Final Report:
Harmonised European Railway Diagnostics

Project acronym:	HERD
Starting date:	15/04/2024
Duration (in months):	6
Call (part) identifier:	Call EU-Rail.OP.01.22 "Europe's Rail System Pillar"
Grant agreement no:	Grant Agreement No 101101966
Due date of deliverable:	14. October 2024
Actual submission date:	11. October 2024
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Status:	Final report

Reviewed: (yes)

This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101101966.

Document history		
Revision	Date	Description
1	03.09.2024	First Issue
2	10.10.2024	Final Issue
3	02.12.2024	Approved Issue

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Abbreviation / Acronym	Description
AI	Artificial Intelligence
API	Application Programming Interface
CBA	Cost-Benefit-Analysis
CBM	Condition Based Maintenance
CBO	Common Back Office
CCS	Control-Command Signalling
CSM	Common Safety Methods
CSV	Comma-Separated Values
EC	European Commission
ECM	Entity in Charge of Maintenance
EESC	European Economic and Social Committee
EPCIS	Electronic Product Code Information Services
ERA	European Union Agency for Railways
ERJU	Europe's Rail Joint Undertaking
EULYNX	A collective of railway Infrastructure Managers, united by a common purpose: to reduce the lifecycle costs of signalling systems while maintaining the highest levels of safety and operational efficiency.
FAx	Flagship Area x (1, 2, ..)
GCU	General Contract of Use for Wagons
GS1	International organisation developing and maintaining standards for barcodes
HDDI	Harmonised Diagnostic Data Interface
HERD	Harmonised European Railway Diagnostics
IEC	International Electrotechnical Commission
IM	Infrastructure Manager
IP	Innovation Pillar
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
KPIs	Key Performance Indicator

LCC	Life Cycle Cost
LTAM	Long Term Asset Management
MBSE	Model-Based System Engineering
OEM	Original Equipment Manufacturer
OOR	Out-Of-Roundness
OPC UA	Open Platform Communications Unified Architecture
PoC	Proof of Concept
RCM-DX	Rail Condition Monitoring - Data Exchange
REST	Representational State Transfer
RFID	Radio Frequency Identification
RINF	Registers of Infrastructure
RLC	Radlast Checkpoint
RS	Rolling Stock
RU	Railway Undertakings
SD	Sub-Deliverable
SERA	Single European Railway Area
SIPOC	Supplier-Input-Process-Output-Customer
SOAP	Simple Object Access Protocol
SP	System Pillar
TCCS	Traffic Control and Command System
TMS	Traffic Management System
TSI	Technical Specification of Interoperability
UC	Use Case
UC-AG	Use Case Assessor Group
UIC	International Union of Railways
VDV	Association of German Transport Companies/ Verband der Deutschen Verkehrsunternehmen
VK	Vehicle Keeper
WILD	Wheel Impact Load Detector
WIM	Weighing In Motion
WPMS	Wheel Profile Measuring System

WPx	Work Package number X (e.g., WP29)
WTMS	Wayside Train Monitoring Systems
XML	Extensible Markup Language

Abstract

Currently, there is no mechanism in the ERJU which coordinates the activities related to the harmonisation of the diagnostic data exchange and ensures the sharing of the respective outcome, lessons learned, and best practice.

As a logical consequence of the EESC targets, the EU-Rail objectives, and the identified need, HERD (Harmonised European Railway Diagnostics) generates a set of proven technically and procedurally harmonised diagnostic data use cases and will provide a guideline for a harmonised diagnostic data exchange for all relevant assets diagnostic data, which will enable the continuous gain of condition information for integrated asset management.

According to a new standardised process, HERD evaluates the potential applications for railway data harmonisation and identifies the most relevant of them to generate use cases for further investigations.

The purpose of HERD is to develop an architecture for harmonising the European railway diagnostic data that principally consists of flexible combination of a mix of trackside sensor and onboard systems. It aims to regularly review the new techniques which automatically and autonomously can acquire the diagnostic data and to integrate them. Furthermore, HERD intends to generate operational, use case dependant concepts for harmonised diagnostic data of the railway assets – both rolling stock and track – and their interfaces beyond the current specifications, with much greater standardisation than at present.

We have concentrated our work on two use cases selected from the outcome in Phase 1 "Track Side Vehicle Monitoring for Maintenance" and "On-Board Track Monitoring". The outcome of the work on both UCs includes expected benefits, description of the gap between the needs and the actual status, analysis of the specific HDDI (Harmonised Diagnostic Data Interface) parameters, definition of the use case dependant cost benefit analysis structure, initial risks and opportunities analysis, and recommendations for the next steps.

The work in UC1 shows that harmonising the diagnostic data provided by WTMS can generate many direct and indirect benefits for both data user and data provider. The impact of HDDI was separately evaluated for the different data users RU, VK, ECM and IM and the outcome describes exemplarily the positive effect on increased safety, improved maintenance, reduced operating costs, shorter off-service times, higher availability and reliability, reduction of secondary damage, better planning and optimisation, data-driven decisions, compliance with regulatory requirements, increased customer satisfaction, environmental improvement, etc.

The evaluation of two anonymised real applications shows following opportunities:

1) In cross-border freight transport downtimes can be reduced by 77% thanks to digital vehicle control based on WTMS. This is thanks to the known condition of the vehicle and the automated control system.

2) With the development of the digital vehicle inspection, based on the WTMS condition information, the manual inspection effort of a wagon inspector for each individual technical train inspection is reduced by 58%.

Today, despite the widespread use of track measurements based on EN 13848 and EN 14363 standards, no standard exists for the exchange and formatting of track condition data. Missing a HDDI leads to inconsistent data outputs, making data analysis more difficult. Additionally, it increases

costs associated with developing and maintaining multiple custom interfaces, updating data across different systems, etc. which can cause delays and potential data quality problems.

UC2 has carried-out a target-oriented study on Harmonisation of Railroad Infrastructure Diagnostic Data in Europe with various European IMs. The purpose of that study was to investigates the data-driven methods used by European infrastructure managers to monitor the condition of railroad infrastructure. It explores the potential benefits of harmonising diagnostic data across Europe, aiming to understand how a unified approach could improve efficiency in infrastructure management.

The outcome of that study shows divers benefits which are relevant for most IM like increased safety and reliability, reduced costs for data import and resources for data management, accelerated data access, improved data comparison and analysis, enhanced data quality, facilitated interoperability, etc.

Additionally, there are some specific opportunities such as utilising best practice information, optimisation, and standardisation in tenders with a profit for both the customer (IM) and the supplier, as well as enhancing the legal compliance with a data standard which guaranties the data comparability over many years.

The need of a unified approach to data exchange is a clear outcome of the questionnaire and it states that harmonisation of the diagnostic data, setting standards at least for the data interface to avoid adopting multiple file formats. At least 50% of the responses confirmed that they are already collecting measurements from the commercial trains; others do see the benefits of such practices in the future.

The success of harmonisation of the railway diagnostic data directly depends on the quality of cooperation between the stakeholders. Even if the absolute best and optimised architecture is in place, the utilisation of the opportunities and the gain of the benefits need the collaboration between the main players in Europe.

Our work clearly shows that the implementation of HDDI Europe wide is not only a challenge to harmonise railway diagnostic systems but much more to overcome established habits, doubting and borders. Proceeding only with the well-instituted local, national, and/or bilateral cooperations won't be sufficient to boost the competitiveness of the European railway transport.

We have recognised that in terms of HERD there is a need of much more collaboration between HERD and the Flagship Areas in IP, especially FA1, FA3 and FA5. There are WPs like FA1/WP29 and FA3/WP7 which would be perfectly eligible to implement a demonstrator for the use cases in HERD. Unfortunately, there are too many formal obstacles which hinder an effective conducting with a reasonable effort.

In the next period we have committed to develop the needed specifications for UC1-HDDI and the plan for the implementation of a UC1 demonstrator/pilot. Regarding the execution of a UC1 pilot project we need a strong support from ERJU because of the missing budget for it.

We also plan to proceed working on UC2 and depending on our resources to initiate the investigations on other UCs.

Our conclusion is that harmonising the Railway Diagnostic Data will improve and intensify the collaboration between IM, RU, VK and the railway industry supplier. The higher degree of utilising the data creates a win-win situation that significantly enhances effectiveness, efficiency, and safety in the railway sector and generates valuable benefits for the stakeholders.

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1 Introduction

The European Economic and Social Committee (EESC) considers while a lot happened in respect of opening markets and technical harmonisation in thirty years of liberalisation, a lot remains to be done in the Single European Railway Area (SERA). EESC states that measures are needed to facilitate cross border operations by eliminating problems and delays at border crossings. It underlines that integrated railway systems can guarantee fair allocation as well as non-integrated systems. The EESC points to the fact that many of the bigger and the successful railway countries in Europe decided in favour of integrated railway companies to ensure synergies, better coordination, and flexibility. In that context, SERA, as the EU-wide system of rail networks, aims to allow the expansion of the rail sector based on competition, technical harmonisation, and joint development of cross-border connections, by opening and restructuring the rail market.

To improve rail freight traffic, the EESC recommends additional measures, e.g. cooperation among companies and transport modes to better achieve environmental and social sustainability and efficiency, relaunch of a European single wagon load system, link of strategic infrastructure to rail solutions (e.g. ports), investments in industrial sidings, involvement of large logistics companies in a modal reorientation of their flows, ensuring environmentally and socially exemplary performance of all transport modes.

Rail transportation systems are characterised by important features:

- they serve a significant share of passenger traffic in Europe,
- their functioning relies on the cooperation of many stakeholders operating a fixed timetable, often with competing objectives, and
- they have been characterised by quite a fragmented development following national borders.

For these systems, the European Commission envisages a common future in terms of an increase of efficiency and elimination of national borders.

HERD, focusses on the harmonisation of the asset diagnostic data – rolling stock and track – and is fully aligned with the EU-Rail objectives to:

- contribute towards the achievement of the Single European Railway Area (SERA),
- to ensure a fast transition to more attractive, user-friendly, competitive, affordable, easy to maintain, efficient and sustainable European rail system, integrated into the wider mobility system,
- to support the development of a strong and globally competitive European rail industry.

A specific task of EU-Rail is to ensure that the system is maintained, error-corrected and able to adapt over time.

HERD perfectly corresponds to the third priority area for EU-Rail “Sustainable and digital assets”. These priorities are underpinned by a system view to ensure a harmonised approach to the evolution of the Single European Rail Area.

1.1 Purpose of HERD

The purpose of HERD is to develop an architecture for harmonising the European railway diagnostic data that principally consists of flexible combination of a mix of trackside sensor and onboard localisation systems. It aims to regularly review the new techniques which automatically and autonomously can acquire diagnostic data (like drones) and to integrate them. Furthermore, HERD intends to generate operational, use case dependant concepts for harmonised diagnostic data of the railway assets – both rolling stock and track – and their interfaces beyond the current specifications, with much greater standardisation than at present.

HERD will develop the UC specific operational models and requirements for the Harmonised Diagnostic Data Interfaces.

As a logical consequence of the EESC targets and the EU-Rail objectives, HERD, generates a set of proven technically and procedurally harmonised diagnostic data use cases and will provide a guideline for a harmonised diagnostic data exchange for all relevant assets diagnostic data, which will enable the continuous gain of condition information for integrated asset management.

According to a new standardised process, HERD evaluates the potential applications for railway data harmonisation and identifies the most relevant of them to generate use cases for further investigations. Selecting the use cases there are some main topics to be considered: identifying the data user needs, defining need of harmonisation in the European railway system, direct alignment with the relevant stakeholders, investigating the synergies with other projects and initiatives to ensure best possible impact.

HERD collects and processes the information about all activities and projects in EU-Rail related to collecting, processing, and implementing of diagnostic railway asset data.

There are some topics which are not part of the purpose of HERD: specification and standardisation of measuring methods, definition of the diagnostic systems or the analysis calculations as well as the diagnostic data governance, Intellectual Property Rights (IPR), the data exchange between Railway Undertakings (RU), Vehicle Keepers (VK), Entity in Charge of Maintenance (ECM), OEM, or system supplier.

HERD will not deliver Cost-Benefit-Analysis (CBA) due to the lack of information about the individual cost structures and the costs of the diagnostic data users. HERD will support with a CBA-structure models which will allow to identify the main influencing factors and enablers for cost reduction, improving the fleet and maintenance planning efficiency, etc.

HERD will collect and analyse the market and the users' needs to identify the most important areas for diagnostic data harmonisation and the expected benefits.

The HERD team consists of experts as representatives of the data user as well as of the data provider from supplier industry, infrastructure managers (IM), railway undertakings (RU), and vehicle keepers (VK). Strong alignment with the with the System Pillar Tasks 1, 2 and 4 as well as with the Innovation Pillar Flagship projects FP1, FP3 and FP5 is ensured by the team members.

1.2 Contribution to SERA

The Single European Railway Area (SERA) aims to remove technical, administrative, and legal obstacles across the EU-Rail sector, creating a single, open market for rail services. This includes harmonising standards, ensuring fair access to infrastructure, and opening markets to competition.

Railway traffic planning priorities, capacity planning and information – e.g. about the asset condition – need to be improved to enable greater flexibility and asset availability. Investments are needed in infrastructure but also in digitalisation and technical updating of rolling stock, including investment in just transition and skills development, to improve smooth traffic flows, optimise resource utilisation, and ensure employment.

EU-Rail has identified several challenges related to the future development of the sector:

- Offering reliable services that are reactive to demand, adaptable to customer requests.
- Improving performance and capacity of the passenger and freight transport.
- Generating more cost-efficient solutions and services compared to the present day.
- Improving the climate and environmental footprint of rail itself (e.g. reduce the noise).
- Moving to common European network with stronger implementation of the objective of having an increasingly integrated SERA and be more flexible to introduce and scale up new technological and operational solutions.
- Making rail a more attractive mode overall so that it can become central to future mobility.
- Strengthen the European rail supply industry to stand its world leading position.

HERD activities are fully focussed on giving an answer to those challenges and to pave the way for future improvements and innovations for the asset diagnostic data harmonisation.

Providing harmonised railway diagnostics data will lead to:	
Cost and time savings	Reduced time for maintenance, improved planning, reduction of numbers of spare parts on the stock, higher efficiency of resources, reduction of energy consumption, efficient asset use, higher asset availability, less damage impact, reduction of data conversion costs, etc.
Interoperable and seamless rail transport	The data user can collect diagnostic data independently from the data supplier and the specific national standards in the pre-defined data quality.
Safety improvement	Higher availability, reliability, and quality of the diagnostic data will facilitate faster and much reliable recognition of technical discrepancies and accelerate the mitigation actions. More qualified diagnostic data will improve the quality of services and compliance with safety levels.
Competitiveness improving	The reduced costs, increased reliability, and availability of both – infrastructure and rolling stock – will strengthen the customer trust and increase the benefit of the data users.

Providing harmonised railway diagnostics data will lead to:	
Digitalisation boosting	Having the chance to continuously collect data thanks to standardised format from different data supplier or country, the data user will be able to generate much precise digital models of his assets, improve the digital data management and documentation. The increased and stable availability of qualified diagnostic data is the only way to implement new methods like artificial intelligence.
Innovation boosting	The standardised diagnostic data layer will motivate data user and data supplier to continuously optimise the systems and increase the information flow under guarantied high-quality conditions. It will pave the way for real technical innovations by removing the data exchange obstacles.
Achieve sustainability objectives	Reduction of material and spare parts wasting, energy consumption, noise emissions will increase the attractiveness and the market share of the rail transport (road2rail, air2rail).

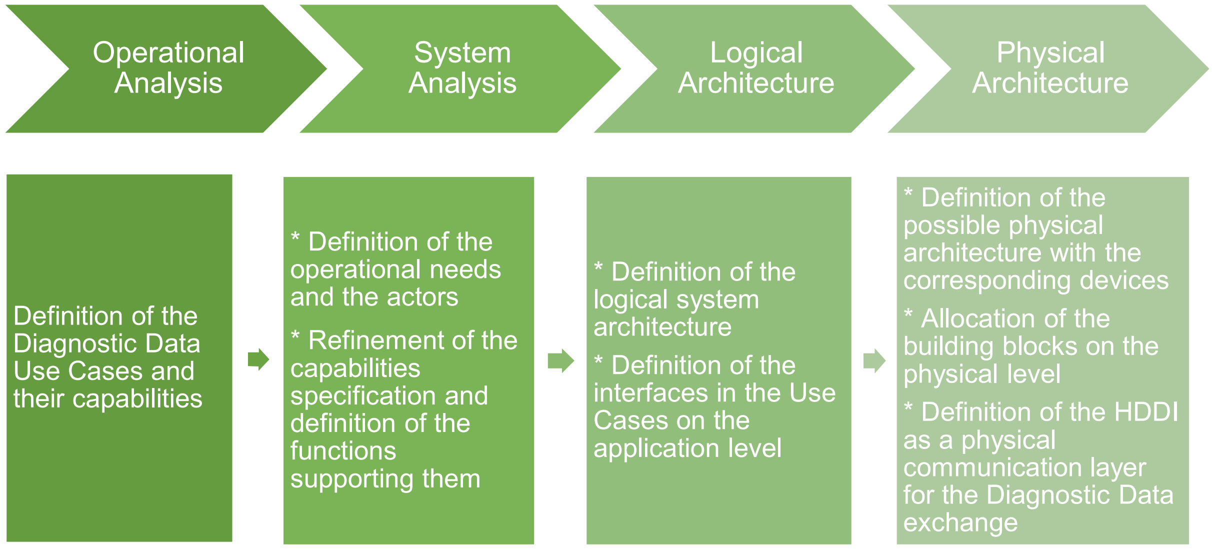
Table 1: Objectives of Harmonised Railway Diagnostics Data

The harmonisation of the asset condition data will lead to improvements which will have direct and indirect positive impact on realising the EESC/SERA goals:

- Standardised data exchange: generate a HDDI (Harmonised Diagnostic Data Interface).
- Improved information flow: ensure the diagnostic data quality and stabilise the diagnostic data availability.
- Supports to expand the data exchange mechanism between infrastructure managers and operators to help towards the achievement of optimised efficiency.
- Strengthen the co-operation between European projects in the Innovation Pillar (FA3 and FA1) as well as in the in the System Pillar.
- The purpose of the Harmonised Diagnostic Data Interface (HDDI) is to strongly improve the data exchange between the data users and data providers. Implementing HDDI should help to compare the diagnostic data generated for the same application resp. object.

1.3 Collaboration with SP and IP

To achieve the specification that offers the demanded functional improvements concerning performance, reliability, quality, and cost as well as the effective implementation, HERD follows the process defined by the System Pillar (SP) which is based on the Model-Based System Engineering (MBSE) principles.



In parallel, we have started with the identification of the existing and prospective needed interaction between HERD and the other SP-tasks.

The operational design work and the organisational structure of the System Pillar are defined as displayed in Figure 1.

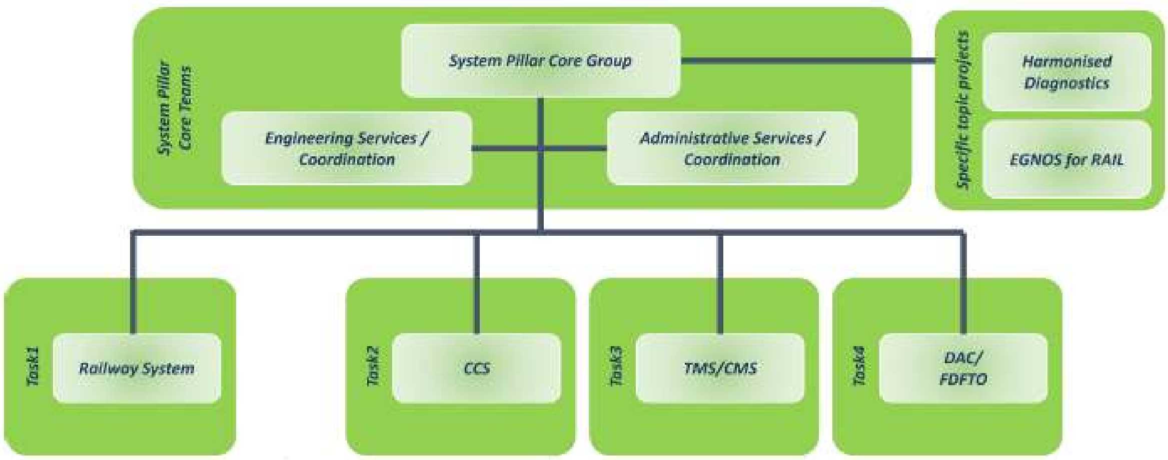


Figure 1: System Pillar Structure

The interaction between HERD and Task 1 is important because it handles the impact of new technologies and processes with regards to rail (e.g. from the innovation pillar) with the clear goal to harmonise across Europe.

HERD also aligns with the Transversal Topic of Task 2 to make certain an efficient synchronisation of the scope and the outcomes of both activities.

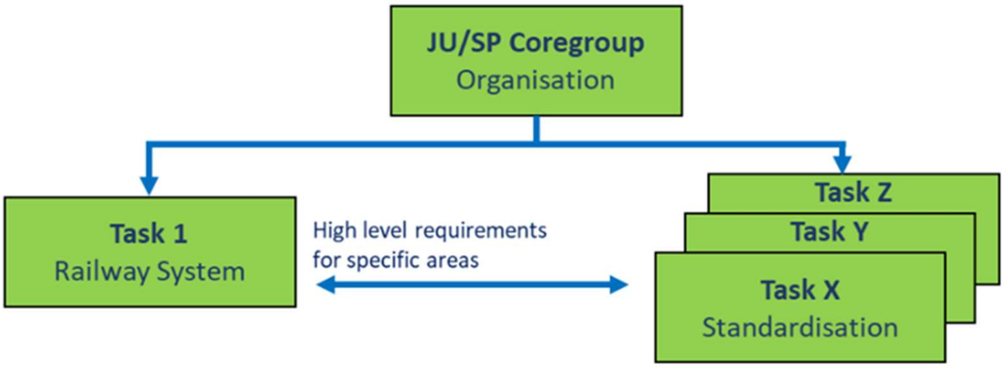


Figure 2: Way of working in the SP.

To ensure best possible interaction between HERD and the Innovation Pillar (IP) we have started to:

- identify the main technical standardisation areas of collaboration between HERD and other projects in the Flagship Areas of IP,
- define the necessary details of the continuous process integration to reach together the EU-Rail outcomes that will achieve target system complying with the CBO,
- investigate possibilities to generate PoC as pilot projects in some of the Flagship Areas.

We have identified that HERD has a direct interface to FA3 "Asset Management & Rolling Stock". The main objective of this demonstrator is the monitoring of rolling stock (including on board and wayside technologies) leading to decisions and planning of interventions and redirecting rolling stock to workshops to execute the (re)scheduled work both manually as well as by new technologies and solutions to conduct inspection tasks automatically. The main objective of FA3 directly correspond to the objectives of HERD – to generate harmonised diagnostic data exchange which is based on the overall collected monitoring of the rolling stock assets.

One of the benefits of HERD is the immediate contribution to improving the Life Cycle Cost (LCC) of the railway assets – rolling stock and infrastructure – using cross-border and cross-system collected diagnostic information. This corresponds to FA3 "Long Term Asset Management (LTAM)" which objective is the development of LCC models for infrastructure and rolling stock. The FA3 LTAM-demonstrator includes cross-border infrastructure remaining useful-life analysis and space-time cross-analysis and visualisation.

Furthermore, using many different systems to collect, link, and consolidate the diagnostic information to satisfy the various customer needs will generate a huge amount of data. Therefore, a close collaboration with FA3 "Asset Management & Infrastructure" can be beneficial for the railway business. The outcome could help to integrate on field and on-board systems with central platforms capable of managing Big Data.

1.4 Expected Benefits

The main benefit of HERD is the continuous gain of condition asset information (infrastructure and rolling stock) to enable best possible integrated asset management.

Today, many different data sources across Europe deliver important data for planning, maintenance, and procurement for the different stakeholders. Unfortunately, the different providers have defined their own specific, not-harmonised data formats. These data users also have set-up national respectively own specific interfaces for data exchange. Therefore, crossing the country borders respectively the measurement points of different providers of diagnostic data systems, the data user will face additional costs, time delays, data quality reduction or even total loss of usability of data.

Figure 3 shows an example of how data user and data provider will benefit of the harmonised data interface specification – equally valid for IM and RS.

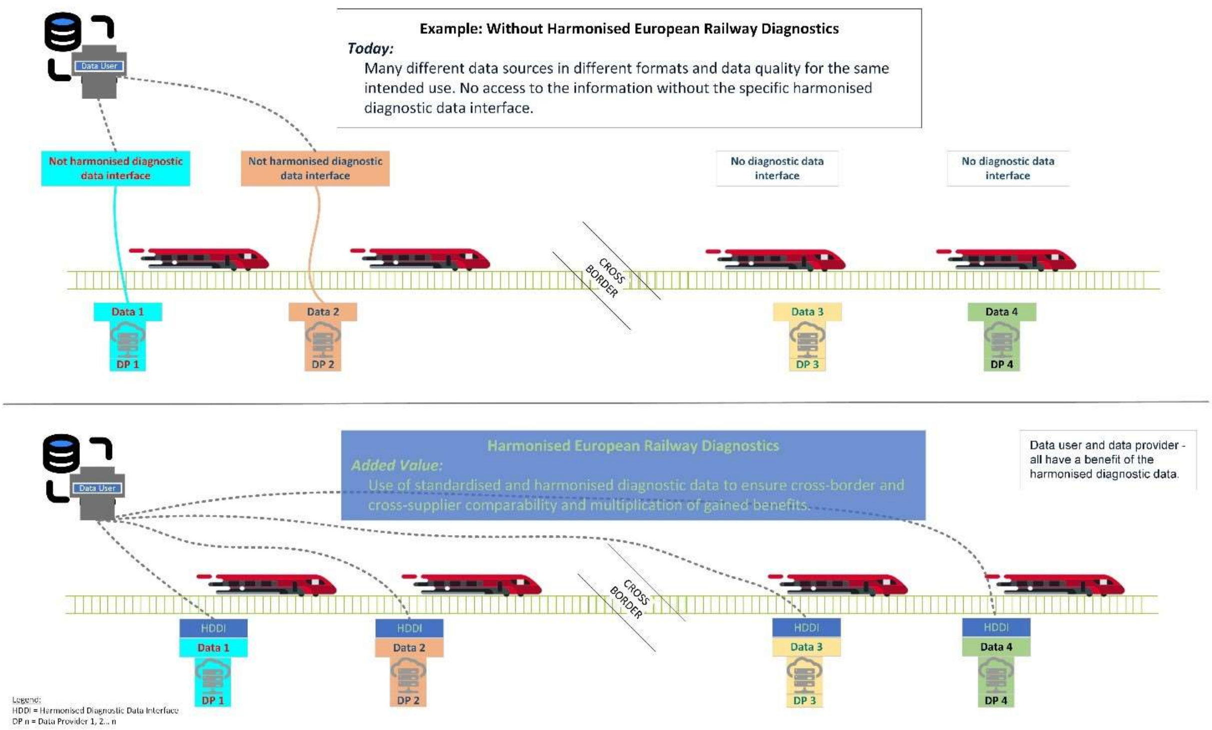


Figure 3: Benefits of HERD implementation (example equally valid for IM and RS)

HERD supports to progressively close those gaps – to establish a standard process to identify the relevant use cases for railway diagnostic data, to evaluate the discontinuities on the data exchange interfaces, to align with the stakeholders on a harmonised interface, to define and implement demonstrators.

There are many implementations of the railway systems diagnostics, and some of them are described below.

The outcome of diagnostics can be used to define new design principles. Processing the results from the diagnostic analysis, e.g. the condition of components and systems over time or their reaction of defined influences like static and dynamic forces, vibration, temperature, humidity, etc. and especially the interaction between different systems in and between the assets, can be directly implemented to improve the asset design (rolling stock and infrastructure).

The design of rolling stock plays a key role for the attractiveness of rail transport. Only trains that are comfortable, reliable, affordable, and accessible can convince passengers to use rail transport instead of other modes. At the same time, the train design must meet the requirements of the railway undertakings and the urban operators, who are the main customers of the rail supply industry, to deliver high quality and cost-efficient services to their customers.

The expectations of the EC concerning the reduction of the noise emissions for the railway transport are clear but extremely difficult to be achieved – the zero-pollution action plan aims to reduce by 2030 the number of people chronically disturbed by transport noise by 30% compared with 2017. The diagnostic of the noise and vibration sources in the assets and on the interfaces are the most important input for the investigations because of the very different properties of the assets (locomotives, passenger trains, freight trains, special trains, different track qualities and profiles, environmental conditions, nature, etc.).

If rail is to integrate more effectively with other modes and attract more passengers to further develop its role as the backbone of multi-modal mobility in the future, it needs a future generation of passenger trains that will be lighter, automated, more energy and cost-efficient, while at the same time providing a comfortable, connected, reliable and affordable travel experience for all passengers at a defined level of safety and security.

The continuous collecting of diagnostic data in real time or off-line is the perfect supplement to other methods like simulation, analytic and numeric calculation, testing, or other investigations.

1.5 Achievements in Phase 1 of HERD

- Investigation and designation of Top 5 areas for harmonisation:
  - Area 1: Maintenance Rolling Stock – Trackside Vehicle Monitoring.
  - Area 2: Maintenance Infrastructure – Onboard Track Monitoring.
  - Area 3: Operational Safety – Trackside Vehicle Monitoring on safety issues.
  - Area 4: Train Preparation – Preceding data collection.
  - Area 5: Vendors and Participants in the Railway Industry – R&D, standardised interface.
- Detailed description of 7 Use Cases embedded in the Top 5 areas: objectives of harmonisation, qualified benefits, roles, and responsibilities, expected conditions for harmonisation, high level KPIs; very detailed description of the data collection methodology for the selected Use Cases. The designated Use Cases will be reviewed and depending on the outcome nominated for diagnostic data harmonisation.
- Evaluation of existing railway diagnostic systems based on the selected use cases in terms of data quality, interfaces, benefits regarding interoperability, competitiveness, sustainability, and identification of the standardisation gaps.
- Draft of the criteria set for assessing diagnostics systems and measuring systems with respect to their connectivity to the data exchange infrastructure. Description of the boundary conditions which should be assessed to ensure the needed interoperability.

For more details, please see the HERD report from Phase 1.

1.6 Project work description in Phase 2

In Phase 2 of the SP Specific Project HERD, it was important to generate a common understanding of the achievements in Phase 1 and the next steps. For that, we have aligned on following objectives:

- Evaluation of the existing railway diagnostic systems based on selected use cases in terms of data quality, interfaces, benefits (safety, interoperability, competitiveness, sustainability, etc.), standardisation gaps, etc.
- Harmonisation of the description of use cases (to achieve a common understanding of the respective different use cases and their benefits).
- Harmonisation of data needed for these use cases (definition of data, data quality and data availability) as a functional specification (e.g. data format) for diagnostics systems on track and on board.
- Development of a standardised process for implementation of new use cases.
- In April 2024, we have started with a 2-days workshop. The outcome of this workshop was:
  - To proceed with the methodology of "Use Cases" (UC)
  - To focus on two Use Cases, selected from the in Phase 1 identified UC-set:
    - Use Case 1: Track Side Vehicle Monitoring for Maintenance
    - Use Case 2: On-Board Track Monitoring
  - To develop a new, standardised process for evaluation and acceptance of new diagnostic data UC
  - To analyse the stakeholder and synergies in SP and IP
  - To prepare a specific draft for the benefit analysis separately for UC 1 and UC 2

In this workshop we have defined the project structure, the sub-deliverables, the teams working on the sub-deliverables, and a draft for the outcomes. We have discussed and aligned on the preliminary project plan and project structure, the communication and reporting management, the meetings policy, the project data governance, etc.

We have also discussed and identified some risks and opportunities, and the list was update during the project. We have regularly (in a bi-weekly rhythm) discussed the challenges and have agile proactively acted, respectively tried to mitigate some unexpected obstacles, like the loss of team members (3 persons from project partner).

The table in the next paragraph describes the main risks/opportunities and the respective mitigation actions/benefits without analysing the impact and the probability, and without calculation the expected financial effort/profit (e.g., as a change in the budgeted FTE).

This document describes the methodology and deliverables of HERD in Phase 2 as a Specific Project of SP.

Section 2 explains the Use Case methodology and the new, standard process of evaluation and acceptance of new UC. Section 3 shows the work on Use Case 1 and its outcome. In Section 4 we express Use Case 2 and the related topics. Section 5 and Section 6 describe the roles and responsibilities of the stakeholder as well as the synergies with other projects and activities in the SP and IP.

Finally, we summarise the results and give an overview of the next steps in the last section.

1.7 General Risks and Opportunities

	Risk description: *There is a risk that…*	**Mitigation action**
R1	the budgeted resources of 2 FTE/year are not sufficient to cover a fast and effective work, resp. there is no reserve for unexpected changes.	Voluntary additional work Reduction of the total amount of work Definition of new priority order during the project
R2	the resources unplanned decrease during the project work for different reasons like new priorities for the team members, illness, etc.	additional voluntary overwork by other team members re-order of the deliverables plan
R3	some team members become frustrated because of the needed overwork to close the gaps	additional support by the project assistance regular exchange
R4	the vacations in summer are not harmonised to ensure seamless work	implementation of a transparent overview (but not an aligned planning) of the vacation time of all team members work package meetings take uninterrupted place
R5	the interviews and questionnaires for collecting the users' needs are not completed on-time due to the unavailability of the participants: summer vacation, intensive project work in parallel, etc.	early planning and start with the activities. regular reporting in the Jour Fixe and support from all members reduction of the interviews scope
R6	the ambitions of the special project HERD are not matched by the outcomes of EU-Rail Programme due to the limitation in terms of available resources to cover the related activities. This might negatively affect the image of the special project.	Analysis of feasibility of requirements expressed by the sector and appropriate management of expectations. Constant communication on outputs, focusing on concrete results that can be implemented, considering the legacy system, use cases, etc.

	Risk description: *There is a risk that…*	**Mitigation action**
		Request to the contractor evidence allowing matching the foreseen outputs with resources allocation.
R7	the additional, voluntary effort of the team members drops in the last weeks which will cause a delivery delay of the final report. The reasons are the parallel and long summer vacation time, the preparations for and participation on the Innotrans fair in Berlin in CW39, the increase of the responsibilities of some team members in their home companies, etc.	Ask to postpone the delivery date by 2 weeks – new due date 14.10.2024. Explanation: if we try to more distribute the project work and to frequently hand-over, we will produce a very high administrative effort and inefficiency to implement, edit and finalise the single sections as well as the whole document.
	Opportunities: *There is an opportunity to…*	**Benefit/Impact**
O1	establish a close collaboration between Task 5 and IP, especially FP3 and FP5	Taks 5 and IP will profit by the supplementary activities and outcomes, and it will boost the standardisation and innovation in EU Rail
O2	generate and implement new use cases, which were not identified in Phase 1.	more diagnostic data to be harmonised for more information and implementation
O3	align data sharing and communication in the Rail Sector to the European Data Strategy	making the Rail Sector both a contributor and a beneficiary of the "single market for data" for a "data-driven" European society
O4	boost digitalisation and especially application of AI.	harmonise not only the interfaces for the harmonised diagnostic data but also to share experiences with AI analysis.

Table 2: Risks and Opportunities

At the beginning of Phase 2 of the specific project HERD, 20 persons from 12 companies were nominated. The companies were committed that they will deliver the availability of the nominated persons and will support with an additional voluntarily work of their experts.

Because of different reasons, there were changes in the availability of some experts which was reduced or even stopped. These unplanned and unexpected reduction has caused delays and re-prioritisation of the deliverables. Other companies like voestalpine or FS have nominated additional experts to ensure high-quality of deliverables.

The most effective mitigation action was the extraordinary and voluntary engagement of most of the team members which has partly compensated the lack of availability. In the bi-weekly JF the status of completion and the resource availability are regularly monitored, and the gaps are specifically closed.

2 Methodology of working

The purpose of HERD is to develop an architecture that implements the flexible combination of a mix of trackside sensor and onboard localisation systems. HERD develops operational models and requirements for the specific Harmonised Diagnostic Data Interfaces beyond the current specifications with much greater standardisation than at present.

2.1 Use Cases

HERD generates and expands the set of guidelines for the harmonised diagnostic data exchange for all relevant assets diagnostic data, which will enable the continuous gain of condition information for integrated asset management.

To achieve these targets, the HERD-team has decided to apply the Use Case methodology.

A Use Case is a concept to describe how a system can be used to achieve specific goals or tasks. It outlines the interactions between the actors and the system to achieve a specific outcome.

The main purpose of the use cases is to:

- Define and manage the scope.
- Analyse the relevant market.
- Outline the ways a user will interact with the system and the expected benefits.
- Collect and consolidate the stakeholder needs.
- Communicate recommendations of technical requirements (HDDI).
- Perform risk management.

The selected HERD Use Cases help to bridge the gap between business justification and technical requirements. They comprise the customer needs, the system properties – inclusively the monitoring systems of the railway assets (rolling stock and infrastructure), and the improvements which will enable the expected benefits.

In our workshop in April 2024, we have decided to define and implement a standard process for evaluation and acceptance of new Use Cases for harmonisation of railway diagnostic data. The motivation to generate this standardised process is to ensure a transparent, professionally prepared, and high-quality selection of use cases. Our goal is on the one side to stay open and supportive, and on the other site to use the restricted resources carefully and effectively for working on HERD.

We have decided to keep the process description as clear and easy to understand as possible Figure 4.

The process of accepting a new UC in the HERD starts with a formal proposal.

The applicant describes what the purpose of the diagnostic data harmonisation of the intended use case is, what the technical respectively the economic needs are, and very detailed what should be harmonised. The document outlines the state-of-the art, the gaps, and the intended change.

The proposal emphasises what the expected benefit is and provides examples if available. It explains what will improve after harmonising the diagnostic data respectively the interface. The applicant should provide a simplified cost-benefit-structure or any other relevant information, like time and/or material savings, efficiency improvement, outcome increasing, etc.

The document describes the roles and responsibilities of the data provider and the data user. Explain how they interact and ideally the SIPOC (supplier-input-output-customer) principle.

The applicant evaluates the main risks and the opportunities which are relevant for the harmonisation of the intended use case and provides suggestions how to mitigate or accelerate.

The proposal outlines the suggested steps for harmonisation. If there is already a demonstrator in place, explains the functionality and maturity of the demonstrator and what is needed to become its full functionality.

Finally, the applicant is asked to provide a self-assessment according to Table 3.

Criteria	Score 0-5 (5 is max)	Short justification of the scores
EU dimension (benefit for EU)		
Priority		
Urgency		
Cost savings		
Time savings		
Contribution to interoperability		
Safety improvement		
Competitiveness of Railway Transport		
Contribution to EU Digitalisation		
Contribution to EU Innovation		
Contribution to EU Sustainability		
Maturity of demonstrator		
Specific criteria		

Table 3: Self-assessment table evaluating the impact of the new UC.

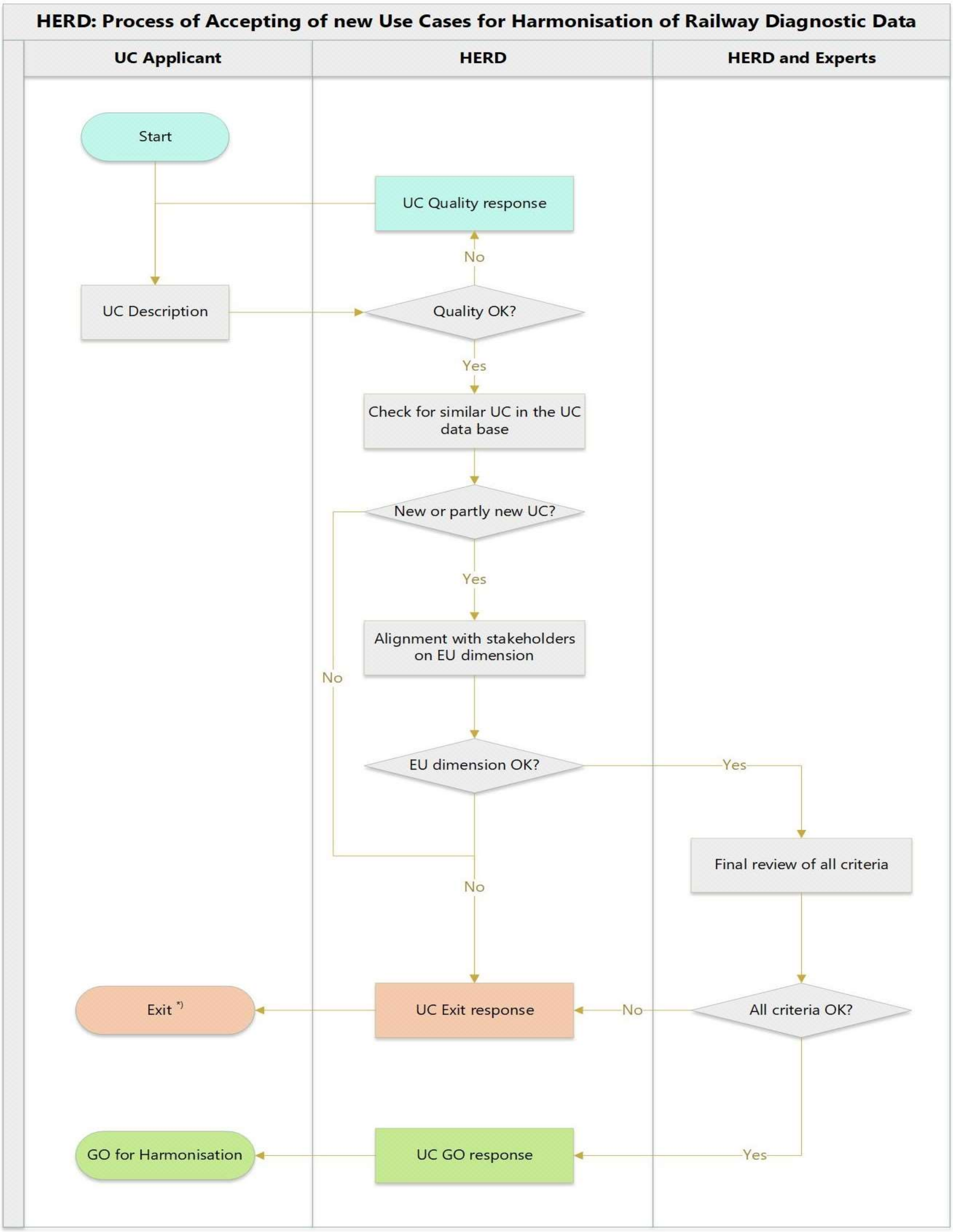
The completed application is sent per e-mail to the HERD leads. They review and then distribute the proposal to the UC assessor group (UC-AG). The HERD leads are responsible to organise the alignment in the UC-AG and are the interface to the applicant. If there is a need of clarification and additional information, the HERD leads manage the update and organise additional meetings with the applicant.

If required, other HERD team members or external experts will be invited to support with their expertise to decide if the suggested UC will be accepted as a part of the HERD UC-set and if yes, what the urgency and priority are.

The HERD leads inform the applicant about the decision and manage the further steps.

In July 2024 we have received the first application for a new Use Case for Harmonisation of Railway Diagnostic Data and the process is (by end of September 2024) still not completed.

We will collect our experiences for 12 months and then review the process.



*) There is an option to re-apply in case of additional information

Figure 4: Standard Process for Acceptance of new Use Cases for Harmonisation of Railway Diagnostic Data.

2.2 Collecting information about the user needs

As already mentioned, part of the UC purpose is to gather and consolidate the stakeholder needs. In this phase, we have focussed on the collection and analysis of the user needs in UC 1 and UC 2 separately.

At the beginning of this step, we have discussed how to gain the information, considering the limited resources and time.

Data collection is a systematic process of gathering, classifying, and labelling essential parameters. We have decided to apply a qualitative data collection methodology to formulate valid hypotheses, and to perform interviews with selected representatives. We will analyse the answers to identify and explain themes and outline correlations as well as to determine general characteristics and tendencies.

In general, the interview method has several advantages, like:

- Questions are restructured as for the requirement.
- Samples can be easily controlled.
- Interviewer can overcome the resistance by respondent.
- Non-response by the respondent is minimised.
- Spontaneous response of the respondent is secured.
- Language of the questions can be modified according to the level and understanding of respondent.
- Based on the response of the respondent if required additional questions can be asked by interviewer.
- Misunderstanding of questions can be removed by better clarification by interviewer.
- The interviewer is well prepared and so the interview is conducted in a focused manner.

The disadvantages can be described as:

- High impact on the results in case of limited resources of the interviewer and time.
- The data may remain inadequate if high profile persons are not contactable.
- Over response by respondent may lead to imaginary answer.
- Under the process of interviewing systematic errors may be introduced.

Using our (HERD) professional network, we have identified a large group of candidates for the interviews, but have recognised for both, UC1 and UC 2, that the willingness and the availability to be interviewed strongly varied from company to company. It was a challenge for the interviewers to organise the timeslots and the process of interviewing and consolidating the outcomes has taken longer than intended.

For more detailed information, please refer to section 3 and section 4.

2.3 Synergies with other projects and initiatives

To ensure high efficiency of working and producing the deliverables, HERD has decided to identify synergies with existing initiatives and collaboration opportunities. We have investigated the interfaces to the other tasks in the SP as well as the wide space of projects in the IP. Additionally, we have also collected information about funding programs on a national level respectively based on other private agreements.

Figure 5 shows an overview of the main interfaces.

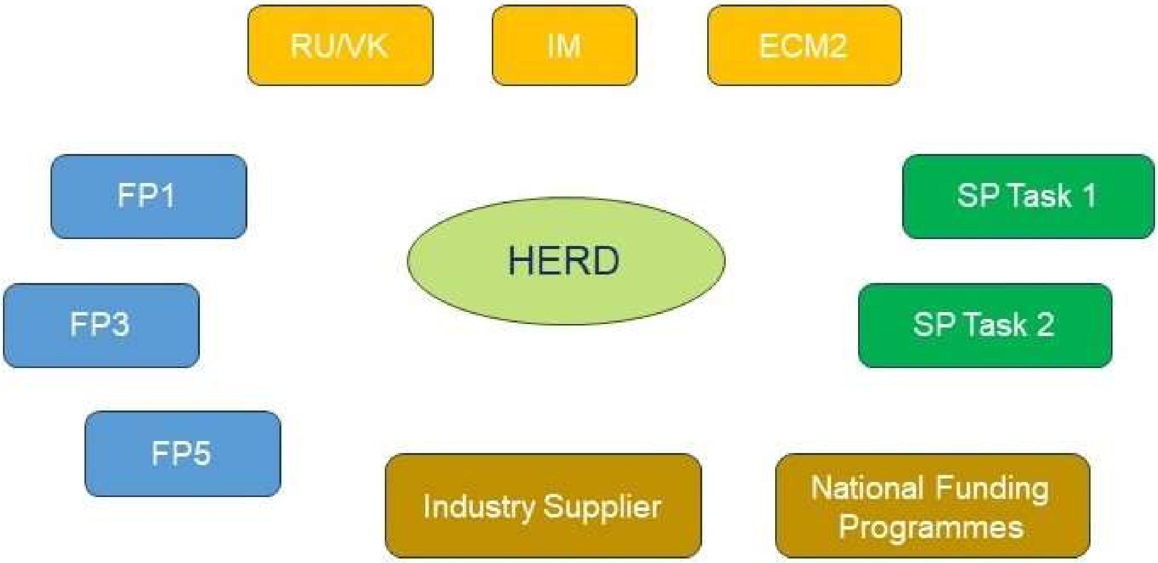


Figure 5: Synergies Overview.

Our focus was on activities and projects which generate asset (rolling stock and infrastructure) diagnostic data, collecting and exchanging railway data, generating data spaces for data governance, developing technical specifications for more standards in the measurement systems.

The process of identifying the synergies and the potentials for collaboration shaped up as complex and time consuming. We have used two ways to collect the information:

- Search in the official websites.
- Analysis of Working Programs and Reports.
- Interviews with HERD team members and other persons in our network.

We have recognised, that there are important and relevant interfaces to other activities and the urgent need to realise the agreed purpose of HERD to coordinate the interfaces to the Innovation Pillar and the other System Pillar Tasks in terms of HERD to avoid redundancy and duplication.

Today, due to the very limited resources in HERD we can only perform this function to a limited extent and therefore, we highly recommend planning more human resources to be allocated in the next contracts.

Table 4 shows the categories of potential synergies with projects in ERJU. Each category reflects specific areas where collaboration could enhance the outcomes of the HERD project.

Category	**Subcategory**	**Description of synergies and related open topics**
Data model	framework	Integration into the railway system, e.g. the SEMP process starting with an operational analysis
	static structure	UML Class diagrams: attributes, relationships, description
	Ontologies	Showing properties and relationships
	Semantics	Specify the meaning of classes, attributes, and relationships
	Attribute classification	Classify the attributes in various categories like type: raw data, symptom, diagnosis, prognosis, or accuracy: (1 sigma)
	Syntax	the structure of statements in a computer language like XML, JSON, HDF5. In many cases, a schema is defined to evaluate the validity of a document.
Identification	Diagnosed entity	How are the diagnosed entities identified: e.g. a vehicle has a European vehicle number (EVN), or a track might have a number, km/m, and direction etc.
	Location	How are linear (e.g. track nr/km/m/direction) and geographic coordinates defined
Data analytics	Models, learning	Are there algorithms we can use to calculate values; e.g. how the longitudinal height is calculated from accelerations.
Data transfer	Protocol	What data transfer protocol is used (https, sftp, mqtt, P2P...). Is an information model available for specific protocols like OPCUA?
Data distribution	Policy (who is getting what)	Based on the identification we need to know who is authorised to get which data. E.g. who is getting information on a wheelset (RU;EIM;owner;IM;...). Where to get this information?
	Exchange network architecture	Centralised: queue; stream processing, DDS Decentralised: Peer to peer
Billing		Models how the data provider gets data from data consumer

Table 4: Synergies by Category

Table 5 shows an overview of projects and initiatives identified in SD34 and SD27.

Area of standardisation		**Existing initiatives (SD34.02) and synergies (SD27.01)**				
		Tool Box	EU Rail	Federated Dataspaces	DB "CTM" project -> UC2	DB/SNCF: HotBoxDetector "DEUFRAKO" (Karl) -> UC1
data model	framework		Traffic CS system Concept		n.a.	n.a.
	static structure		EULYNX procedure (Level 5)		Excel-Based	static model (class diagram) for checkpoints, specifically for HotBoxDetectors
	ontologies		ERA ontorail;		n.a.	n.a.
	semantics		EULYNX procedure (Level 5)		n.a.	attributes Excel list of semantics of the static model
	attribute classification (status, date, diagnosis, prognosis, accuracy, 1 sigma, etc.)		EULYNX attribute classification schema		n.a.	attributes Excel list includes classification of attributes
	syntax	XML, JSON, HDF5	TCCS-SD1 uses json and json-schema; EULYNX (uses OPC-UA build in binary syntax)		xls-doc	OPC-UA binary syntax
identification	diagnosed entity		European Vehicle Register EVR (https://www.era.europa.eu/domains/registers/evr_en); European Vehicle Number (EVN)		track (DB GIS-data)	n.a.
	location		TCCS-SD1		WGS84 (GPS) to DB-GIS	n.a.
data analytics	models, learning				longitudinal height according to the rulebook	n.a.
data transfer	protocol	OPCUA	OPCUA; Motional (WP31)		SMNP (Mail)	OPC UA (including OPC UA information model for static model)
data distribution	policy (who is getting what)			IDSA: simple policies, extensions needed	People responsible for the track get an e-Mail; list from Enterprose Resource Planning system (SAP)	n.a.
	network architecture	Topics; DDS; P2P		P2P: peer to peer	Mail	n.a.

Table 5: Example for synergies analysis.

As a concrete outcome, we would like to emphasise the opportunity to become a use case for DataSpace. That means, that we will define plan for a practical ramp-up, how to monitor and evaluate the process.

In the next contract, SC2.4, we will continue to identify further initiatives and to strengthen the cooperation and collaboration within the EU rail sector.

3 UC1: Track Side Vehicle Monitoring (WTMS)

3.1 UC1 description: Wheel condition monitoring

Many European IMs operate Weighing In Motion (WIM) or Wheel Impact Load Detector (WILD) measurement systems for their own applications, e.g. for infrastructure protection. UC1 targets the challenge that there are currently neither standards nor data interfaces in place to make the measured wheel condition information available to interested data users (RUs, VKs, and their ECM) for their own applications.

The most important thing is to exchange the wheel condition information in a harmonised format via a standardised interface between the various data providers and all data users.

The measuring systems can be designed differently and measure different characteristics of the wheel condition. Each IM can individually decide which of the measured condition information is prepared to make available to the data users and under what conditions. Examples of wheel condition information: Dynamic wheel contact forces, quasi-static wheel weights, characterisation of wheel tread defects, geometry of wheel profile, etc.

Together with the condition information, also meta information needs to be provided, such as: type, name, accuracy class and geographical location of the measurement system, time, and operational information on the measurement. This allows the data users to combine the condition data from different sources and to obtain the desired information on the wheel condition over-all.

Use Case:

Monitoring the condition of railway vehicle wheels using WTMS (Wayside Train Monitoring Systems)

Actors:

- Infrastructure managers (IM)
- Railway undertakings (RU)
- Vehicle keepers (VK) and their entities in charge of maintenance (ECM)
- Suppliers of WTMS

Objective:

Improve the safety and efficiency of railway operations through continuous monitoring and early detection of irregularities in wheel conditions.

Description:

IMs deploy Wayside Train Monitoring Systems (WTMS) along railway tracks to monitor the condition of the wheels of passing trains in real time. These systems capture various data parameters such as wheel wear, flat spots, crumbling, polygonisation or flange measurement. The collected information is processed and analysed by the IMs for their application. With UC1 the wheel condition information is going to be distributed to the designated data users of asset owners (VK) and train operators (RU).

Process:

Data Collection:

WTMS automatically collect the necessary data as a train passes the monitoring point. Sensors and other technical devices continuously measure parameters such as wheel profile, temperature, and vibrations.

Data Transmission:

The collected data is transmitted in real time to a central data platform of the IM. Here, the data is aggregated and processed using specific algorithms.

Data Analysis and Evaluation:

The data platform analyses the incoming information, identifies potential issues, and assesses the condition of the wheels.

Notification of Actors:

If deviations from the norm or critical conditions are detected, automatic alerts can be generated for specific applications and processes of the IM.
With HERD UC1 the results of the analysis and any alerts shall be made available to the relevant actors: RU, VK, and their ECM.

Actions:

Based on the provided information, the RU and VK can initiate proactive maintenance actions to ensure operational safety and reliability. This could involve planning inspections, repairs, or wheel replacements. As a result of early detection and proactive maintenance, further damage can be avoided.

Conclusion:

Utilising WTMS for wheel condition monitoring represents a crucial step towards safer and more efficient railway operations. Through close collaboration between IM, RU, and VK, potential problems can be detected and addressed early, ultimately contributing to a more reliable and safer railway infrastructure. Further damage on the assets and on the infrastructure can be avoided thanks to early detection.

3.2 Expected benefits through wheel condition monitoring.

Continuous measurement and monitoring of wheelsets through WTMS installations, operated by IMs, offer numerous benefits in the railway sector. Here are some of the key advantages:

1. Increased Safety.

   ➔ Continuous monitoring can detect potential issues such as cracks, flats, or out-of-round conditions early. This reduces the risk of derailments and other safety-critical incidents.

2. Improved Maintenance.

   ➔ Knowing the exact condition of wheelsets allows for targeted and needs-based maintenance, leading to more efficient use of resources and extending the lifespan of the wheelsets.

3. Reduced Operating Costs.

   ➔ Early detection of damage prevents costly repairs and breakdowns, helping to lower overall operating costs.

4. Higher Availability and Reliability.
   - ➔ Proactive maintenance can minimise unplanned outages, resulting in higher availability and reliability of trains.
5. Reduction of Secondary Damage.
   - ➔ Improved wheelset condition, resulting from continuous monitoring, reduces secondary damage to both infrastructure and vehicles. This not only prolongs the lifespan of tracks and rolling stock but also minimises the need for extensive and costly repairs, ensuring smoother and more efficient operations across the entire railway network.
6. Better Planning and Optimisation.
   - ➔ Data provided by WTMS systems can be used to optimise maintenance cycles and better plan maintenance activities.
7. Data-Driven Decisions:
   - ➔ Continuous data collection enables RU and VK to make informed decisions based on real-time and historical data.
8. Compliance with Regulatory Requirements.
   - ➔ Monitoring and documenting the condition of wheelsets can help meet legal and regulatory requirements and demonstrate compliance with safety standards.
9. Increased Customer Satisfaction.
   - ➔ Reliable and safe train operations lead to higher customer satisfaction and trust in the rail system.
10. Environmental Benefits.
    - ➔ More efficient maintenance practices and damage prevention can also lead to a reduction in energy consumption, carbon, and noise emissions, resulting in a positive environmental impact.

Collaboration between IM, RU and VK in utilising the data provided by WTMS systems creates a win-win situation that significantly enhances both efficiency and safety in the railway sector. Through detailed interviews, insights are gained into how various actors leverage wayside monitoring data to address their individual needs and improve overall system performance.

3.2.1 Benefits for railway undertakings (RU)

Analysing wayside monitoring data usage by RU revealed various priorities, strategies, and benefits among the RUs.

Improved Maintenance Efficiency

By transitioning from schedule-based to condition-based maintenance, RUs can monitor components in real time, extending inspection intervals and reducing unnecessary downtime. For instance, some passenger companies have successfully extended axle box inspection intervals from two to three years.

Cost Reduction

Wayside monitoring enables RUs to address components based on actual wear and tear, avoiding premature replacements, and optimizing material planning. Freight companies often adjust wheelsets and axles based on specific operational patterns, like curve dominance, leading to significant cost savings through targeted maintenance.

Noise Reduction in Highly Populated Areas

Wayside monitoring can help identify and address components that contribute to excessive noise, such as worn wheels or brakes. This is particularly valuable in shunting yards and on highly frequented lines in densely populated areas, where reducing noise pollution improves the quality of life for nearby residents.

Increased Operational Reliability

Monitoring the condition of key components like wheelsets, axles, and brakes helps detect potential issues early. This leads to fewer unexpected failures, ensuring smoother and more reliable service for both passenger and freight operations.

Optimised Maintenance Strategies

Wayside monitoring allows RUs to develop tailored maintenance strategies based on specific operational conditions, such as curve patterns or track geometry. This prolongs the life of critical components, reduces maintenance frequency, and enhances operational efficiency.

Safety Improvements

Real-time monitoring systems can detect early signs of critical issues, such as axle bearing damage or wheel profile degradation. Addressing these issues proactively improves overall safety, reducing the risk of failures or accidents.

Shorter Off-Service Times

With a longer planning horizon enabled by real-time condition monitoring, RUs can better plan maintenance schedules. This reduces the distances that railway vehicles must travel to depots, minimizing downtime and shortening off-service periods, ensuring vehicles are available for operation more frequently.

Enhanced Passenger Experience

In addition to the direct reduction of noise and vibration, ensuring smoother, more reliable service through condition-based maintenance leads to a more comfortable and dependable passenger experience overall, making journeys smoother and quieter, and enhancing comfort during travel.

Harmonised Cross-Border Operations

Sharing wayside monitoring data across borders facilitates seamless cross-border operations for pan-European rolling stock. By making condition data accessible across countries, railway undertakings can individually monitor the condition of each international rail vehicle, wherever they are, reducing delays and enhancing the efficiency of cross-border rail travel.

Following two in detail calculated benefits. These examples had to be anonymised. We are not allowed to publish the details or to mention the RU in this document. Within HERD the specific cases are known.

In cross-border freight transport downtimes can be reduced by 77% thanks to digital vehicle control based on WTMS. This is thanks to the known condition of the vehicle and the automated control system.

> Based on the existing specifications for technical train inspections, we hypothesise that the downtimes that are currently required for the time-consuming manual inspections can also be reduced by the same order of magnitude in domestic transport with digital vehicle inspections.
> Note: This application and the resulting benefit relate to a digital vehicle inspection, where all possible condition data that can be recorded by WTMS is used. The condition information on the wheelset is an important part of this. But not the entire calculated benefit relates to UC1.

With the development of the digital vehicle inspection, based on the WTMS condition information, the manual inspection effort of a wagon inspector for each individual technical train inspection is reduced by 58%.

> Note: This application and the resulting benefit relate to a digital vehicle inspection, where all possible condition data that can be recorded by WTMS is used. The condition information on the wheelset is an important part of this. But not the entire calculated benefit relates to UC1.

3.2.2 Benefits for vehicle keepers (VK)

All VKs interviewed were asked to highlight what they considered to be the main benefits of wayside wheel condition monitoring and the impact of its application in their maintenance process. These benefits are summarised below as a concise summary of the individual responses:

- Enable early detection of faults or potential issues to prevent breakdowns and accidents.
- Improve decision making providing data-driven insights for informed decisions.
- Allow the implementation of predictive maintenance based on real data to reduce unexpected failures.
- Increase vehicle availability by reducing downtime due to planned maintenance and fewer breakdowns.
- Lower maintenance costs due to corrective maintenance to reduce unnecessary repairs.
- Increase railway vehicles lifespan.
- Perform data analysis to help identify areas for improvement.

Following two in detail calculated benefits. These examples had to be anonymised. We are not allowed to publish the details or to mention the VK in this document. Within HERD the origin of the specific cases are known.

- A passenger transport company (VK) often experiences disruptions in the scheduling of vehicles and in the planning of maintenance work. By using the wheel-condition information known with WTMS the costs of unplanned wheel defects have been reduced by 10% (calculated carefully).
- We also interviewed some vehicle maintainers that are implementing WTMS in their asset management process. They reported 2 main benefits of the adoption of such systems: the first is once again the possibility to prioritise those wheels and vehicles that display trends that could lead to an anomaly. This system was tested in operation and an estimated 30% of anomalies have been avoided

by monitoring the data collected by the system. Additionally, they reported that they are using the system also to monitor the impact of maintenance activities on the measures detected and, by extension, on the service provided. In one case, they have been able to detect a defect on a particular new wheelset that would have gone undetected until it caused a disservice (excessive vibration or noise) if the WTMS was not in operation.

- Another passenger transport company (VK) suffers from downtimes because wheel faults are not detected in time by manual checks. The deterioration of wheel tread defects can lead to safety-critical situations, which are signalled by the IM. The resulting downtime and the business case for the savings by utilising the wheel-condition information known with WTMS are shown in the following table.

Number of vehicles for passenger transport (fleet size)	4,500	pcs
Number of tread damages per year	350	pcs
Detection rate of tread damage with conventional means (internal inspections, diagnosticians, etc.)	70	%
Potential for immediate suspensions (30%)	105	pcs
Downtime costs per day per passenger transport vehicle	3,000	EUR
Total estimated savings	945	kEUR

Table 6: Benefit for the vehicle management process.

3.2.3 Benefits for entity in charge of maintenance (ECM)

Among the ECMs consulted, two entities agreed to conduct an interview in which the same questions were asked. The overall application and interest related with HERD among both can be summarised as two main benefits:

- Allow items (vehicles) to be fully used up to their full admissible wear.
- Improve maintenance plannings such that maintenance is always planned at the most efficient times.

A specific benefit is decision making for wheel LCC optimisation and cost reduction. Problems related to wheel defects such as comfort, vibration, and noise can be reduced.

Following an example for a benefit of different ECM, calculated in detail. The example had to be anonymised. We are not allowed to publish the details or to mention the ECM in this document. Within HERD the specific case and its calculation details are known.

- A company in the ECM-4-role measures the wheel profiles with hand-held measuring devices. If the wheelsets can be measured with track-side wheel profile measurement systems, the manual labour required for inspection is reduced by 97%. This leaves only 3% compared to today's expenditure.

In addition, investments for hand-held measuring devices can be reduced by 80%.

3.2.4 Benefits for infrastructure managers (IM)

The benefits of the IMs are concluded in the following chart. The most applied use cases and biggest benefits for the IMs are:

- to push RUs to better detect bad wheel-conditions so train stops or issues when in service can be reduced,
- to get VKs maintaining their rolling stock properly so further damage impact on the infrastructure can be reduced.

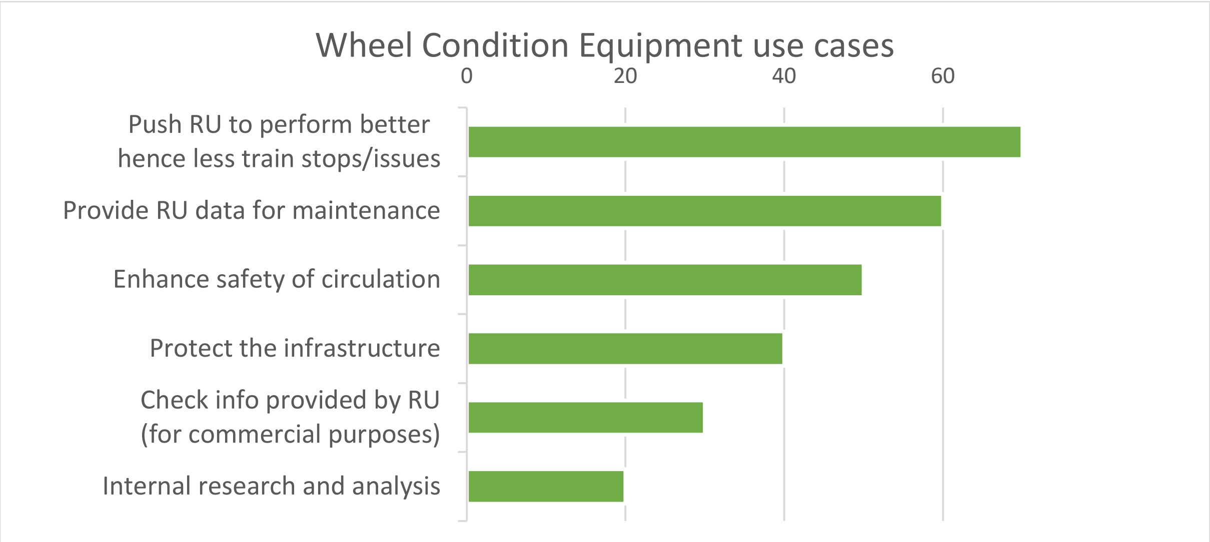


Figure 6: Use cases and benefits of IMs.

As an indirect consequence of this approach some additional benefits are reported, namely a safer train circulation and infrastructure protection/preservation from damages produced by overloaded or defective wheels.

A minority of IMs also reported the use of the data to check the information provided by RUs: In such contexts RUs are paying a track access fee based on the vehicle weight and mileage run across the network and trackside data are used for double-checking the information.

An opportunity that certain IMs in Europe already utilise is to charge penalties for vehicles with very poor wheel tread condition. With the wheel-condition information known from WTMS, it is also possible for IMs to charge the train path prices according to the originator and vehicle.

3.3 Market overview

3.3.1 Requirements of railway undertakings (RU)

This chapter synthesises insights from interviews conducted with experts from three RUs, two from the passenger segment and one from the freight segment. The aim was to explore how wheel condition information gained with wayside monitoring systems are leveraged within the railway industry. Each expert responded to eight standardised questions, and their answers were analysed to uncover commonalities, differences, and specific requirements relevant to their operational contexts.

Desired Measurement Data and Condition Information

Across all RU, the value of dynamic force and static weight measurements was consistently highlighted. It became clear that the purpose of analysing the data differs depending on the operational context. RU operating passenger trains focus more on ride comfort and noise pollution, setting limits based on their own experience. In contrast, freight train operators are more interested in fleet condition information according to relevant industry standards such as EN 15313 Ann. C, GCU App. 9, or VDV 758. Temperature data from wheel sets, brakes, and axles was universally deemed essential, primarily for safety purposes. Nuances emerged in the specifics of desired data. For instance, one company expressed interest in advanced computer vision systems for monitoring wagon information, door conditions, and handle positions, alongside wheel profile and axle condition data. Another company, however, focused on data from weigh-in-motion systems for flat spot detection and emphasised the importance of roundness and static forces, without a preference for computer vision systems. The freight operator, while aligning with the general data needs, placed a particular emphasis on identifying imbalances and flat spots through a structured system of three alarm levels.

Frequency of Data

There was a consensus on the preference for data collection each time a sensor is passed. However, the urgency and timing of data availability varied. One passenger company did not consider the data to be time-critical, instead relying on visual inspections and frequent wayside collection of wheel roundness fingerprints. Conversely, another passenger company required data to be available within three minutes after measurement, indicating a need for near-instantaneous access. In contrast, the freight company linked their data availability requirements to the feasibility of interventions, preferring data collection aligned with station proximity to minimise scheduling disruptions.

Preferred Data Providers

Differences also emerged in preferences for data sources and integration. Although passenger companies typically operate only on national railway networks, one passenger company advocated for cross-country data exchange to support cross-border cooperation and operations at border stations, reflecting a broader need for seamless international collaboration. Another passenger company emphasised the integration of more supplier data and internal information alongside existing IM data. The freight company, however, preferred receiving data from IMs wherever the wagons are running, highlighting a more Europe-wide approach.

Data Requirements

The requirements for data accuracy, tolerance, and the density of measuring systems were critical for all RUs, though specific needs varied. One passenger company emphasised that system density and positioning should align with their operational requirements, advocating for a shift of measurements from depots to tracks for greater efficiency. Another passenger company highlighted the insufficiency of sensors on certain point-to-point lines, indicating a need for improved sensor distribution. The freight company called for system installations at all network nodes, main lines, and border stations, underscoring the necessity for comprehensive coverage. Additionally, it was noted that current data are provided in various formats, standardised by the train operating companies themselves. This approach was considered overly complicated. All companies expressed a need for data and format standardisation, though they did not specify particular data quality or format requirements. Instead, the railway Undertakings expected the relevant industry to provide practical, standardised solutions.

Applications and Desired Automations

All companies sought to leverage wayside-acquired data for automating and improving maintenance planning and data analytics. One passenger company utilised a maintenance management system and developed data analytics applications in Power BI, aiding in management-level decision-making. Another passenger company focused on integrating condition information into their maintenance planning processes, streamlining operations and improving efficiency. The freight company processed data in SAP and other planning systems for production and condition data management, reflecting a structured and systematic approach to utilizing data for operational efficiency. This emphasis on data-driven maintenance planning highlights the industry's shift towards more proactive and predictive maintenance strategies.

Current Use of WTMS

All train operating companies currently use WTMS data from various sources. One passenger company receives data from vehicle diagnostic systems, IMs, and maintenance management systems, leveraging these multiple sources to enhance the level of insights and decision-making capabilities. Another passenger company was provided data solely by a national IM, relying on this centralised source for their monitoring needs. The freight company, however, processed temperature data solely to handle safety related interventions due to the quality of data provided by the IM, which did not allow for accurate wheel set condition monitoring. This highlights a disparity in the utility and quality of WTMS data across different RUs, underscoring the need for improved data quality and integration for more effective condition monitoring.

Conclusion

The analysis reveals significant overlaps in the fundamental needs for wayside monitoring data between passenger and freight train operating companies. All companies value accurate and timely data from weigh-in-motion systems, using this data to improve maintenance planning and operational efficiency. However, passenger companies tend to focus more on technological integration, such as computer vision systems, and enhancing the passenger experience by reducing noise and improving safety. In contrast, freight companies prioritise practical maintenance improvements and operational efficiency, such as allowing more wheel overhauls per wheelset and optimizing material planning. Understanding these specific needs and differences is crucial to harmonise wayside monitoring solutions and effectively meet the diverse requirements of each segment in the railway industry.

3.3.2 Requirements of vehicle keepers (VK)

For the purpose of UC1, different vehicle keepers in Europe were contacted. All of them have been asked with the same questions. The resulting answers were then anonymised and are reported in the table below.

Question	Answer
In connection with wheel condition information, what measuring systems do you have in your product portfolio?	A variety of monitoring solutions are used in the railway world, ranging from COTS (Components of the Shelf) roducts (such as HBK Argos) all the way across to prototype and specific applications developed for the specific situation.
Which parameters can be measured by the monitoring systems used?	Depending on the solution applied, different parameters are collected and analysed. The most common and requested are: Dynamic Forces Static Forces Wheel Shape / Profile Wheel Diameter
Which are the characteristics of the data collected? Specifically: What is the accuracy class? What are the tolerances per measurand? For which speed ranges is the product intended? What influence does the speed have on the quality and tolerance of the measured values?	Concerning the wheel shape/profile monitoring, these are the characteristics of the monitoring solutions identified: Shape (Polardiagram), Δ-r (±0.05mm) Diameter, Flange height (±0.1mm), Wheel flange thickness (±0.1mm), qr-measure (±0.1mm), Wheel Tire Width (±0.2mm), gauge (±0.5mm), Concerning the force monitoring, most of the solution reported a 0.5% average error on weight detection and a maximum of 2% error on balance detection.

Question	Answer
	The different solutions had different operational speed intervals, ranging from a minimum of 5-10 km/h to a maximum of 250 km/h for an accurate reading. Averaging all requirement, we can identify the range between 20 km/h and 150 km/h as the optimal interval to optimise the accuracy of the collected data and avoid invalid readings.
What are the requirements for the superstructure and the track?	Most of the solutions analysed were designed to be installed on different kind of environment (ballast, concrete, etc) to maximise their applicability both in a railway and metro environment.
Which technical interface is used? In which data format or protocol is the data transmitted?	No standard was implemented for the sharing of data outside the application, most of the solution allowed the possibility to retrieve information via APIs specifically developed for the purpose. The most common data format implemented by the different solution is JSON, even though XML and CSV format were also commonly supported.

Table 7: Results of interviews with VKs

3.3.3 Requirements of entity in charge of maintenance (ECM)

The interviewed ECMs have the following requirements for wayside wheel-condition monitoring:

No.	Question	ECM 1	ECM 2
01	In connection with wheel condition information: What measurement data and condition information would you like to have?	Quasistatic Wheel load Dynamic Wheel load Roundness Wheel profile, geometry Diameter Flats, cracks	Quasistatic Wheel load Dynamic Wheel load Roundness Wheel profile, geometry Diameter Flats, material flow, cracks
02	How often do you want the data?	Profile: depends on multiple factors: vehicle type, wear rate among others. In general, around 3 or 4 measurements between reprofiling, which leads to measurements around every 1 to 3 months. Wheel flats: visual inspection every 15 to 30 days.	Every 1-2 years. Ideally, to be done every 6-12 months.
03	Who do you want the data from?	In general, maintenance entity.	Currently data is measured by Entity 2. It would be desirable to obtain data gathered automatically by 3rd parties if possibles.
04	What are your data requirements? (e.g. accuracy, tolerance, availability, density of network of measuring systems)	Tolerance Traceability Availability Periodicity Automation capabilities	Tolerance Accuracy Availability
05	What applications do you want to use it for? What do you want to automate or improve?	Life cycle cost of wheels: wear status/wear prediction and forecasting, maintenance	Better plan and management for vehicle intervention, optimisation of machine stops.

No.	Question	ECM 1	ECM 2
		planning, reprofiling cost optimisation.	
06	What is this condition information worth to you (financially)?	Between 1 – 2-person month per year.	Cannot/does not want to quantify.
07	Do you already use wheel condition information measured with WTMS? From whom do you receive the condition information? Which technical interface is used? In which data format or protocol is the data transmitted?	Yes, sometimes. Provided by maintenance entity or by operator.	No.

Table 8: Results of Interviews with ECM

3.3.4 Installed systems at infrastructure managers (IM) and their willingness to share the measured wheel condition information.

The most important IMs in Europe have been invited for a structured interview with the HERD project team. The following questions have been asked:

- How many systems for wheel condition monitoring have you installed in your network?
- Can you share the suppliers?
- Which is the accuracy/uncertainty of each system?
- In connection with wheel condition information: Which measurement data and condition information are you willing to share with data consumers?
- To whom are you willing to send data (RUs, VKs, other roles)?
- On what (financial) terms are you prepared to provide data?
- Do you already supply measurement data and condition information to data consumers?
- What's your benefit as an IM if you share wheel condition information? What is the cost benefit on the value add with this approach for your company?
- What is the advantage (business case) as an IM using wheel condition equipment?
- Could you provide statistics regarding failures detected in your network?

Country overview and results of the interviews

Not every invited IM volunteered for the interviews. Eleven European IMs have provided their feedback based on the questionnaire.

The answers they gave showed quite a variable presence of trackside equipment for wheel-condition monitoring in Europe, not depending on the network size but rather on specific national projects and particular agreements (contracts) between IM and RU.

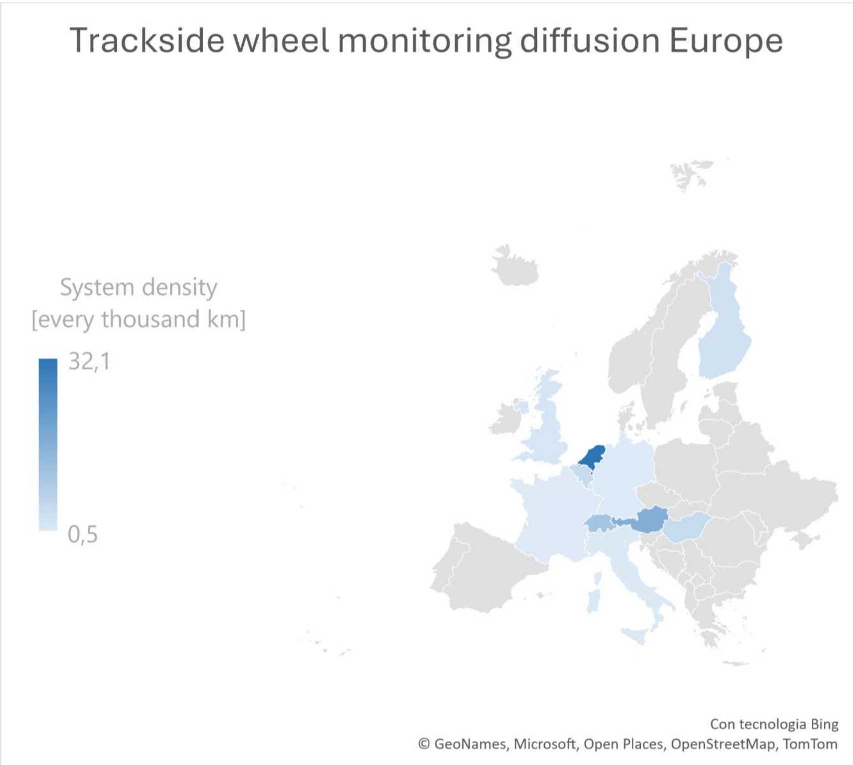


Figure 7: Countries and IMs participated on the interviews.

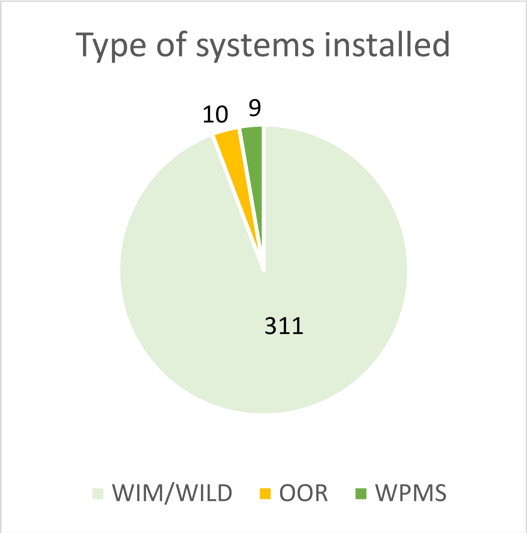
The table below recaps the number of systems installed on the different infrastructure being interviewed, highlighting the biggest network and the biggest number of systems installed.

	Prorail	OBB	MAV	SBB	Infrabel	FTIA	NR	DB	SNCF	RFI	ADIF	CFL	IDP
Network Size (10^3 km)	2.8	5	7.2	3.2	3.5	6	16	34	29	16	15	0.6	2.8
Num of Systems	90	83	38	34	15	19	30	25	15	15	12	1	4
Density Score	32.1	16.6	5.2	10.6	4.2	3.1	1.8	0.7	0.5	0.9	0.8	1.6	1.4

Table 9: Number of systems installed on the different networks.

The evaluation below reports the type of system installed.

- Weigh In Motion type (WIM) with Wheel impact Load Detector (WILD). These types represent the majority of the systems installed and is a force-based measuring/monitoring system. Dynamic factors are measured as train pass over the system to extract the axle/wagon weight and detect the presence of Wheel defects (flat spots).
- Out-Of-Roundness (OOR): A force-based measuring system to measure the circularity of the wheel and the wheel/rail contact point and extract the radial runout. It represents the 3% of the systems installed.
- Wheel Profile Measuring Systems (WPMS): optical system based on laser scanning to extract the wheel profile and assess the global wear of the wheel. It represents less than 3% of the systems installed.



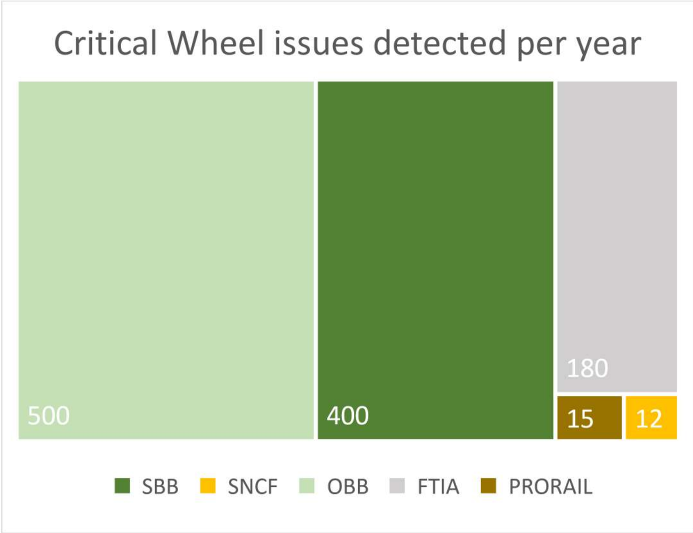
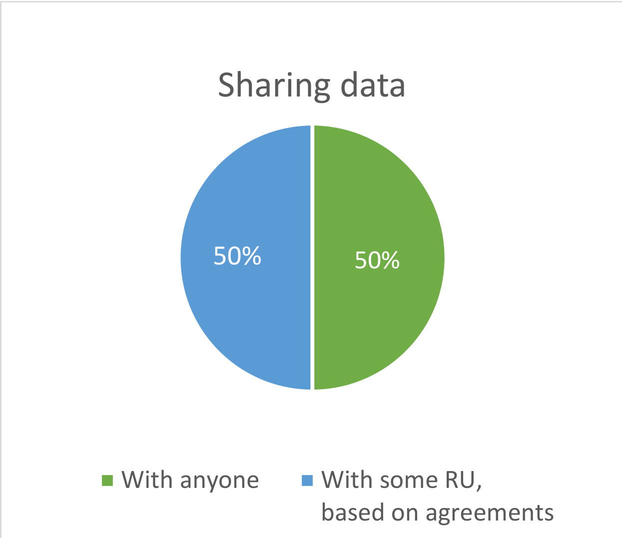


Figure 8: Evaluation of installed system types and detected wheel failures.

As shown in the chart below all the IMs in Europe are willing to share data with RUs and in some cases also with VKs. However, the reasons, the requirements, the objectives, and the information delivered are quite different. The following charts show the variability of these elements across IMs in Europe.



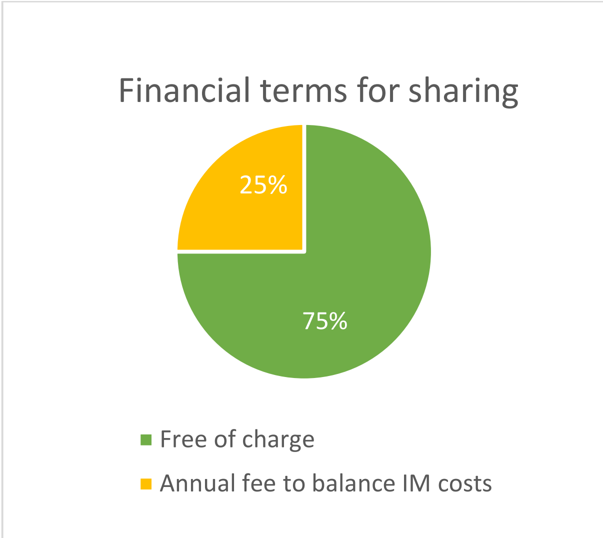
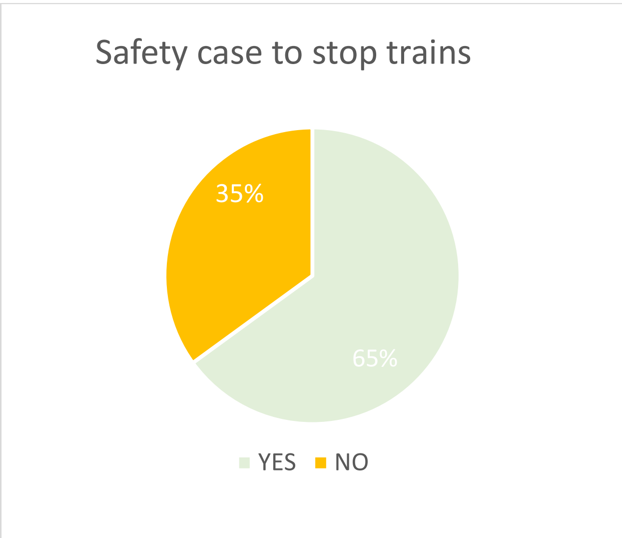


Figure 9: Data sharing and its terms.



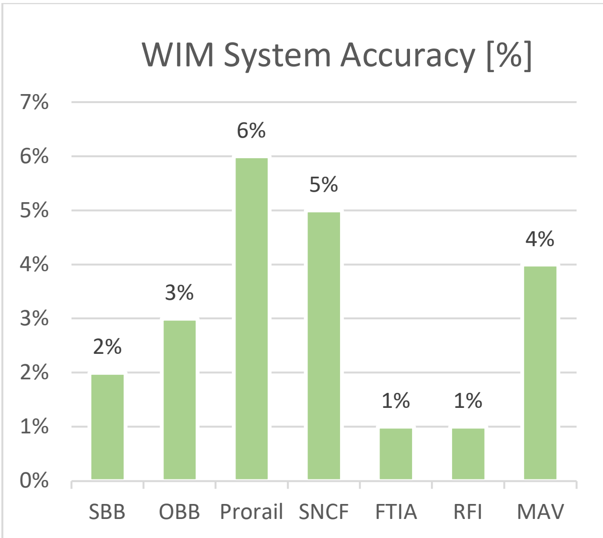


Figure 10: Train stops and WIM accuracy classes.

Conclusions

The feedback collected from IM in Europe showed that the use case on wheel condition monitoring is quite different from country to country. Although such trackside equipment is at present time spread in Europe and new installations are growing, the relationship between IM & RU are highly different and so do contracts/agreement: the local railway market structure and national railways regulations are indeed playing the biggest role in influencing the willingness and the approaches of IM about investing in this technology and sharing data with RU/VK.

Unfortunately, the existing standard EN 15654, supporting the adoption of dynamic force measuring systems, seems not enough to yield harmonisation of the use cases and allow for exchange of information between countries: for instance, there is no consensus about the use of data for safety purposes, some IM use data to stop trains some other simply don't or can't.

Table 10 provides a final overview of the common points, valid in each national context, and the difference points to be addressed and overcome to build a European network for rolling stock diagnostics and truly exchange data.

COMMON POINTS	DIFFERENCE POINTS
• Trackside equipment help ensuring trains are in better conditions. • Trackside equipment help protecting the infrastructure.	• Financial terms: data for free or annual fee • The safety case about wheel monitoring is country dependant. • The RUs and VKs getting data are different from country to country, it depends on local market agreements. • As the system accuracy is different the use cases are different too.

Table 10: Summary of common and difference points.

3.3.5 Available measurement systems and their characteristics from different suppliers

The following table provides a list of suppliers and their products for wheel-condition monitoring. These companies have been asked to volunteer for an interview.

The system suppliers did not allow to share the detailed answers publicly. Their detailed answers are known within HERD project team.

Supplier	Product name	WIM / WILD	Wheel Surface	Wheel Profile
CAF Cetest	LeadMind Wayside WIM / WILD	10 km/h to 320 km/h wheel defects, out of roundness, delta R, fingerprint, polygonisation, degradation of stiffness	---	---
CAF Digital Services	LeadMind Wayside Wheel Profile	---	---	wheel profile, flange parameters, diameter
Evopro	eRDM	wheel load: 10..400 kN ±2% up to 120 km/h ±3% up to 160 km/h	---	---
HBK	Argos WIM	Vehicle weight: ±0.5% to 30 km/h, ±1% to 100 km/h, ±2% to 200 km/h	---	---
HBK	Argos OOR	50 km/h to 250 km/h Resolution better than 0.01 mm, Flat point: 30 mm or bigger, Polygonisation order: 2nd to 32nd	---	---
HBK	Argos PROFIL	---	---	up to 250 km/h cross-wheel profile measurement system

Supplier	Product name	WIM / WILD	Wheel Surface	Wheel Profile
				certified according to ISO 17025
Hitachi	WIM / WILD (Ansaldo STS)	±0.5% up to 40..60 km/h ±10% up to 220 km/h	---	---
L.B. Foster	WILD-IV	±2..3% up to 160 km/h incl. Truck hunting index (regulated in US)	---	---
Mermec	WIM / WILD	class 1 (±1%) for the axle weight up to 30 km/h	---	---
Mermec	Wheel profile	---	---	at line speed highest accuracy at lower speeds (< 80 km/h) flange parameters (QR) in [mm] and in [°] acc. EN 15313, tread rollover, wheel width, wheel diameter, wheel out-of-roundness, distance between wheels
Mermec	Wheel surface inspection system	---	up to 90 km/h detection of issues on the wheel surface	---
Progress Rail	WIM / WILD	max. ±2% on vehicle weight up to 250 km/h	---	---

Supplier	Product name	WIM / WILD	Wheel Surface	Wheel Profile
Progress Rail	OOR	20 - 250 km/h out of roundness, delta R fingerprint (as a graph)	---	---
SBB	RLC (Radlast Checkpoint)	class 2 (±2%) for vehicle weight up to 160 km/h	---	---
Siemens	VEMS (Vehicle Equipment Measurement System) wheel tread (WTMS)	---	---	up to 40 km/h various parameters like wheel flange angle acc. to ISO 17025
voestalpine	zentrak	±3% for vehicle weight up to 350 km/h wheel defects: optimum at 80 km/h	---	---
Wabtec	Kinetix Wheel Condition Monitoring	up to 140 km/h	---	---
Wabtec	Kinetix Wheel View	---	---	up to 120 km/h diameter +- 0.5 mm
Wabtec	Kinetix Tread View	---	up to 80 km/h tolerance for defects on the surface 0.1 - 0.3 mm	---

Table 11: Measurement systems and their characteristics from different suppliers.

Conclusion:

Most of the suppliers have

- systems for weighing in motion (WIM)
- systems for dynamic wheel impact load diagnostic (WILD)

in their product portfolio. These systems work at line speed and are used for the measurement of wheel load, axle load, vehicle load and detection of wheel defects.

Safety relevant use cases of the IM are detection of overloading, asymmetric loading, and detection of major wheel defects.

The WILD systems are used to measure the wheel-condition. Measured variables or derived variables provide various information on the wheel-condition, such as:

- wheel flats
- out of roundness
- polygonisation
- ovalisation
- fingerprint
- dynamic peak load
- dynamic coefficient (dynamic factor)
- bogie problems
- bogie twisting
- wagon twisting

This information can be used for condition-based maintenance.

There are only a few suppliers who have wheel profile measuring systems in their product portfolio that deliver reliable results even at line speeds.

3.4 Summary and gap analysis

3.4.1 Summary of interviews with railway undertakings (RU)

RUs can be divided in two major groups working under different operational conditions.

RUs operating passenger trains have a focus on

- comfort of the ride and
- low noise.

RUs operating freight focus on industry standards like GCU or EN 15313 to identify defects according to a given catalogue. All RUs require to receive accurate and reliable data stream with differences in frequency and speed. All RUs identified potentials to improve maintenance processes, increase quality and decrease operational disturbance.

3.4.2 Summary of interviews with vehicle keepers (VK)

VKs were interviewed about already used systems, measured values, requirements regarding accuracy and advantages of harmonised diagnostic data. The results showed that there is an appetite to consume diagnostic data to

- improve processes,
- extend the life cycle of rolling stock and
- reduce cost of maintenance.

There is a need to receive data from different measurement system in a standardised format, because nowadays data format / interfaces are different for every supplier.

3.4.3 Summary of interviews with entities in charge of maintenance (ECM)

Two ECMs were interviewed during this project: The result showed a good match in major points where ECMs see an advantage in using harmonised diagnostic data to move away from periodic measurements in the workshop towards a condition-based approach. There is a focus on

- tolerance
- traceability
- availability
- periodicity

Availability of diagnostic data is seen as a driver for condition-based maintenance that will allow optimised repairs and better planning in the workshop.

3.4.4 Summary of interviews with infrastructure managers (IM)

Diagnostic data is produced in most cases by IMs owning and operating wayside monitoring systems. This leads to the question, aside technical limitations, which IMs are willing to share diagnostic data to which stakeholder. This is different in every country. As a rule of thumb, most IMs share data to RUs, because there is a contractual relationship between them.

Existing regulations regarding data sharing are not standardised. They differ for each IM: SNCF offers data sharing based on their network statement, ÖBB in their SNNB, SBB establishes contracts with the data users, other IMs are more reluctant.

In addition to this, data formats are not standardised, there is a broad variety. Some IMs established a well-documented API (e.g., ÖBB InfoHub, SBB Wayside Intelligence), others share Excel-files by mail on request.

Table 12 gives a non-exhaustive overview about the willingness of the IMs and who they share data with.

Infrastructure Manager (IM)	**Railway Undertaking (RU)**	**Vehicle Keepers (VK)**
CFL	X	
MAV	X	
NetworkRail	X	
ÖBB Infra	X	X
ProRail	X	X
RFI	X	
SBB CFF FFS	X	X
SNCF	X	X

Table 12: Matrix Data Sharing based on interviews with Infrastructure Managers.

3.4.5 Gap Analysis

This chapter describes the gaps between the requirements of the data users and the capabilities of the installed systems provided by the IMs. Aside this, there are some characteristics to be kept in mind.

Fortunately, it can be summarised that most installed systems deliver data that fulfil the requirements of the data users. Provided wheel-condition information allows data users to understand the condition of wheels, bogies, and wagons with the required accuracy, reliability, and frequency. Aside this high-level view, there are points that must be kept in mind:

Comparability of measurements:

Measurements of dynamic forces between different locations reveals significant differences. Based on the measuring principle the track structure itself is part of the measuring system or sensor. Dynamic forces of the same wheel might be higher on slab track compared to ballasted track because slab track is stiffer. Normalisation of data seems to be a possible solution, which enables the consumer of the data to make use of the measurements without any location specific knowledge.

The most promising approach is to provide data users with a suitable amount of meta data. Examples: Location of the measuring system, construction of the track, calculation of any normalisation.

Differences in accuracy:

Measurement systems supply their data with different accuracies. In addition, the accuracy of a single system might deviate based on speed or calibration results. To make measurements comparable and useable, metadata like current accuracy or confidence level should be supplied.

Accuracy requirements:

Depending on the application, different accuracy classes of measurement systems are required. WIM/WILD systems installed on the railway tracks measure the trains and their wheel conditions at line speeds. They typically have accuracy classes suitable for IM applications. The wheel condition information obtained in this way is also fully sufficient for RU, VK and ECM applications. Planning the necessary maintenance measures, reducing train noise, or detecting safety-relevant wheel faults does not require very high standards of measurement accuracy.

In contradiction, the ECM maintenance plants require very precise measuring systems. There, the standardised wheel condition measurements are carried out after maintenance at walking speed.

Table 13 gives a brief comparison between both classes of measuring systems.

Location of measuring system	**velocity**	**accuracy**	**frequency**
ECM workshop	line speed	high	low
Railway tracks	walking speed	low	high (continuous)

Table 13: Comparison workshop vs. WTMS diagnostics.

3.4.6 Methodology of collecting the user needs

To advance UC1 and to establish a set of user needs for future steps, HERD Phase 2 focused on conducting interviews with key stakeholders (RUs, VKs, ECMs, IMs, suppliers).

We did not use electronic questionnaires and favoured direct interviews. Interviews are an effective methodology for collecting needs because they provide direct, detailed insights into the requirements, expectations, and challenges faced by those impacted by or involved in the issue being addressed.

Risks, disadvantages:

- Typically, an interview is conducted with ONE person from a key stakeholder. This person represents your entire company. However, the opinion of the individual surveyed is not the same as other individual opinions of the same company.

- Participation in structured interviews or enquiries is voluntary. Many of the companies contacted did not respond. Nevertheless, we form our opinion based on the responses received and derive a picture of the needs of data users and the readiness of data providers.

Opportunities, advantages:

- The aim of a structured interview is to obtain answers to the previously defined questions. All interviewees in a stakeholder group are asked the same questions. The answers received can be summarised to form an overall picture. Similarities and differences between the stakeholders are recognisable.
- The interview is a dialogue format between two people. In addition to answering the questions, it invites you to engage in dialogue and an open exchange. In this way, valuable additional information, an understanding of the wider context, further application possibilities etc. can be gained that were not considered in the preparation phase.

3.5 Specific HDDI (Harmonised Diagnostic Data Interface) needs

3.5.1 Key Needs

The Harmonised Diagnostic Data Interface (HDDI) for HERD applications has several specific needs to ensure interoperability, reliability, and efficiency. Here are some key needs:

Standardised data formats:

- Data consistency: Ensure that data from various sources is consistent and follows the same format.
- Interoperability: Facilitate seamless data exchange between different systems and operators across Europe.

Real-time data access:

- Timely diagnostics: Enable real-time access to diagnostic data to quickly identify and address issues.
- Condition-based maintenance: Support condition-based maintenance by providing up-to-date information on the condition of railway assets.

Scalability:

- Futureproofing: Ensure the interface can handle increasing amounts of data as more systems and sensors are integrated.
- Flexibility: Accommodate new types of diagnostic data and evolving technology without significant redesign.

Security and privacy:

- Data protection: Implement robust security measures to protect sensitive diagnostic data.
- Access control: Ensure that only authorised personnel and systems can access the data.

Integration with existing systems:

- Compatibility: Ensure that the interface can work with existing diagnostic systems and tools.

- Minimal disruption: Facilitate a smooth transition to the new standard without major disruptions to current operations.

User-friendly design:

- Ease of use: Design the interface to be user-friendly for both technical and non-technical users.
- Training and documentation: Provide comprehensive training and documentation to help users understand and utilise the interface effectively.

Data analytics capabilities:

- Advanced analytics: Support advanced data analytics to derive actionable insights from diagnostic data.
- Visualisation tools: Include tools for visualizing data trends and anomalies.

Regulatory compliance:

- Adherence to standards: Ensure compliance with relevant European and international standards and regulations.
- Reporting requirements: Support mandatory reporting requirements for railway operators.

Reliability and redundancy:

- High availability: Design the interface to be highly reliable and available.
- Redundancy measures: Implement redundancy measures to ensure data integrity and availability in case of system failures.

Cost-effectiveness:

- Affordable implementation: Ensure that the interface is cost-effective to implement and maintain.
- Efficient resource use: Optimise resource use to minimise operational costs.

Modularity:

- Modular design: Design the interface to be modular, allowing for easy updates and additions.
- Customisability: Allow for customisation to meet specific needs of different railway operators.

Collaboration and governance:

- Stakeholder collaboration: Foster collaboration among various stakeholders including railway operators, manufacturers, and regulatory bodies.
- Governance framework: Establish a governance framework to oversee the development and maintenance of the interface.

Addressing these needs will help ensure that the HDDI becomes a robust, reliable, and widely adopted standard for railway diagnostic data exchange across Europe.

Cybersecurity is a crucial aspect of any modern data interface, especially in critical infrastructure like railway systems. Here's an additional point specifically focused on cybersecurity needs:

Advanced cybersecurity measures:

- Encryption: Implement end-to-end encryption to protect data in transit and at rest, ensuring that sensitive diagnostic data is not accessible to unauthorised parties.
- Intrusion detection and prevention: Deploy advanced intrusion detection and prevention systems to monitor network traffic for suspicious activities and respond to potential threats in real-time.
- Regular security audits: Conduct regular security audits and vulnerability assessments to identify and address potential security gaps in the interface.
- Multi-Factor Authentication (MFA): Require multi-factor authentication for all users accessing the diagnostic data interface to add an extra layer of security.
- Incident response plan: Develop and maintain a comprehensive incident response plan to respond to cybersecurity incidents quickly and effectively.
- Security patching: Ensure timely application of security patches and updates to all components of the interface to protect against known vulnerabilities.
- Access logs and monitoring: Maintain detailed access logs and continuously monitor user activities to detect and investigate suspicious behaviour.
- Compliance with cybersecurity standards: Ensure that the interface complies with relevant cybersecurity standards and regulations, such as the EU Network and Information Systems (NIS) Directive.

Incorporating these cybersecurity measures will help protect the integrity, confidentiality, and availability of the diagnostic data, thereby enhancing the overall security and trustworthiness of the HDDI.

3.5.2 Harmonised Data Exchange

During the first phase of the HERD project, a search was conducted for existing standards and methods. The ongoing aim is to harmonise European railway diagnostic data and exchange it in a standardised way between data providers and data users.
In the second phase of HERD, four selected options for harmonised data exchange were examined in more detail and compared with each other. Here a summary in a nutshell.

3.5.2.1 TCCS / TMS format, developed by EU's rail.

The TCCS (Traffic Control and Command System) TMS (Traffic Management System) data exchange format, under the Europe's Rail Joint Undertaking, integrates OPC UA (Open Platform Communications Unified Architecture) as its main architectural backbone. Additionally, it utilises the EULYNX procedure to standardise its interface specifications and data structures, ensuring interoperability and facilitating efficient data exchange among railway systems across Europe.

Main architecture: OPC UA

Unified data model:

- OPC UA information model: Defines standardised objects, attributes, and data types, ensuring consistent data representation and interoperability.
- Node management: Dynamically manages data points and their relationships within the TMS ecosystem.

Communication protocols:

- OPC UA Client-Server model: Implements synchronous communication for real-time data exchange.
- OPC UA PubSub model: Supports asynchronous communication for efficient broadcasting of critical information.

Real-time data exchange:

- Secure channels: Establishes encrypted communication pathways for data confidentiality and integrity.
- Event notification: Provides immediate updates and alerts on significant operational events.

Scalability and flexibility:

- Modular design: Allows scalable deployment, from local networks to trans-European systems.
- Interoperable interfaces: Integrates with legacy systems and future enhancements.

Security and reliability:

- Authentication and authorisation: Uses robust mechanisms for secure data access.
- Data integrity: Ensures data reliability through redundancy and failover mechanisms.

Compliance and integration:

- Standards compliance: Adheres to EU regulations, including CSM and TSI.
- Seamless integration: Uses standardised OPC UA interfaces for integration with existing systems.

EULYNX procedure:

The EULYNX procedure provides a standardised framework for specifying interfaces and data structures in railway signalling systems. By integrating EULYNX, the TCCS TMS data exchange format ensures interoperable and efficient communication between various railway control systems, enhancing the overall effectiveness of the European rail network.

3.5.2.2 ISO/IEC 19987 – EPC Information Services (EPCIS)

EPCIS (Electronic Product Code Information Services) is an international standard (ISO/IEC 19987), developed by GS1 and the railway industry. This standard specifies a framework for the capture and exchange of event data related to the movement and status of objects. EPCIS enables seamless data exchange between different systems and stakeholders, enhancing visibility, interoperability, and operational efficiency. Here's a brief technical summary of how data exchange with EPCIS works in railway applications.

Key components and data exchange

Event data model:

- Capture real-time data from WTMS, indicating the current condition of vehicle components (e.g., wheel condition, brake wear, engine vibration) and results of technical checks (e.g., brake tests, signal system checks).

- Aggregate multiple inspection and condition monitoring results into comprehensive reports for each vehicle.

Data capture: Utilise existing WTMS installed in the European railway network to continuously monitor critical components' condition.

Middleware: Process raw data from WTMS, filtering and aggregating it into structured EPCIS-compliant event data.

Data exchange mechanisms:

- Serialise WTMS and inspection data into XML or JSON formats for standardised communication.
- Use SOAP (Simple Object Access Protocol) or REST (Representational State Transfer) web services to transmit EPCIS event data to central maintenance management systems and operational systems.

Query and subscription interfaces:

- Maintenance and operational teams can query the EPCIS repository for real-time condition and inspection data using specific parameters (e.g., asset ID, time range, condition thresholds, inspection results).
- Teams can subscribe to specific condition and inspection events (e.g., high vibration alerts, safety equipment inspection failures) and receive real-time notifications.

Security considerations:

- Use HTTPS to secure data transmission.
- Implement OAuth for secure access control.
- Conduct regular audits to identify and mitigate vulnerabilities.

By leveraging EPCIS (ISO/IEC 19987) and the capabilities of WTMS, RU and VK can achieve a unified approach to condition-based maintenance and technical checks, enhancing the overall safety, efficiency, and reliability of railway operations.

EPCIS is a well-established data exchange format that is used operationally by various European IM, VK and component suppliers.
During the presentation, the participants were able to see this 1:1 in a live demo.

3.5.2.3 Phoenix CMS Webhooks, developed by Voestalpine

Phoenix CMS Webhooks allows automated data export from the Phoenix CMS to a 3rd-party integration. A build or set up integration subscribes to certain topics of the Phoenix CMS webhook interface and is enabled to process the contained information.

Every time an event is triggered within Phoenix CMS, a HTTP POST payload is sent to one or more configured URLs on an event specific topic.

Phoenix CMS Webhooks has been developed by the system supplier Voestalpine. It’s a data exchange format which is used internationally with its WTMS systems.

3.5.2.4 RCM-DX, open source

Rail Condition Monitoring - Data Exchange (RCM-DX) utilises on-board sensors on regular trains in operation to supervise railway infrastructure and facilitate condition-based maintenance (CBM). This approach provides real-time monitoring and data exchange capabilities, enhancing the maintenance and supervision of railway networks.

Key components and data exchange:

On-Board sensors:

- Types of sensors: Vibration sensors, temperature sensors, acoustic sensors, accelerometers, and gyroscopes.
- Data collected: Real-time data on track geometry, rail wear, temperature variations, structural integrity, and environmental conditions.

Data collection and transmission:

- Wireless communication: Data from on-board sensors is transmitted wirelessly to central servers or cloud-based platforms using cellular, Wi-Fi, or satellite networks.
- Data formats: Sensor data is serialised into standardised formats such as XML or JSON for consistent communication and interoperability.

Middleware and data processing:

- Data aggregation: Middleware processes raw sensor data, filtering and aggregating it into structured, RCM-DX-compliant event data.
- Analytics: Advanced algorithms and machine learning models analyse the aggregated data to identify patterns, anomalies, and potential failure points.

Data exchange mechanisms:

- Web services: Use of SOAP or REST APIs to facilitate data exchange between trains, central systems, and maintenance management systems.
- Real-time communication: Ensures that data is relayed in real-time to enable timely decision-making and intervention.

Query and subscription interfaces:

- Query interface: Engineers can query the RCM-DX repository for specific event data using parameters such as location, time range, and condition thresholds.
- Subscription interface: Engineers and systems can subscribe to specific events (e.g., track misalignment, excessive rail wear) to receive real-time notifications and alerts.

Security considerations:

- Data encryption: Use of HTTPS for secure data transmission.
- Access control: Implementation of OAuth for secure access management.
- Regular audits: Conduct regular security audits to identify and mitigate vulnerabilities.

By implementing RCM-DX with on-board sensors on regular trains, the European railway industry can achieve a robust and efficient approach to infrastructure supervision and condition-based maintenance, enhancing the overall safety and reliability of railway operations.

RCM-DX is used by various European IMs as a data exchange format for infrastructure-related condition information.

RCM-DX was developed by SBB. Today, RCM-DX is available as open source. The further development and coordination of the releases is carried out by the open-source community, in which several railway companies are represented.

3.5.2.5 Conclusion

This as a brief overview of the four different data exchange approaches.

Conclusion: According to the EU's Rail program the format developed for TCCS/TMS is to be used for data exchange. It is newly developed and very generic.

EPCIS, RCM-DX and Phoenix CMS webhooks are established data exchange formats, especially for condition information of infrastructure and rolling stock.

During the next phase of the project, the data exchange format and the specific HDDI (Harmonised Diagnostic Data Interface) to be used for HERD will be specified. It should offer the opportunity to realise UC1 and UC2 in a targeted manner.
It may be possible to use higher-level concepts from TCCS/TMS (EU's Rail) and at the same time utilise the advantages of the already established DX approaches.

3.6 Cost Benefit Analysis Structure for UC1

A cost benefit analysis (CBA) is a method used to evaluate the advantages and disadvantages of a decision or project. The aim of this analysis is to assess the economic efficiency of a measure by evaluating and comparing all relevant costs and benefits arising from the project or decision in monetary units.

These are the basic steps of a cost-benefit analysis:

1. Identifying the costs and benefits:
2. First, all potential costs (e.g. investments, operating costs, opportunity costs) and benefits (e.g. revenues, savings, societal benefits) are identified.
3. Monetisation of costs and benefits:
4. In this step, the identified costs and benefits are converted into monetary amounts. This can be particularly challenging when dealing with intangible or difficult to quantify variables such as environmental damage or social benefits.
5. Discounting:
6. Costs and benefits that will be incurred in the future are discounted at a discount rate to calculate their present value. This is necessary because monetary values may be worth less in the future than in the present (due to inflation and other factors).
7. Calculation of the net value:
8. The net value of the project is calculated by subtracting the total costs from the total benefits. If the net value is positive, the project is considered favourable from an economic point of view.

Cost benefit analysis is used in many areas, including the public sector, infrastructure project planning, health economics, environmental protection, and business investment decisions. The analysis provides a structured and quantitative basis for decision-making, but it is also subject to uncertainties and subjective assumptions, particularly when evaluating intangible benefits and costs.

3.6.1 Identification of costs and benefits

As a basis for a proper cost base analysis all relevant entries must be identified. This can be tangible or intangible factors like material, time, or money. It must be considered that a cost benefit analysis will provide different results based on the role of the user and, inside this role, different results for every company.

It is not the purpose of this document to create a CBA that calculates a specific result, because circumstances, processes, cost structures are different for every company, in some cases they can be contrary.

This document should give guidance how to structure a CBA in regards of HERD.

Prior to a CBA a stakeholder analysis should be performed to identify affected roles of data sharing.

Aside this structure, there might be company standards how to create and calculate CBAs taking company specific rules into account.

3.6.2 Quantifying Costs and Benefits

Identified costs and benefits must be quantified and transferred into monetary terms. This allows costs and benefits to be offset against each other, leading to a positive or negative result. It must be considered that costs and benefits might occur at different time point and need to be adjusted to reflect their present value. Examples for this could be initial costs like setting up IT infrastructure and user training or, recurrent costs like licencing or depreciation. It should be kept in mind, that financial rules and regulations inside a company must be considered.

A CBA allows to calculate a break-even point where the benefits should exceed the costs.

3.6.3 Examples of cost and benefits

Based on the structure of costs and benefits there might be factors that must be considered once or as part of an ongoing costs and benefits. This depends heavily on the availability of the data itself and the organisation of the user.

Table below gives an overview where exemplary costs and benefits ca be found.

	Cost	Benefits
Data consumer	**Fehler! Verweisquelle konnte nicht gefunden werden.**	**Fehler! Verweisquelle konnte nicht gefunden werden.**
Data provider	**Fehler! Verweisquelle konnte nicht gefunden werden.**	**Fehler! Verweisquelle konnte nicht gefunden werden.**

No.	Factors	Quantification
01	Provision of data	• Initial setup of data connection and operation • Data safety and security • Ongoing costs (per measurement, flat rate) • Legal requirements • Serialisation of wheelsets • RFID Tagging
02	Provision of application to use harmonised data GUI (Graphical User Interface)	Application to convert received data into a visible form to allow the user to understand and interpret data. • Initial setup of application • Software maintenance • Hosting of data • Labour cost for data scientists
03	Implementation	Chosen application must be implemented into the organisation of the user. • Changes in the repairs process of the organisation • Interfaces to existing ERP systems • Training of the users

Table 14: Exemplary costs of data usage for data consumers.

No.	Factors	Quantification
01	Provision of data	• Initial implementation of harmonised data interfaces • Efforts for type approvals • Maintenance of software • Implementation of new functions • IT Security • Support for data users

Table 15: Exemplary costs of data usage for data providers.

No.	Factors	Quantification
01	Vehicle Keeper (VK)/ECM	• Measurements of diagnostic systems reveal defects, which cannot be found during manual inspection. • Measurements are already available when wagon comes in • Enabler for condition-based maintenance, no need to return wagon into the workshop, status of the wagon is always available. • Based on measurements, wheels can be processed without further inspection. • Condition-based maintenance of wheels results in longer runtime of wheels and earlier detection of wheel defects, increased utilisation of wear stock. • Diagnostic data allows to plan maintenance actions which will lead to a better utilisation of resources. • Move the inspection of wagons away from the workshop into the track. • Perform data analysis to help identifying areas for improvement
02	Infrastructure Manager	Provision of data should result in better wheel quality. • Improved wheel quality reduces wear of infrastructure. • Improved wheel quality reduces the number of unplanned stops in the network that results in increased utilisation of the infrastructure. • Accumulation of diagnostic data allows to calculate the wear and tear of the infrastructure. This helps to plan repair or exchange of parts of the infrastructure. • Supply of diagnostic data allows the IM to implement a bonus/malus system that rewards well maintained vehicles
03	Railway Undertaking	The usage of diagnostic data provides an overview of the fleet of the RU or VK. This allows to optimise maintenance of the vehicles and the exchange of vehicles before they fail. • Higher availability of the fleet, due to less unplanned events like unloading or repair • Less speed reductions • Less efforts for rescheduling of defect wagons • Enables RU to benchmark the quality of their lease provider. • Automation of the technical train inspection

Table 16: Exemplary benefits of data usage for data consumers.

No.	Factors	Quantification
01	Data Provider	• Created data can be sold to a broader range of data users. • Offering harmonised interfaces creates opportunities to sell diagnostic systems inside ERA (European Union Agency for Railways).

Table 17: : Exemplary benefits of data usage for data providers.

3.6.4 Exemplary Structure of cost benefit analysis

A CBA will look different for every stakeholder because roles, processes and commercial environments aren't the same. The CBA lists every factor that might produce cost, either as one-off (initial costs) or recurrent costs (e.g. yearly costs). Factors itself must be identified case by case, it is crucial to identify every component.

The table below shows an exemplary structure of a cost benefit analysis. It shows the calculation of costs, the calculation of benefits uses the same structure and is not shown here.

Factors	Details of Factors	Amount One-Off	Amount recurrent	Cost (€)	Labor (h)	hourly rate (€/h)	Cost sum One-Off (€)	Cost sum recurrent (€)
Provision of data	Setup of data connection	1		1.200	12	75	2.100	-
	Data Safety and Security	1					-	-
	Ongoing costs p.a.						-	-
Provision of application	Initial setup of application						-	-
	Software maintenance p.a.						-	-
	Hosting of data						-	-
	User License p.a.		10	25			-	250
Implemen-tation	Changes in the repair process	1			180	75	13.500	-

Factors	Details of Factors	Amount One-Off	Amount recurrent	Cost (€)	Labor (h)	hourly rate (€/h)	Cost sum One-Off (€)	Cost sum recurrent (€)
	Interface to ERP system	1			80	75	6.000	-
	Training of users	10			40	74	29.600	-
							51.200	250

Table 18: Exemplary calculation of initial and recurring costs.

Costs and benefits should be offset against each other over a specific period. It is likely that the benefits of using the Harmonised Diagnostic Data Interface will result in a positive result when initial efforts are compensated by the increasing benefits.

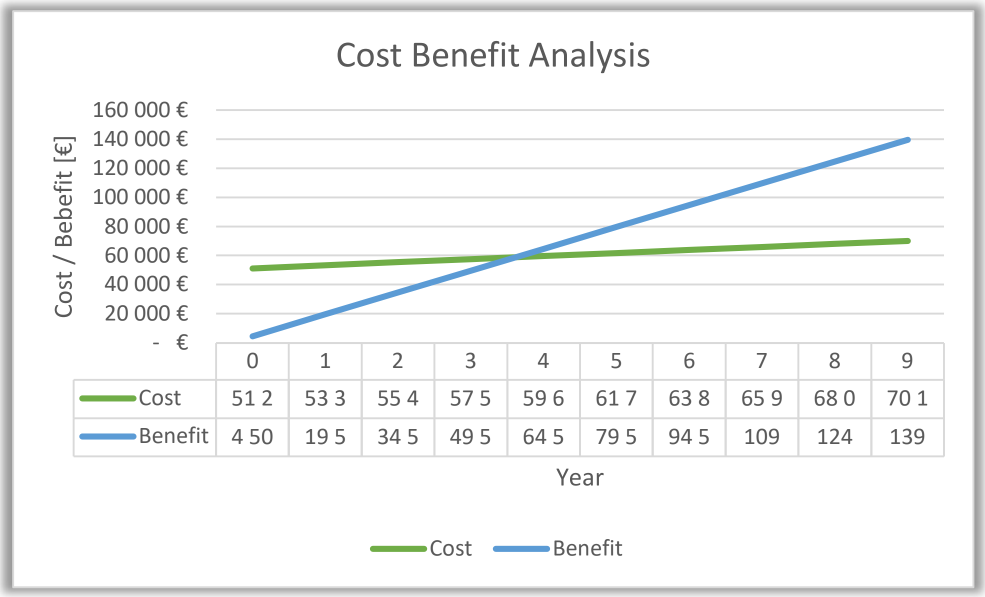


Figure 11: Break-even of cost vs. benefits.

Table 11 shows an exemplary comparison of cost vs. benefits where benefits show effect in year 4.

3.7 Risks and Opportunities

Risks

Lengthy decision-making processes until a common, harmonised data format and exchange protocol was agreed.

Opportunities

VKs and ECMs want and demand more information on the wheel-profile. Today, these measurements are often very time-consuming and involve manual measuring systems. Automation would bring major economic benefits. So far, only a few wheel-profile measuring systems have been installed on the European railway network, which can be travelled at line speed.

This creates the opportunity for IM to procure additional wheel-profile measurement systems, install them on the tracks, operate the measurement systems and pass on the condition information to interested data users. (Investment cost per wheel-profile measurement: approx. 700 kEUR). The data users are prepared to pay a contribution to the data providers for qualitatively appropriate status information on the wheel-profile condition.

This will ensure cost-effectiveness for the data provider (IM) as well as for the date users (VK, ECM).

We recommend to further investigate on this business case.

3.7.1 Next steps

During the next phase of the project, the data exchange format and the HDDI to be used for HERD will be specified. It should offer the opportunity to realise UC1 and UC2 in a targeted manner. It may be possible to use higher-level concepts from TCCS/TMS (EU's Rail) and at the same time utilise the advantages of the already established DX approaches.

4 UC 2: On-Board Track Monitoring

4.1 UC2 Description

Track quality is a crucial aspect of the railway system, with influence over safety, maximum speed, and passenger comfort amongst other factors. Understandably, track quality is subject to deterioration over time so, as part of its responsibility of maintaining its infrastructure, the Infrastructure Manager (IM) must carry out activities to counteract the effect of time and the loads that are exerted on the track.

The IM must assess the track quality beforehand and with that information plan out the required actions. Therefore, IMs across Europe allocate a great amount of resources to monitor the track parameters used to determine the state of the track and ascertain the need of any intervention. Track monitoring is generally carried out by on-board sensors, meaning sensors on board a train that runs through a track recording different parameters. These parameters are fundamental for both safety and maintenance purposes.

The object of Use Case 2 On-Board Track Monitoring (UC2) is **the harmonisation of the track condition data** that results from this monitoring of the track using on-board sensors.

Today, despite the widespread use of track measurements based on EN 13848 and EN 14363 standards, no standard exists for the exchange and formatting of track condition data. Without a HDDI, IMs and suppliers rely on custom solutions, which often require data conversions even when the data represents the same content. This lack of standardisation leads to inconsistent data outputs, making data analysis more difficult. Additionally, it increases costs associated with developing and maintaining multiple custom interfaces, updating data across different systems, etc. Lack of harmonisation also contributes to delays and potential data quality problems.

More details on this use case can be found in the detailed description included in the final Phase 1 report Harmonised European Railway Diagnostics (HERD), 22/01/2024 HERD Master Document Ver. 2.1).

4.2 Expected benefits for track maintenance.

Track condition data harmonisation can bring the following benefits:

- **Increased Safety and Reliability:** With accurate and standardised data, potential issues can be identified and addressed promptly, enhancing the overall safety and reliability of the railway network.
- **Reduced costs for data import:** Harmonised data does not require the development of data converting tools. These tools are required for correlating data from different systems and need to update over time.
- **Freed resources for data management**: In general, data conversion is not only about implementing a tool but also using, managing, and updating it. If a tool is not required, the resources consumed by the tool (and all the other tools in place) can be re-used for other added value tasks.
- **Reduced time to data access:** no extra time is required to access to harmonised data.
- **Evolved Maintenance:** Harmonised data allows for better comparison and analysis, enabling more accurate predictive maintenance and resource allocation. Predictive maintenance requires that data are comparable in time and space. Advanced analytics requires the analysis of several streams of data regardless the data sources and the data format.
- **Enhanced Data Quality:** Consistent data formats and measurement techniques reduce discrepancies and errors, leading to more reliable data. In general, data quality could be reduced due to potential data loss in the data conversion process or less opportunity to audit them.
- **Facilitates Interoperability:** Standardised data can be easily shared and interpreted across different systems, stakeholders, and countries, promoting seamless collaboration. Moreover, interoperability avoids discarding potentially useful data due to barriers to access them.
- **Supports Regulatory Compliance:** Standardised data helps in meeting regulatory requirements and industry standards, ensuring compliance and reducing legal risks.
-

Some additional more specific benefits that may not affect all IMs are:

- **Getting access to best practices:** Sharing data and experience between IMs is difficult but standards can facilitate the process if any collaboration agreement/project arises. This would facilitate the evolution of the current adopted practices.
- **Tender standardisation:** with the existence of a harmonised standard, IMs have the opportunity to reference it when issuing a tender for a contract related to track condition data.

- **Legal compliance:** In the case of SBB, harmonisation at national level was required by national rules imposing the possibility to access and read the data for 15 years, so the stability of a data storage format is essential to making sure that the data are readable.

The expected benefits are derived from a survey carried out with various European IMs. The results and analysis of the survey are presented in subsequent sections of this document.

4.3 Market overview

To maintain safety and comfort, prevent accidents, and optimise maintenance planning, it is crucial for the IM to monitor the condition of its infrastructure assets. This includes measuring key track parameters and verifying their compliance with regulatory thresholds.

Today, IMs use dedicated diagnostic trains and commercial trains equipped with certified measuring instruments to inspect national railway lines with high precision. These onboard monitoring systems measure and evaluate various aspects of the track, such as:

- Track geometry parameters.
- Dynamic behaviour of vehicles, including axle box accelerations
- Condition of rails, ballast, fastenings, and sleepers

Currently, the scanning of railway infrastructure using diagnostic trains is performed on a periodic basis. The frequency of these scans depends on the length and type of the railway lines and the inspection modality (dedicated vs. commercial train), typically ranging from a few days to several months.

Technologies employed for onboard rail track monitoring and their applications include:

- Laser-based measurement systems.
- Track image capture systems.
- Inertial Measurement Units (IMUs) with accelerometers and gyroscopes.
- Ultrasonic systems.
- Infra-Red (IR) and Ultra-Violet (UV) monitoring systems.

The data collected by these systems are often recorded in real-time and transmitted to the train's computer system, which can alert operators and maintenance crews if abnormal values are detected. Additionally, this data can be stored and further exchanged with other systems for later analysis to assist in defining maintenance schedules and planning track works.

Different standards are used by the market, some standards are used for maintenance (based on EN 13848, EN 12299 or other complementary national standards) and other used also for characterisation for sections involved in the rolling stock homologation process (based in EN 143563 or UIC 518).

In summary, onboard rail track monitoring systems provide essential information. By detecting potential issues early, these systems help prevent safety hazards, optimise maintenance schedules, and improve the overall efficiency of the rail network. As the number of these track condition monitoring systems continues to grow, the need for efficient track condition data exchange is becoming increasingly important.

4.4 Methodology of collecting the user needs

With the aim of understanding the needs of the IMs regarding on-board track diagnostic data, a study was carried out. The study consisted of a series of questions conforming a questionnaire that was forwarded to many European IMs. The same questions were also posed to different IMs in the form of online face-to-face interviews depending on availability.

The main objective of this study is to investigate the data-driven methods used by different infrastructure managers in Europe to monitor the condition of railway infrastructure, including how data is stored, processed, and formatted. The study will help to understand the benefits that a Europe-wide harmonisation of railroad infrastructure diagnostic data would offer to infrastructure managers.

4.4.1 Questions and Data Exchange Impact

The questions were sent together with a "sample answer" to help understand the question and the type of information sought, but in all cases, the interviewee was informed that their answer is completely free and does not have to match the example in any way.

The topics addressed by the questions of the study are the following:

- Documents and standards used.
- Data quality, frequency, and formats.
- Application of mobile systems.
- Data usage and key stakeholders.
- The impact of harmonised data on organisational practices.
- The value proposition of harmonised data.

The questions sent to the IMs, and the sample answers they received as example can be found in Appendix 1.

In the table in Appendix 1 can also be found a justification as to why the response is valuable to assess the data exchange impact, however this justification was not sent to the interviewee.

4.4.2 Sample

The sample consisted of representatives from 16 major European infrastructure managers. The selection of these operators focused on organisations that play an important role in the European rail network. The contact persons in these organisations were identified based on their expertise and responsibilities related to infrastructure monitoring and data management.

4.4.3 Further considerations

All participants were informed about the purpose of the study, the nature of their participation and the use of the data collected. Before participation, it was ensured that all responses were voluntary and confidential. The data is presented anonymously in the study analysis, thus protecting the identity of the participants and their respective organisations.

It must be noted that the consulted IMs come from very large companies, and even though the contacted people have in all cases functions, related with the management of track maintenance data within their respective organisations, they are still one example and may not perfectly reflect the vision of the whole company.

The tendency towards more detailed answers in face-to-face interviews as opposed to the online questionnaire seems to reflect a difference in data depth rather than a difference in perspective. Therefore, the study provides valuable insights into the harmonisation of on-board trackside monitoring data between European infrastructure managers.

4.5 Study results

4.5.1 Analysis

A detailed analysis of the responses received from the survey is provided in Appendix 2, however, the following is a summary of the main findings and observations.

- **Data Format and Integration**: There is considerable variation in data formats across European infrastructure managers. This necessitates complex and error-prone data conversion processes. Harmonisation would streamline data chains, making it easier to compile and analyse data from multiple systems, improving efficiency and reliability.
- **Perceived Benefits of Harmonisation**: Managers using advanced diagnostic systems see clear advantages in harmonisation, including improved data quality and simplified management. A unified approach could reduce the complexity of managing multiple systems and enhance data reliability.
- **Technological Disparities**: Some infrastructure managers have implemented sophisticated diagnostic systems, such as commercial trains equipped with advanced algorithms, while others rely on basic monitoring tools. These discrepancies in technological development create challenges for standardisation.
- **National Standards and Practices**: European infrastructure managers use a range of standards, with EN 13848 being the most common for track geometry measurements. However, additional standards and non-standardised methods are often employed, complicating cross-border data integration. Differences in measurement practices, including the adoption of dynamic measurements, further hinder harmonisation.
- **Data Quality and Format Inconsistencies**: Data is collected in various formats, including proprietary ones, leading to integration challenges. A lack of standardised data formats makes sharing and analysis difficult, and manual processes often slow down metadata updates.
- **Track Localisation Data**: The number of formats in use for the meta data is the same in terms of track condition data formats. Most IMs are using custom algorithms to localise.
- **Stakeholder Involvement**: Infrastructure condition data is used by a range of stakeholders, including internal organisational units, external providers, and data analysis contractors. The lack of harmonisation increases costs and workload for managing different data interfaces and systems.
- **Operational and Financial Constraints**: Smaller organisations face difficulties in adopting new technologies due to high costs, and they prioritise operational tasks over harmonisation efforts. Larger organisations are more likely to adopt advanced systems and collaborate on standardisation initiatives.
- **Impact of Lack of Harmonisation**: Infrastructure managers report various negative effects, including discarded valuable data, resource consumption for data conversion, project delays, and reduced data

quality. These impacts underscore the importance of harmonisation for improving data reliability and operational efficiency.

- **Time to Deliver Diagnostic Data**: There is a wide variation in the time required to deliver diagnostic data. While some infrastructure managers can deliver data within 48 hours for urgent needs, most report standard delivery times of up to a week.

4.5.2 Conclusions

As conclusion, the harmonisation of infrastructure diagnostic data could significantly enhance the efficiency and quality of European railroad infrastructure management. Standardised data would streamline processes, simplify system integration, and improve decision-making. However, achieving this goal requires overcoming challenges related to national standards, technological disparities, data quality, and coordination among stakeholders. While the path to harmonisation is complex, the potential benefits make it a worthwhile endeavour for infrastructure managers across Europe.

4.5.3 Challenges of track diagnostic data harmonisation

Despite its benefits, harmonizing infrastructure diagnostics data poses several challenges.

The diversity of national standards and regulations complicates the creation of a uniform framework, with differences in track parameters, measurement methods, and maintenance threshold values adding to the complexity.

Variations in implementation practices and the development status of monitoring systems further hinder harmonisation efforts, as some managers use advanced technologies while others rely on basic parameters.

Inconsistencies in data formats, ranging from proprietary formats to CSV and TXT, make integration and analysis challenging, increasing the workload and risk of errors.

Operational and financial constraints also pose significant barriers, especially for smaller organisations struggling with the high costs of implementing and maintaining modern systems.

Ensuring consistent and reliable data quality across different systems and providers is difficult due to variations in calibration, data processing algorithms, and reporting standards.

Finally, extensive coordination among diverse stakeholders with differing interests, priorities, and technical capabilities is required for successful harmonisation, making alignment towards a common goal complex and time-consuming.

4.5.4 Track localisation data.

Track condition monitoring via onboard measuring systems on trains and vehicles involves accurately associating measurement points to their precise locations where the measurement takes place on the track. This process, known as localisation or positioning, ensures the reliability and accuracy of the collected data, which is essential for any subsequent usage of the collected data.

The questionnaire confirmed that as part of the metadata also localisation require proper harmonisation considering that overall, the number of formats in use for the meta data is the same in terms of track condition data formats. Most of the railways confirmed they are using custom algorithms to localise.

4.6 Cost Benefit Analysis Structure for UC 2

4.6.1 Introduction to the Cost Benefit Analysis

Based on the questionnaire responses, the key impact of a track condition data interfaces has been explored and this has led to the creation of a cost-benefit analysis structure.

Below a CBA template is proposed outlining both the costs and benefits of a proposed HERD initiative for UC2. The figures are provided at both infrastructure manager level and industry level. Because specific benefits estimate might vary from company to company here just a minimum viable cost has been considered. If the CBA is considered positive with only a minimum set of benefits, it would be considered even more beneficial if other cost drivers are included.

4.6.2 Benefits

The overall benefits are described below.

Benefit	Description	Included in CBA
Share common practices to evolve in the industry.	Harmonising track condition data exchange allows industry players to adopt and share standardised practices, leading to overall industry improvement and collaboration.	
Less costly data correlation/fusion from different sources	By standardising track condition data formats and structures, the cost and effort required to correlate and integrate data from different sources are significantly reduced.	
Drastically reduce barriers to access and manage data	Harmonisation simplifies data access and management, making it easier for stakeholders to retrieve and use the data without facing technical or structural barriers.	
Less complex data specification	With standardised data specifications, there is less complexity in understanding and implementing data exchange, simplifying processes for all involved parties.	
Less cost for management and update of different data interfaces	Standardised data exchange reduces the need for custom interfaces and the associated costs of maintaining and updating them.	x
Valuable resources that can be used for other tasks.	By reducing the time and effort spent on data integration and management, resources can be reallocated to more strategic or valuable tasks.	
Extra time within projects to get access and use the data	Harmonised data exchange speeds up data access within projects, providing more time for analysis and decision-making rather than dealing with data processing issues.	
Increase data quality	Standardisation helps in ensuring consistent data quality, as harmonised data exchange enforces common standards and practices across the board.	

Table 19: CBA structure.

In the current CBA analysis only the cost for "**management and update of different data interfaces**" has been considered.

4.6.3 CBA structure template for Track Condition Data Interface

Below the key parameters considered:

CBA Configuration Parameters	**Value**	**Unit of Measure**
Market Size		
Number of suppliers that design and develop the interface for the IM (5 systems and 2 software vendors)	7	n.
Number of railways in Europe that can adopt the standard	26	n.
Data Interfaces and Systems		
Number of custom data interfaces per railway (one kind of data type)	3	n.
Project Management Cost for Harmonisation	5000	Euro
Data Interface Implementation Cost		
Effort to harmonise per railway	3	personal months
Effort to harmonise by the supplier	6	personal months
Coordination effort by EU or ERA to harmonise	60	Personal months
Design & Development (custom/standard new data interface)	25K	Euro
Annual maintenance calculated on the development costs of a new data interface	7	%
Annual support calculated on the development costs of a new data interface	10	%
Life span of a system using the data interface (e.g. track condition system, a data analytics software tool, etc.)	15	Years

Table 20: CBA structure parameters.

By calculating the overall cost at company and industry level, a saving can be achieved as illustrated in the following table:

	Value in Euro	Unit of Measure	Custom Single Railway	Harmonised Single Railway	Custom Industry (Railways and Suppliers)	Harmonised (Railways and Suppliers)
			The cost for a single railway implmenting the number of custom data interfaces.	There should be no cost for the railway with the exception of the contribution required to harmonise the data interface. Key question: do you pay to convert Word in PDF or viceversa?	Total cost of ownership if all the railways implement the same number of the custom data interface	Total cost of ownership if all the suppliers implement a common standard data interfaces (only once for the entire European Railway Industry).
Market Size						
Number of suppliers that design and develop the interface for the IM (5 systems and 2 software vendors)	7	n.				
Number of railways in Europe that can adopt the standard	26	n.				
Data Interfaces and Systems						
Number of custom data interfaces per railway (one kind of data type)	3	n.				
PM Cost for Harmonisation	5 000	Euro				
Data Interface Implementation Cost						
Effort to harmonise per railway	*3*	*PM*		€ 15 000		€ 390 000
Effort to harmonise by the supplier	*6*	*PM*				€ 210 000
Coordination effort by EU or ERA to harmonse	*60*	*PM*				€ 300 000
Design & Development (custom/standard new data interface)	25 000	Euro	€ 75 000		€ 1 950 000	€ 175 000
Annual maitenance calculated on the development costs of a new data interface	7	%	€ 78 750		€ 2 047 500	€ 183 750
Annual support calculated on the development costs of a new data interface	10	%	€ 112 500		€ 2 925 000	€ 262 500
Life span of a system using the data interface (e.g. track condition system, a data analytics software tool, etc.)	15	Years				
			€ 266 250	**€ 15 000**	**€ 6 922 500**	**€ 1 521 250**
Harmonisation Saving				**€ 251 250**		**€ 5 401 250**

Table 21: Harmonisation savings.

Considering the fact a pessimistic approach has been considered in this CBA, there is an evident benefit in moving toward a harmonised data format.

We emphasise that the example above is just one selection of a large set of applications. We should proceed with the analysis in the next project period.

4.6.4 Assumptions and exclusions

Below the assumptions made in the CBA

- As for UC1, CBA will look differently for every stakeholder, because roles, processes and commercial environments aren't the same. The CBA lists some key factors that might produce cost, either as one-off (initial costs) or recurrent costs (e.g. yearly costs). Factors itself must be identified case by case.
- A life cycle for a system of 15 years has been considered, for simplicity the costs have not been actualised.
- The adoption of CCS/TMS could be considered as part of the Cost Benefit Analysis but it has been decided by the HERD UC2 team that because this data model should be adopted by the railway industry for other reasons rather for track condition data harmonisation and existing RCM-DX file format covers already the meta data, in this phase the CCS/TMS is not considered.
- A set of 26 railways have been considered for the adoption, they are reported in the table below.
- At least two different data interfaces are used by a railway, one for each supplier (so it is assumed that at least 2 suppliers are operating for each railway)
- The harmonised format could be adopted also to load the data in a third-party application which might require a data transformation. (so, it is assumed that at least at the customer one additional supplier is operating and another custom data interface).
- Other benefits and cost that might vary depending on the project's specific requirements and complexity of the data interface have not been considered.

- It is assumed that the cost of integration of the new data format in existing visualising and processing tool is included in the data exchange cost.
- Any system vendor can use both existing format (e.g. custom) and new harmonised format, so no extra cost to make the new format readable by old application might be considered if this new format is applied only to new systems being commissioned.

Below the railways in Europe that can adopt the standard considered in the CBA.

	Country	**Railway Infrastructure Manager**
1	Austria	ÖBB-Infrastruktur AG
2	Belgium	Infrabel
3	Bulgaria	National Company Bulgarian Railway Infrastructure (NRZI)
4	Croatia	Hrvatske željeznice Infrastruktura d.o.o. (HŽ Infra)
5	Czech Republic	Správa železniční dopravní cesty (SŽDC)
6	Denmark	Banedanmark
7	Estonia	AS Estonian Railways (Eesti Raudtee)
8	Finland	Finnish Transport Infrastructure Agency (Väylävirasto)
9	France	SNCF Réseau
10	Germany	DB Netz AG
11	Greece	Hellenic Railways Organisation (E.O.Σ.)
12	Hungary	Magyar Közúti Közlekedési Holding Zrt. (MK)
13	Ireland	Irish Rail (Iarnród Éireann)
14	Italy	Rete Ferroviaria Italiana (RFI)
15	Latvia	Latvijas valsts dzelzceļš (LDz)
16	Lithuania	Lietuvos geležinkeliai (LTG)
17	Luxembourg	Administration des chemins de fer (ACF)
18	Netherlands	ProRail
19	Norway	Jernbaneverket
20	Poland	PKP Polskie Linie Kolejowe S.A. (PLK)
21	Portugal	Infraestruturas de Portugal (IP)

	Country	Railway Infrastructure Manager
22	Romania	CFR Infrastructură SA
23	Switzerland	SBB (Schweizerische Bundesbahnen AG)
24	Slovakia	Železničná spoločnosť Slovensko, a.s. (ZSSK)
25	Slovenia	Slovenske železnice d.d. (SŽ)
26	Spain	Administrador de Infraestructuras Ferroviarias (ADIF)
27	Sweden	Trafikverket

Table 22: Candidates to adopt the HDDI.

4.7 Risks and Opportunities

4.7.1 RCM-DX

The main opportunity identified is that SBB, Switzerland's infrastructure manager, has developed an open-source format named RCM-DX (Rail Condition Monitoring Data Exchange format) to exchange track diagnostic data. It is based on HDF5, a data format that structures information in trees.

This format could be used as is or as a baseline to develop a subsequent format that covers all the identified needs.

SBB has developed the specifications for this format as well as a viewer to present all the data graphically.

There are two main reasons why this format seems so interesting as a base for the harmonisation of the track condition data. The format is open source, meaning that there are no proprietary solutions belonging to one specific company. The other reason is that the SBB is willing to share and does so publicly in their webpage, all the resources regarding the RCM-DX, including the specifications to the format as well as their viewer. (https://bahninfrastruktur.sbb.ch/en/products-and-services/bahninformatiksysteme/anlagenmanagement/rail-condition-monitoring.html).

The risk of using RCM-DX as a possible baseline is that it may be specific to SBB's requirements and not generic enough to cover other circumstances.

4.7.2 CCS/TMS

Because the CCS/TMS data model has the potential to include all the meta data required for track diagnostics, it could be re-used without considering any specific design and development effort also for diagnostic application. It must also be considered that:

- CCS/TMS is being aligned with the ERA vocabulary and it is expected to be a STIP (Specific Technical Implementation Plan) input for the next TSIs.
- The CCS/TMS model has a wide range of users and covers several use cases identified in MOTIONAL WP26 for ERJU

- The final users adopting the CCS/TMS model can benefit from focusing only once on the input and output to their software avoiding worrying about intermediate data models to support data transformations refereeing to custom models.
- Different stakeholders are already piloting the implementation of a version of the model at National level.
- Future CCS products are using the model to build the new CCS products generation.

The risk of proposing CCS/TMS for localisation is that currently, only a few railways do have access to the model and are using this system and therefore it could be not applicable in all European countries and/or necessitate adaptation from those who are not updated in this regard. However, based on the last information collected from System Pillar, by the end of 2024, CCS/TMS the data model is going to be published on the Internet, so at least the data model will be made available to all the railways.

4.7.3 Current circumstances of each infrastructure manager

After consulting many of the European infrastructure manager it is showed that harmonisation could prove beneficial for almost all of them, however, their current methods for gathering and sharing diagnostic data are very varied and could lead to some challenges.

Also, the level of priority placed on harmonisation is heterogeneous, with some countries going to great extents to provide harmonised solutions they are willing to share freely and some sparing only the strictly necessary resources to maintain their infrastructure with little room for new developments or adaptations.

4.8 Next steps and recommendations

Summarising what has been presented throughout the document, we can conclude that the harmonisation of the track condition data will bring benefits to the stakeholders in the railway sector. The different IMs that were consulted have different perspectives with respect to harmonisation but in general there is a predisposition to collaborate in some capacity and it is evident that there are problems that IMs are dealing with presently that would be solved thanks to this harmonisation. It is also shown that the endeavour is interesting from a cost-benefit perspective point of view. And finally, to evolve in the entire sector, and transition into more efficient planning of the maintenance activities, this harmonisation is a step in the right direction.

Considering the value of this harmonisation, we must explore the next steps to be followed to achieve HERD's goal.

In the following paragraphs the possible avenues of research that have been identified so far are outlined. In addition to exploring the points described below, we must ensure that no other possibilities are overlooked. Therefore, in addition to those points we must conduct a thorough review of any other options that can be viable starting points for the work that is to be done.

4.8.1 RCM-DX

Due to the lack of common formats for representing track diagnostic data the HERD project has come to the preliminary conclusion that RCD-DX is the most suitable baseline for a harmonised track diagnostic data format considering its maturity and open-source availability.

A next step of the HERD project is a detailed evaluation of RCM-DX format, including how to best take advantage of the work that has already been done by SBB as well as evaluate any potential issues it might bring if globally used across Europe and how these might be solved. This task alone will require more resources than what the HERD project has had so far, requiring subject matter experts with the necessary experience and time allocation to complete it satisfactorily.

4.8.2 CCS/TMS

CCS/TMS shall be explored as a reference for localisation data.

4.8.3 Workshop and Interviews

The HERD team has contacted as many infrastructure managers as possible to gather their experience and needs.

In future phases it would be appropriate to:

- Try to establish contact with more infrastructure managers and other type of stakeholders e.g. railway undertakings providing track monitoring, system suppliers, etc.
- Deliver the survey results to the infrastructure managers that responded to the interviews in the form of an online workshop or other means.
- Continue to consult and inform all stakeholders of the progress and results.

4.8.4 Other initiatives in Europe

Some EU initiatives in the railway industry that could be considered synergic to the attempt to harmonise track condition data and should be explored in further phases include:

- Registers of Infrastructure (RINF)
- Federated Data Space
- Data Act
- IRS50405

5 Roles and responsibilities of the stakeholders

This chapter describes the roles and responsibilities of the main HERD stakeholders. It outlines their interaction on the Harmonised Diagnostic Data Interface.

The success of harmonisation of the railway diagnostic data directly depends on the quality of cooperation between the stakeholders. Even if the very best and optimised architecture is in place, the utilisation of the opportunities and the gain of the benefits need the collaboration between the main players in Europe.

The structure of the stakeholder analysis is described in Table 23.

Field Name	**Description**
Provider / Consumer	Providers supply harmonised data; consumers receive and use harmonised data. It must be considered that a stakeholder might act in these two roles at same time.
Level of Support	Estimation if the stakeholder will hesitate to supply data or tries to support data exchange.
Reason for Resistance or Support	Description of motivation of the stakeholder.
Role and responsibility	List of roles and responsibility in terms of HERD.

Table 23: Description of fields.

5.1 Matrix of Roles and Responsibilities

Fehler! Verweisquelle konnte nicht gefunden werden. gives a general overview of roles and responsibilities defined in the use cases using the RACI (Responsible, Accountable, Consulted, Informed) standard.

R: Responsible A: Accountable C: Consulted I: Informed	**Roles**	System Supplier of Detection System	Service Provider for Diagnostic System	Approver & Notified Body	Infrastructure Manager	Data Supplier / Hosting / IT Infrastructure	Railway Undertaking	Vehicle Keeper	Entity in charge of maintenance	HERD
Responsibilties										
Development of HDDI (Harmonised Diagnostic Data Interface)		A			R					
Approval of HDDI		A								R
Obtaining of Type Approval for Diagnostic System		A		C	R					
Delivery of Data / Cleansing of Data			A		R					
Data Use					A		R	R	R	
Provision of Sharing platform / Data Brokerage										
Specification of the HDDI		C	C	I	C	C	C	C	C	R
Evaluation of the Use Cases for Diagnostic Data harmonisation										R

Table 24: RACI overview.

5.1.1 System Supplier of detection system

The system supplier is responsible for implementing the HDDI (Harmonised Diagnostic Data Interface). This includes:

- initial implementation,
- maintenance of the system in case of updates/changes in the specification of HDDI,
- testing and validation and
- type approval if based on local regulations.

Implementing the HDDI interface inherits additional efforts for the system supplier. It is up to the system supplier to receive compensation for these efforts. Implementing the HDDI interface can be seen as an investment into the product itself to broaden the range of possible customers.

5.1.2 Service provider of diagnostic system

The service provider is responsible for the availability of the data. Once a diagnostic system has been installed, it must be kept in good condition to supply data according on its specification. This includes regular checks, cleaning, calibration, and updates/upgrades based on the documentation of the systems supplier and the owner.

5.1.3 Approver and Notified Body

Based on local regulations, diagnostic and monitoring systems need a type of approval from an approver or notified body. In most cases changes in the functionality of the diagnostic and monitoring system trigger an approval process. Approvers and notified bodies should be integrated in the implementation phase of HDDI at an early stage.

5.1.4 Infrastructure Manager

In most cases the infrastructure manager owns the diagnostic and monitoring system. IM is responsible for the complete life cycle and takes care of proper installation, commissioning, maintenance and deinstallation. IM uses the data for its own purposes, like protection its own assets, but makes data available to other stakeholders using the HDDI interface. IM is responsible that HDDI data is

- available in time,
- with defined quality and availability.

In most cases IM starts the development of the HDDI interface for its diagnostic and monitoring systems.

5.1.5 Data Supplier / Hosting / IT Infrastructure

This is a set of stakeholders that take care of the transfer and storage of the HDDI data.

5.1.6 Railway Undertaking / Vehicle Keeper / Entity in charge of maintenance

RU, VK und ECM are the users of HDDI data (data users). Data users receive data to generate actionable insights to improve their processes. This should allow data users to profit from the benefits laid out in chapter 3.2 Expected benefits through wheel condition monitoring.

5.2 Stakeholder Analysis

5.2.1 Introduction

A stakeholder analysis is a tool to identify, assess and understand groups and organisations that might be affected by changes, in this case the implementation and usage of HDDI. A stakeholder analysis is performed in different steps:

- Identify stakeholders: Find out individuals or groups who have an interest in HDDI.
- Understand stakeholders and their interest: What are the expectations of a stakeholder? What is their role in a project? Do they see an advantage using HDDI? Is there any hesitation or resistance that might be foreseen? What could be the reasons for this behaviour?

Based on this basic analysis individual steps should be performed including:

- Develop engagement strategies: How can a stakeholder be onboarded? How to take care of expectations and concerns? How to communicate?
- Mitigate risks: By understanding stakeholders' concerns from an early stage, potential challenges can be mitigated and strategies to mitigate risks can be devised.

In short, the purpose of stakeholder analysis is to ensure that all parties who can influence or are affected by HDDI are properly engaged, aligned, and managed throughout the project lifecycle, maximizing the chances of success.

The participants mentioned below are stakeholders regarding the possible actual use cases. For future it is necessary to check for every single use case the stakeholders and interests new.

The sections below list major stakeholders that might be affected by HDDI, this list is non-exhaustive.

5.2.2 System Supplier of Detection System

Provider/Consumer:

Provider

Level of Support:

Resister

Reason for Resistance or Support:

"Never touch a running system".
System is End-of-Life (EOL) and no longer supported.
Type approval needed.
Product might lose conservation of status quo.
Risk of exchangeability of detection system due to harmonised protocol.
Additional costs.

Roles and Responsibilities:

Performs development of the system, esp. Implementation of Harmonised Protocol.

5.2.3 Service Provider for Diagnostic System

Provider/Consumer:

Provider

Level of Support:

Resister

Reason for Resistance or Support:

Additional data layer / data connections must be established.
Increased transparency regarding accuracy and maintenance status of diagnostic systems might be perceived as problematic.

Roles and Responsibilities:

Responsible for availability of the systems. Ensures correct measurements and supply of data.
Guaranties the data quality.

5.2.4 Approver & Notified Body

Provider/Consumer:

-

Level of Support:

-

Reason for Resistance or Support:

Neutral

Roles and Responsibilities:

If type approvals are affected, approvers and notified bodies must be consulted.

5.2.5 Infrastructure Manager (IM)

Provider/Consumer:

Consumer

Level of Support:

Supporter

Reason for Resistance or Support:

Benefits from higher utilisation of track.
Benefits from lower rescheduling due to unplanned actions.
Less wear on infrastructure due to better maintained fleet.

Roles and Responsibilities:

Owner of the track. Keeps the track in best possible quality/availability/cost.

5.2.6 Infrastructure Manager (IM)

Provider/Consumer:

Provider

Level of Support:

Resister/Supporter

Reason for Resistance or Support:

Provides data from On-track Detection Systems: Additional higher costs and unproved return on investment.
Interested in selling Data to VK/RU/ECM.

Roles and Responsibilities:

Owns the Diagnostic and Monitoring systems that supply data for RU/VK/ECM.

Delivers the diagnostic data in the contractual quality.

5.2.7 Vehicle Keeper (VK)

Provider/Consumer:

Consumer

Level of Support:

Supporter

Reason for Resistance or Support:

Consumes data from Wayside Detection Systems: Interested in measurements to optimise workshop processes.
Fears competition/ comparison / transparency with other VK reg. quality of fleet.
Increase lifespan of assets.

Roles and Responsibilities:

Owner of the vehicle. Keeps the fleet in best possible quality/availability/cost.

5.2.8 Vehicle Keeper (VK)

Provider/Consumer:

Provider

Level of Support:

Resister/Supporter

Reason for Resistance or Support:

Provides data from Onboard Detection Systems: Interested in selling Data to IM.
Fears competition and comparison with other VK reg. accuracy of measurement.
Additional higher costs and unproved return on investment.

Roles and Responsibilities:

Owns the Diagnostic and Monitoring systems that supply data for IM.
Delivers the diagnostic data in the contractual quality.

5.2.9 Data Provider / Hosting / IT Infrastructure

Provider/Consumer:

Provider

Level of Support:

Resister

Reason for Resistance or Support:

Fears changes in infrastructure, interfaces, security problems.
Never touch a running system.
Profits from supplying data / brokering.

Roles and Responsibilities:

Are responsible for the data connections between the producer and the consumer of the data.

5.2.10 Railway Undertaking (RU)

Provider/Consumer:

Consumer

Level of Support:

Supporter

Reason for Resistance or Support:

Increases availability of fleet due to reduced number of unplanned incidents and switch to condition-based maintenance.
Gets overview of quality of leased wagons.

Roles and Responsibilities:

Generates requirements, aligns between IM and VK, ECM.

5.2.11 Entity in charge of maintenance (ECM)

Provider/Consumer:

Consumer

Level of Support:

Supporter

Reason for Resistance or Support:

Develops Rollingstock Diagnostics, condition-based maintenance, predictive maintenance.
Improved planning of resources in workshop.

Roles and Responsibilities:

Analysis of the raw data, generating diagnostic information, update of the technical instructions based on the new information, guidelines for maintenance improvement.

5.2.12 Harmonised European Railway Diagnostics

Provider/Consumer:

-

Level of Support:

Supporter

Reason for Resistance or Support:

-

Roles and Responsibilities:

Responsible for the evaluation of the Use Cases for Diagnostic Data harmonisation.
Responsible for the implementation of the harmonisation process.
Specifies the Harmonised Diagnostic Data Interface (HDDI).

6 Summary, recommendations, and next steps

The specific project HERD has started in the second phase with two major activities: to define the purpose of HERD and to describe the objectives and deliverables for the second phase of the current contract. In the 2-days workshop in April 2024 we have reviewed the outcome of the first phase and have agreed on the purpose, objectives, and the second phase milestones.

The purpose of HERD is to develop an architecture for harmonising the European railway diagnostic data that principally consists of flexible combination of a mix of trackside sensor and onboard systems. It aims to regularly review the new techniques which automatically and autonomously can acquire the diagnostic data and to integrate them. Furthermore, HERD intends to generate operational, use case dependant concepts for harmonised diagnostic data of the railway assets – both rolling stock and track – and their interfaces beyond the current specifications, with much greater standardisation than at present.

HERD focusses on achieving the overall target to develop Use Case specific operational models and requirements for the Harmonised Diagnostic Data Interfaces (HDDI).

Some topics are not part of the purpose of HERD like the specification and standardisation of the measuring methods, the definition of the diagnostic systems or the analysis calculations as well as the diagnostic data governance, Intellectual Property Rights (IPR), and the cost-benefit-calculation.

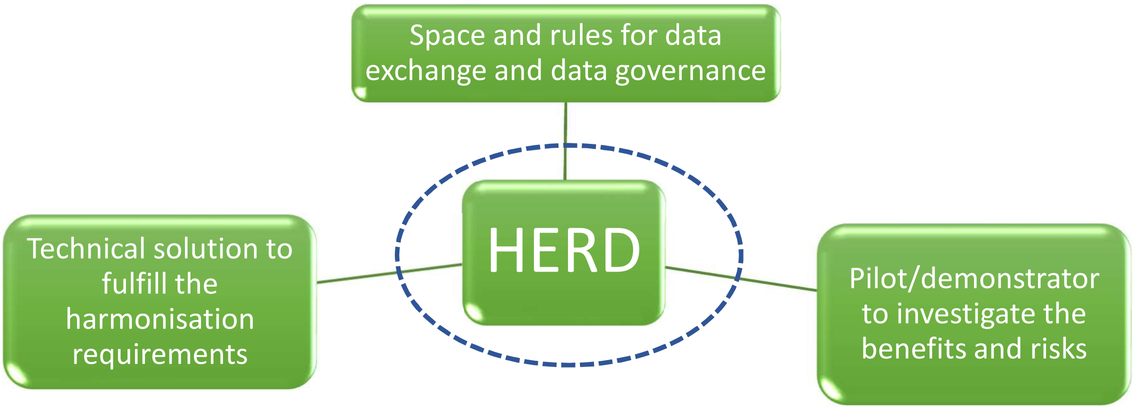


Figure 12: Links between HERD and other external activities.

We have concentrated our work on two use cases selected from the outcome in Phase 1:

- Use Case 1: Track Side Vehicle Monitoring for Maintenance
- Use Case 2: On-Board Track Monitoring

The outcome of the work on both UC includes:

- Expected benefits.
- Description of the gap between the needs and the actual status
- Analysis of the specific HDDI (Harmonised Diagnostic Data Interface) parameters
- Cost benefit analysis structure
- Risks and opportunities
- Next steps and recommendations

We have also developed a new, standard process to evaluate new use cases for harmonisation of the railway diagnostic data to be accepted for further investigations.

Furthermore, we have identified the strong need to investigate and evaluate other relevant projects in the SP respectively IP and to intensify the collaboration with them. We have also reviewed the relevant stakeholder and their role in respect to HERD to ensure best possible effectiveness.

We have realised, that currently, there is no mechanism in the ERJU which coordinates the activities related to the harmonisation of the diagnostic data exchange and ensures the sharing of the respective outcome, lessons learned, and best practice.

The objective of **Use Case 1: Track Side Vehicle Monitoring (WTMS) (UC1)** is the harmonisation of the monitoring data needed for the diagnostic of the vehicle wheels condition using WTMS (Wayside Train Monitoring Systems).

Utilising WTMS for wheel condition monitoring represents a crucial step towards safer and more efficient railway operations. Implementing a HDDI will pave the way for a closer collaboration between IM, RU, and VK. The risks can be detected and addressed early, ultimately contributing to a more reliable and safer railway infrastructure. Further damage on the assets and on the infrastructure can be avoided thanks to early detection.

The work in UC1 has shown that harmonising the diagnostic data provided by WTMS can generate many direct and indirect benefits for both data user and data provider. The impact of HDDI was separately evaluated for the different data users RU, VK, ECM and IM and the outcome describes exemplarily the positive effect on increased safety, improved maintenance, reduced operating costs, shorter off-service times, higher availability and reliability, reduction of secondary damage, better planning and optimisation, data-driven decisions, compliance with regulatory requirements, increased customer satisfaction, environmental improvement, etc.

We have evaluated two anonymised real applications which determine following benefits:

1) In cross-border freight transport downtimes can be reduced by 77% thanks to digital vehicle control based on WTMS. This is thanks to the known condition of the vehicle and the automated control system.

2) With the development of the digital vehicle inspection, based on the WTMS condition information, the manual inspection effort of a wagon inspector for each individual technical train inspection is reduced by 58%.

The analysis of the gap between the diagnostic data user and capabilities of the actual data providing systems has shown that most installed systems deliver data that fulfil the expectations of the data users. Provided wheel-condition information allows data users to understand the condition of wheels, bogies, and wagons with the required accuracy, reliability, and frequency. To make measurements comparable and useable, additional metadata like current accuracy or confidence level should be supplied. The harmonised WTMS collected diagnostic data can and will not replace the ECM workshop generated data.

The specification of the respective HDDI for each UC is the key for successful implementation in the real environment. We have identified a set of HDDI-parameters which we will investigate in detail to generate the UC specific HDDI description. Some of the most important are the standardised data formats, predefined time for data access and response, scalability, security and privacy, smooth integration with existing systems, user-friendly design, data quality for analysis, reliability and redundancy, easy process of implementation, and modularity.

The initial cost-effectiveness analysis has endorsed the potential of direct and indirect benefits for both, data user and data provider.

For more details about the approach and the results in UC1, please refer to section 3.

The objective of **Use Case 2: On-Board Track Monitoring (UC2)** is the harmonisation of the track condition data generated by on-board sensors.

Today, despite the widespread use of track measurements based on EN 13848 and EN 14363 standards, no standard exists for the exchange and formatting of track condition data. Missing a HDDI leads to inconsistent data outputs, making data analysis more difficult. Additionally, it increases costs associated with developing and maintaining multiple custom interfaces, updating data across different systems, etc. which can cause delays and potential data quality problems.

UC2 has carried-out a target-oriented study on Harmonisation of Railroad Infrastructure Diagnostic Data in Europe with various European IMs. The purpose of that study was to investigates the data-driven methods used by European infrastructure managers to monitor the condition of railroad infrastructure. It explores the potential benefits of harmonising diagnostic data across Europe, aiming to understand how a unified approach could improve efficiency in infrastructure management.

The outcome of that study shows divers benefits which are relevant for most IM like increased safety and reliability, reduced costs for data import and resources for data management, accelerated data access, improved data comparison and analysis, enhanced data quality, facilitated interoperability, etc.

Additionally, there are some specific opportunities such as utilising best practice information, optimisation, and standardisation in tenders with a profit for both the customer (IM) and the supplier, as well as enhancing the legal compliance with a data standard which guaranties the data comparability over many years.

The need of a unified approach to data exchange is a clear outcome of the questionnaire and it states that harmonisation of the diagnostic data, setting standards at least for the data interface to avoid adopting multiple file formats. At least 50% of the responses confirmed that they are already collecting measurements from the commercial trains; others do see the benefits of adopt such practices in the future.

The harmonisation of infrastructure diagnostic data can significantly enhance the efficiency and quality of European railroad infrastructure management. Standardised data will streamline processes, simplify system integration, and improve decision-making. While the path to harmonisation is complex, the potential benefits make it a worthwhile endeavour for infrastructure managers across Europe. Extensive coordination among the stakeholders with differing interests, priorities, and technical capabilities is required for successful harmonisation, making alignment towards a common goal complex and time-consuming.

As in UC1 the target was not to calculate savings in Euro due to missing the companies' cost structures and a transparent data from the IM. Nonetheless, we have prepared an example to show potential cost savings based on selected applications and realistic assumptions. Despite the very conservative approach it shows is an evident benefit in moving toward a harmonised data format.

To learn more about the methodology and the outcome in UC 2, please refer to section 4.

The success of harmonisation of the railway diagnostic data directly depends on the quality of cooperation between the stakeholders. Even if the absolute best and optimised architecture is in place, the utilisation of the opportunities and the gain of the benefits need the collaboration between the main players in Europe.

HERD has intensively analysed the stakeholders and their roles and responsibilities. It outlines their interaction on the Harmonised Diagnostic Data Interface (HDDI) and the impact on the process.

It clearly shows that the implementation of HDDI Europe wide is not only a challenge to harmonise railway diagnostic systems but much more to overcome established habits, doubting and borders. Proceeding only with the well-instituted local, national, and/or bilateral cooperations will be not sufficient to boost the competitiveness of the European railway transport.

We have also recognised that in terms of HERD there is a need of much more collaboration between HERD and the Flagship Areas in IP, especially FA1, FA3 and FA5. There are WP like FA1/WP29 and FA3/WP7 which would be perfectly eligible to implement a demonstrator for the use cases in HERD. Unfortunately, there are too many formal obstacles which hinder an effective conducting with a reasonable effort.

Since 1st of October 2024 the Specific Project HERD will proceed as Task 5 in the System Pillar.

In the next period we have committed to develop the needed specifications for UC1-HDDI and the plan for the implementation of a UC1 demonstrator/pilot. Regarding the execution of a UC1 pilot project we need a strong support from ERJU because of the missing budget for it. We have undertaken many attempts to step in in the actual wave of IP, in FP3, but for formal reasons it seems not be possible. We are extremely willing to collaborate with IP, but we do recognise that the current boundary conditions are not favourable for starting with a pilot in IP. Therefore, a delay of at least 2 years for the implementation should be expected. As a next step we will look for a consortium to join the coming wave 2 of the IP.

We also plan to proceed working on UC2 and depending on our resources to initiate the investigations on other UC.

Our conclusion is that harmonising the Railway Diagnostic Data will improve and intensify the collaboration between IM, RU, VK and the railway industry supplier. The higher degree of utilising the data creates a win-win situation that significantly enhances effectiveness, efficiency, and safety in the railway sector and generates valuable benefits for the stakeholders.

At the end of the current project phase, we have achieved and partly over-achieved our targets. This very positive outcome is due to the superior engagement of many of the team members, the very high level of expertise and professionalism, and the structured, reliable collaboration in HERD. Both leaders sincerely thank for the excellent work!

We also thank for the valuable support and worthwhile advice we received from representatives in the SP and the mirror group.

7 Appendices

7.1 Appendix 1: UC2 questionnaire for IMs

No.	Question	Sample Answers	Why the response is valuable to assess the data exchange impact
01	What track parameters are measured by your systems:	1: Track gauge acc. to EN13848 2: Longitudinal level acc. to EN13848 3: Can't deviation acc. to EN13848 4: Tack alignment acc. to EN13848 5: Dynamic accelerations at bogie level acc. to EN 14363 6: Dynamic accelerations at passenger compartment acc. to EN 12299 7: Others	Understanding the specific parameters being measured or not helps in defining the scope of harmonisation in the short term as well as long term (if a standard is not yet in use it could represent an opportunity for the future).
02	For the same condition data type do you use more than one level of quality?	1) Dynamic measurements according to EN 14363 on commercial trains are used only for qualitative analytics 2) Track geometry according to EN13848 and Dynamic measurements according to EN 14363 with dedicated diagnostic	If the same condition data from different system has different quality level, it means that this quality level must be known when sending or receive such data in order to support consistent decision making.

No.	Question	Sample Answers	Why the response is valuable to assess the data exchange impact
		vehicle are used for quantitative analytics	
03	Are your systems mounted on commercial or dedicated diagnostic trains:	Geometric measurements: Dedicated diagnostic vehicle act to EN13848 belonging to the company. Dynamic measurements: Dedicated diagnostic vehicle belonging to the company. Third-party rolling stock (e.g. dedicated cars, wagons, rail-road vehicles, etc)	Knowing whether systems are on commercial or dedicated trains impacts on scalability of the data exchange. If only dedicate trains are used the data exchange problem is mainly national issue involving one or few railway vehicles. If commercial trains are used or expected to be used in the future, the data exchange get a higher relevance not only in number but also because a train can cross national borders.
04	Frequency of track measurements, and variations for different track types or other conditions:	Geometric measurements: Regional lines: 1 every year Main lines and commuter lines: 1 every 6 months HS lines: 1 every 3 months Dynamic measurements: >160 Km/h: 1 every 2-3 months HS lines: 1 every month	Because the data exchange occurs each time a new measurement is taken and a harmonised data interface would be used at least once after a new measurement is taken, it helps to estimate the data interface value would have. If the data exchange is not very frequent (e.g. one per year), data exchange inefficiencies could be tolerated compared to very frequent data collection (e.g. daily data exchange).
05	How many data formats are you using to exchange the track diagnostic data?	One data format for each system (in order to compare data coming from two different systems data conversion is required)	The variety of data formats used reveals the complexity of current data exchanges and underscores the importance of standardisation to facilitate seamless data integration and analysis.

No.	Question	Sample Answers	Why the response is valuable to assess the data exchange impact
		One data format for each contractor.	
06	1) How many data formats are you using to extract and load the metadata required by the localisation system (e.g. line names, station names, GPS track linear reference mapping, etc.) 2) Does it involve a manual data exchange, or it is automatic? 3) How long does it take to update the metadata? 4) What processing systems are used?	1) One data format per contractor 2) Yes, it is manual, and a part time operator is allocated on this task. 3) An update for a single route can take up to 1 week. 4) Specific custom data processing algorithms.	The variety of data formats used reveals the complexity of current data exchanges and underscores the importance of standardisation to facilitate seamless data integration and analysis.
07	What data exchange channels are used?	SharePoint/other data cloud Private internal server API Email Removable disks	The types of data exchange channels provide insights into the current communication infrastructure and the potential for improving speed, security, and reliability in data sharing.
08	What stakeholders are involved in the	1) Contractor for capturing data 2) Contractor for data conversion	Identifying stakeholders involved in data exchange highlights the complexity of coordination and collaboration required, which is

No.	Question	Sample Answers	Why the response is valuable to assess the data exchange impact
	data exchange process?	3) Contractor for data analysis software 4) Internal Organisation Unit for final analysis of the data for maintenance activities	key to successful data harmonisation and integration efforts at company and industry level.
09	How long does it take to deliver the track diagnostic data from the measurement to the final user (for derivation of measures / handover to analytic tools)	immediate intervention if needed, information is transferred once a week	When compared with the measurement frequency, the delivery time of is crucial for assessing the efficiency of the current data exchange process.
10	Does lack of harmonisation of track condition related data (e.g., parameters, metadata, etc.) exchange impact your organisation? If yes, how?	1) discard potentially useful data due to barriers to access them 2) costly data correlation/fusion from different sources, 3) high cost for management and update of different data interfaces 4) data conversion consumes valuable resources that can be used for other tasks. 5) extra time within projects to get access and use the data 6) reduced data quality due to potential data loss in the data conversion process or less opportunity to audit them	Responses allow to extract the needs and the benefit expected.
11	Would your company be willing to collaborate with	- Share examples of diagnostic data of the track measured by on board systems for the HERD	A key requirement to introduce a standard in the railway industry is broad stakeholder alignment and collaboration.

No.	Question	Sample Answers	Why the response is valuable to assess the data exchange impact
	the harmonisation process.	project (can be anonymised or mock data) - Provide mandatory and optional requirements for harmonisation such as list of primary and derived parameters/ units / accuracy required - Other	
12	Based on your past experiences in track condition monitoring and maintenance, what do you think European Rail should consider for the challenging objective to harmonise track diagnostic data? What could be your (or your organisation) future role in this challenge?		This additional feedback might offer valuable perspectives on potential challenges and solutions for harmonisation, helping to shape strategic approaches and identify key contributors in the industry.

7.2 Appendix 2: UC2 questionnaire analysis

Diverse National Standards and Regulations

In addition to the current European standards, European railway infrastructure managers have developed their own procedures for carrying out condition monitoring, considering railroad standards that reflect local practices, technologies and legal frameworks. These standards determine which track parameters are measured and which threshold values apply for maintenance measures. This diversity makes it difficult to create a uniform framework for data harmonisation.

Example:

EN 13848 vs. other standards (Question 1). Of the infrastructure managers surveyed, all 12 use EN 13848 for measuring track geometry. However, only three operators state that they use EN 14363 and another mentions EN 12299. In addition to these standards, other non-standardised methods are used to determine the condition of the infrastructure. For example, two infrastructure managers explicitly stated that they would record travel comfort or would do so in future. One infrastructure manager mentioned the assessment of pantographs as an indication of expected infrastructure wear. This indicates that EN 13848 is predominant, but that some operators use additional or other standards, which makes cross-border data integration more difficult.

Differences Implementation of Practices

As much as the basic properties and values are defined in EN standards, the methods for determining them are varied.

Example:

Dynamic measurements (Question 2). There are also significant differences in the implementation of these practices. While 3 out of 12 managers are starting to implement dynamic measurements, these projects are still in the early stages. For example, one manager mentioned that dynamic measurements are planned but not yet operational, while another already conducts detailed measurements like ride quality on commercial trains. Furthermore, the variety of measured parameters also varies, with one respondent noting the use of various specialised systems such as the Dynamic Overhead Line Measurement System (DOLMS) and Pantograph Interaction Video System (PIVS), while others rely on more basic track geometry parameters such as Track Gauge, Longitudinal Level, Cant Deviation and Track Alignment. An infrastructure operator uses information that originates from the post-processing of various raw data. Another infrastructure manager also uses fibre optic and acoustic sensors in addition to known methods and also integrates data from switches into its maintenance regime.

Variations in Technologies implemented.

The technical development status of the monitoring systems was described very differently by the infrastructure operators. Differences are particularly evident in the hardware (e.g. sensors and measurement vehicles) and software (e.g. data analysis tools and data storage systems). These differences have an impact on the detail and accuracy of the data collected.

Example:

Advanced vs. Basic Systems (Question 3). While 8 out of 12 infrastructure managers indicated that they use diagnostic trains or vehicles, only 3 mentioned that they have implemented or plan to implement advanced diagnostic systems on commercial trains. This suggests that while many rely on traditional dedicated inspection vehicles, few have introduced more comprehensive, advanced technologies.

Categories of Inspection Frequency, Speed, and Line Type

The study examined the frequency of inspections, the speed categories of the inspections and the types of routes monitored. The responses show considerable differences in relation to these factors.

Example:

Inspection frequency per line type (Question 4).

High-Speed Lines:

- Most high-speed lines are inspected frequently, with intervals ranging from daily to several times a year.
- For instance, one manager reported inspections every day for lines with speeds above 270 km/h, while another mentioned every 3 months for high-speed lines (>160 km/h).

Main Lines:

- Inspection frequencies for main lines vary significantly, typically ranging from monthly to semi-annually.
- One manager reported inspections every 2-6 times per year for main lines, depending on their category.

Regional and Secondary Lines:

- Regional and secondary lines are generally inspected less frequently, with intervals ranging from quarterly to annually.
- For example, some managers reported inspections every 4-6 months for regional lines, while others inspect secondary lines once a year.

Data Format Inconsistencies

The data collected by different systems is often in different formats, including proprietary formats, CSV, TXT or other specialised formats. This lack of standardisation makes data integration and analysis difficult, as data from different sources often needs to be converted and standardised before it can be shared.

Example:

Multiple Formats per System (Questions 5, 6). Of the respondents, 6 use more than one data format between systems and end users, and 4 use different formats from each data provider. Only 2 stated that they use a common data format for all data. This variety of formats makes for complex and potentially error-prone data conversion processes, increasing the workload and likelihood of discrepancies.

Metadata Usage and Management

The number of data formats for extracting and loading the metadata required for the localisation system varies greatly. The process of updating metadata varies between manual, semi-automatic and fully automatic methods. The variability of data formats and the mix of manual, semi-automatic and automatic processes therefore pose a major challenge for data integration and consistency. The time required to update the metadata for localisation systems also shows considerable differences.

Examples:

Number of Data Formats for Metadata (Question 6). Three respondents stated that they use one format for each localisation system, while 2 respondents stated that they use different formats for each data provider. Another 4 respondents use a common data format for all metadata, which is the optimal case.

Manual vs. Automatic Data Exchange (Question 6). Two respondents stated that updating metadata requires manual data exchange. 6 respondents stated that the process is semi-automatic. 4 respondents stated that the data exchange is fully automated.

Time Required to Update Metadata (Question 6). One respondent stated that the updates for inspection runs are very quick or immediate. Two respondents stated that updates can take a few days. For a further 2 respondents, metadata updates can take up to a week. One respondent stated that in the case of new routes, updates can take several weeks. Another respondent stated that the update process may take several months whereas all major changes are made twice per year.

Stakeholders Involved in the Use of Infrastructure Condition Data

The survey responses highlight a variety of stakeholders involved in the use of infrastructure condition data.

Examples:

Types of Stakeholders (Question 8).

Internal Organisational Units:

- Mentioned by 4 respondents where internal teams or departments within the infrastructure management organisation are primarily responsible for processing infrastructure condition data.

External providers and contractors:

- At 7 infrastructure managers measurements providers and contractors are involved in sharing and analysing infrastructure condition monitoring data.

Data Analysis Contractors:

- The service of external contractors for specialised data analysis tasks are used at 2 infrastructure managers.
- External contractors are involved at 3 respondents in using the analysed data to perform maintenance tasks.
- One respondent is using sometimes consulting firms to provide expert advice and additional analysis on the condition data.

Impact of Lack of Harmonisation on Organisations

The responses to the survey show that the lack of harmonisation in the exchange of track condition data has a significant negative impact on European rail infrastructure managers. However, the assessment of these effects is not uniform, leading to a variety of specific impacts being highlighted. Notably, one respondent mentioned that the lack of harmonisation has no impact on the organisation. Below are the individual effects reported by the other respondents.

Examples:

Types of Impacts (Question 10):

- Discarding Potentially Useful Data: Mentioned by 2 respondents, who noted that barriers to accessing non-harmonised data lead to the discarding of valuable information.
- Costly Data Correlation/Fusion from Different Sources: Reported by 5 respondents, highlighting the significant costs and resources needed to correlate and fuse data from various sources.
- High Cost for Management and Update of Different Data Interfaces: Identified by 2 respondents, who pointed out the high costs associated with managing and updating multiple data interfaces.
- Resource Consumption in Data Conversion: Noted by 6 respondents, emphasizing that converting data from various formats consumes valuable resources that could be better used elsewhere.
- Extra Time Required within Projects: Reported by 5 respondents, who indicated that additional time is needed to access and use non-harmonised data, leading to project delays.
- Reduced Data Quality: Mentioned by 3 respondents, who observed that the lack of harmonisation can lead to data quality issues, including potential data loss during conversion and fewer opportunities for thorough audits.

Exchange Channels and Types of Processing Units

The survey reveals a mix of traditional and modern exchange channels and processing units used by European railway infrastructure managers, each with its own advantages and limitations. However, in addition to today's standard procedures, the outdated variant of exchange via data carriers is still being practiced. This indicates that some measuring systems are older assets.

Examples:

Types of Exchange Channels (Questions 7, 8):

- Emails are used in 6 cases as a straightforward and widely accessible method for data exchange but may lack the security and efficiency required for large-scale data transfers.
- SharePoint is used in 4 infrastructure managers to provide a centralised platform for data sharing and collaboration.
- Usage of a private cloud and public cloud was mentioned in just one case each.
- Removable Disks was still mentioned in 5 cases.
- The use of API, which indicates the usage of automated and real-time data exchange between systems, improving efficiency and reducing the potential for human error was just indicated by one infrastructure manager.
- The mention of RCM-DX files for the secure exchange of diagnostic data stood out. However, only used in one case.

Processing unit (Question 8). Only three responses could be evaluated. However, these showed that the analysis of the data is evaluated differently. 2 infrastructure operators feed their data to specific custom data processing algorithms, whereas one respondent explicitly excluded the processing of their data in special algorithms.

Time to deliver the track geometry diagnostic data

The responses to that subject highlight the varying timelines and methods for delivering track geometry diagnostic data to final users. Overall, the answers reveal a mix of standard and accelerated delivery timelines, depending on the urgency and nature of the data, with a general trend towards quicker turnaround times for critical track geometry diagnostics. Among the respondents, 5 out of 11 reported that data is delivered within one week of collection, indicating a standard turnaround time for many organisations. However, 3 respondents noted that data can be delivered within 48 hours, reflecting a more expedited process for urgent or critical data.

Examples:

Varying timelines (Question 9). Among the respondents, 10 out of 12 reported that most data is delivered within one week of collection, indicating a standard turnaround time for many organisations. However, 3 respondents noted that data can be delivered within 48 hours, reflecting a more expedited process for urgent or critical data. In cases where immediate action is required, such as safety-related defects, 2 respondents indicated that data is made available immediately to ensure swift corrective measures. Additionally, 1 respondent mentioned that data is typically transferred within 24 hours, further emphasizing the importance of timely data communication in maintaining track safety and reliability.

Operational and Financial Constraints

The implementation and maintenance of modern monitoring systems incurs high costs. It turns out that infrastructure operators consistently weigh up these costs against other priorities, e.g. routine maintenance, and expansion of the infrastructure. Smaller organisations find it difficult to bear the financial burden of introducing new technologies or standardizing their data formats.

Examples:

Focus on Internal Priorities (Question 12). One infrastructure manager explicitly stated that harmonisation is not a priority due to limited resources that need to be focused on immediate operational tasks. This statement illustrates the challenge of aligning different organisations with different immediate needs and resource constraints towards a common goal.

Data Quality and Reliability Concerns

Ensuring consistent and reliable data quality across different systems and providers is a major challenge. Differences in the calibration of measuring devices, data processing algorithms and reporting standards can lead to variations in the accuracy and reliability of the data.

Example:

Single vs. Multiple Quality Levels (Question 2). Only 3 out of 12 infrastructure operators stated that they use a single quality level for data. Two stated that they apply different quality levels depending on the use case. One infrastructure manager stated that they had stricter requirements for strategic asset management data than for operational maintenance data; all others did not specify. One infrastructure manager reported stricter requirements for strategic asset management data than for operational maintenance data. These differences complicate efforts to standardise and compare data between different regions and systems.

Coordination and Collaboration

Harmonisation requires extensive coordination among diverse stakeholders, including infrastructure managers, national regulators, and technology providers. Each group may have different interests, priorities, and technical capabilities, making it challenging to align them towards a common goal.

Example:

Joint Standards Development (Questions 10, 11). The collaboration between two national infrastructure operators on the RCM-DX format is an example of a successful, albeit complex, coordination effort. However, this example is unique among the respondents and illustrates the rarity and difficulty of achieving such coordination across the sector. In contrast to the bilateral cooperation. The challenge is exacerbated by the characteristics of rail infrastructure and the operational requirements of individual countries.

Considerations for the challenging objective to harmonise track diagnostic data.

The responses to question 12 reveal diverse perspectives on the challenges and considerations for harmonizing track diagnostic data across European railways. Several infrastructure managers emphasised the need for standardised measurement methods, especially in complex areas such as alignment in sharp curves and track geometry parameters on unguided sections of crossings. There is also a call for common rules to manage false or missed measurement results, which would help mitigate the need for extensive post-processing.

Many respondents highlighted the importance of open-source data to facilitate third-party access and enhance collaboration. Some managers pointed out the necessity of harmonizing localisation identification methods, such as GPS coordinates and mileposts, to ensure consistent data interpretation across different systems.

There is a shared recognition of the potential benefits of harmonised diagnostics, including improved data quality and more efficient maintenance planning. However, some managers noted the complexity and cost associated with implementing harmonised systems, suggesting a need for phased approaches and collaborative efforts to share best practices and develop unified standards.

Overall, the feedback underscores a collective willingness to work towards harmonisation, despite the challenges, with an understanding that a standardised approach would ultimately lead to greater efficiency, reliability, and safety in railway operations.

7.3 Appendix 3: Sources

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