# SIA

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# Deliverable D9.4
# Guidelines for SIA implementation

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# Authors



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|---|---|
| **Author(s)** | **Union Internationale des Chemins de fer (UIC)**<br>Alain Scherrer<br>Giulia Russo<br>Bernd Rositzka<br>Christine Hassoun<br>Mercedes Gutierrez<br>Charles Rosseel |
| **Contributor(s)** | **CEIT**<br>Unai Alvarado |



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| 1.0 | 15/07/2021 | First version, for internal review by contributors |
| 2.0 | 31/08/2021 | Second version, for internal review by consortium partners |
| 3.0 | 02/09/2021 | Final version, reviewed by all partners, ready for external review (EUSPA) |

# 1 Executive Summary

The present Deliverable D9.4 “Guidelines for SIA implementation” has been developed in the framework of the Project titled “System for vehicle-infrastructure Interaction Assets health status monitoring” (Project Acronym: SIA; Grant Agreement No 776402).

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# 3 Abbreviations and acronyms

| Abbreviation / Acronyms | Description |
|---|---|
| SIA | System for vehicle-infrastructure Interaction Assets health status monitoring |
| TSI | Technical Specification for Interoperability |
| IM | Infrastructure Manager |
| RU | Railway Undertaking |
| IRS | International Railway Solution |
| RCF | Rolling Contact Fatigue |
| RAMS | Reliability, Availability, Maintainability, and Safety |
| KPI | Key Performance Indicator |
| T2G | Train to Ground |
| ECM | Entity in Charge of the Maintenance |

# 4 Introduction

These guidelines for implementation have been designed to facilitate the uptake of SIA innovations in a step-by-step process. They are composed of two main sections:

- The first part "How to make optimal return on investment from SIA innovations?" is addressed to decision-makers, and proposes the most effective ways to implement iWheelMon, iRailMon, iPantMon and iCatMon, given current maintenance policies and asset types within the organisation. The aim of this first part is to help estimate implementation costs, benefits and phasing, in order to obtain a desirable return on investment.
- The second part "How to efficiently integrate SIA innovations?" is addressed to technicians. It summarises pre-requisites, applicable standards, inventories of necessary SIA components, as well as required interfaces and background data (other than directly provided by the SIA system) that are necessary to monitor wheels, rails, contact wires and pantographs.

**Methodology**

As mentioned above, the guidelines are divided in two parts, one part dedicated to the decision-making process associated to the implementation of the SIA solutions, and one part dedicated to the optimal technical implementation of the solutions, therefore proposing a complete process guiding the uptake of the SIA solutions.

### Part 1: How to make optimal return on investment from SIA innovations?

- **Step #1: Carrying out the top-down analysis related to SIA innovations.**
  This step intends to present to the decision maker all the features and benefits of the SIA innovations. It is "top-down" in the sense that this step starts with all possibilities available for the decision maker, and is intended to cover a scope wider than the needs of the organisation willing to implement the solution, which is foreseen to be a subpart of the possibilities offered.

- **Step #2: Carrying out the bottom-up analysis related to SIA innovations.**
  This step targets to help the decision-maker gathering and formalise the needs of the organisation with regards to maintenance of rail, wheel, catenary and pantograph. It is "bottom-up" in the sense that the source of information is directly emerging from the actual configuration of the organisation.

- **Step #3: Identifying the implementation targets through the convergence of the top-down and bottom-up analyses.**
  This step intends to match needs (step #2, bottom-up) and the possibilities offered by the SIA innovations (step #1, top-down).

- **Step #4: Estimating the investment needs to reach the implementation targets.**
  This step is adding a layer of selection criteria of innovations being suitable for implementation by the organisation, by guiding the decision maker in the costs benefits analysis.

- **Step #5: Phasing the high-level action plan.**
  This step is providing support of the macroscopic organisation set up giving the suitable framework to ensure that the technical implementation described in part 2 can be done in relevant conditions within the organisation.

### Part 2: How to efficiently integrate SIA innovations?

- **Step #6: Mapping pre-requisites.**
  This step is targeting to guide the end user in defining the technical conditions of the implementation environment to ensure that the boundary conditions are clarified and formalised, providing a robust base for the implementation.

- **Step #7: Mapping applicable standards.**
  This step is helping to make the inventory of all applicable standards involved in the implementation of the SIA solutions to ensure a smooth and aligned integration of the innovations toward standards applicable within the organisation (internal rules and processes) as well as external standards applicable at national and European level, either obligatory (regulations, etc.) or voluntary (International Railway Solutions, best practices, etc.).

- **Step #8: Making the inventory of necessary SIA technical components and required interfaces.**
  This step is going further in the technical implementation by guiding the end user in making the detailed inventory of SIA technical components that will be necessary, as well as the inventory of the detailed interfaces (mechanical, electrical, etc.) needed for the integration of the solution in the organisation assets.

- **Step #9: Mapping background data necessary to monitor wheels, rails, contact wires and pantographs.**
  This step has the function of setting a Data Management Plan for the SIA innovation implementation. This will help the end user identifying all detailed formats of data (as well as related levels of confidentiality) involved in the measurement and analysis of data to ensure consistency and robustness in the data formats.

- **Step #10: Integrating iWheelMon, iRailMon, iPantMon and iCatMon at technical and organisational levels.**
  This step is a project management guiding phase to help the end user establish check lists and timely actions in the concrete implementation within the organisation assets.

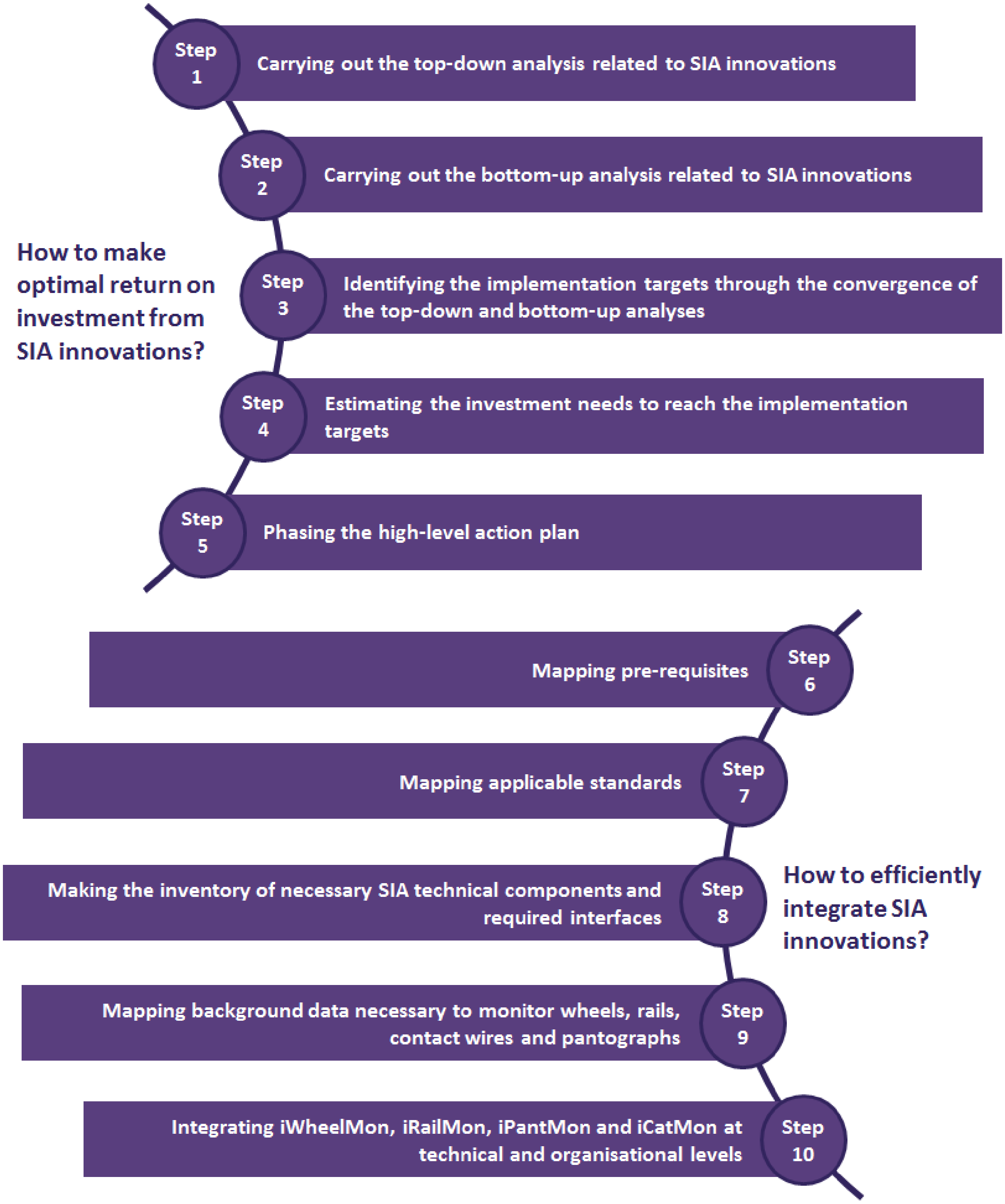


**Figure 1. Summary of Process**

# 5 How to make optimal return on investment from SIA innovations?

## 5.1 Step #1: Carrying out the top-down analysis related to SIA innovations.

### 5.1.1 Mapping of key features and benefits of iWheelMon, iRailMon, iPantMon and iCatMon.

SIA products overview:

- iCatMon: wear, incorrect height and/or stagger of the overhead contact wire;
- iPantMon: wear of the pantograph's carbon strips;
- iWheelMon: wheel flats and polygonisation wear;
- iRailMon: rail corrugation and short-wave defects.

The high-level functionality of the four system that SIA will bring to the market can be summarised through the following functions:

- F1. Configuration and Installation;
- F2. Introduction of inspection data;
- F3. Introduction of auscultation data;
- F4. Inform about the historic health status of assets;
- F5. Inform about the current health status of assets;
- F6. Inform about early detection of failures;
- F7. Propose maintenance recommendations.

Detailed description of SIA products functionalities and corresponding benefits:

#### iWheelMon:

Depending on the technology used for identifying defects on the wheel, the iWheelMon and the IRailMon, information must be jointly analysed.

**Table 1. iWheelMon functionality checklist**

| System | High-level functionality | Corresponding benefits | Checklist |
|---|---|---|---|
| iWheelMon | F1. Configuration and Installation.<br>For the needed list of information see TSI (Technical Specification of Interoperability) Wagon and Loc & Pas. | The status of each axle of a given fleet of trains is defined in a database accessible to the RU. | The data collected by the RU or given by the train provider must be automatically transferred in this data base. |
| iWheelMon | F2. Introduction of inspection data. | After each replacement, inspection or reprofiling done the dimensions and state of the surfaces are collected. | The needed information is:<br>o Dimensions of axle and the profile of wheels<br>o Flats, polygonisation<br>o Excoriation on the wheel treads<br>o Cracks |
| iWheelMon | F3. Introduction of auscultation data. | This information should be introduced automatically. | The position of the wheel in the train and its reference must be secured. |
| iWheelMon | F4. Inform about the historic health status of assets. | Evolution of the dimensions of each wheel profile and surface defects. | Speeds of the evolutions are used to see when to organise the next reprofiling or changing of an axle. |
| iWheelMon | F5. Inform about the current health status of assets. | | |

| | | | |
|---|---|---|---|
| iWheelMon | F6. Inform about early detection of failures. | Identification of an evolution law, limits one of them being limit before replacement or reprofiling. | Excoriation on the wheel treads and cracks must be identified. The algorithm identifies the evolution speed of those defects. |
| iWheelMon | F7. Propose maintenance recommendations. | | |

### IRailMon:

Rail corrugation and short-wave defects: SIA_CDM: an algorithm to provide estimations about the expected future asset degradation development based on the historic sensor data and additional information provided by the SIA_VP:

- Assessment of the health status of the rail: an accurate estimation of the train speed is required, which is necessary to convert the measured frequencies to wavelength. This is crucial for the classification of track defects. Furthermore, precise absolute and relative positioning is necessary to locate track defects on the track and to measure the relative distance between irregularities to link them to e.g., joins of track segments
- The use of E-GNSS increases the number of visible satellites in the challenging rail environment: this effect is reflected in an increased satellite count when a higher elevation mask is applied and in the dilution of precision (DOP) parameters, which relate to the quality of the best obtainable positioning solution. Incorporating E-GNSS therefore directly correlates to the success of the track monitoring and track health status assessment.

iRailMon is intended for Infrastructure Managers and maintenance subcontractors and will provide real time information about the rail status and prognostic health status information in a certain time frame such as squats, corrugation, wear and RCF, and maintenance recommendations according to Infrastructure Managers specific maintenance requirements.

**Table 2. iRailMon functionality checklist**

| System | High-level functionality | Correspondent benefits | Checklist |
|---|---|---|---|
| IRailMon | F1. Configuration and Installation. | The health status and the wear of the rails for | The data collected by the RU or given by the train |

| | | | |
|---|---|---|---|
| | | each section of a line are defined in a database accessible to the IM. | provider must be automatically transferred in this data base. |
| IRailMon | F2. Introduction of inspection data. | After evaluating the measurement results, further measurements by hand are necessary depending on the set of rules. After replacing rail components, these should be recorded in the systems. | To identify the speed of evolution of the rail components enabling the IM to create a degradation law considering other parameters such as quoted in IRS 70712 [1]. |
| IRailMon | F3. Introduction of auscultation data. | This information should be introduced automatically. | Additional information such as quoted in IRS 70712 [1] shall be added. |
| IRailMon | F4. Inform about the historic health status of assets. | The evolution of the wear of the rails and of rail components (turnouts). The development of the failure of the rails and each rail components (turnouts). | Speeds of the evolutions are used to see when to organise the replacement of the rail. |
| IRailMon | F5. Inform about the current health status of assets. | | |
| IRailMon | F6. Inform about early detection of failures. | Identification of an evolution law, limits one of them being limit before replacement. | Failures on the rails and the rail components must be identified as well as the wear in general (rail height). |

### iPantMon:

IPantMon and the ICatMon information must be jointly analysed. The state of one can have an incidence on the other.

**Table 3. iPantMon functionality checklist**

| System | High-level functionality | Correspondent benefits | Checklist |
|---|---|---|---|
| iPantMon | F1. Configuration and Installation. | The status of each pantograph of a given fleet of trains is defined in a database accessible to the RU. | The data collected by the RU or given by the train provider must be automatically transferred in this data base. |
| iPantMon | F2. Introduction of inspection data. | After each replacement, of the pantograph bow.<br>The distance on which the pantograph bow was used should be recorded. | To identify the speed of wear there may be different pantographs on the same vehicle steel, coper or carbon strips. They must be identified accordingly. |
| iPantMon | F3. Introduction of auscultation data. | This information should be introduced automatically. | The position of the pantograph in the train and its reference must be secured Information on the corresponding state of the catenary (stagger, contact wire height, percentage of arching) shall be provided to both RU and IM. |
| iPantMon | F4. Inform about the historic health status of assets. | Evolution of the wear of each pantograph bow. | Speeds of the evolutions are used to see when to organise the replacement of the bow. |

| | | | |
|---|---|---|---|
| | | Cracking of carbon contact strips is another known failure mode. | |
| iPantMon | F5. Inform about the current health status of assets. | - | - |
| iPantMon | F6. Inform about early detection of failures. | Identification of an evolution law, limits one of them being limit before replacement. | Cracks on the carbon contact strips must be identified as well as the wear of the strips. |

## iCatMon:

**Table 4. iCatMon functionality checklist**

| System | High-level functionality | Correspondent benefits | Checklist |
|---|---|---|---|
| iCatMon | F1. Configuration and Installation. | The wear of the OCL for each section of a line, its height and stager are defined in a database accessible to the IM. | The data collected by the IM or given by the catenary system provider must be automatically transferred in this data base. |
| iCatMon | F2. Introduction of inspection data. | Each intervention on the catenary and each event on a pantograph of a train should be recorded. | To identify the speed of evolution of the parameter identifying a degradation law considering other parameters such as quoted in IRS 70014 [3]. |
| iCatMon | F3. Introduction of auscultation data. | This information should be introduced automatically. | Additional information such as quoted in IRS 70014 [3] shall be added. |

| | | | |
|---|---|---|---|
| iCatMon | F4. Inform about the historic health status of assets. | Evolution of the<br>o wear<br>o height<br>o stagger<br>of the contact line. | To make a good assessment of the state of the catenary other parameters such as percentage of arching have to be considered. |
| iCatMon | F5. Inform about the current health status of assets. | | |
| iCatMon | F6. Inform about early detection of failures. | Will be done according to the degradation law. | Damage on the catenary causing a stager problem is not always predictable. |
| iCatMon | F7. Propose maintenance recommendations. | | |

### 5.1.2 Selecting key features from the mapping which are benefiting directly to the end-user's organisation strategy.

Starting from the check list of chapter 4.1.1, what can be interesting for the end-users should be defined.

## 5.2 Step #2: Carrying out the bottom-up analysis related to SIA innovations.

### 5.2.1 Mapping asset types and related KPIs

Tracks:

- In the case of ballast track: rails, sleeper-holding set, ballast.
- In the case of slab track: rails, sleeper-fastening system (in case of having it), support layer or slab.

### 5.2.2 Mapping maintenance policies and related KPIs

#### 5.2.2.1 Rail

IRS 70712 [1]

*"The IRS contains recommendations for identifying and classifying rail defects and compiling statistics. These defects are coded, described and illustrated in the General Part - Handbook of Rail Defects. This general coding defines a standard system for classifying broken, cracked and damaged rails.*

*This general coding defines a standard system for classifying broken, cracked and damaged rails according to the location, appearance and cause of the defects."*

*"Each defect is given a number and is described on a sheet indicating the characteristics and appearance of the defect, explaining ways and means of detecting such defect, and giving recommendations as to what measures should be taken once it has been discovered in the track."*

The decisions of making interventions, repairs on the rails and rail components have a huge impact on its availability and will be taken according to the degradation model as said in UIC IRS 70712 [1]. The wear of the rails and rail components will be monitored thanks to iRailMon.

#### 5.2.2.2 Catenary

*IRS 80870* [2]
*"Maintenance of the overhead contact lines refers to a general provision of periodical tasks that go from inspection through to the component replacement. There are many forms of programming it, depending on evaluation criteria by application use and established degradation models. Traffic types, number of pantographs passed at a given period, climate, type of electrification, and system age, all contribute to create different periodicities of maintenance tasks that aims to fulfil system availability while kipping control of life cycle costs."*

The decisions of making interventions, repairs on the catenary have a huge impact on its availability and, will be taken according to the degradation model as said in UIC IRS 80870 [2]. The wear of the overhead contact line, its height and its stagger will be monitored thanks to iCatMon.

IRS 70014 [3] gives guidance on how to organise the maintenance of catenary systems depending on the characteristics of the line, traffic speeds and densities.

IRS 70791-8 [5] (publication in 2021) will give a methodology to calculate a catenary static quality index comparing the geometric state of the OCL with its design requirements. This makes it possible to foreseen part of the upcoming defects of the contact wire concerning

- The stagger;
- The height;
- The wear of the contact line.

The IM will be able to organise the maintenance work

- Reducing the costs;
- Increasing the availability of the line.

#### 5.2.2.3 Rolling Stock

Every vehicle, before being put into service and used on the common railway network in Europe, is assigned by its owner to an entity responsible for its maintenance (ECM) according to of Commission Regulation (EU) 2019/779 of 16 May 2019 and more precisely its annex II. This is to be done for each type of vehicle. The responsibilities of this ECM are divided into 4 parts:

a) The **management function** supervision and coordination the other three maintenance functions to ensure that the vehicle is in a safe condition.

b) The **maintenance development function**, which is responsible for the management of maintenance documentation, including configuration management, based on design and operational data, performance, and feedback.
c) The **fleet maintenance management** function to manage the withdrawal of vehicles for maintenance and their return to operation after maintenance.
d) The **maintenance execution function**, which is the performance of the required technical maintenance of a vehicle or vehicle parts, including the preparation of release documents.

This ECM has therefore, to define a maintenance strategy and after proceeding (RAMS):

- With the listing of the components and
- Their defects, their probability of occurrence
- The impact of these defects on the railway system (risk assessment)
- The way to put them under control (partly by means of SIA services): the corresponding maintenance measures. The impact of those measures on cost and availability of the assets.

The final user of the different services provided inside SIA can use the following UIC IRSs 80881 [6] and 80882 [7] guidelines related to the definition of a railway maintenance strategy:

- Analysis of the existing degradation models for components.
- Results and conclusions of the analysis and the data available.
- Focus on relevant parameters.
- Calculation process of the KPI → risk assessment → track access renewal criteria and renewal scenarios → output for decision making.

The SIA services shall be used to implement predictive maintenance of the considered asset by identifying the speed of the evolution of the defect and the remaining useful life, letting the RU organising the maintenance works in advance (replacement of parts, turning of wheels, more detailed inspections).

The full use of predictive maintenance methods should decrease the maintenance cost for 20% and increase the availability of 20%. The analysis of all the defect modes has to be carried out in order to assess more precisely this estimate.

## 5.3 Step #3: Identifying the implementation targets through the convergence of the top-down and bottom-up analyses.

The ECM is responsible for the safe operation of its assets. Using the services of someone outside of the ECM, it is needed to deal with the following questions:

- How is the responsibility shared to be managed between the Entity in Charge of Maintenance and the Infrastructure Managers / Railway Undertaking?

- How is the tool to be used in the configuration of several Railway Undertakings are running on the same infrastructure (sharing of information)? This point would need to be clarified in particular for signalling and energy providing systems, among others.
- How is the confidentiality of raw data / processed data going to be ensured?
- Where are the responsibilities in terms of raw data quality (including accuracy) and / or of data processing and analysis? More specifically concerning the level of service:
  - Access to a raw data lake limited to specific data.
  - Data processing with decision proposals to the Infrastructure Manager or Railway Undertaking involved?
  - Proposals of maintenance and operational actions according to the situation of specific assets combining the Infrastructure Manager and Railway Undertaking aspects?
  - Combinations of solutions above?

## 5.4 Step #4: Estimating the investment needs to reach the implementation targets.

### 5.4.1 Rolling stock

The new way of practising the maintenance will have an impact on the organisation of the following functions:

- **The maintenance development function**: new tools and skills for data analysis in relation with operations.
- **The fleet maintenance management function** to manage the withdrawal of vehicles for maintenance and their return to operation after maintenance. Reshaping of the usage of the fleets, the tracks in the workshops or shunting yards. New tools and skills for the fleet management.
- **The maintenance execution function**, we need the investment to correctly:
  - Explain the teams how the content of the work and the related responsibilities will change. As they will make fewer inspections with specified parameters and more troubleshooting and repairs their technical skills will be used to a greater extent.
  - Train the employees according to their level of intervention.

### 5.4.2 Infrastructure assets

The new way of practising the maintenance will have an impact on the organisation of the following functions:

- **The maintenance development function**: new tools and skills for data analysis in relation with operations.
- **The fleet maintenance management function** to manage the withdrawal of vehicles for maintenance and their return to operation after maintenance. Reshaping of the usage of the fleets, the tracks in the workshops or shunting yards. New tools and skills for the fleet management.

- **The maintenance execution function**, we need the investment to correctly:
    - Explain the teams how the content of the work and the related responsibilities will change. As they will make fewer inspections with specified parameters and more troubleshooting and repairs their technical skills will be used to a greater extent.
    - Train the employees according to their level of intervention.

## 5.5 Step #5: Phasing the high-level action plan.

The following steps shall be considered

- Adapting the organisation of the IM or the ECM and the entity in charge of the maintenance works:
    - Increase of the technical skills of the workers;
    - Usage of simulation tools to organise the usage of the fleet on the work in the workshop; these tools shall be connected to the other management tools of the company.
- Proof of the maintenance system level of safety: during a specific duration, the results of the inspections done using usual methods shall be compared with the proposals made by the SIA system.

# 6 How to efficiently integrate SIA innovations?

## 6.1 Step #6: Mapping pre-requisites

The safe way to draft maintenance rules is to do it as described in §4.2.2 of this document.

Having the list of the possible defects as defined in 4.2.2, we have for each of them to assess if it is possible to foresee them using the SIA services and to identify the coming defects in a time period that lets the organisation of the repairs be done in a safe and optimised way. The needed time period has to be identified clearly.

For the definition of this time period the end user can rely on his experience with comparable assets or on manufacturer and service provider recommendation.

## 6.2 Step #7: Mapping applicable standards, maintenance policies

This step is to help defining the list of "families" of standards which are component focused, process focused, etc.

The conditions of operation shall be identified and not modified while moving to the SIA methodologies

A table giving every defect of each component shall be created giving for each defect:

- The probability of occurrence
- The consequences
- The time between detection and defect in operation
- The needed time to prepare the repairs
- The time and constraints to realise the repairs
- The KPIs related to the defect

A comparison to other assets can be useful.

The return of experience on the same assets not maintained with predictive maintenance needs to be capitalised and further exploited.

## 6.3 Step #8: Making the inventory of necessary SIA technical components and required interfaces

In this chapter, the list of "families" of components and required interfaces (mechanical interfaces, IT interfaces, electrical interfaces, etc.) has to be defined.

In particular for IT interfaces → the share between the Data Lake and pre-analysed data has to be considered, also the IT capabilities of the components analysed in terms of their own auto-diagnostic needs to be considered.

## 6.4 Step #9: Mapping background data necessary to monitor wheels, rails, contact wires and pantographs

In this step, the following data are to be listed:

- The data necessary for the monitoring;
- The unit of measurement of the data;
- The time steps;
- The kind of data and its context:
  - Is it a maximum value?
  - Is it an instant value?
  - Is it an average value?

## 6.5 Step #10: Integrating iWheelMon, iRailMon, iPantMon and iCatMon at technical and organisational levels

In this step, the share of roles of the several stakeholders in the implementation has to be described:

- Is it externalised? Or internalised?
- Which is the role of ECM? Of the IM?
- What can be the links between IM and RU, what data can be shared?

### 6.5.1 Phasing the technical integration action plan

Project Management phases related to the implementation are the following:

Phase 1 Preparation

- Determination of the test intervals depending on the line parameters;
- Specification for handling the measurement results in the case or permanent monitoring;
- Definition of intervention threshold and associated measures;
- Definition of substitute measurements in the case of a system failure;
- Coordination with national supervisory authorities.

Phase 2 Implementation

- Organisation of monitoring (automated, manual, time period);
- Define responsibilities with regard to recording the measurements and forwarding them to the infrastructure;

- Announcement of the timetable for the measurement runs to the infrastructure.

Phase 3 Test operation

- Based on the experiences during the project and already established measurement procedures in the respective company, determination of the time span for test operation;
- Parallel operation of SIA and conventional measurements.

Phase 4 Regular operation

- Regular operation;
- Implement monitoring audits on the effectiveness of the process.

### 6.5.2 Phasing the organisational integration action plan

In this step, a description of the team needed and their interaction with the internal organisation of the company is to be provided:

- Which are their skills?
- How they interact in line with the internal organisation of the company?
- Would be necessary a modification of the internal organisation of the company?

# 7 Conclusion

These guidelines for implementation have been designed to facilitate the uptake of SIA innovations in a step-by-step process for two types of users, namely for decision makers and for technicians.

The first part "How to make optimal return on investment from SIA innovations?" proposed the most effective ways to implement predictive maintenance and reduction of the frequency of the inspections on Wheels, Rails Pantographs and Catenaries via iWheelMon, iRailMon, iPantMon and iCatMon, given current maintenance policies and asset types within the organisation. This first part proposed guidance to estimate implementation costs, benefits and phasing, in order to obtain a desirable return on investment.

The second part "How to efficiently integrate SIA innovations?" summarised pre-requisites, applicable standards, applicable processes, inventories of necessary SIA components, as well as required interfaces and background data (other than directly provided by the SIA system) that are necessary to monitor wheels, rails, contact wires and pantographs.

# 8 REFERENCES


- [1] IRS 70712, “Rail Defects”, UIC, 1st edition, May 2018.
- [2] IRS 80870, “Technical guidelines for the use of grooved contact wires”, UIC, 1st edition, February 2021.
- [3] IRS 70014, “Railway Application - Fixed installations - Maintenance Guidelines for OCL”, UIC, 1st edition, September 2016.
- [4] IRS 70791-6, “fixed installations general framework” (under publication)
- [5] IRS 70791-8, “evaluation of the OCL static and dynamic quality” (under publication)
- [6] IRS 80881, “Guidelines for the implementation of EN 50126 to mechanical components of railway vehicles” (under publication 2021)
- [7] IRS 80882, “Railway applications: Guideline for the application of Life Cycle Cost analysis to railway vehicles” (under publication 2021)