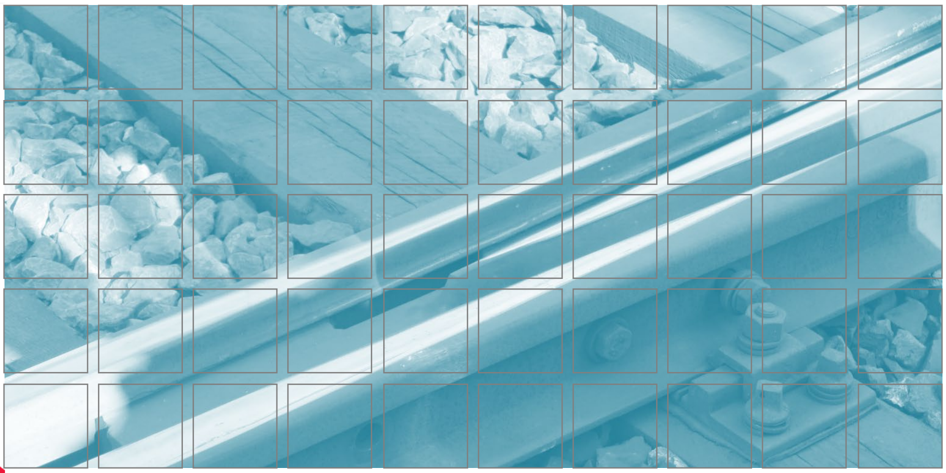
COMET-Projekt Rail4Future

Resilient Digital Railway Systems to enhance performance



D2.2.2 Report of Requirements

2021

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Preface

The first part of the project contains the definition of necessary data and methods. The three streams need partly different, but also overlapping and similar data. In order to figure out, which data need to be achieved from where, the research partners have to document their needs.

ÖBB and voestalpine are mainly the addressees for data needed in the streams lead by Graz University and Technology and Virtual Vehicle. The stream lead by Joanneum Research is executed in close cooperation with Plasser & Theurer and HBK.

The interim report was delivered on 30th November. The sections were written/delivered by the work stream leaders, the final document assembled by EBW.

Content

1 Descriptive Approach New Measuring Devices (JR)

This section describes the hardware concept of the proposed railcar mounted multi-sensor platform. It provides a combination of non-invasive measurement methods for recording and monitoring rail infrastructure such as turnouts, rail joints, etc. The measured vibration and visual data of the rail tracks are combined with highly precise time and spatial (geo-reference) synchronisation data. This enables the recording and annotation of ground truth (training) data, needed for subsequent evaluation and monitoring.

1.1 Overview Measurement System

The figure below shows the block diagram of the overall hardware concept of the measurement system including all sub components and its communication channels.

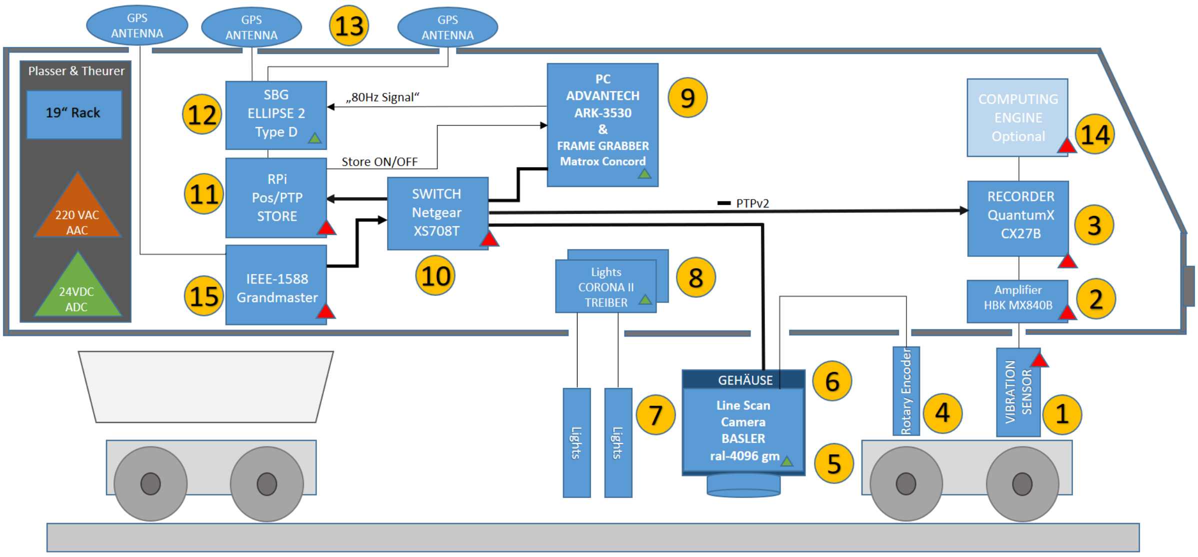


Figure 1: Hardware concept of the measurement system

The concept is developed by Joanneum Research in collaboration with the project partners Plasser & Theurer and HBK. The measurement system will be installed on a track recording car by the project partner Plasser & Theurer. HBK will provide the vibration sensors and the vibration signal recording hardware.

The main sensors for data acquisition are a vibration sensor (1-3, 14) and a line-scan camera (4-8). For time and geo-synchronicity of the recorded data (9), we utilize the Precise Timing Protocol v2 (PTPv2) (10, 11, 15) and a high-end GNSS receiver (12, 13).

1.2 Sub Components

The following chapters list the subcomponents of the measurement system and defines their specifications.

1.2.1 Vibration Sensors (1)

Analysing a dataset of acceleration data recorded on a moving rail car results in the selection of the **Bruel & Kjaer Triaxial CCLD Accelerometer Type 4529-B**. It has a sensitivity of ~100 mV/g and a maximum operation level of 71 g.

1.2.2 Vibration Sensors Amplifier (2)

The **HBK QuantumX MX840B** module is a universal measuring amplifier. The amplifier provides a constant current supply to the vibration sensors as well as amplifying the signals to operational level. It is also planned to attach a temperature sensor to one of the inputs of this amplifier to log air temperature during recording.

1.2.3 Vibration Data Recorder (3)

The **QuantumX CX27C** gateway module allows for recording the vibration signals as well as the air temperature. The data is recorded onto a hard disk. The gateway supports the Ethernet IEEE1588:2008 PTPv2 standard, used for precise time synchronisation within the whole measurement system.

1.2.4 Rotary Encoder (4)

The rotary encoder of the type **Lenord & Bauer GEL293/10000 differential** is already installed on the track recording car by Plasser & Theurer and will be used to trigger the recording of single video frames of the camera.

1.2.5 Camera (5, 6)

The **Basler raL4096-24gm** is a GigE line scan camera with a maximum line rate of 26 kHz for using all 4096 Pixels. Limiting the number of pixels to 1024 pixels allows to speed up the line rate to the maximum readout speed of the sensor of 80 KHz. This enables a recording of reliable vision data up to a rail car speed of 80 km/h with a resolution of approximately 0.33 mm/line in traveling direction and a comparable resolution along the height of the rail. The housing of camera and lens as well as for the LED illumination will be provided by Plasser & Theurer. They also provide proper mounting to their vehicle and adequate power supply.

1.2.6 Lights (7, 8)

For guaranteeing perfect light conditions for visual recording we decided to go for the **Corona II lights** and **LED-Control Units of the type XLC4-1 by chromasens**. Since visible light is not allowed for this rail vehicle, we selected a LED version with a central wavelength of 850 nm – a wavelength, where the corresponding camera still has a good sensitivity. The light beam is focused to an approximately parallel sheet of light, which allows us to illuminate a stripe on the rail of approximately 2 cm with high intensity and high uniformity.

1.2.7 Industrial Computer (9)

The **Advantech ARK-3530** is a high performance fanless embedded Computer. In this setup it is used to record and buffer the video frames from the camera. It also gets real-time geo information from the GPS system. By referencing this data to the camera data, full time and geo synchronicity will be achieved.

1.2.8 Network Switch (10)

The network switch is the core of communication of the measurement system. It ensures system wide time synchronisation as well as data exchange. The selected model **Netgear XS708T** is an 8-port 10-gigabit smart managed switch that fulfils the systems requirements in terms of reaction times and switching capacity.

1.2.9 Embedded Computer (11)

An embedded computer of the type **Raspberry Pi 4** will be used to connect to the GNSS-System (12). It is responsible for managing the received geo data from the GNSS System, storing the data and providing it to the local network in synchronized way. Additionally the embedded computer is connected to the line scan camera via hardware trigger. It is used for sending store commands after the camera requests geo data for each recorded camera frame from the GNSS System via an additional hardware trigger (12). Additionally a location based triggering of the camera can be provided via the embedded computer.

1.2.10 GNSS Sensor (12)

The **SBG Elipse 2 Type D** is a versatile miniature inertial navigation system integrat-ing a dual-band-antenna and a multi-band GNSS receiver. The Sensor provides highly precise navigation data to the embedded computer (11). It also connects to the line scan camera (5, 6) via hardware trigger to provide geo data to each recorded camera frame. The GNSS receiver features 0.05° Roll and Pitch (RTK), 0.2° Heading (Dual An-tenna RTK GNSS), is immune to magnetic distortions and provides a spatial resolution of up to 1 cm in RTK Mode and up to 1.2 m in Single Point Mode. Its output rate is 200 Hz or 100 Hz for IMU data

1.2.11 Antennas (13)

The GNSS system (12) as well as the masterclock (14) use antennas of the Type **Antcom G5Ant-42AT1**. These antennas are flat mounted and therefore ideal for installation on the roof of the track recording car.

1.2.12 Vibration Computing Engine (14)

This computing engine is an optional within the measurement system. It could be implemented in a later stage in the project for live data classification of the real-time acquired vibration data. Regarding the type of the device an **Intel NUC BXNUC10I7FNHN2 i7** is proposed.

1.2.13 Masterclock / GNSS Grandmaster (15)

The grandmaster generates a time-stamp for synchronizing the whole measurement system Plasser & Teurer will provide a **Trimble GM200** system that fulfils the PTPv2 Standard.

2 Descriptive Approach Standard Measuring Car (TUG-EBW)

The aim of this subproject is to describe the condition and deterioration of individual turnout components based on existing data. In contrast to open track, manual inspection is still the primary method for assessing the condition of turnouts. Although this enables safe railway operation due to the high level of competence of the employees, some disadvantages such as personnel in the danger zone, track closures, high costs and an unloaded measurement exist. In addition, the data obtained from the inspection is not suitable for forecasts, which means that decisions in favour of the economic optimum can only be implemented with difficulty or not at all. Therefore, measurement data is needed to provide additional support for decision making leading to economic efficiency and safety, of course. The main data source for this project is ÖBB's measuring car, the EM250. More precisely, it is the output of the IMU system and various optical measuring systems. From this data source, robust prediction algorithms are to be implemented for use in a predictive maintenance concept. Additional data will be used for model verification and calibration.

2.1 Required Data sources

This section of the report lists and describes the data required for the project objective. On the one hand, it describes basic characteristics of the different data sources in order to give an impression of the expected potential of the data. On the other hand, it is briefly explained why these data sources are necessary for the planned evaluations.

2.1.1 Track recording car - EM250

Since 2001, the EM250 has been the track recording car for main lines in the ÖBB network. While some additional measuring systems have been mounted on the vehicle in recent years, the basic parameters, depicted in the following table, have remained compatible and thus comparable.

measurement signal	measurement channel group	sampling rate	available
half gauge unfiltered*	1 - optical gauge measure	25 cm (1 DB)	since 2001
half gauge filtered*	1 - optical gauge measure	25 cm (1 DB)	since 2001
gauge filtered	1 - optical gauge measure	25 cm (1 DB)	since 2001
gauge	2 - optical profile measure	> 250 cm	till 2015
base gauge	2 - optical profile measure	> 250 cm	till 2015
cant*	2 - optical profile measure	> 250 cm	till 2015
gauge	2 - optical profile measure	100 cm (4 DB)	since 2015
base gauge	2 - optical profile measure	100 cm (4 DB)	since 2015
cant*	2 - optical profile measure	100 cm (4 DB)	since 2015
alignment *medium* (3-25 m)*	3 - inertial measure	25 cm (1 DB)	since 2005
alignment *long* (1-70 m)*	3 - inertial measure	25 cm (1 DB)	till 2015
alignment *long* (25-70 m)*	3 - inertial measure	25 cm (1 DB)	since 2015
profile *medium* (3-25 m)*	3 - inertial measure	25 cm (1 DB)	since 2005
profile *long* (1-70 m)*	3 - inertial measure	25 cm (1 DB)	till 2015
profile *long* (25-70 m)*	3 - inertial measure	25 cm (1 DB)	since 2015

Table 1 - Basic measurements of the EM250 [1]

The measurement channel group indicates whether the signal is measured by the inertial unit or via optical measuring systems. Most signals contain one data point (data break, DB) every 25 cm, so that 25 cm is the usual sampling rate for all signals. Some measurements (gauge, base gauge and, cant) are only available every 4 DB (100 cm). The entry "available" refers to the last update of the storage options for a signal. This does not necessarily mean that the signal is not compatible with older versions. For example, the sampling rate of the gauge signal before 2015 was different in the sampling rate compared to after 2015. Nevertheless, the signals are comparable and compatible with each other.

The following sections provide a more detailed overview of the EM 250 data relevant to the project.

2.1.1.1 Data measured by the IMU

The core of the EM250 is an inertial measurement unit (IMU) recording accelerations in different directions and angles and returns the parameters profile (3-35m/25-70m) and alignment (3-35m/25-70m). In addition, the curvature, cant and twist are calculated from the IMU data and stored in separate channels. These parameters together describe the track geometry and are therefore a solid basis for further evaluations. The sampling rate of the IMU parameters is 25 cm. Figure 2 shows the measurement principle of the IMU-system.

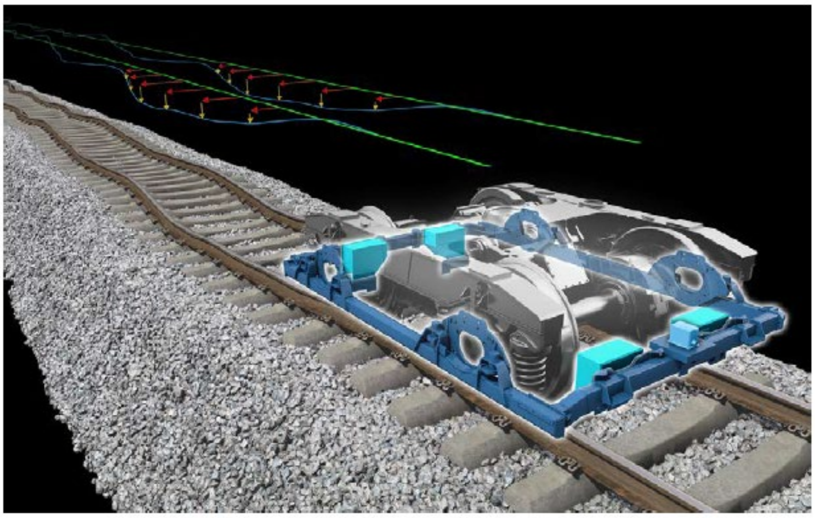


Figure 2 - Measurement principle of the IMU [2]

2.1.1.2 Gauge – filtered half gauge – half gauge filtered – cant

Several optical measuring systems are mounted onto the EM250 providing additional information for assessing the track quality. Furthermore, these signals are used to assign the parameters described above to the right or left rail. The unfiltered half gauge signal is a directly measured quantity, the filtered half gauge signal, the cant and the track gauge itself are calculated signals. These measurements are essential for the project, as they form the basis for a subsequent necessary data positioning.

2.1.1.3 Rail surface measurement signal

All parameters mentioned above have in common that they are well investigated and already used for various condition assessments of railway lines and turnouts. This does not apply to the rail surface signal. The rail surface signal is obtained from the rail surface measurement system, a chord-based system using three optical distance sensors all mounted in a row. The following figure shows the basic structure of the laser sensors.

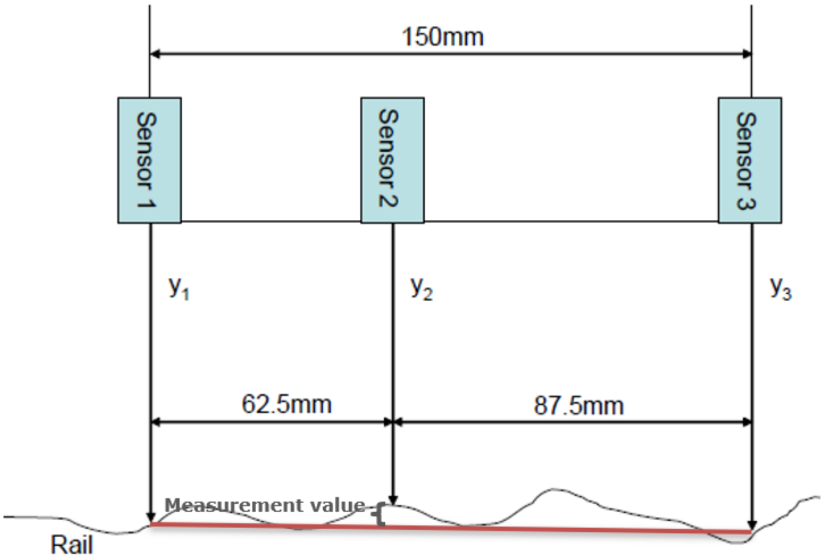


Figure 3 - Measurement principle of the rail surface signal [3]

The first and the last laser build a virtual chord. The actual measurement value describes the distance between the rail surface of the middle laser and the chord surface at the same position. The real rail surface shape can be recalculated with a defined transformation function. The measurement system can be mounted onto vehicles with speeds up to 250 km/h and still returns a data point every 5 mm. This fact is potential and challenge in signal handling at the same time. On the one hand, a very detailed image of the rail surface can be generated without reducing track availability if mounted on a regular (inspection) vehicle. On the other hand, an advanced data positioning algorithm and powerful data analysis are required for working with this kind of data.

Although, the measurement system has been mounted onto the EM250 since 2005 and some modified parameters are already partly in use, the original output signal of the system was not investigated up to now. The main reason might be the already mentioned precondition of an exact positioning process. Without this re-positioning, the potential of a small sampling rate cannot be exploited.

Since several potentials arise from analysing this data source, it is the research focus for this part of the project. In particular, results are expected for the condition assessment of the crossing nose and of insulating joints, but also the assessment/detection of rail defects and welds could be a relevant output of the planned investigations. The first focus, however, is clearly the evaluation of the crossing nose.

2.1.2 Asset classification and load spectrum

In order to draw correct conclusions, information about the asset classification and the load spectrum is essential. Therefore, data on switch type, rail type, diverging radii, switch angle, and sleeper type as well as daily loads and the year of installation are included for an assessment.

2.1.3 Documented executed maintenance actions

Documentation of maintenance measures already carried out serves to validate significant changes in the signal characteristics of the analysed measurement data. Since the focus of the project is on the metal parts of the turnout, all maintenance works affecting the condition of these components are to be included in the evaluation. This includes the replacement of the crossing nose or the insulated rail joint, welding processes, deburring processes and grinding processes. In addition, the results of the visual inspection with relevant additional information are included in the evaluation.

2.1.4 Calibri measurements

The measurement of the rail surface reflects the corrugation of the rail surface. However, as the measurement system is designed for the open track, the actual measured part of the crossing nose is not exactly defined, although initial evaluations show that a large part of the crossing is included in the measurement. Calipri measurements are used to correlate the rail surface measurement with the actual geometry of the crossing nose. The basic output of this measurement is a 3D point cloud reflecting the surface geometry of the crossing nose. With additional algorithms from the data provider – Voestalpine Railway Systems GmbH – it is possible to use this data in a suitable way.

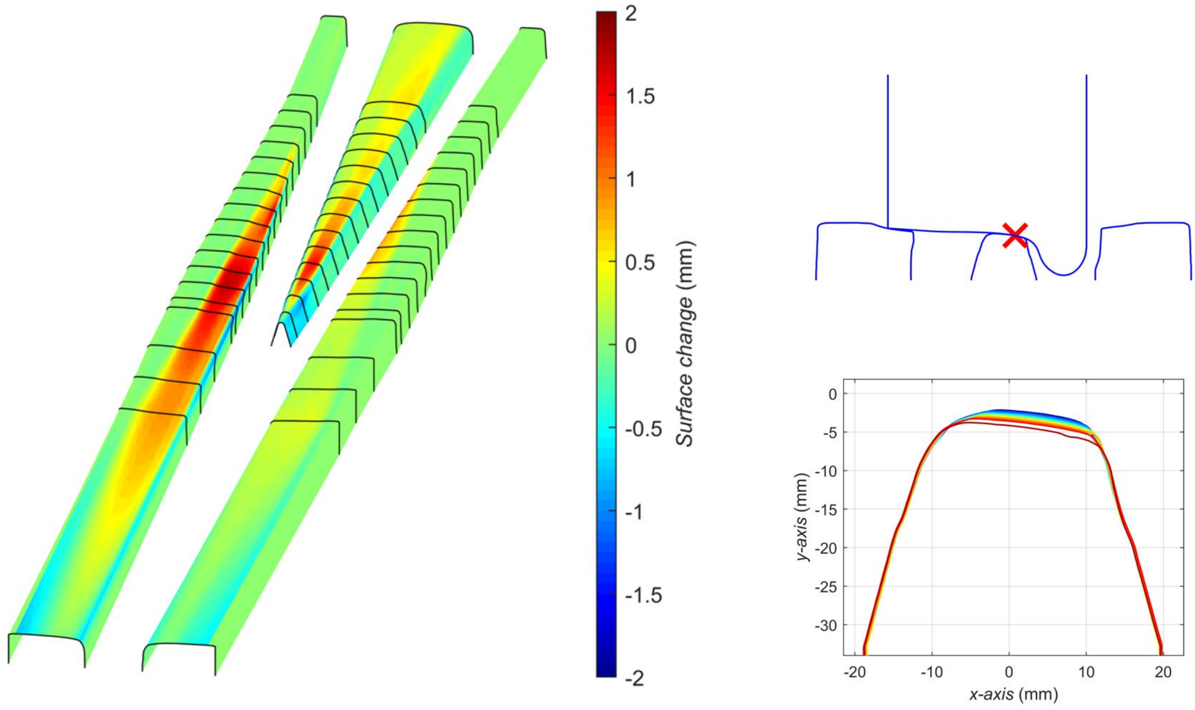


Figure 4 - Data visualisation of the Calibri measurements [4]

The left part of Figure 4 shows a 3D visualisation of a Calipri measurement. The colour code shows which parts of the crossing nose are most subject to wear, which in turn gives information about the actual interaction between the rail and the wheel. In this part of the figure, also the 20 measured cross-sections are visible. The distance between the cross-sections is significantly smaller in the relevant area of the crossing nose than in the other areas.

A visualisation of the actual contact point between rail and wheel is available for the corresponding cross-sections. The upper right quarter of Figure 4 shows an example of that.

Since Calipri measurements are available over several years and the measurements are positioned relative to each other, visualisation of wear over time is possible, as can be seen in the lower right quarter of the figure. This information can be used for a better understanding of signal characteristics of the rail surface signal.

2.1.5 Turnout layouts – technical drawings

For a detailed mapping of the signal characteristics to the actual asset, information about the location of the different parts of the turnout is required. This information can be obtained from the technical drawings of the installed turnouts. The following figure shows an example of a technical drawing for one of the project turnouts.

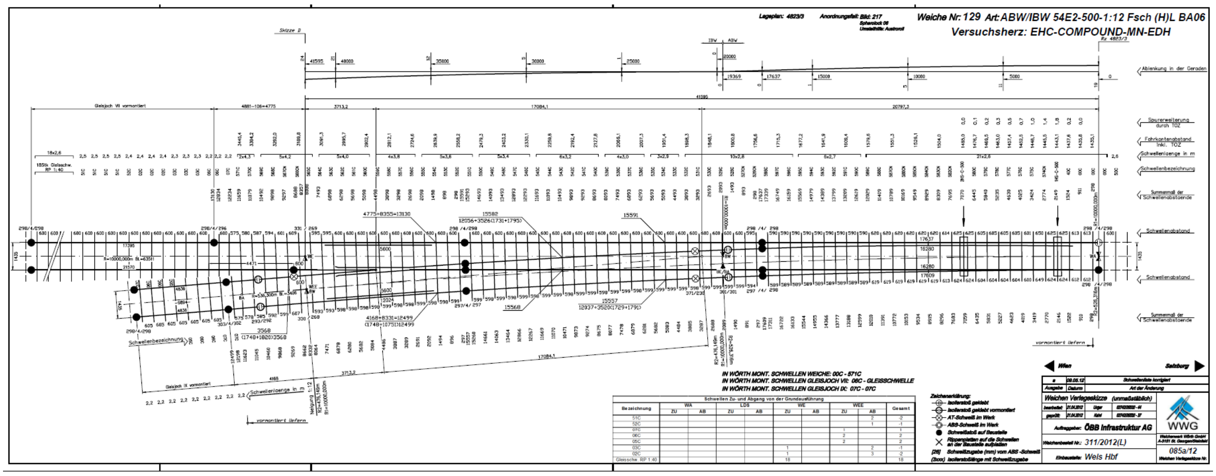
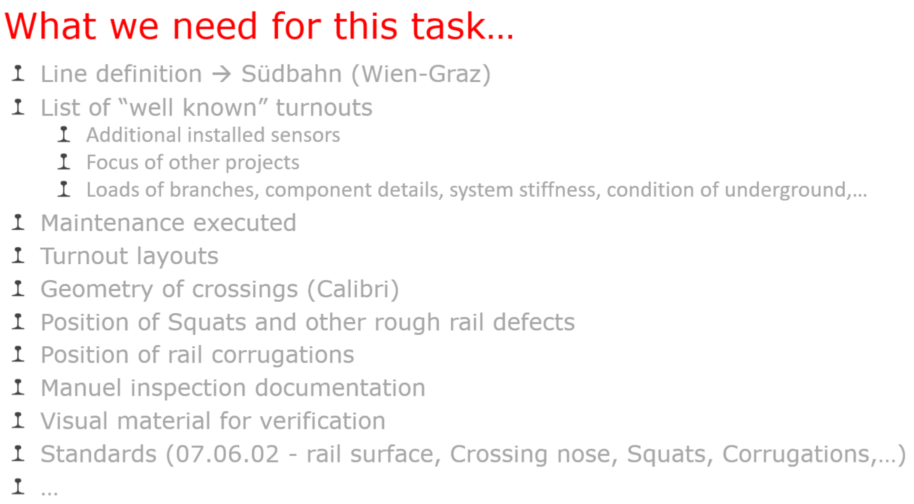


Figure 5 - Technical drawing of turnouts [5]

The dimensions of all installed components as well as the distances between the components can be taken from the technical drawing. In addition, information on different welding processes (in the factory or on site) is available. Although the technical drawings of the different turnouts do not always contain information presented in the same way, the essential information is available for each turnout.

2.2 Data exchange process

The aim of the kick-off meeting of area 2.2 was to present the research concepts of the academic partners of the project and to define the project goals of all project partners. For the second meeting, the input data needed for a successful implementation of these goals should be defined. The list of necessary input data presented at the project meeting on 28 April 2021 is as follows.



What we need for this task…

- Line definition → Südbahn (Wien-Graz)
- List of "well known" turnouts
  - Additional installed sensors
  - Focus of other projects
  - Loads of branches, component details, system stiffness, condition of underground,…
- Maintenance executed
- Turnout layouts
- Geometry of crossings (Calibri)
- Position of Squats and other rough rail defects
- Position of rail corrugations
- Manuel inspection documentation
- Visual material for verification
- Standards (07.06.02 - rail surface, Crossing nose, Squats, Corrugations,…)
- …

Figure 6 - List of necessary input data

It was communicated to the project partners which of the points were the most relevant and which would provide additional useful information. The aim of this phase of the project was to define a list of turnouts that can be used for the development of algorithms for the condition assessment of turnouts. Since this task is only feasible for turnouts assessed by the EM250 on the one hand and allowing for additional information from the crossing nose geometry and good documentation of executed maintenance work on the other hand, a list of 30 turnouts was created for which this applies.

Turnout	Location	Local Number	DB776	Position	Type	Crossing nose material
T_R4F_1	Bf. Niklasdorf	1	8130	10,527	EW-60E1-500-12-Fz-Be-be	CENTRO Mn13 EDH
T_R4F_2	Bf. Niklasdorf	2	8130	10,626	EW-60E1-500-12-Fz-Be-be	CENTRO Mn13 EDH
T_R4F_3	Bf. Niklasdorf	5	8130	10,674	EW-60E1-500-12-Fz-Be-be	CENTRO Mn13 EDH
T_R4F_4	Bf. Niklasdorf	6	8130	10,773	EW-60E1-500-12-Fz-Be-be	CENTRO Mn13 EDH
T_R4F_5	Bf. Niklasdorf	53	8130	11,949	EW-60E1-500-12-Fz-Be-be	W360
T_R4F_6	Bf. Niklasdorf	54	8130	12,048	EW-60E1-500-12-Fz-Be-be	400UHC/K600
T_R4F_7	Bf. Niklasdorf	62	8130	12,119	EW-60E1-500-12-Fz-Be-be	400UHC/K600
T_R4F_8	Bf. Niklasdorf	63	8130	12,218	EW-60E1-500-12-Fz-Be-be	W360
T_R4F_9	Bf. Wels	126	4012	213,31	EW-54E2-500-12-FSch-H	COMPOUND Mn13
T_R4F_10	Bf. Wels	127	4012	213,41	EW-54E2-500-12-FSch-H	COMPOUND Mn13
T_R4F_11	Bf. Wels	128	4012	213,41	EW-54E2-500-12-FSch-H	COMPOUND Mn13
T_R4F_12	Bf. Wels	129	4012	213,505	ABW/IBW-54E2-500-12-FSch-H	COMPOUND Mn13
T_R4F_13	Bf. Wels	130	4012	213,519	EW-54E2-500-12-FSch-H	CENTRO Mn13
T_R4F_14	Bf. Wels	131	4012	213,529	EW-54E2-500-12-FSch-H	CENTRO Mn13 EDH
T_R4F_15	Bf. Zeltweg	59	8131	232,521	EW-60E1-500-12-Fz-Be-be	DB Witten Chrom Bainit
T_R4F_16	Bf. Zeltweg	61	8131	232,531	EW-60E1-500-12-Fz-Be-be	BWG Chrom Bainit
T_R4F_17	Bf. Zeltweg	62	8131	232,629	EW-60E1-500-12-Fz-Be-be	DB Witten Chrom Bainit
T_R4F_18	Bf. Zeltweg	54	8131	232,426	EW-49E1-190-9-FSch-H	keine Messdaten!!
T_R4F_19	Bf. Zeltweg	67	8131	232,9	IBW-60E1-500-12-Fz-Be-be	CENTRO Mn13 EDH
T_R4F_20	Bf. Zeltweg	68	8131	232,997	ABW-60E1-500-12-Fz-Be-be	DB Witten Chrom Bainit
T_R4F_21	Bf. Marein/ St. Lorenzen	51	8051	147,386	EW-60E1-500-12-Fz-Be-be	VC Mn13
T_R4F_22	Bf. Marein/ St. Lorenzen	53	8051	147,415	EW-60E1-500-12-Fz-Be-be	CENTRO Mn13 EDH
T_R4F_23	Bf. Marein/ St. Lorenzen	54	8051	147,512	EW-60E1-500-12-Fz-Be-be	Bainit Prestige
T_R4F_24	Bf. Marein/ St. Lorenzen	55	8051	147,519	EW-60E1-500-12-Fz-Be-be	Bainit Prestige
T_R4F_25	Bf. Marein/ St. Lorenzen	56	8051	147,619	EW-60E1-500-12-Fz-Be-be	CENTRO Mn13 EDH
T_R4F_26	Bf. Atzgersdorf	1	2052	7,72	ABW-60E1-500-12-Fz-Be-be	-
T_R4F_27	Bf. Atzgersdorf	2	2052	7,827	IBW-60E1-500-12-Fz-Be-be	-
T_R4F_28	Bf. Atzgersdorf	3	2052	7,827	IBW-60E1-500-12-Fz-Be-be	-
T_R4F_29	Bf. Atzgersdorf	4	2052	7,938	ABW-60E1-500-12-Fz-Be-be	-
T_R4F_30	Bf. Atzgersdorf	5	2052	7,948	IBW-60E1-500-12-Fz-Be-be	-

Table 2 - List of "project-turnouts"

As all information is not available for every turnout in the same quality, seven of the 30 turnouts will be focused on in the next part of the project. These turnouts are highlighted in Table 1 and include T_R4F_03, T_R4F_08, T_R4F_12, T_R4F_21, T_R4F_22, T_R4F_24, and T_R4F_25. The following table shows the main criteria for this decision.

Turnout	Criteria of consideration
T_R4F_03	Main turnout of project partner
T_R4F_08	Documented crossing nose exchange
T_R4F_12	Worn out insulated rail joint documented
T_R4F_21	Good documentation incl. crossing nose exchange
T_R4F_22	Good documentation incl. crossing nose exchange
T_R4F_24	Good documentation incl. crossing nose exchange
T_R4F_25	Good documentation incl. crossing nose exchange

Table 3 - List of the first turnouts to be examined

For the turnouts in Table 2, the following data have been provided or will be provided by the project partners.

- Asset classification and load spectrum - were provided by ÖBB-Infrastruktur AG
- Relevant measurement data of EM250 - were provided by ÖBB-Infrastruktur AG
- List of executed maintenance actions (data base) - were provided by ÖBB-Infrastruktur AG
- Additional information about executed maintenance actions – will be provided by ÖBB-Infrastruktur AG within the next weeks
- Technical drawings - were provided by ÖBB-Infrastruktur AG
- Calipri measurement for T_R4F_22 – was provided by Voestalpine Railway Systems GmbH (If required, this data can be made available for further turnouts; there will be corresponding coordination here)

In addition, data on the asset classification, the load spectrum, data on maintenance measures carried out and measurement data from the EM250 are available for 29 of the 30 turnouts originally defined. For 19 of the 30 turnouts (ASC Leoben), additional information on maintenance measures already carried out is currently being collected.

2.3 Status quo - Descriptive Approach Standard Measuring Car (TUG-EBW)

As can be observed from the project schedule, the aim of the passed project phase was to define a focus and the assets to be investigated. For working group 2 of area 2.2, the focus lies on the quality behaviour of turnout components, especially the crossing nose. The rail surface signal, which is measured with a measuring system already mounted on the EM250, is the focus of the investigations. Since a turnout can only be meaningfully evaluated as a complete system, other data sources are also taken into account, some of which have already been investigated. Considering as many effects as possible, reliable prognosis algorithms are to be implemented for a predictive maintenance concept of turnouts.

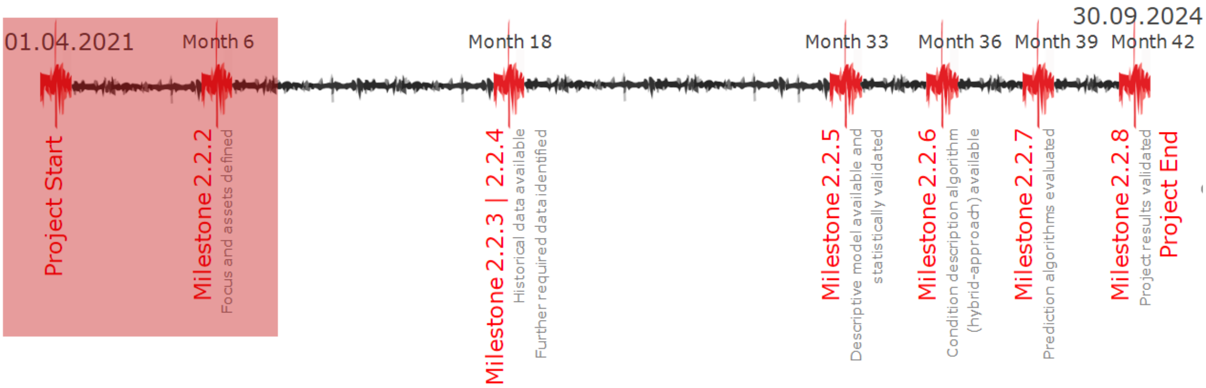


Figure 7 - Timeline for the project

A list of 30 turnouts was defined for further evaluations. Basic data is available for 29 of these 30 turnouts. More detailed evaluations are planned for seven turnouts which, according to current knowledge, are defined as particularly relevant for various reasons. As further information on maintenance measures is collected and other unique features might occur in the upcoming weeks, this list is still kept flexible.

From today's perspective, all data required is already available or will be available within the next few weeks. In the event that further data is required during the course of the project, regular coordination with the project partners will take place.

In summary, it can be stated that the existing data situation is solid. Work on the following work packages could already be started.

3 Model-based assessment of S&C (VIF)

3.1 Motivation & research question

Switches and crossings (S&C) cause a significant portion of the overall costs related to track maintenance activities. Currently, inspection is carried out by means of fixed inspection cycles based on manual measurements or special inspection vehicles. In order to increase the efficiency of switch maintenance, more focus is placed on continuous monitoring of S&C. Information on the condition of the S&C can be collected by means of attached sensors on track or in-service vehicles with the aim of detecting faults at an early stage, analysing of root causes and making condition prognosis [6].Therefore, methods and models are necessary to determine the operating state of the S&C on the basis of physical effects (model-based approaches) or on the basis of statistical behaviour (data-driven models) [7]. In many cases, the combination of both methodological approaches in the sense of hybrid modelling represents the best solution.

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 important role here. Through the reliable simulation of vehicle/track interaction, physical effects can be determined 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. Even with appropriately selected measuring intervals, measurements always represent a certain snapshot (measured variable plus environmental influences). In contrast, simulations have the great advantage that unknown parameters can be varied in a controlled manner. However, this requires validated models with a corresponding model depth as well as precise input data for the simulation scenarios.

Input sources for MBD simulation are profile geometry in rails and turnout zones, track irregularities and layout and operating conditions of the vehicle and track. There are different methods and procedures to capture this information. Data and information can be obtained from diagnosis vehicles, inspections, operational plans and external sources (e.g. weather). The questions arising in this context are, which steps are necessary for the preparation of data in order to be able to use them in MBD simulation and is it possible to simulate the development of the turnout condition with the current scope of data?

3.2 Concept

The concept of the work in this approach is shown in the following figure:

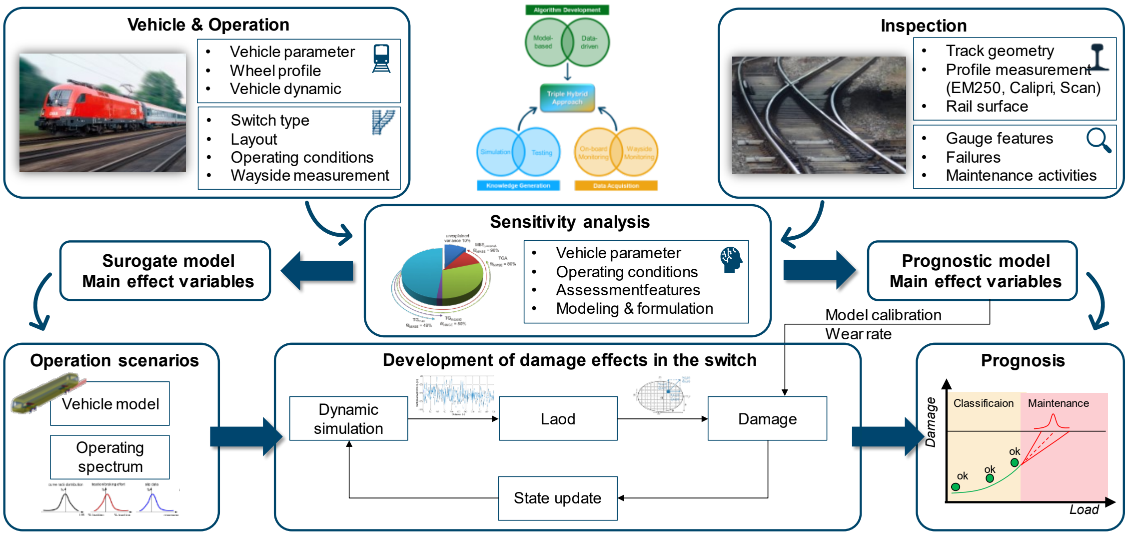


Figure 8: Concept for evaluation of S&C condition based on simulation

Based on the 'Trible Hybrid Approach' 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.). 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 MBS simulation results. Furthermore, parameters are derived for the corresponding virtual modelling of the operation and for the prediction of the change of state of the S&C. 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.

3.3 Requirements

In order to implement the concept introduced before, the following requirements are stated regarding the data as input for the simulation:

3.3.1 Inspection data

- Rail profiles of the S&C
    - Cross sections of the S&C (Calipri or inspection car)
    - 3D scan of the S&C (point cloud)
- Track Irregularities

  - Longitudinal level (D1 3 – 25 m)
  - Alignment (D1 3 – 25 m)
  - Cross level
  - Gauge
- Track Layout
  - Curvature
  - Superelevation
- Surface Defects
  - Rail surface signal (inspection car)
- Inspection data of selected S&C
  - S&C type (z.B. EHZ 500 1:12)
  - Geometry of the S&C
  - Material information
  - Speed permitted
  - Maintenance activities

3.3.2 Vehicle and operation

- Wheel profiles
  - Cross section of the wheel (Calipri or wayside system)
- Vehicle parameters (if available)
  - Geometry of specific vehicles for analysis
  - Mass of the vehicle
  - Design parameters of coupling elements
- Operation condition (for vehicles at selected S&C)
  - Vehicle speed (permitted)
  - Vehicle typ
  - Vehicle loading (if available)
  - Vehicle route through S&C (facing/trailing/straight/curve)

3.3.3 Pre-selected S&C for the studies

In a first step, the following switches were selected for analysis in the course of 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)

4 Outlook

Most of the requirements could be defined in detail. The overwhelming part of data needed is already available, respectively provided by the addressees. Of course, some question marks remain as this is fundamental research and it might be that additional data is needed when proceeding with the evaluations.

Anyhow, the cooperation between the partners in WP2 is as good as needed. The work is within the time frame and investigations could already start.

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