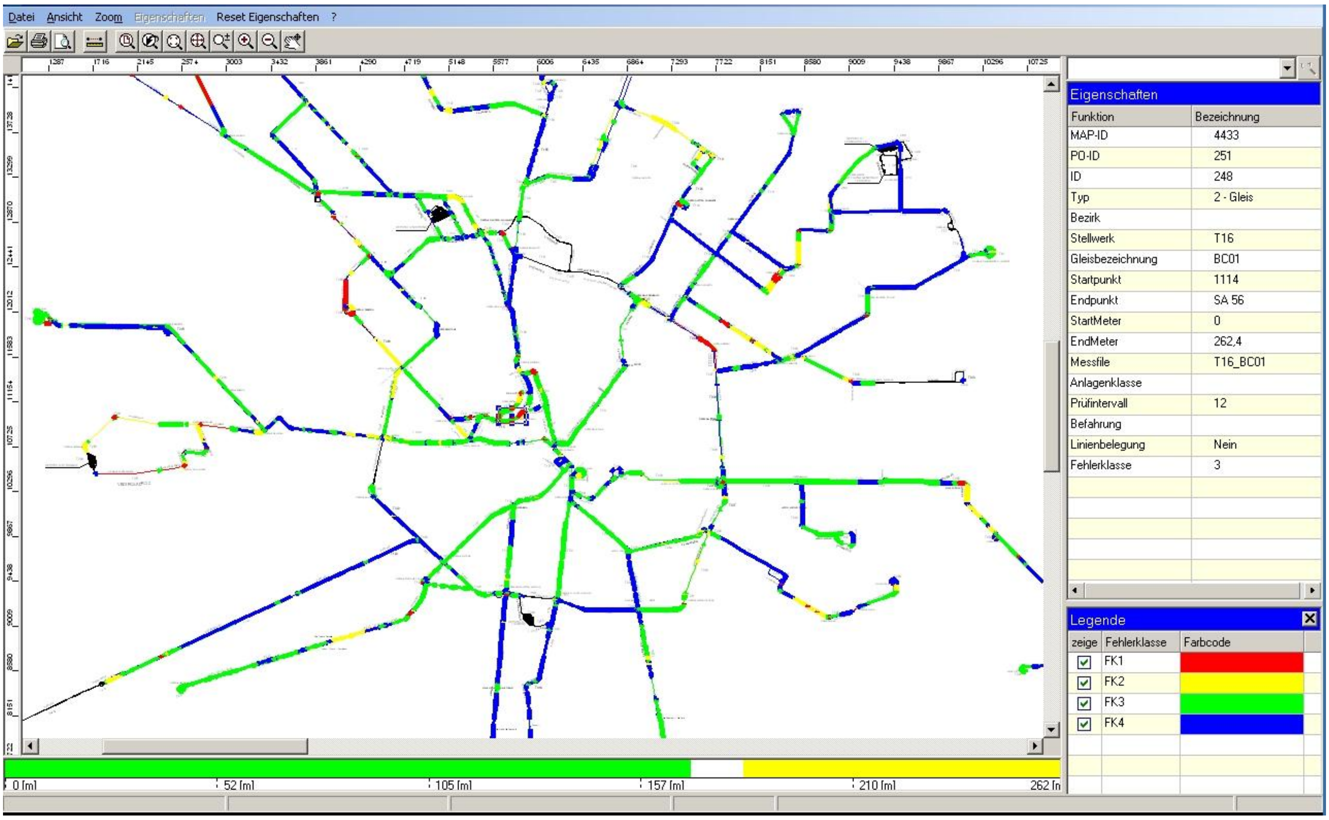
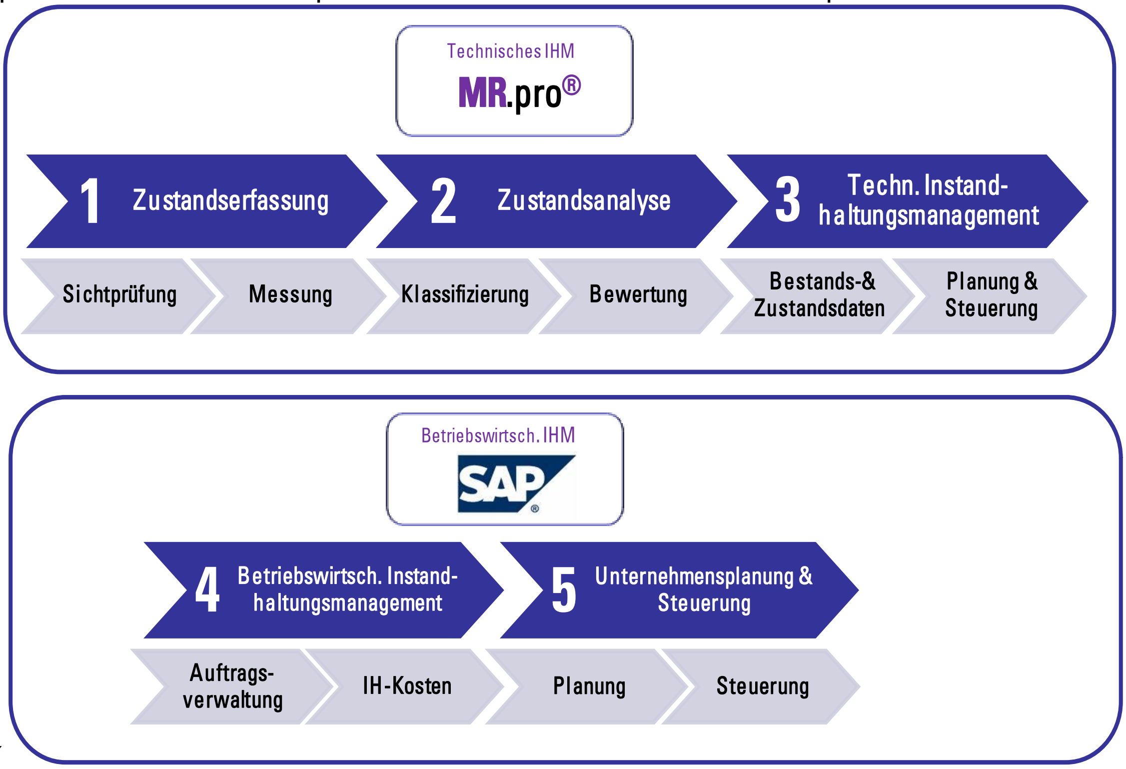


Fig 8: The integrated RailMap offers a good overview of condition and also has direct access to inventory and condition data as well as all allocated documentation – also for larger networks. (Source: Tram network ATM Milano).

MR.pro® disposes of an integrated application module for commissioning and managing of predictable maintenance measures. Through various database queries it is possible to change maintenance measures into orders for own-use or for external allocation. External quotations may be requested and compared. Orders may be assigned per object or assigned and controlled in complex. The completeion of an order sets all related measures to “completed” and starts the related waranty time. For this part of the maintenance process it is also sensible to have the optional interface to an



ERP-system (

Fig 7: Two software systems for all tasks of maintenance management: Technical = MR.pro® Comercial = SAP PM. The underlying data structure allows data transfer to corresponding enterprise information systems.

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The next step is to implement a fault- and life span management system with which ATM envisages to conduct object related vulnerability assessments to determine the replacement time. The request and analysis results are exported as office documents – with which for example the results from the waranty management can easily be output in table form for further analysis.

5 Result

Since the implementation of MR.pro® ATM Milano have to their disposal structured condition- and inventory information in a digital form. This significantly simplifies the overall analysis and evaluation of the results gathered through measurements and visual inspections, because the users always have access to current and non-redundant data. This also holds for the document management system with which MR.pro® can allocate centrally stored photos, drawings, graphs and various documents and files for each object.

With this infrastructure-datamanagement-system ATM will in future not only be able to manage the maintenance relating to condition but also plan and control the preventative and maintenance measures of their network. For example the regular revision and maintenance activities can be monitored and documented in view of their timely and qualitative execution.

MR.pro® offers a combination of all technical tasks required for maintenance management and thereby considerably reduces the number of software products required.
In combination with a business management ERP software (see picture) the combined functional spectrum of a modern maintenance management system is ensured in a continuous workflow.

Besides ATM a number of reputable rail network operators use MR.pro® for the management of their infrastructure, amoungst other:

- Basler Verkehrs-Betriebe
- Dresdner Verkehrs AG
- Hamburg Port Authority AöR
- IFTEC GmbH & Co. for Leipziger Verkehrs AG
- Kasseler Verkehrs-Gesellschaft AG
- Kölner Verkehrs-Betriebe AG
- Magdeburger Verkehrsbetriebe GmbH
- Mainzer Verkehrsgesellschaft mbH
- Münchner Verkehrsgesellschaft mbH
- Rhein-Neckar-Verkehr GmbH, Mannheim
- Stadtbahn Saar GmbH
- SWK Stadtwerke Krefeld
- VAG Verkehrs-Aktiengesellschaft Nürnberg
- Verkehrsbetriebe Karlsruhe GmbH
- Verkehrsbetriebe Zürich

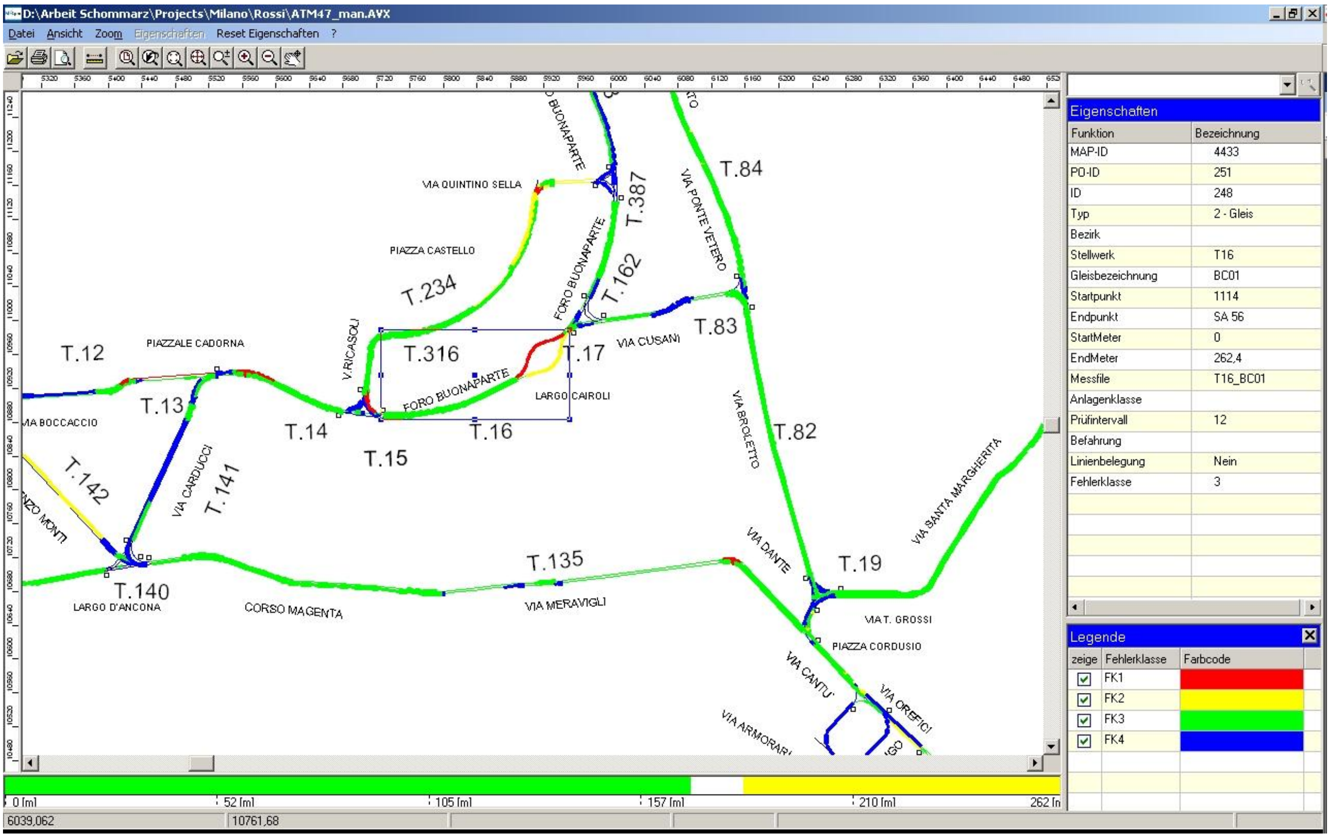

Fig 9: The RailMap of MR.pro® displays dynamic track segments to high light complex properties close to reality. This not only is true for the inventory data (master data) but also holds for all condition data. This 'cut-out' of the Milano tram network displays the fault classes coded in colour.

Further information under: www.mr-pro.de

CUSTOMER STATEMENT (Prelim.):

Track Management Solution: MR.pro for Milano Tram network
In our search for an optimised and efficient management solution we decided to go for the Schreck-Mieves solution, a German based subsidiary of BBRail. The supplied professional all-in-one solution consisting of both – the measurements and visual checks as well as the relating software management tool, MR.pro®. The software is linked to a database and has all options of controlling the maintenance and service tasks of our network. Very useful are the analysis tools as well as the visual and graphical display options. All criteria and data can be displayed on a geographical map of Milano.

The first-time inventory inspection of our complete tram network was done in no more than 8 weeks during July and August 2010. Thereafter the software installation and training of our staff followed. We now have access to a consolidated database of each section of our network with up-to-date inspection results.

With MR.pro® and the professional Schreck-Mieves services we are well geared to manage our tram line for the future.

Dr. Alessandro Ruocco
Head of infrastructure

((Captions))

Andreas Marx, 13.05.2011

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Active in various industrial branches with the accent on materials management and maintenance. In charge of the department services of the company Schreck-Mieves GmbH since 1994. Schreck-Mieves presently belongs to Balfour Beatty Rail GmbH, Germany, an internationally operating supplier of rail infrastructure services.
Develops management concepts for the global optimisation of maintenance of wheel and track, e.g. data collection and diagnostic systems, evaluation and classification methods for the judgement of infrastructure quality and wear margins, technical information systems, training programs for professionals and managers of rail-bound freight, urban and rural traffic.