Digital wheelset management: Digitalisation makes wheelset wear predictable

To ensure that rail vehicles and railway assets are reliably and safely available for operation at all times, correct maintenance tasks need to be executed at the optimum time.

The reasons for wheelset wear are mainly due to various forces acting during wheel-rail contact.

Motivation

Advances in digitalisation in the railway industry are creating numerous new possibilities to monitor vehicles, assets and components. Nowadays, meaningful results are achieved in many areas by integrating economically and technically viable diagnostic functions into assets and processes. Thanks to an increasingly sophisticated IT infrastructure and less expensive sensor technology, maintenance personnel can have an access to huge amounts of operational data and use it for decision making procedures.

Reliable and consolidated forecasts and analyses are difficult or almost impossible to be implemented manually or when using isolated IT solutions. Data, which must be collected and which is necessary for a meaningful forecast are usually too comprehensive for this. A digital asset management system such as zedas®asset can support the evaluation of large amounts of data as well as the integration of the analysis results into the complex maintenance management process. All relevant maintenance procedures, such as corrective and preventive actions, are recorded in the system, measurement and operating data are loaded into the system via interfaces and then stored in the history of each vehicle or component. Mobile apps with an online and offline functionality, make it possible for both workshop employees and mobile service teams to record data digitally.

The analysis and integration of data specifically involve:

- automatic evalution and generation of meaningful fearures on condition and wear,
- extraction of features to detect faults and forecast the condition,
- optimising maintenance planning on the basis of the information obtained regarding the condition of the vehicles, assets and components.

The same also applies to repair and maintenance processes of wheelsets. The regular automated or semi-automated measurement and assessment of wheelsets forms the basis for new approaches in data evaluation with the aim of optimising maintenance processes.

This is where ZEDAS GmbH comes in with its new module Wheelset Analyser for visualising and forecasting of wheelset data. More precise planning of wheelset reconditioning or wheelset exchanges is to be achieved on the basis of new innovative approaches.

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The integrated dashboard for wheelset monitoring offers functions to

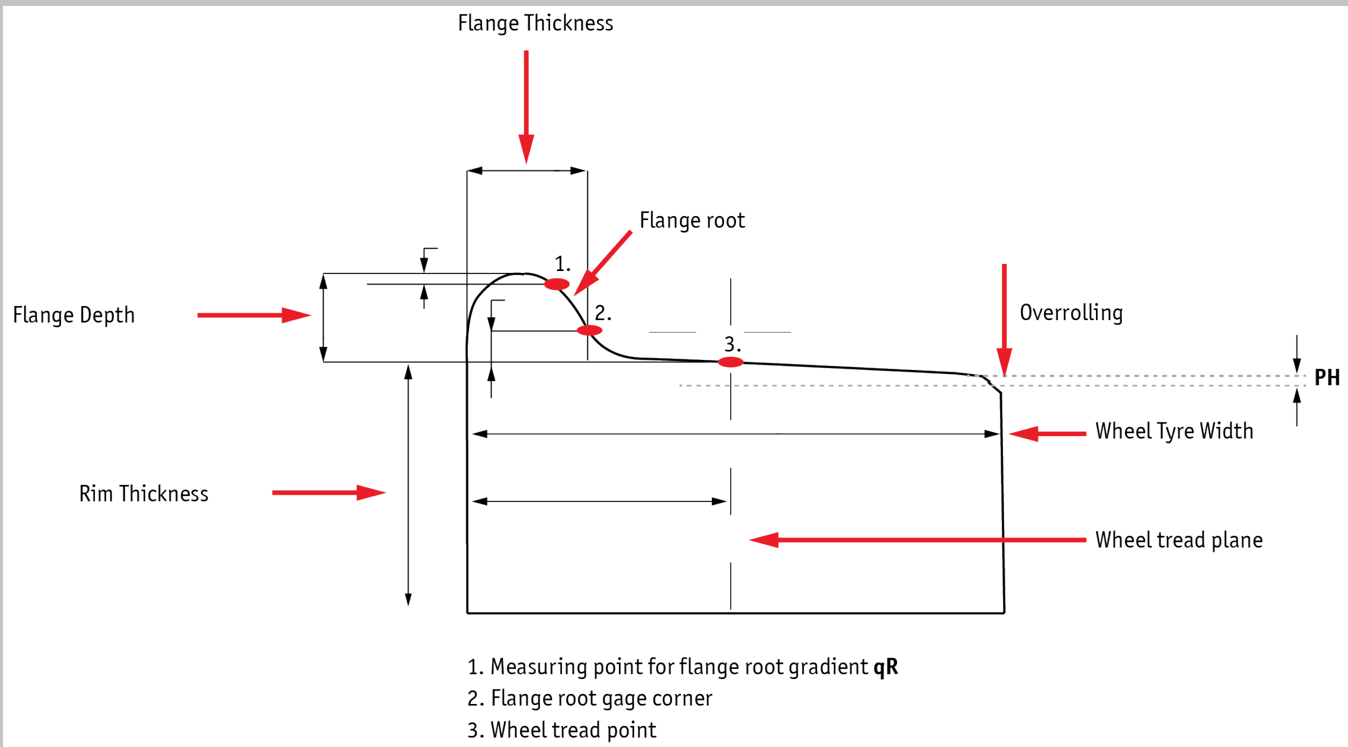
- visualise the wear process at different measuring points on the wheel or axle,
- forecast the time when the limit will be exceeded or undercut for the running tread diameter and other measured variables,
- determine the remaining useful life and remaining service life,
- automatically transfer the calculated data to maintenance planning.

Process

The reasons for wheelset wear lie primarily in the action of various forces during wheel-rail contact. As a result, damage occurs to the wheels, especially to the wheel tyres and axles after a certain duration.

Some typical damages are:

- Flat spots - local material erosion due to wear on the non-rotating wheel, e.g. due to blocking of the wheels when braking,
- Crack formation,
- Crumbling - pieces of material crumble away from the running surface,



1: Typical flange dimensions

- Polygonisation - the wheels becoming unround,
- Overlapping - material offset due to high mechanical stress.

Severity and frequency of damage to the wheel depend on several factors, such as the wheel profile used, speeds during use, loads transported, outside temperatures, rail profiles of the tracks and switches crossed.

Furthermore, track position errors, errors in track gauge, direction, longitudinal height (e.g. corrugation) or transverse height also lead to an increased wear and damage to the wheel due to the intensive wheel-rail contact.

Wheelset maintenance – current situation

To evaluate the condition of the wheelsets, fixed wheel parameters are usually measured, as shown in the diagram (figure 1).

The measurements are taken either time-cyclically or mileage-dependently. The results are then transferred to the zedas®asset maintenance planning system via an automated interface and stored related to components. In addition, a visual inspection of the condition is made, e.g. with regard to cracks, break-outs or flat spots that have occurred, but this is usually the case for more comprehensive inspections, as these are associated with a greater time expenditure.

The wheelset's installation histories may vary greatly, e.g. as certain axles had to be replaced prematurely due to defects. As a result, each wheelset needs to be monitored separately with regard to its mileage, damages experienced and the development of measured values.

Without the use of special software support, it is quite complex to handle the administration of wheelset data. This is due to the fact that there is a large amount of data to be handled, special requirements to be considered. Many engineers responsible for planning are keeping Excel files in which measured values are listed on the one hand and due dates of the wheel revisions are calculated on the other.

When determining the remaining operational life (remaining mileage) and when planning reprofiling measures using Excel files a number of parameters is predefined or assumed on the basis of experience, such as

- Mileage per month in km,
- Average wear per month,
- Mileage until the next reprofiling work,
- Removal during the next reprofiling work.

With the help of this information, specified limit values, last measured tread diameter and the assumption of a linear relationship between mileage and wheel diameter reduction, the smallest mileage reserve is calculated for all wheelsets of the vehicle.

This approach has several disadvantages. First of all, the wear behaviour is not linear but in most cases exponential plus removal via measures to revise the wheel profiles (reprofiling) needs to be considered. The factors that determine the degree of wear, such as mileage, weather conditions, route profile, load can change spontaneously or cyclically (e.g. timetable, season). The amount of material removed during reprofiling also depends on a variety of wear parameters and can therefore vary greatly. These influences are rarely taken into account in Excel calculations.

With an improved approach, the forecast wear curve shall be brought as close as possible to the actual wear behaviour. The aim is to make wear calculable on the basis of historical measurement data.

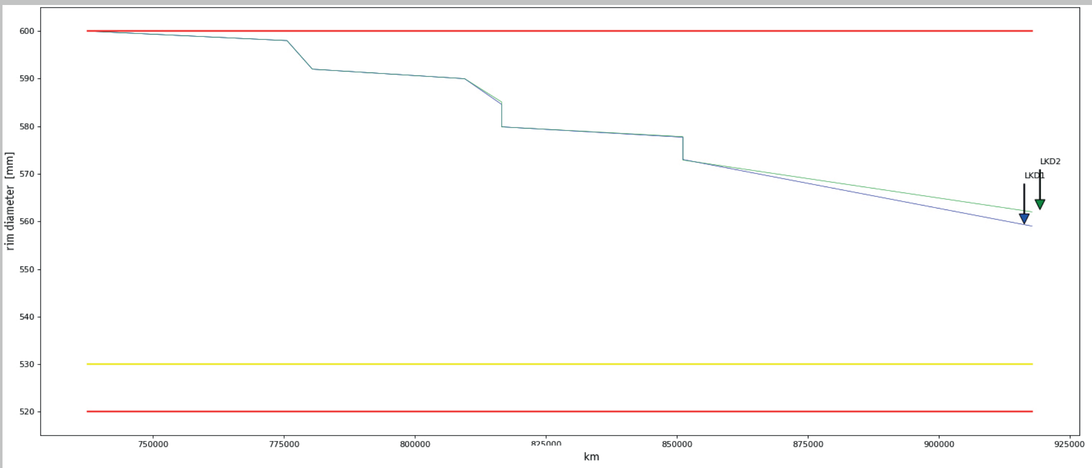
Forecasting approach

First, a suitable non-linear regression model had to be found, which describes the relationship between the reduction of the wheel diameter based on wear and covered mileage, taking into account the fact that the wheelset measurements only represent a relatively small sample quantity. For a larger number of wheelset measurements, other approaches may also be used.

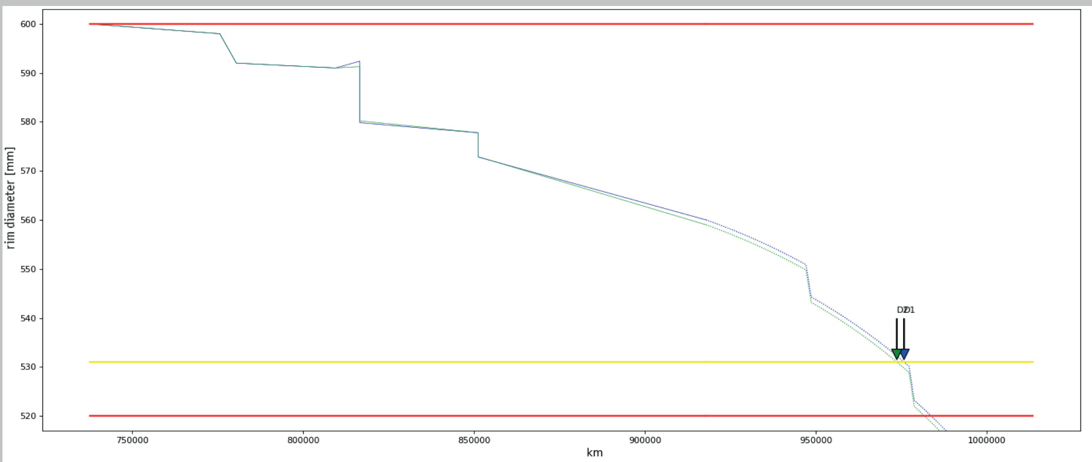
The integrated regression model is based on the function:

$$d(s)=d_0+\alpha e^{\beta s}$$

in which d(s) is the determined wheel diameter, d_0 the starting diameter at the time of installation, s the distance travelled



2: Typical measurement data curve for the tread diameter of the two wheels on a wheelset with warning threshold and limit values incl. typical reprofiling jumps



3: Display and forecast (dotted sections) of the tread diameter on a left and right wheel of a wheelset including reprofiling measures

and α,β the function parameters. This function explains the behaviour in detail. If, for example, the initial wheel diameter is a bit smaller after reconditioning, the entire wear function is shifted to the left and the intervention threshold for taking maintenance measures is therefore reached much earlier.

How much the function decreases with increasing mileage is determined by the parameters α and β.

The wear curve for the running tread diameter is obtained by removing the parts of the reduction in the running tread diameter caused by reprofiling measures from the measured data.

Using the Gauss-Newton approximation method, the parameters α,β shall then, on the basis of the historical measurements, be optimally adapted to the real wear behaviour. This method is suitable to solve „non-linear smallest squares problems" and to estimate our searched parameters appropriately. To apply this method you need the partial derivatives of the function according to the parameters to be estimated and the set up Jacobi matrix based on them $\nabla f(s)^T$.

Once the required parameters have been determined, the further course of wear must be calculated using the regression model listed above.

After each new measurement of the wheelset, it is possible to update the calculation with the new values and tweak the forecast values.

Subsequently, the values „learned" from the history for the average removal during reprofiling or the average mileage between reprofiling measures are to be integrated into the measurement curve.

In combination with the limit and warning values, you obtain the required information on the mileage reserve (see Figure 3).

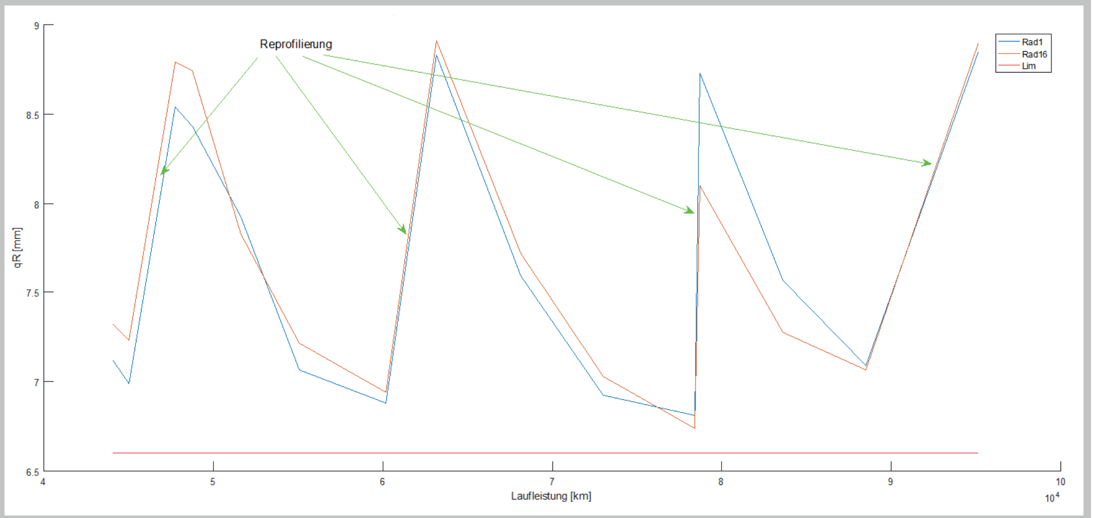
As the measurement curves for the running tread diameter show, the frequency and intensity of the reprofiling performed have a major influence on a wheelset's mileage reserve This provides an additional approach for further increasing the forecast accuracy. If the behaviour of the parameters which are frequent triggers for reprofiling, e.g. flange thickness, flange height or flange steepness, is also trained and included in the forecast, prediction results can also be obtained with regard to the times for reprofiling and the removal rate required to produce a specified flange profile at the time of reprofiling. The following graphs (no. 4 - 6) show the measurement data curve, the learned wear curve and, based on this, the prediction of the mileage until the next limit value for the flange slope (qR) is reached.

Similar to the example of the flange slope, it is possible to do the analysis based on data history and forecast of further flange parameters if these ones influence the reprofiling times. Previously fixed values for reprofiling time and for reduction of the tread diameter are now learned from history and replaced by predicted values.

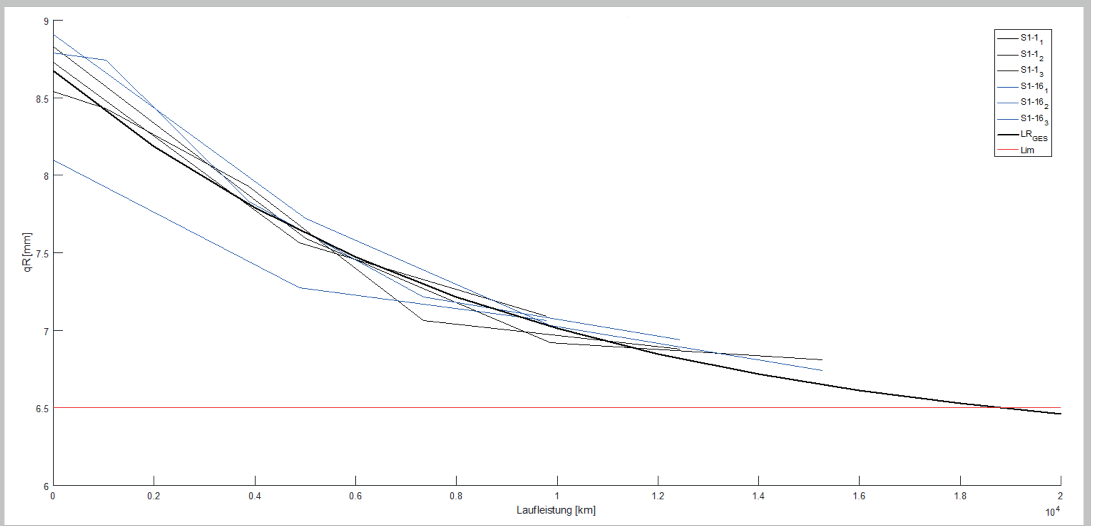
Application and results

The new zedas®asset module for wheelset diagnosis helps the maintenance coordinator to make the right investment/reinvestment decisions based on the parameters of all wheelsets of the vehicle. The user can select the relevant wheel set via variable filters in the integrated dashboard to graphically display the progress of the various wheel flange measurement data in relation

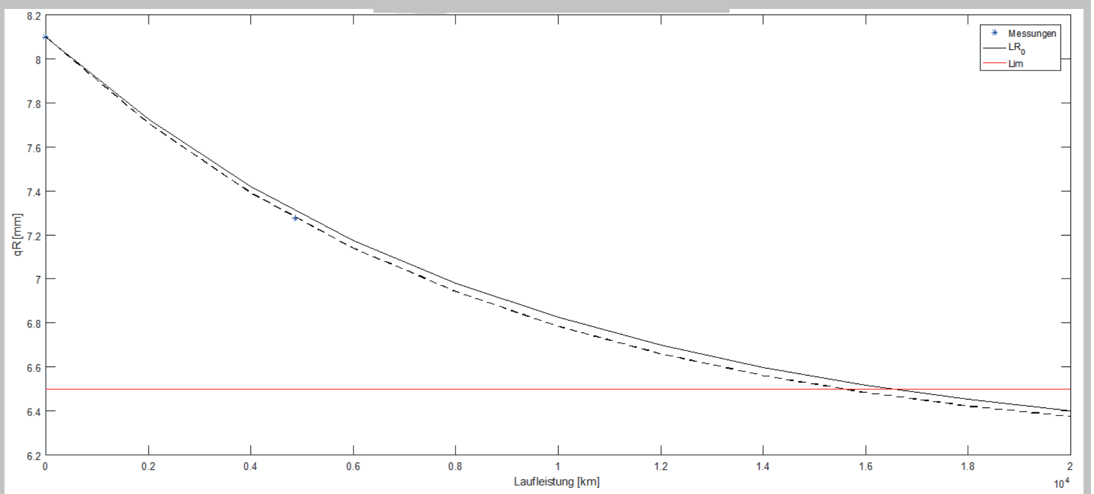
4: Typical qR measurement history incl. reprofiling of a wheelset on a tram



5: Learned qR-wear curve (black) the history shown in Figure 4



6: Forecast of the next reprofiling with the initial value directly after reprofiling (continuous line) and fine adjustment of the forecast after the first measurement (dotted line)



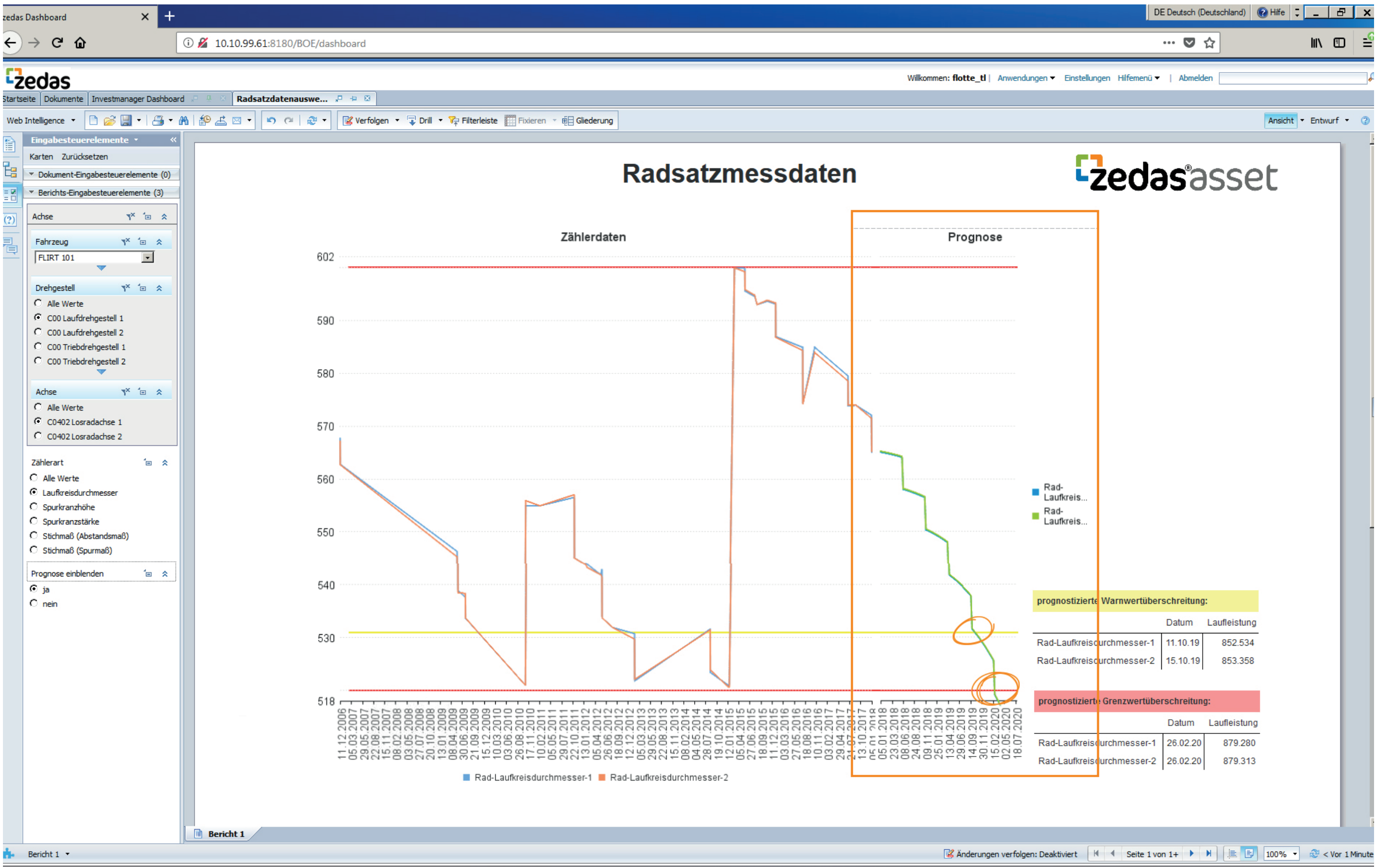
to mileage or time.

When the forecast function is selected, the green graph (see Figure 7) shows the predicted progress of the wheelset wear, the mileage and the date of the expected shortfall of the warning threshold and the limit value. Forecast values are updated on a time-cyclical basis and are used to calculate due dates of event-related deadlines. Planning of maintenance tasks and component changes is now being done on the basis of up-to-date forecast values.

Outlook

As already described, the wheel-rail contact has quite a significant influence on the wear behaviour of wheelsets. Using the module zedas®asset Track Analyser users have a tool at their disposal with which measurement data and condition analyses of tracks and switches can be recorded and which can be used to forecast meaningful track parameters (please see Figure 8).

Based on the analysis and forecast results of the Wheelset and Track Analyser, it will be possible to find correlations between track condition and wheelset wear in future.



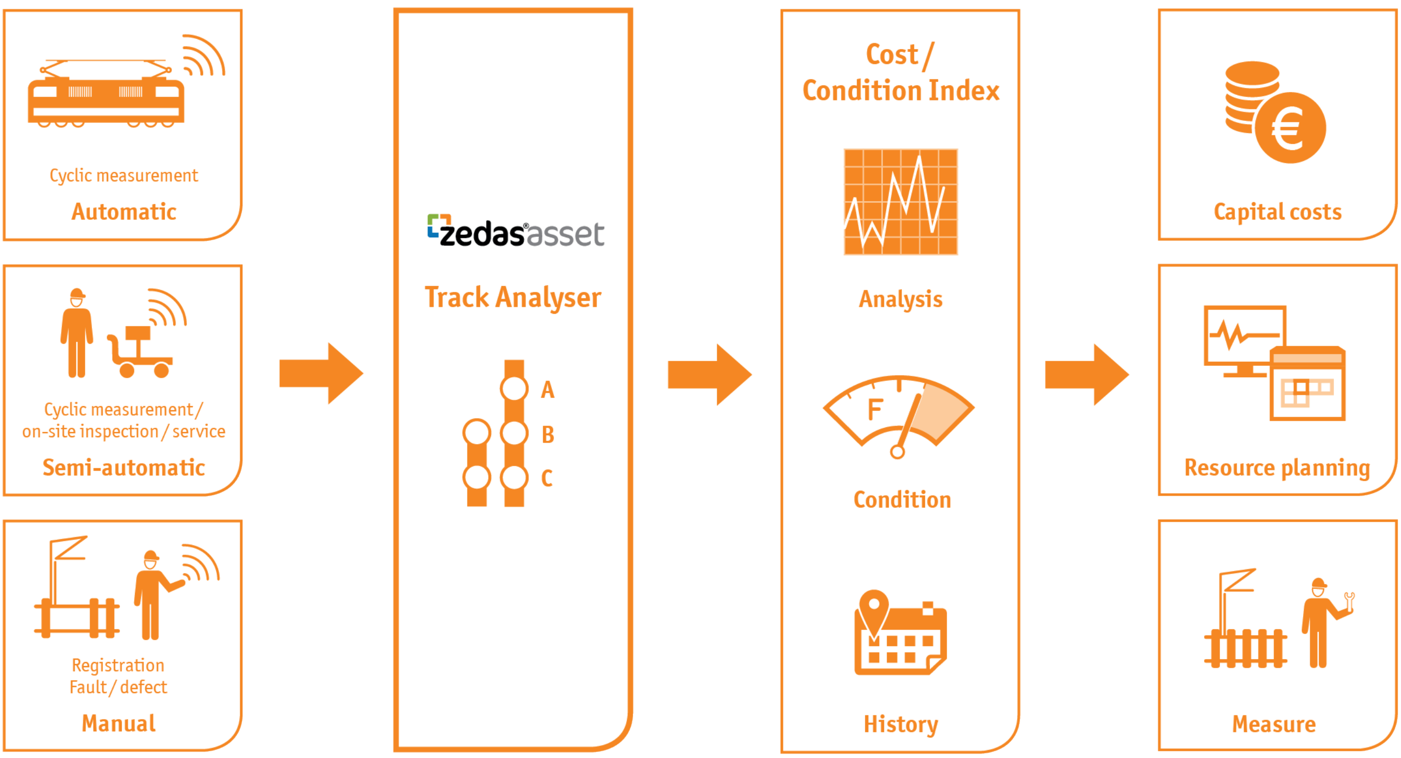
7: zedas® dashboard issued using the wheelset data module

Summery

Digital wheel set management: Digitisation makes wheel set abrasion predictable

The wheel-track contact has a not insignificant influence on the wear behaviour of the wheel set. The user available module zedas®asset Wheelset Analyser is able to record measurement data and condition assessment of wheelsets and to forecast significant wheelset parameters. Based on the analysis and forecast results by the Wheelset an the Track Analyser, it is possible to detect correlations between track condition and wheel set abrasion.

On the basis of the analysis and forecast results of the Wheelset and the Track Analyser, it will in future be possible to find correlations between track condition and wheelset wear.



8: The Track Analyser module in the track infrastructure maintenance process