Digital maintenance of railway facilities

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1 Introduction and background :

The shift of traffic volume to rail, which is both ecologically and economically desirable and makes sense, not only has capacity limits in terms of network size. More traffic load also means faster wear and tear of the infrastructure and exacerbates the need for economic and above all value-preserving maintenance as well as a significantly more progressive renewal policy for railway facilities.

2 Expensive construction versus substance-preserving maintenance

"*Rising construction costs threaten building projects*" Headlines like this one we will read more often in the future. The fact is that construction prices rose by more than 40 % between 2015 and May 2022 - by the end of 2021 inflation was still just under 30 %. (Construction price indices road construction in NRW)
https://www.it.nrw/statistik/eckdaten/ausgewaehlte-baupreisindizes-bauleistungen-am-bauwerk-2038

In view of the hardly predictable development of building prices, doesn't it make much more sense to focus on sustainable, because substance-preserving, maintenance instead of renewal?

A recognised rule of superstructure maintenance practice describes at its core the implementation of a resource-conserving methodology:

Grinding goes before welding - welding goes before renewing.

In any case, the goal of maintenance can be realised quite well:

> The aim of maintenance is to provide vehicles and infrastructure:
> - in an agreed condition,
> - with an agreed availability,
> - at the lowest possible economic cost.
>
> (VDV document 170)

Resource-conserving behaviour is definitely in line with the economic efficiency of maintenance. Maintenance, repair and conversion instead of new construction contribute to a large extent to the fact that grey energy can continue to be used instead of generating new energy. Grey energy refers to the cumulative primary energy that has to be used for the extraction of raw materials, production, transport, maintenance, demolition and disposal of an asset. Using the grey energy used in existing plants for as long as possible through revitalisation saves up to 70 % of CO2 emissions in buildings, for example.

According to the recently tightened climate protection law, Germany is to become climate neutral by 2045. To achieve this ambitious goal, CO2 emissions in the building sector must be successively reduced in the coming years[i].

3 Maintenance as a business management and technical task

The economic-technical approach understands infrastructure as an economic good for which the longest possible economic service life of the objects is to be realised on the basis of positive economics[ii]. Every extension of the useful life is also reflected positively in the ecological balance sheet through better utilisation of the grey energy.

In order to be able to achieve an economic optimum in terms of costs and performance, it is worth taking a closer look at

- actual costs of parts and measures,
- Lifetime structure of the plant objects, as well as
- Effects of maintenance measures.

Infrastructure maintenance influences the substance of the facilities during the entire period of use. From the orientation towards the long-term preservation of the asset substance, a truly holistic infrastructure management (asset management) can very easily be developed through targeted efficiency optimisation.

It would be advantageous if the condition of the system did not deteriorate to such an extent that the substance is severely attacked, but could be maintained at a quality level corresponding to the traffic load in good time with measures appropriate to the cause.

But how can the type, scope and time of the need for action be recognised in time and countermeasures be initiated? For this purpose, it is helpful to use the key parameters of the plant strategy to build up predictive maintenance, as the medium-term substance development of the plant objects can be taken into account in addition to the current operational safety and availability (condition quality). Fig. 1 shows how the substance is influenced by the renewal of the facilities. An outdated infrastructure has a greater need for maintenance than a new facility. Operational safety and availability can then only be maintained through costly, condition-improving measures as part of operational maintenance.

4 Condition-based and predictive maintenance

The task of predictive maintenance is to detect surprises and risks, such as unplanned failures or sudden malfunctions, at an early stage, to prevent them or at least to prepare for them. The basis of this predictive maintenance [iii] is DATA and the KNOWLEDGE about the concrete maintenance of the plant substance that can be derived from it.

But DATA is not yet INFORMATION:

Structured data is highly specific and is stored in a predefined format. Unstructured data, on the other hand, is a hodgepodge of many different types of data stored in their native formats. Structured data can be used by average business users, while unstructured data requires data science expertise to derive usable information from it.[iv]

The better and more structured the database, the more precise the analyses. The condensed information on the condition and remaining service life can also be used to solve a core task of predictive maintenance, the service life forecast. This is ideal for a planning horizon oriented to the average useful life of the objects - for the superstructure this is about 25-30 years.

A modern maintenance strategy must take into account not only economic but also ecological aspects. In addition to a functioning obsolescence management[v], grey energy should remain usable through the longest possible service life and through consistent reuse of plants and components.

5 Wear-and-tear inventory as an indicator of the economic useful life

While the condition quality of assets is the input for a prioritised maintenance decision, in which safety and the risk of worsening damage play a role, the timely replacement of old and maintenance-intensive assets is also crucial for long-term substance preservation.

The substance of technical objects is referred to in DIN 310151 as the wear reserve, which can be evaluated as a technical indicator. The currently still existing wear reserve can be determined as a supplementary analysis within the framework of cyclical inspections as the KAV wear reserve indicator® [vi]. In addition to the defect classification, a wear and tear equivalent, which evaluates the recorded wear and tear with regard to its irretrievable substance depletion, is determined and deducted from the new condition as the used-up wear and tear reserve. Individual object types are included in the overall evaluation with the corresponding weighting, taking into account the individual operational framework conditions.

In addition to the evaluation of individual objects, the wear stock indicator allows any number of abstraction levels up to the entire network, which provides valuable insights into the amount, quality and use of the resources employed and the development of the system over time, especially in a multi-period comparison. In many cases, this opens up room for manoeuvre for a flexible adaptation of machining cycles to certain damage rates or in the selection of optimised machining strategies with cost reduction potential. Fig. 2 shows the diagram of the economic service life. The index KAV® is calculated from the difference between new condition (1.0 = 100 %) minus substance losses. The substance quality asset index (SAX) focuses this wear reserve on the actual economic service life, taking into account categorised traffic loads (asset class A, B, C). Fig. 3 shows the remaining useful life RUL. It can be roughly determined from the empirically determined useful life assumption. By taking into account the cyclically determined asset substance (KAV)® , the actual condition of the asset is included in the specification of the useful life forecast.

6 Big Picture

Big picture means the big picture and thus means the overall picture and the overall context of complex content.

The overall picture of the railway infrastructure is made up of a wide variety of object types, e.g.

1. Track superstructure
2. Properties, stations, loading points
3. Buildings, workshops, substations
4. Overhead line, masts, signalling systems
5. ...

which are all related in terms of space and content and therefore cannot exist in isolation from each other. Each type of object adds an additional level of observation to the overall system and completes the so-called big picture.

However, each additional level of observation also increases complexity and it becomes increasingly difficult for those responsible to get a picture of the current situation. Without a common database that unites all infrastructure objects in a single system, there is a risk of fragmentation into many independent subsystems, which makes a big picture impossible in the long run. (Fig. 4)

It makes more sense to manage all types of objects in a structured manner in a single data model with a uniform organisational framework in order to avoid system and media discontinuities from the outset. This is because a holistic data model facilitates understanding and communication and contributes decisively to an efficient division of labour.

A hodgepodge of many subject-related apps for individual tasks does not make sense in the long run, as neither a common structure nor a uniform organisational framework can be established afterwards without losing a large part of the historical data collected up to that point.

The importance of a structured data history can be surmised from the long service life of the superstructure. Detailed knowledge about the development of the condition and the maintenance measures carried out over the entire life cycle represents an elementary input for maintenance decisions of all kinds. A metre-by-metre allocation of planned and/or executed maintenance measures is not always easy for line elements such as tracks or overhead lines, but it is an excellent basis for tracking and documenting maintenance measures in detail and for identifying and eliminating weak points and cost drivers in good time. Also for the tracking of warranty and defect claims, a consistently accurate documentation is extremely helpful.

These interrelationships, diverse analyses, the maintenance of data and predictive maintenance can be excellently managed and administered from a track network size of about 20 km with database-supported information systems.

7 One central system for all railway infrastructure objects - instead of fragmented data management

The MR.pro®[vii] software offers a convenient way to store all information of all railway infrastructure objects in a structured form so that derivations for the right decisions can be made from the data in a future-proof manner.

MR.pro® has been supporting the recording, diagnosis and derivation of measures for parameters that provide direct information about the actual condition of the infrastructure for almost 25 years (Fig. 5). In the process, the findings collected through measurements, visual and functional inspections are evaluated with regard to their impact on the infrastructure.

- on operational safety and availability, as well as
- the current substance (KAV wear reserve indicator) of the assets

analysed and prioritised in a standardised database-supported procedure and supplemented with specific corrective measures.

It is essential to map the entire process chain from the commissioning to the preparation of the offer to the precise invoicing of the respective technical site. The current software version has been expanded to include digital construction site management, with which construction and maintenance processes can be planned, controlled and invoiced simply and stress-free: Work preparation, construction schedule, construction diary, completion notification and invoicing of repair orders. This ensures an overview in the office as well as on the construction site.

MR.pro® masters not only the dynamic segmentation of line elements but also the correct data handling of project data and object data. Through the consistent coupling of project-related data with the respective plant objects, the object reference is maintained throughout the entire maintenance process. This means that the software is able to automatically link all project data, such as action, location and time, with the respective plant object being treated, from the recording of the condition to the notification of completion of the repair, so that the plant history and inventory documentation is automatically updated without additional data maintenance effort.

The maintenance concept of the MR.pro® software, which is based on condition and asset classification, not only supports the extension of the useful life, but also a material and component cycle system, in which dismantled asset objects are reused in less heavily used areas, for example, and thus grey energy is used sensibly.

MR.pro® enables the analysis of data from a wide variety of sources, e.g. rail cross-section, eddy current and ultrasonic measurement values or results of permanent wayside track monitoring, as well as their implementation in the object history of the MR.pro® database.

The asset management software offers both active service life management and the determination of the wear and tear inventory indicator (KAV)® to forecast the economic service life of each individual asset. The life cycle of objects, components and individual parts can be precisely tracked down to the last detail and used for obsolescence management.

8 Output decisive for the database design

The digitisation of the railway infrastructure ideally starts with the object-based recording and segmentation of the existing tracks and track constructions. It is important here to create a common database whose granularity should be in a 1:1 relationship to the intended level of detail of the asset maintenance. In order to create clarity here, it is useful to answer the following questions:

- What information should the technical information system for maintenance management provide per object?
- In what quality (reliable and up-to-date) are evaluation and presentation available?
- To what extent can historical data be taken over?
- How is the collection, storage and maintenance of data organised?
- Which interfaces to subsystems, measuring devices or departments are to be expected?
- Is it possible to have a continuous workflow from recording to evaluation, triggering and execution to updated documentation - or are there media discontinuities?
- Are the databases analysed in a meaningful way and do they provide valuable input for knowledge management?

9 Summary

Rummaging through mountains of photos, formatting Word documents, filling out Excel lists - who hasn't experienced this? Where scattered data storage and multiversional competing data statuses are kept, multiple entries, untraceable values, impurities and their elimination are a permanent task.

Especially for complex maintenance tasks, such as those that historically evolved railway networks entail, intelligent instruments are needed that enable economic maintenance of the complex railway infrastructure. Efficient, comprehensible and easy to handle - in other words, simple and reliable.

The infrastructure of the railways is a complex interaction of many different disciplines, each of which has a different view of the network objects. If each individual discipline uses its own digital tools, this usually leads to a fragmentation of data management. However, in order to avoid the cardinal errors of surprise and fragmentation, focusing and limiting to a common database from the very beginning is crucial for sustainable success.

MR.pro® is designed for the overall railway infrastructure system and yet is structured in such a way that it meets the specific requirements of each type and category of facility. This means that the software is able to provide those responsible for the facilities with all the necessary information and to show interrelationships (big picture). This is realised through an integrated workflow with minimal data maintenance effort, as the data, once recorded, is used throughout the entire maintenance process and double recording is no longer necessary.

MR.pro® is developed by railway technology specialists who are familiar with the needs of the users. The integrated expert system makes it a kind of "sponge" for the experiential knowledge of the specialists in the transport companies. It also has interfaces to ERP systems, such as SAP.

The software maps the entire process chain of infrastructure maintenance and provides all the information required for modern asset management.

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He studied business administration and economics in Trier and Hagen and established the maintenance service and the BahnWege-Seminare® for Schreck-Mieves in 1994. The author develops concepts for maintenance and data management for the overall optimisation of rail networks, for example diagnostic systems for quality and substance assessment of the track infrastructure.

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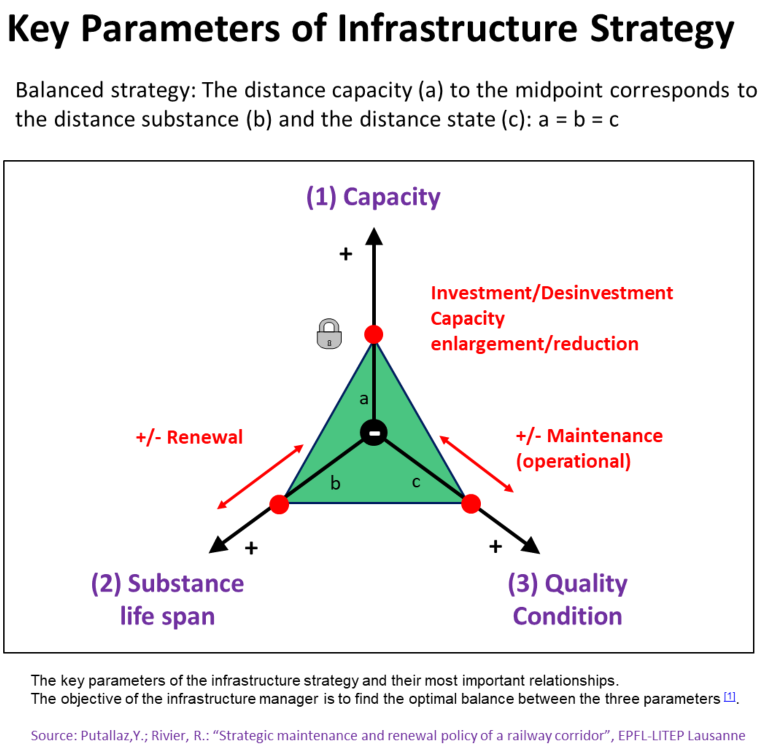


Fig. 1: The substance is influenced by the renewal of the facilities. An outdated infrastructure has a greater need for maintenance than a new facility. Operational safety and availability can then only be maintained through costly, condition-improving measures as part of operational maintenance.

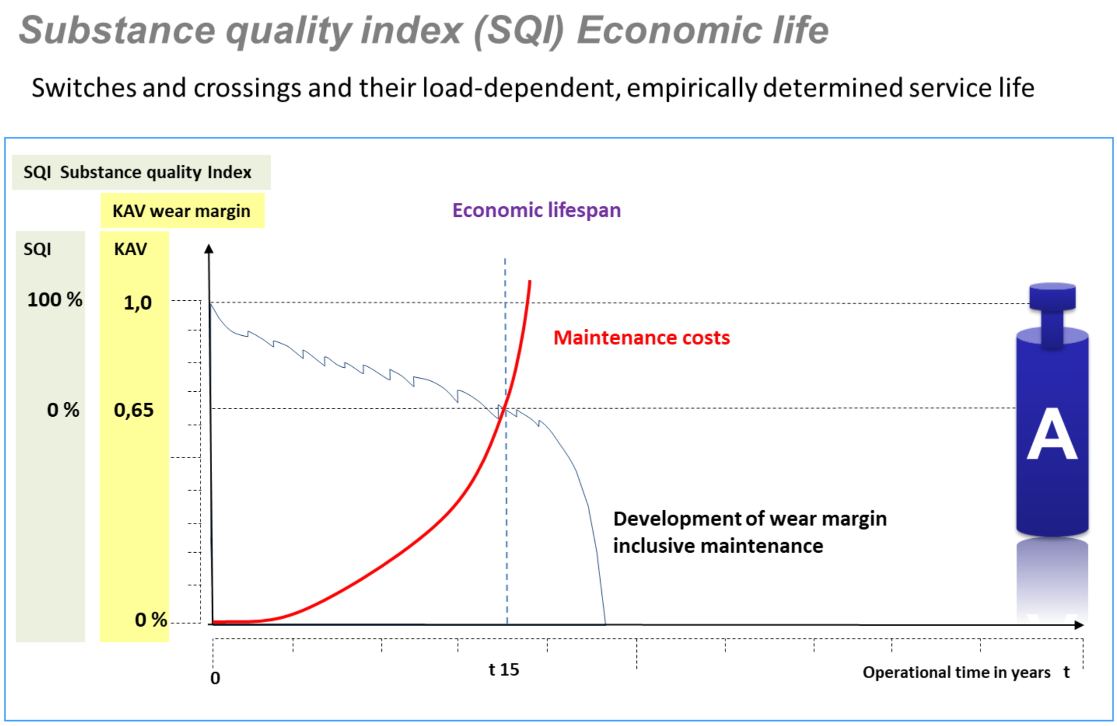


Fig. 2: The KAV® wear reserve indicator is calculated from the difference between new condition (1.0 = 100 %) minus substance losses. The substance quality asset index (SAX) focuses this wear reserve on the actual economic service life, taking into account categorised traffic loads (asset class A, B, C).

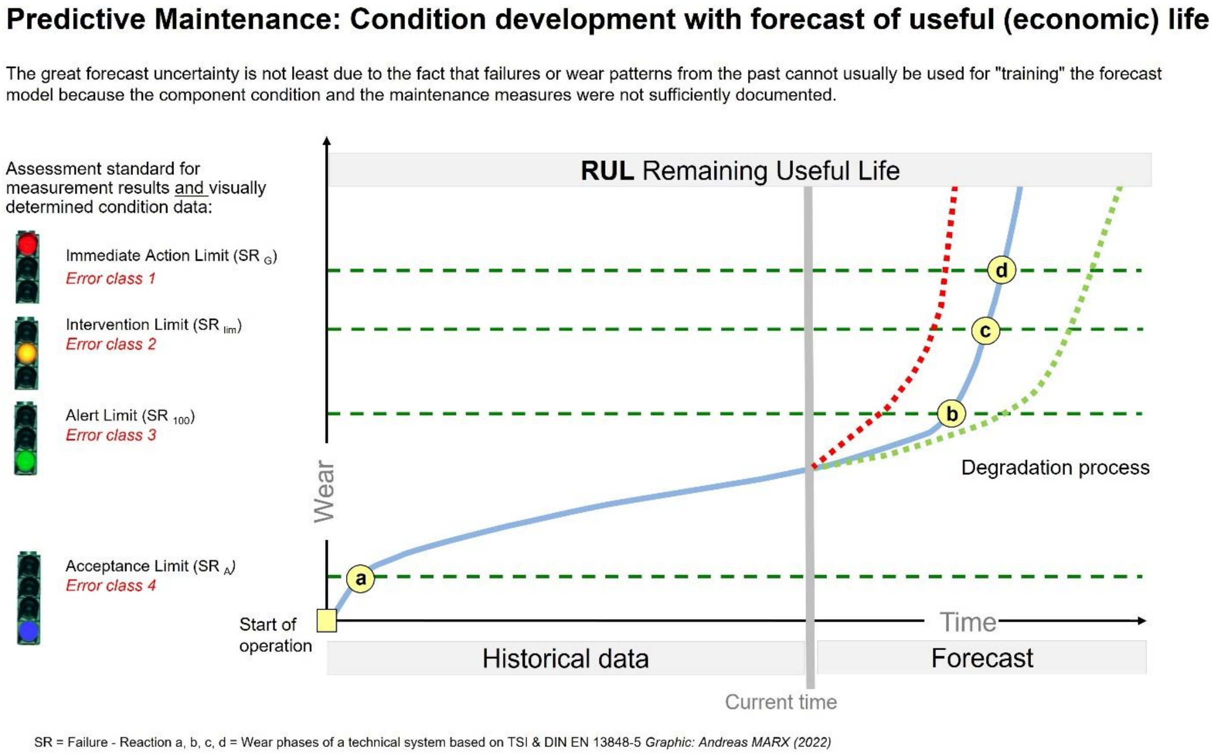


Fig. 3: The remaining service life RUL can be roughly determined from the empirically determined service life assumption. By taking into account the cyclically determined plant substance (KAV)®, the actual switch condition is included in the specification of the service life prognosis.

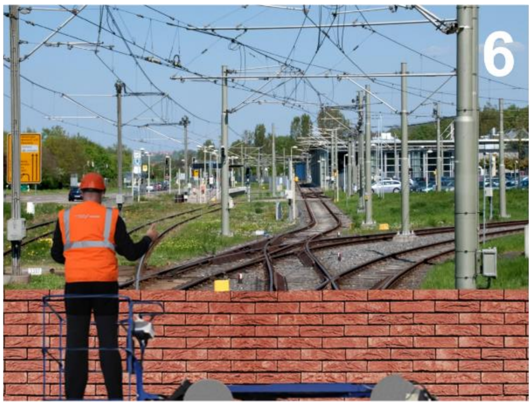
Track network superstructure (tracks and switches) forms the central organising framework, as all objects on the track can be referenced. The overview is still relatively simple.

Properties, stations, loading points increase the complexity. Several tools (apps) are already required to gain insight.

Buildings, workshops, substations. Without the appropriate tools, no overview of the infrastructure is possible. Multiple apps for the individual object types complicate the work.

Overhead lines, masts, signalling systems. It doesn't matter how many resources you have. If it is not clear how they are used, there are never enough. The many apps, even in combination, are no good for gaining the necessary insight into the overall context.

Solution MR.pro®: offers a holistic approach for all types of facilities. The software can be individually designed and scaled to the respective object type and task.



Solution MR.pro®: Big Picture Railway Infrastructure. Digitalisation without media discontinuity facilitates communication and processing through efficiency.

Fig. 4 : Interrelationships of the sub-disciplines. With MR.pro®, those responsible for the installation retain a view of the **big picture** and the interrelationships of the sub-disciplines of the railway infrastructure at every level of observation.

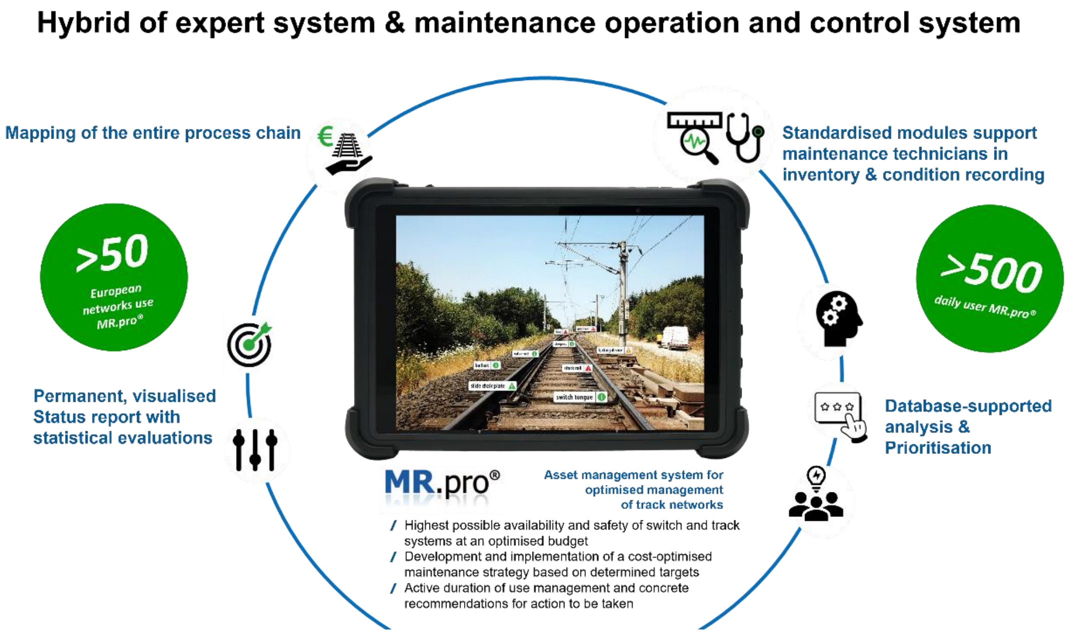


Fig. 5: MR.pro® supports the maintenance management of the entire track infrastructure as a central data collection point (data warehouse) and analysis system (data mining), in making correct, comprehensible and technically substantiated decisions.

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[i] https://www.bauenimbestand24.de/die-oekobilanz-spricht-fuer-die-sanierung-09092021

[ii] Positive economics deals with the empirical analysis and explanation of what is and what will be (cause-effect relationships). Its central task is the analysis of the actual situation (description of the current state, its explanation as well as the prediction of the future development (forecast). The analysis is concluded with a decision on any need for action.

[iii] Predictive maintenance (PM) is to be understood as a supplement to both periodic and condition-based maintenance, as PM takes into account additional influencing factors, event patterns and analytical methods for automated plant evaluations and forecasts.

[iv] https://www.talend.com/de/resources/strukturierte-vs-unstrukturierte-daten/

[v] Obsolescence management ensures that components that will no longer be produced in the future and are installed in products are replaced in good time by comparable types or stocked for repairs.

[vi] Marx, Andreas "Prognosis and prevention - a holistic approach in infrastructure maintenance to ensure substance quality (part 1)" in ZEVrail 137 (2013)

[vii] The inspection and maintenance management software MR.pro®, a hybrid of expert system and technical information system, specially tailored to practical asset management for the entire railway infrastructure (www.mr-pro.de)