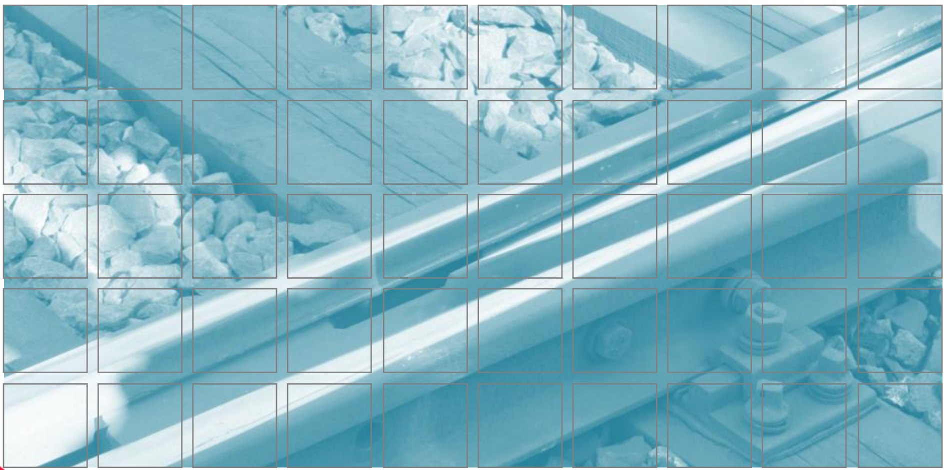
COMET-Projekt Rail4Future

Resilient Digital Railway Systems to enhance performance



D2.2.3 Report on available historical Data and identified further required data

D2.2.5 Report on the descriptive Model

2022

virtual vehicle

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Preface

Although one of the most safety-critical and highly stressed components of the railway track (due to dynamic impact loads and slip), decisions regarding necessary maintenance activities and renewals of turnouts are still made based on visual inspections. This approach builds on the extensive experience of those responsible for the system and en-sures safe operation, but also comes with critical disadvantages. The inspection is time-consuming and expensive, and employees are in the danger zone. A particularly critical aspect is that assuming a same number of qualified employees available in the medium term (labour market situation) is simply unrealistic. In addition, it can be assumed that the population will demand a higher utilisation of the railway network (climate change) increasing the loads on the components and at the same time shortening the time slots for inspection and maintenance. For these reasons, one of the aims of the project is to advance the condition assessment of frogs using measurement data and thus to provide the re-sponsible railway staff a tool supporting their decision-making processes.

Content

1 D2.2.3. Report on available historical Data and identified further required Data (M18)

For the development of S&C condition monitoring algorithms, a broad dataset consisting of measured data (geometry and vehicle/track interaction) and simulation results is required. Multibody dynamic (MBD) simulation plays a particularly key role here. Through the reliable simulation of vehicle/track interaction, physical effects can be deter-mined as a function of the condition and brought into model-based approaches as well as the parameter space of the existing measured datasets can be extended.

1.1 Available data

The required data identified in "D2.2.2 Report of Requirements" has been made available in the project. This data includes:

- Entry switch Niklasdorf W5 (10 datasets from 2012 to 2017)
    - Profile sections of crossing nose
    - Track irregularities
    - Track layout
    - Rail surface signal
    - Gauge
- Measurement car EM250
    - Wheel profiles worn (before reprofiling)
    - Wheel profiles after reprofiling
    - Measurement data of line between Bruck and Graz (2001 – 2021) for sub-project A2.1
- Surface scans of crossing noses at 26. May 2021 for switches W2, W5, W6

This data is currently used for the development of the MBD model and the subsequent sensitivity analysis.

In a first step, the following switches were selected for analysis during the studies:

- Turnouts for methods and model development
  - Crossing: Entry switches at Niklasdorf railway station W1, W2, W5, W6
  - Tongue: Station Oberaich W101, W102, W103, W104
- Site-specific wear behaviour
  - Crossing: Station St. Marein/St. Lorenzen W53, W56
- Curved switches later in the project
  - Crossing: Station Zeltweg W67 (IBW)
  - Tongue: Station Villach W403 (IBW)

1.2 Further required data

One of the project turnouts will be equipped with several sensors according to the sensor concept (Figure 1). The data generated from this turnout can be used to further develop and improve the model-based condition monitoring approach with respect to the following:

- Validated models with high information quality required for the calculation of the vehicle/track interaction.
  How well do current models reproduce the dynamics during switch crossing?

- Modelling of physical effects and system properties for geometrical condition assessment.
  How high must the model depth be for the prediction of the switch condition? How precisely must system parameters be known for the parameterization of the model?

- Analysis of vehicle dynamic behaviour.
  Do patterns show up in vehicle dynamics (fingerprint of vehicles)? Can a classification or reduction of the number of vehicle models for simulation be achieved?

- Extension of data set for creation of prognosis models.
  Measurements provide the current state of the turnout in the range of the current operating conditions, whereas the simulation allows scaling and can represent the influence of operating conditions (sensitivity analysis).

For the descriptive approach, the following questions can be answered:

- How much does the measured acceleration scatter according to the same vehicle (of the same vehicle type) at the same switch frog?
  → Influence of stochastic operation conditions.

- How does the same vehicle react to different points?
  →Influence of the switch frog condition on the force effect
- How do vehicles of the same type react at the same switch frog condition?
  → Influence of the vehicle condition (e.g. wheels)
- How do different vehicles react to different points?
- How sensitive are different vehicles when passing the switch?
- → Can the influence of the switch frog condition be clearly (statistically) proven?

To answer these questions, two types of experiments were considered:

- Turnout in 'normal' operation → Influence of vehicle collective on turnout condition
  - Instrumentation of the turnout with small sensors (see Figure 2)
  - Different vehicles passing the turnout during operation
  - Information about the vehicle collective
- Turnout crossing with equipped vehicle → Influence of the turnout condition on the vehicle
  - Turnout equipped with large sensors concept (see Figure 1)
  - Selected vehicle equipped with sensors
  - Variation of operating conditions (speed, direction of travel, etc.)

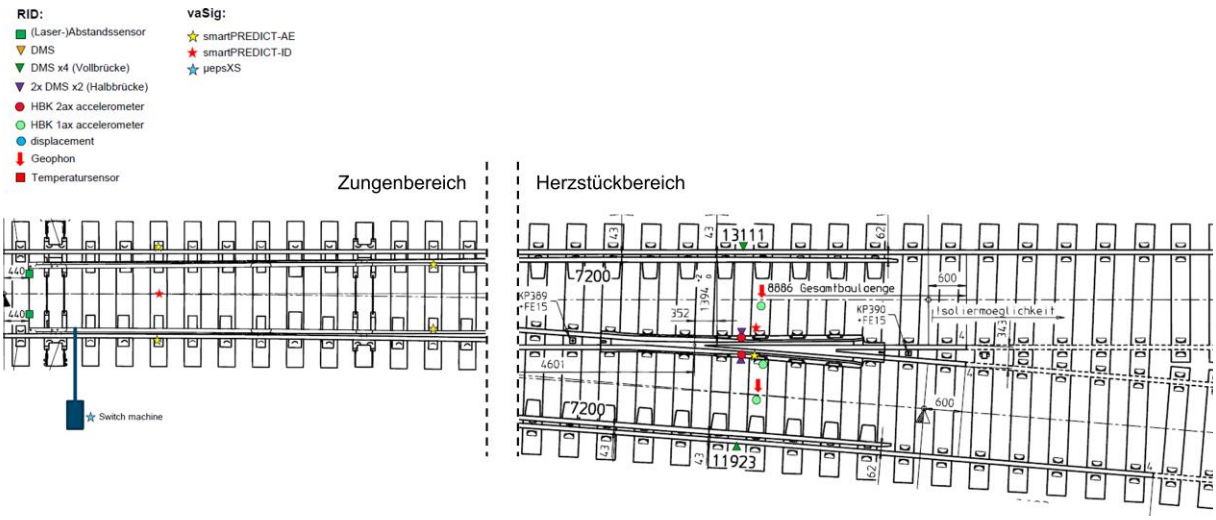

Figure 1: Large Sensor concept for one of the project turnouts

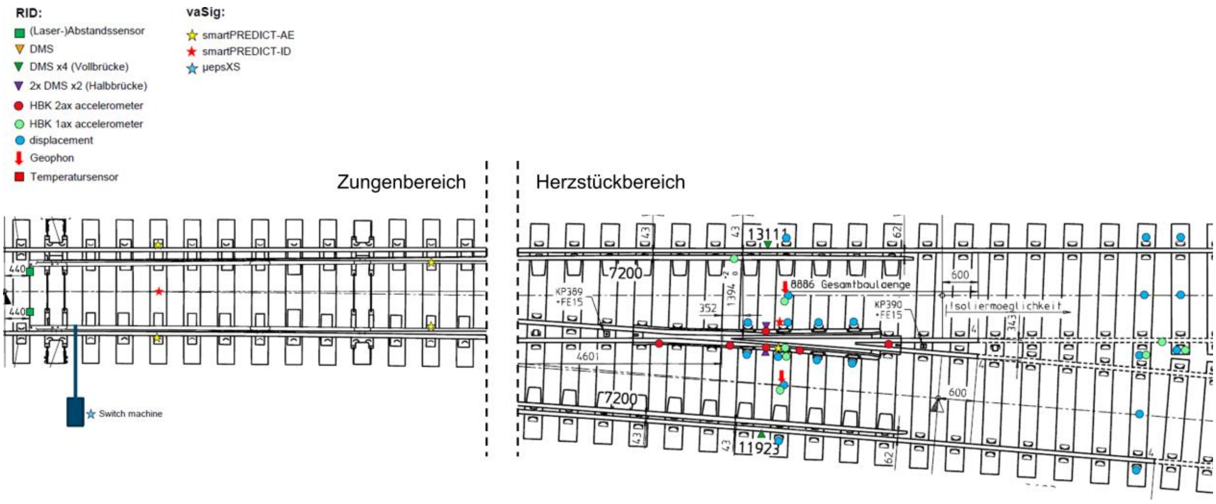

Figure 2: Small sensor concept for one of the project turnouts

The following information should be available at the end of the tests:

- Accelerations at the switch frog, checkrails, sleepers
- Displacement at the switch frog and sleepers
- Tensions at the switch frog, checkrails
- Vibrations in the ballast

Tests are planned for late November 2022 or spring 2023, depending on weather conditions.

2 D2.2.5 Report on the descriptive Model (M18)

2.1 Model-based assessment of S&C

Based on the 'Triple Hybrid Approach' (Figure 3) for solving problems of condition monitoring and condition prognosis of components in the railway system, different data sources are combined. Information on the vehicle and its operation is combined with data from maintenance (track geometry, rail profiles, rail surface, etc.).

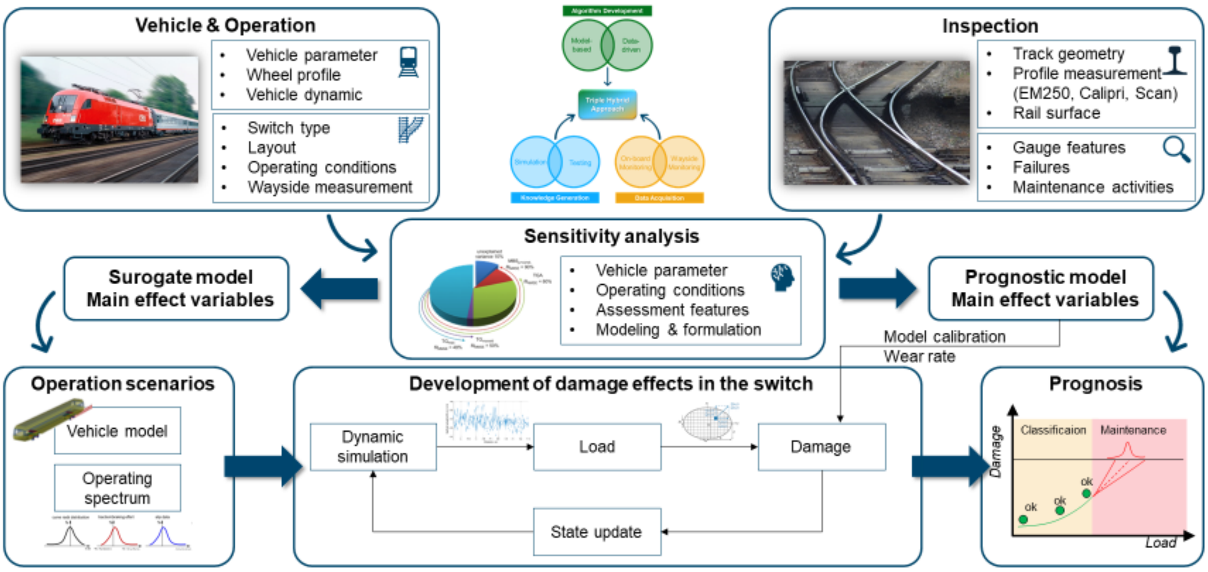

Figure 3: Concept for evaluation of S&C condition based on simulation.

With this database, a sensitivity analysis is performed with the aim of testing the input parameters for their influence on the quality and robustness of the multibody dynamic (MBD) simulation results.

2.2 Data preparation

The provided data of the turnout geometry must be converted to be used in the MBD simulation model, as it cannot be used directly. To convert the crossing nose geometry, which was provided as a series of Calipri measurements, an algorithm was developed. This algorithm loads the measurement data, aligns it to the correct position and converts it to profile data which can then be used in the MBD software. A similar procedure is necessary to convert the data of the measured wheel profiles. With this approach it is possible to combine real world data with the simulation model to identify the influence of historical measurement data on the model output and generate additional knowledge.

2.3 Sensitivity analysis

The sensitivity analysis is executed to test the input parameters for their influence on the quality and robustness of the MBD simulation model and find the main effect variables. For this purpose, a full factorial Design of Experiments (DoE) is developed to test the influence of different input parameters (Figure 4).

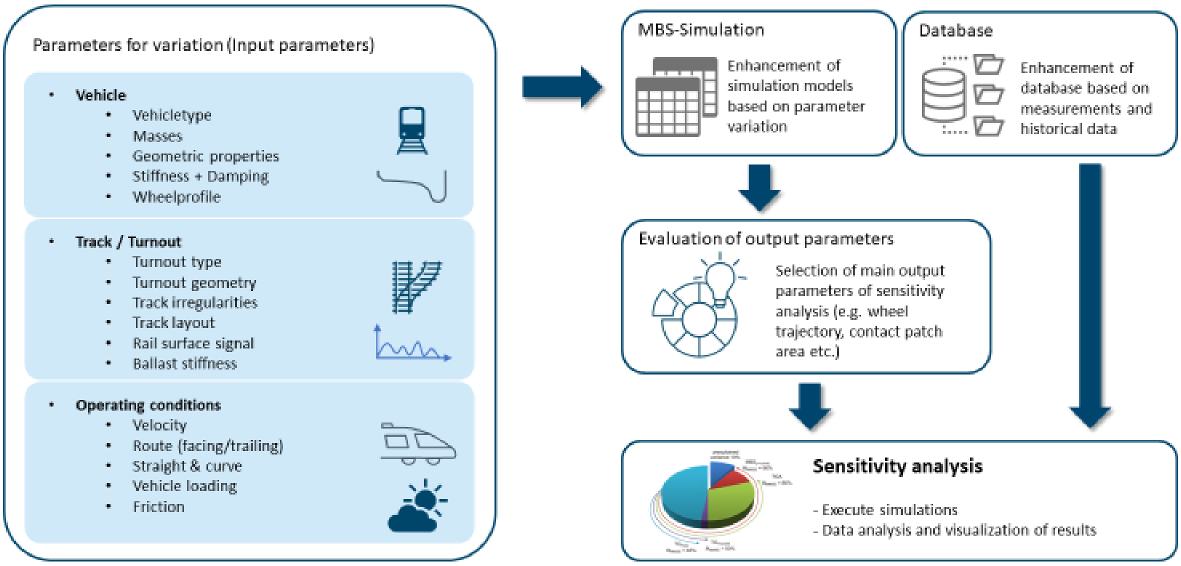

Figure 4: Concept for sensitivity analysis.

The large number of possible different input parameters makes it necessary to identify the most important ones to efficiently perform the DoE. The DoE is prepared and executed automatically based on the desired input parameters which are varied. Then the results of the simulation (e.g., Figure 5) are loaded and analysed.

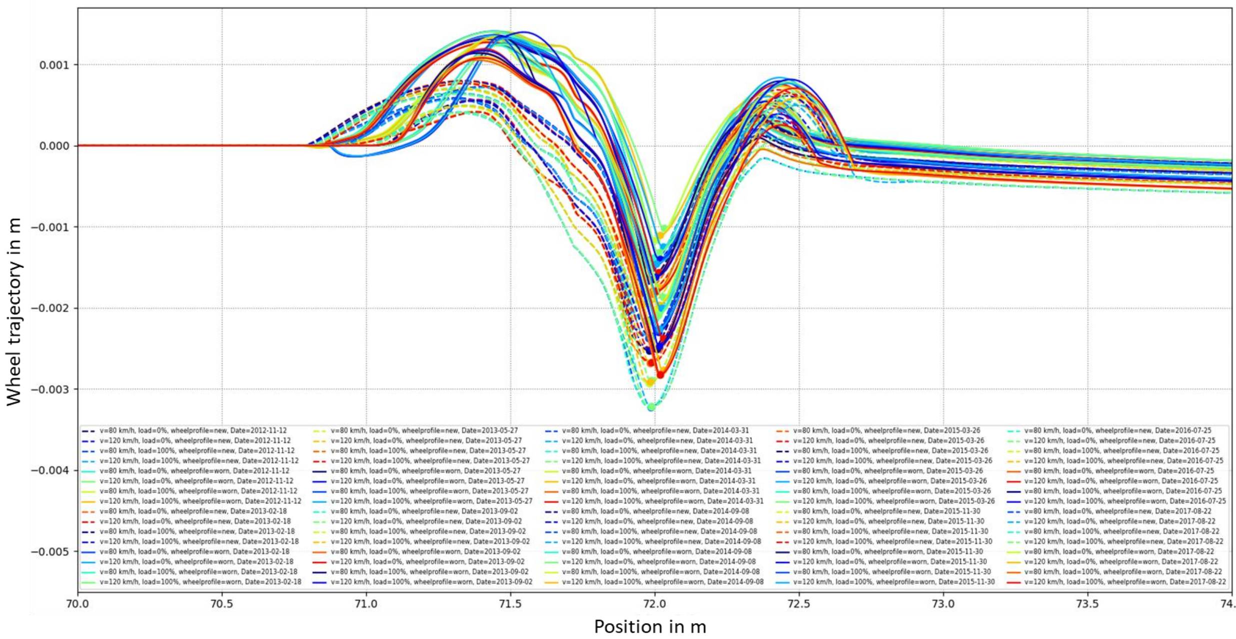

Figure 5: Wheel trajectory – varied Parameters: Velocity, load, wheel profile and historical crossing geometry.

In the next step, features based on the simulation results are defined and analysed with a sensitivity analysis. For example, from the wheel trajectory signal, different features can be extracted e.g., the maximum wheel drop, the position of the maximum wheel drop and the angle between descending and ascending part of the signal. The sensitivity analysis (Figure 6) then gives information about the influence of the varied parameters on the results of the MBS simulation and the previously defined features.

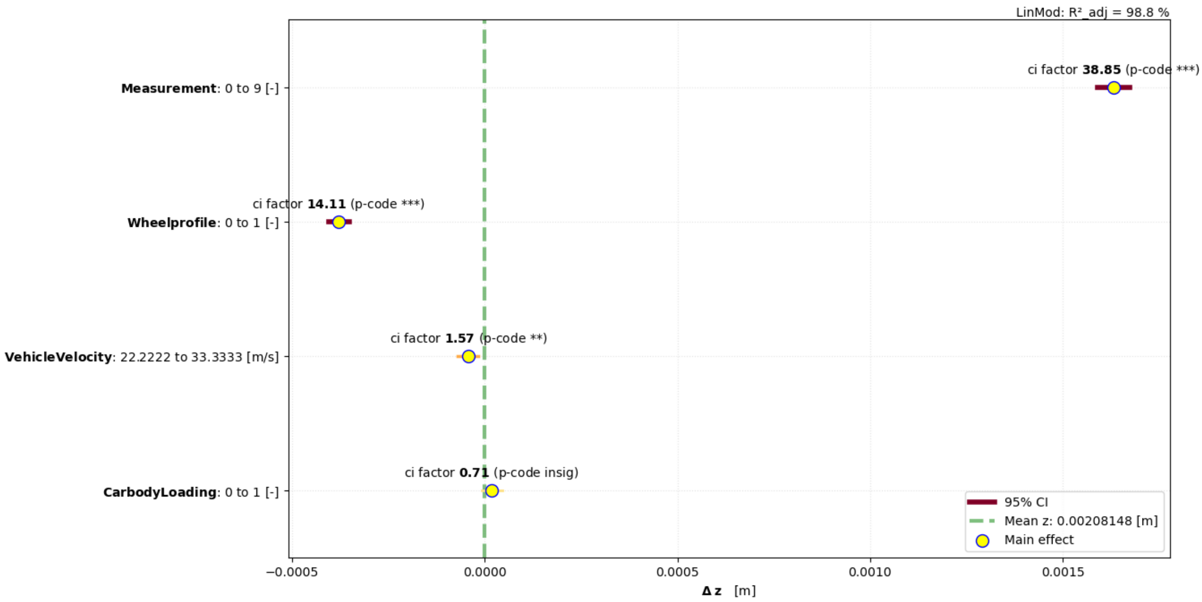

Figure 6: Sensitivity analysis of maximum wheel drop.

Further information about the robustness and the trend of the feature can be found by analysing the variation for different historical measurements of the crossing nose (Figure 7).

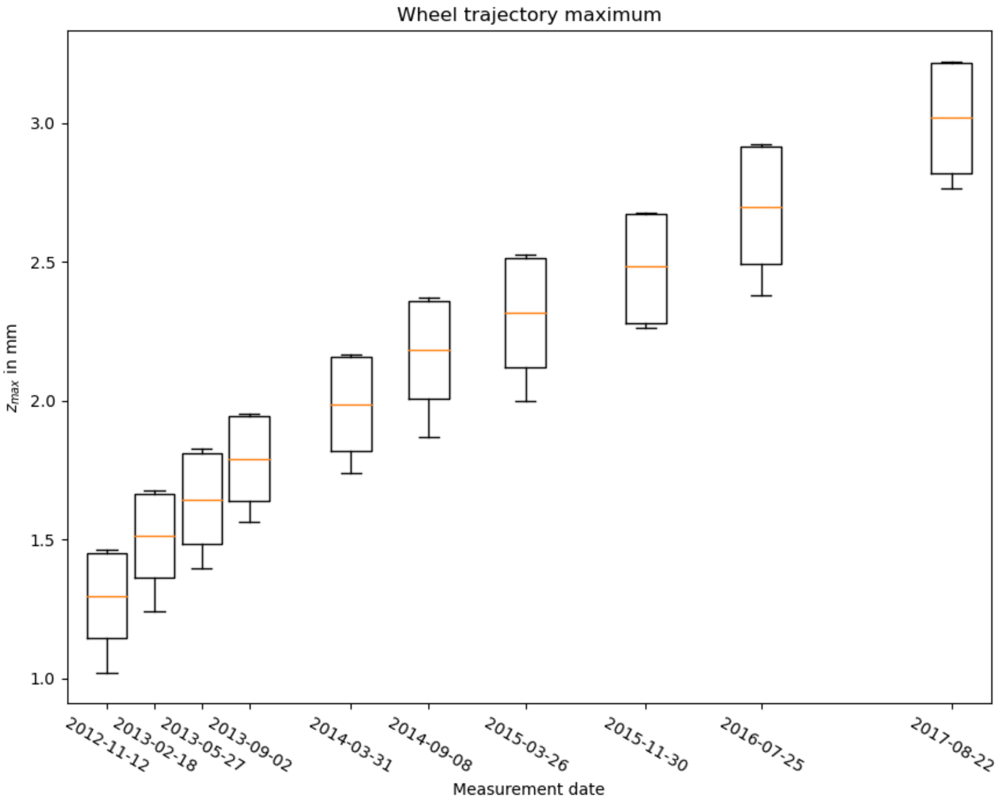

Figure 7: Range of maximum wheel drop for different crossing nose conditions.

The wheel drop for example is significantly influenced by the crossing nose condition with a small variation due to other input parameters. Therefore, this feature can be considered robust and shows that the condition of the crossing nose has a significant influence on the simulation results. This can also be seen as Proof of Concept – i.e., that it is possible to gather information about the crossing nose condition, with MBD simulations. Based on these results, scenarios for the operational simulation can subsequently be created and thus the development in the damage of the switch (in synergy with subproject A 2.1) can be determined.

3 References

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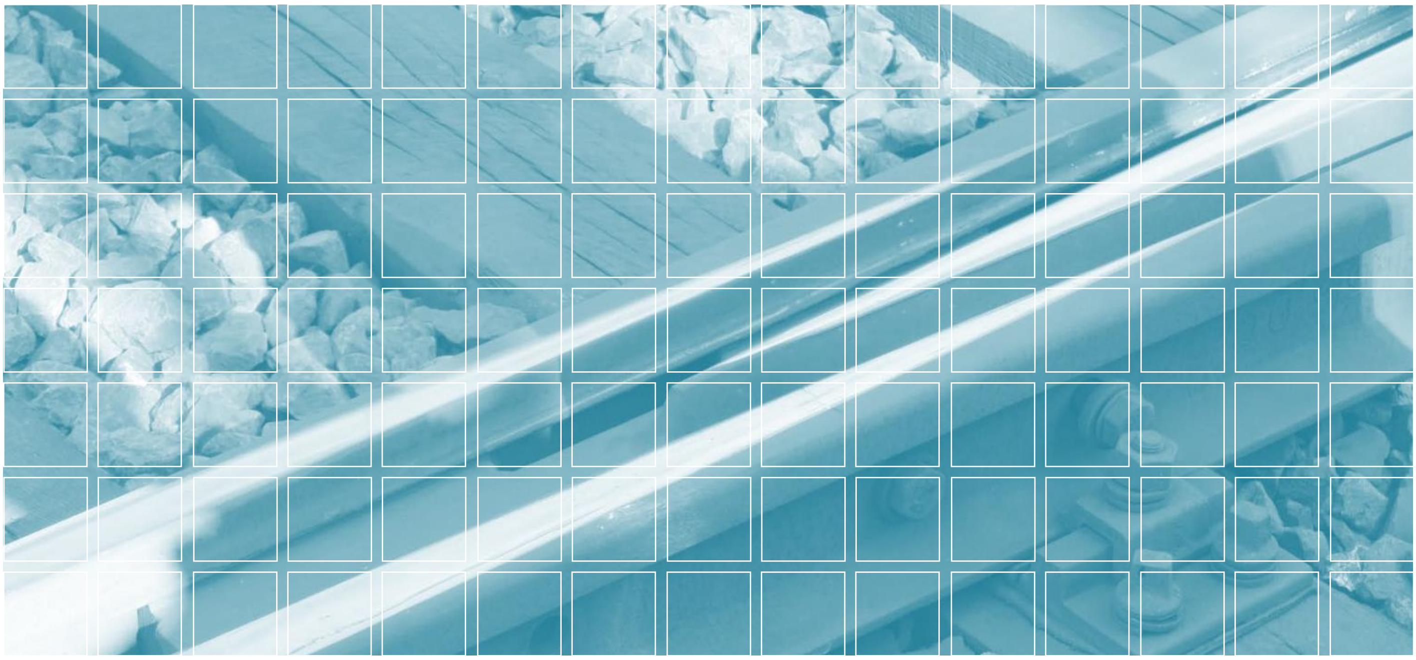
[2] Luber B et al. On-board wheel profile classification based on vehicle dynamics - from physical effects to machine learning. In: Lecture notes in mechanical engineering. Springer International Publishing; 2020. p. 113{118.



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