SIA

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Deliverables D6.1 – D6.2

Definition of vehicle and infrastructure maintenance standard views and framework development

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Executive Summary

The present document constitutes the first complete version of deliverables D6.1 “Definition of vehicle maintenance standard views and supporting framework” and D6.2 “Definition of infrastructure maintenance standard views and supporting framework” in the framework of the Project titled “System for vehicle-infrastructure Interaction Assets health status monitoring” (Project Acronym: SIA; Grant Agreement No 776402). The two deliverables have been merged in only one document for the sake of conciseness and clarity, because they share commonalities as the methodology to develop them, the technological platform and architecture, and many visual interfaces.

Based on the work carried in the project, a software application (Visualization Platform) for the management of maintenance of railway sector assets has been implemented. This application uses extensively georeferenced data provided by Galileo, the European Global Navigation Satellite System, and includes four services focused in catenary (called iCatMon), pantograph (iPantMon), rail (iRailMon) and wheelset (iWheelMon).

Firstly, Section 2 of this document details the methodology followed for the implementation of SIA software application, including end user’s engagement in the design.

Section 3 reviews the overall SIA system architecture and how the Visualization Platform is integrated.

Then, the document continues describing (in Chapters 4, 5 and 6) the Visualization Platform itself and the software framework used in the development. The software is completely made of open source components able to support and display a huge amount of georeferenced data. A maintenance application for railway infrastructure and rolling stock requires these characteristics as railway operators typically manage large networks with many vehicles moving around, and SIA envisions an onboard monitoring system generating huge amounts of data as vehicles go all over it.

Chapter 7 contains a description of the end users’ visualization platform developed using the aforementioned framework. Many sample screenshots for the four services have been included to give an overview of the feature and capabilities of the system using sample data provided by end users in the Consortium, and partners developing the onboard sensors. Namely assets, field measurement and KPIs coming from sensors and auscultation and inspection reports, assets wearing out predictions and maintenance warnings and recommendations are displayed for the four services in the application.

Finally, Chapter 8 and 9 provide means of verification of the accomplishment of the Visualization platform requirements and conclusions of the work done.

With regards to the next steps that will be taken with the visualisation platform, when field testing with the integrated SIA system starts, the present document will be updated accordingly with the feedback received following the tests. This feedback/input may include visualization examples based on real data and may also highlight software changes required to improve the performance of the application and the user experience of stakeholders working with the system.

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Abbreviations and acronyms

Acronym	Description
ABA	Axel Box Acceleration
API	Application Programming Interface
CDM	Component Degradation Models
CEIT	ASOCIACION CENTRO TECNOLOGICO CEIT-IK4 (SIA coordinator)
DH	Data Hub
DOW	Description of work
DLR	DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV (SIA partner)
EGNSS	European Global Navigation Satellite System
FGC	Ferrocarrils de la Generalitat de Catalunya (SIA partner)
GIS	Geographical Information System
GNSS	Global Navigation Satellite System
HTTP	Hypertext Transfer Protocol
IM	Infrastructure Manager
INGECONTROL	INGENIERIA Y CONTROL ELECTRONICO S.A. (SIA partner)
IT	Information Technologies
KPI	Key Performance Indicator
MQTT	Message Queuing Telemetry Transport
OBB	OBB-Infrastruktur AG (SIA partner)
OS	Operating System
PANT	Pantograph-to-catenary
PC	Personal Computer
PHP	Hypertext Pre-processor
POS	Positioning
RCF	Rolling Contact Fatigue
SFTP	Secure File Transfer Protocol
SQL	Structured Query Language
TELICE	TELEFONOS LINEAS Y CENTRALES S.A. (SIA partner)
TOC	Train Operating Companies
UI	User Interface
UX	User Experience
VIAS	VIAS Y CONSTRUCCIONES S.A. (SIA partner)
VP	Visualisation Platform
WIA	Web Information Architecture
WP	Work Package

1 Introduction

1.1 SIA Overview

The SIA project (System for vehicle-infrastructure Interaction Assets health status monitoring) has the objective of developing four ready-to-use new services (iWheelMon, iRailMon, iPantMon and iCatMon) to provide prognostic information about the health status of the railway's most demanding assets in terms of maintenance costs (wheel, rail, pantograph and catenary).

1.2 Purpose and Scope of this Document

This document covers deliverables D6.1 "Definition of vehicle maintenance standard views and supporting framework" and D6.2 "Definition of infrastructure maintenance standard views and supporting framework" of SIA project. These deliverables describe the visualization platform (SIA_VP) introduced in SIA deliverable D2.2 [1] and developed in Work Package 6 "Visualisation environment for railway-specific maintenance applications" of SIA project.

SIA_VP is made up of a development framework and the user interfaces of the four new SIA services (2 related to vehicle and 2 to infrastructure). Work Packages 3, 4 and 5 implement onboard sensors and processing algorithms generating huge amounts of meaningful data and information. SIA end users will be able to exploit this information using the georeferenced field data and KPIs visualization and analytics tools provided by SIA_VP as described in this document. The initial system requirements compiled in WP2 have been extended and refined in WP6 specifically for SIA_VP subsystem, in terms of functionality, software, performance and operability. Accordingly, the software components and technology framework selected have enabled the design and development of a common web-based application as User Interface (UI) for the four SIA services. This web-based UI enables different types of railway domain end-users and stakeholders the operation of SIA system, managing different types of assets, configurations, inspection and auscultation data, SIA onboard monitoring subsystems (SIA_POS, SIA_ABA and SIA_PANT) data, assets health status events and maintenance recommendations provided by the system. The information in the system can be analyzed based on precise geospatial and timeframe basis thanks to the use of EGNSS data, including future assets degradation to support predictive maintenance recommendations.

These deliverables D6.1 and D6.2 are the final output of WP6 and have been led by INGECONTROL with contributions from technical partners CEIT and DLR providing the onboard equipment, and from end users FGC, VIAS, TELICE and OBB.

2 Methodology

As mentioned in the introduction, this document describes the outcomes of WP6 (SIA_VP), which has the following objectives as per the SIA proposal:

- To establish and standardize a set of views of railway specific maintenance issues for the infrastructure and for the vehicle that show both historical and predicted future condition parameters.
- To create the SW framework for these views which will be later customized and used by end users

According to these objectives, the work was divided at proposal stage in 2 tasks led by INGECONTROL addressing each one both objectives for different types of assets:

- Task T6.1. Definition of **vehicle** maintenance standard views and framework development (iWheelMon and iPantMon services)
- Task T6.2. Definition of **infrastructure** maintenance standard views and framework development (iRailMon and iCatMon services)

During implementation, there have been lots of interactions and synergies between the work done in both Tasks. The initial definition of the system architecture and end-user requirements in WP2 already detailed the same architecture and software platform for the four applications in the SIA system and many common functionalities and interfaces.

In general, the functionalities that the Visualization Platform (SIA_VP) had to meet to display to the users the relevant information generated by the rest of SIA modules were detailed in Deliverable D2.1 [2]:

- Display in a simple GIS (Geographical Information System) to map the railway lines in the system
- Manage the list of components
- Manage the list of KPIs associated with components, as well as their limits and thresholds
- Manage the maintenance list associated to each KPI, and the actions to be completed based on the KPIs status
- Report and visualize the raw auscultation data
- Report and visualize the raw inspection data
- Display the current status of the components based on the KPIs
- Display a prediction of the future status of components based on KPIs
- Generate alerts reporting the early detection of future failures
- Display maintenance recommendations based on the asset's status

2.1 User Interfaces Design and Prototyping

Before starting the actual implementation of SIA_VP which is described in following sections of this document, INGECONTROL designed mock-ups for all of the screens. The design was based oninternal discussions with other partners working on the different modules of the system and the technical proposal for WP6 for the four SIA services, to provide the required functionality. The objective was following a user experience (UX) centred methodology to collect feedback from users at an early stage, to meet their expectations and save time and efforts in the development, delivery and approval of the SIA applications so the design is aligned with user's requirements.

The mock-up of the user interfaces were done using Marvel [3], an online service for rapid application prototyping, where INGECONTROL prototyped the different iWheelMon, iPantMon, iCatMon and iRailMon screens and the navigation flows between them. Marvel also allows you to share your prototypes via the Internet, this was done in Tasks 6.1 and 6.2, allowing the other partners to comment to request changes and improvements. Several iterations were carried out and the results were presented in project meetings in Vienna (Oct 2018) and Nottingham (Feb 2019). The following images are screenshots of the SIA_VP design using Marvel.

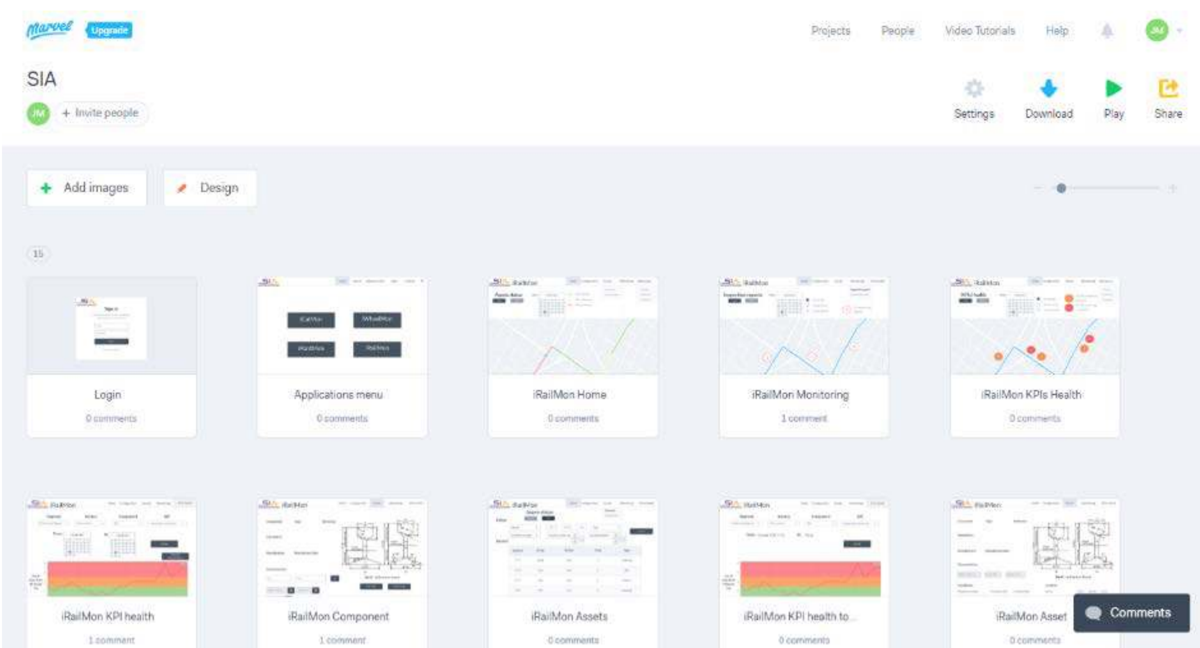


Figure 2-1: Marvel repository of screens designs.

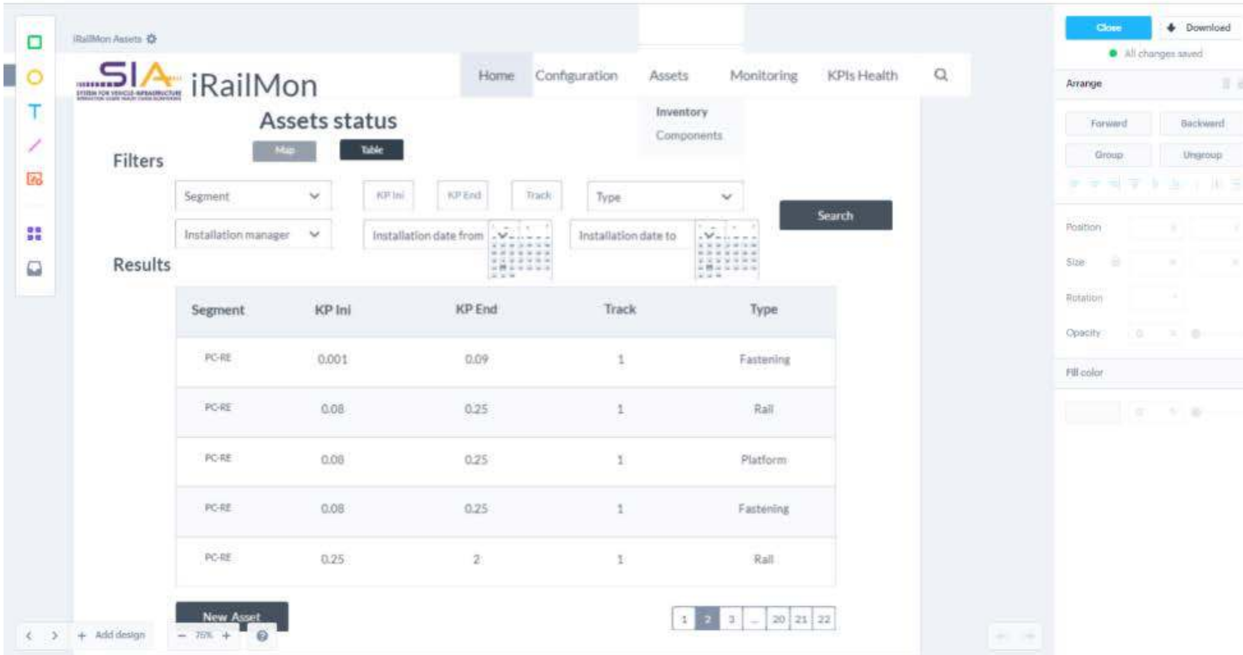


Figure 2-2: iRailMon Assets screen in design mode.

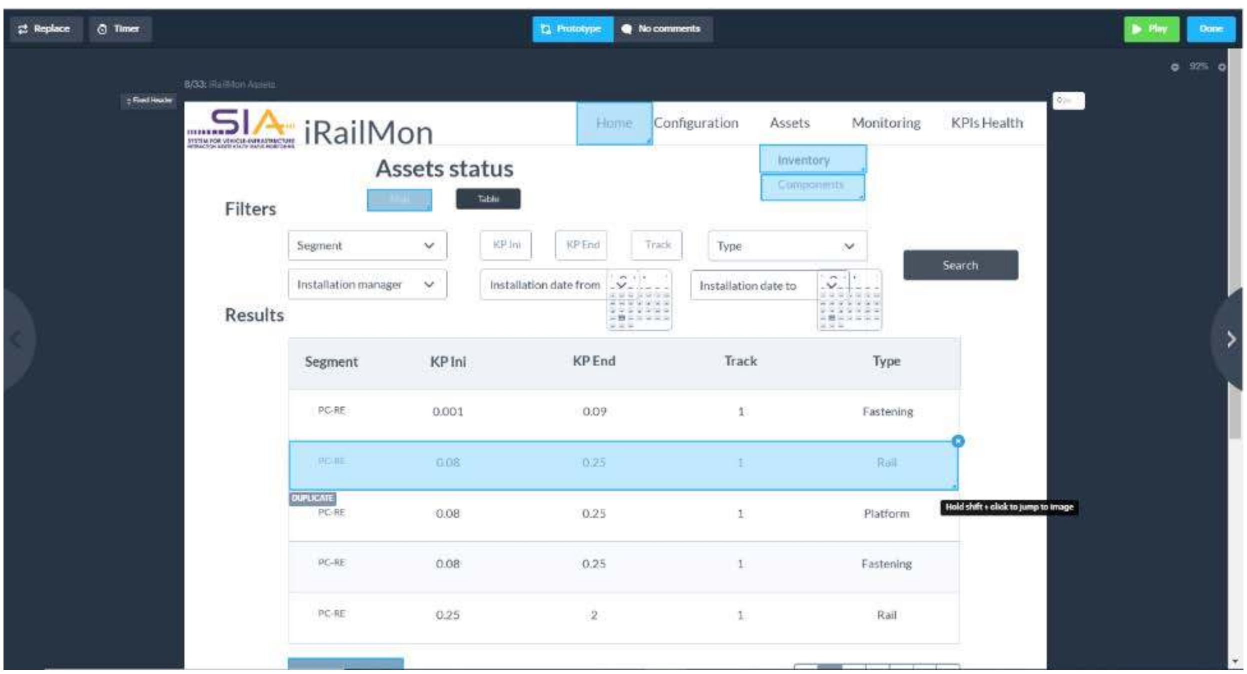


Figure 2-3: iRailMon Assets screen in Marvel test navigation mode.

2

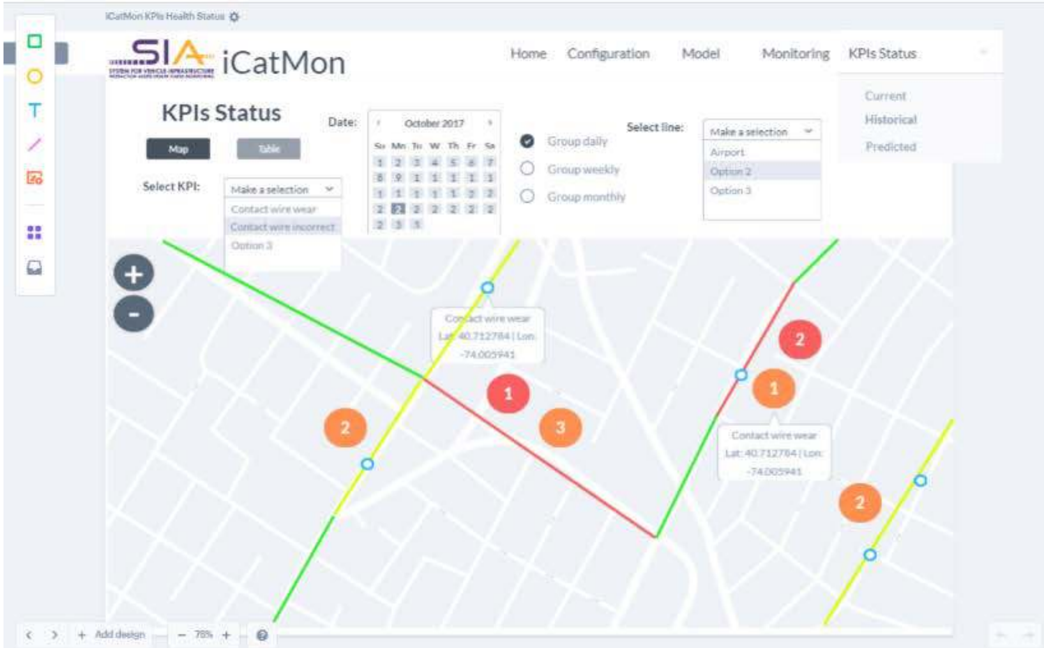


Figure 2-4: iCatMon KPIs status screen in design mode

Once the required user interfaces for SIA_VP had been designed, the following sections in this document describe how partners led by INGECONTROL refined and extended the architecture and development framework designed in WP2 and implemented the four SIA services in SIA_VP. This was achieved in an iterative way, presenting advances to partners in quarterly follow up meetings, gathering feedback and using it to improve work done and continue developing new features.

3 SIA Architecture Overview

According to the deliverable D2.2, and in order to fulfil the requirements defined in D2.1, the following sub-systems have been defined for the SIA system:

- Pantograph/catenary interaction assessment subsystem (SIA_PANT)
- Wheel/rail interaction assessment subsystem (SIA_ABA)
- Positioning subsystem (SIA_POS)
- Data Hub (SIA_DH)
- Component Degradation modelling and algorithms (SIA_CDM)
- Visualisation Platform (SIA_VP)

3.1 Architecture Description

As a visual representation of the above subsystems, the following diagram was created to define the overall architecture and the associated interfaces of the SIA system.

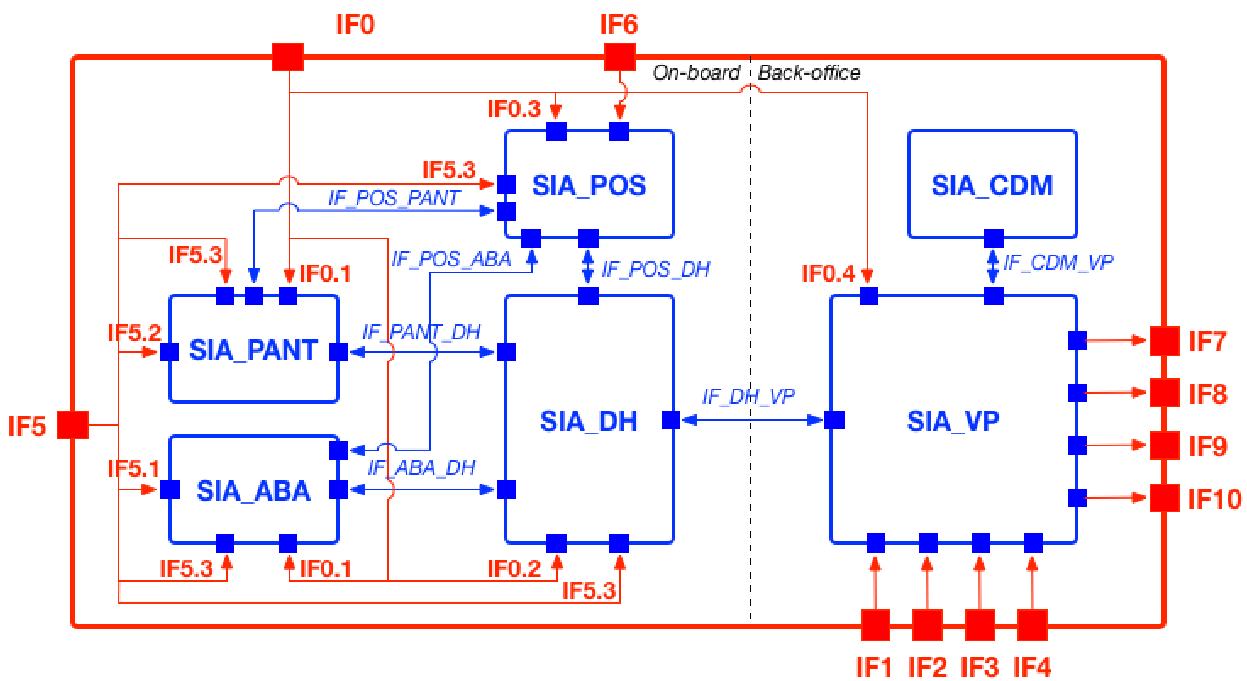


Figure 3-1: SIA Architecture

With this architecture, SIA will provide four services with characteristics defined below:

- *iWheelMon*, which is intended for TOCs and integrated operators, will provide real time information about the status of the wheels(e.g. the presence of wheel flats) and prognostic health status information within a certain time frame such as predicted wear, RCF and polygonization, and maintenance recommendations for meeting ISO 1005-8 [4] and TOC specific requirements.

- *iPantMon*, which is intended for TOCs and integrated operators, will provide real time information about the status of the pantograph (e.g. if there is incorrect vertical damping forces of upper arm) and prognostic health status information in a certain time frame such as wearing of contact stripes, and maintenance recommendations for meeting EN 50405 [5] and TOC specific requirements.

- *iRailMon*, which is intended for IMs and maintenance subcontractors, will provide real time information about the status of the rail (e.g. broken rail) and prognostic health status information in a certain time frame such as squats, corrugation, wear and RCF, and maintenance recommendations according to ISO 5003:2016 [6] and IM specific maintenance requirements.

- *iCatMon,* which is intended for IMs and maintenance subcontractors, will provide real time information about the catenary status (e.g. wearing of cable) and prognostic health status information in a certain time frame such as inclination of the mooring balance with respect to the rail, break of the automatic regulation pulley, wear of cables, and maintenance recommendations for meeting EN50119 [7].

These services will be delivered by the different sub-systems of the SIA system according to the next table.

SIA Subsystems	SIA Services			
	iWheelMon	*iPantMon*	*iRailMon*	*iCatMon*
SIA_PANT		√		√
SIA_ABA	√		√	
SIA_DH	√	√	√	√
SIA_POS			√	√
SIA_VP	√	√	√	√
SIA_CDM	√	√	√	√

Table 3-1: SIA services mapped to sub-systems

The visualisation platform is described in this deliverable, which corresponds to SIA_VP subsystem, focused mainly on end user maintenance standard views and supporting framework.

4 Visualization Platform (SIA_VP)

4.1 SIA_VP Components

In this section SIA_VP subsystem is described in terms of its modules and their interfaces. Next Figure 4-1 displays the architecture of SIA_VP subsystem in a schematic view:

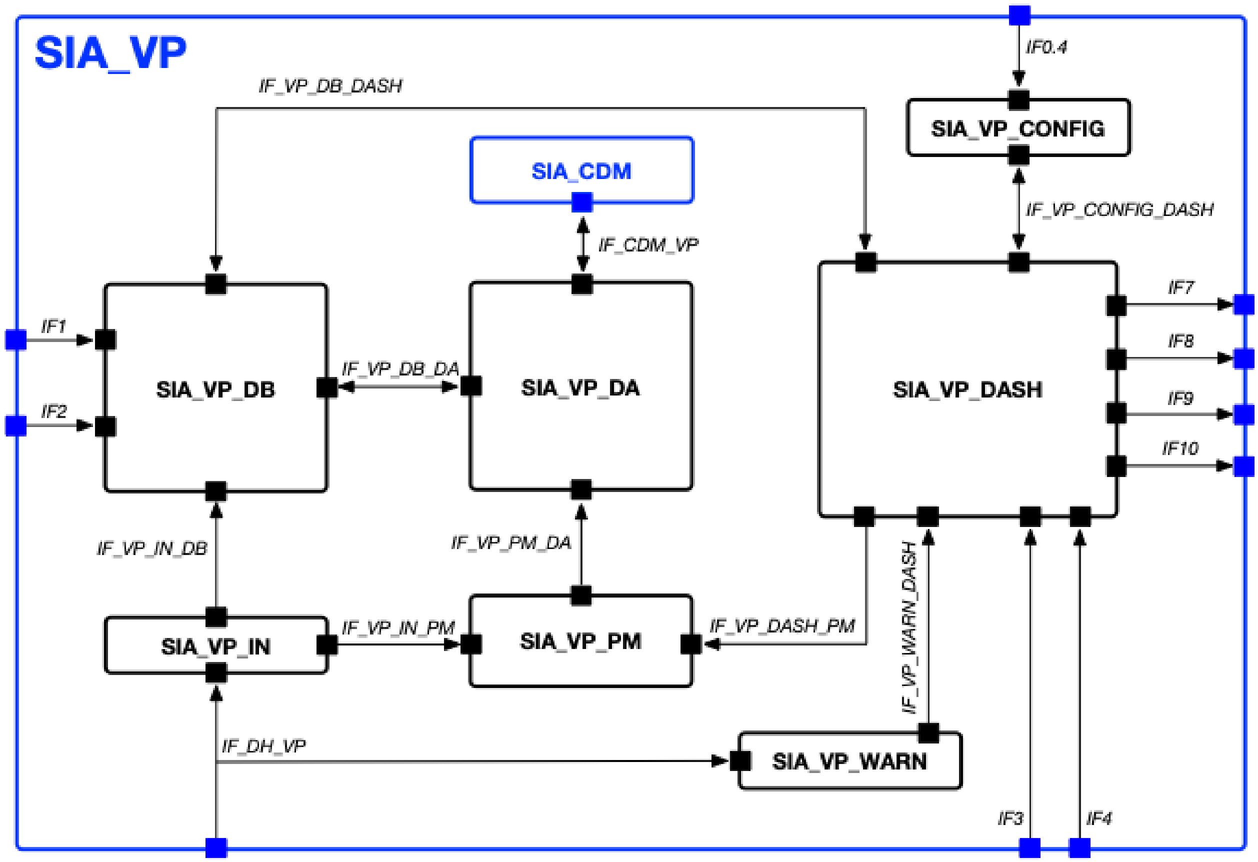


Figure 4-1: SIA_VP subsystem architecture (including SIA_CDM)

Namely, the SIA_VP modules are listed next:

- SIA_VP_DB: Database
- SIA_VP_DA: Algorithms and data analytics (linked to SIA_CDM, hosted in the same server)
- SIA_VP_DASH: Dashboard, Visualization & Reporting
- SIA_VP_CONFIG: Platform configuration (by an end user administrator)
- SIA_VP_IN: Data Input (received from SIA_ABA, SIA_PANT and SIA_POS via SIA_DH)
- SIA_VP_PM: Process Manager

- SIA_VP_WARN: Real-Time Event Manager (connected to onboard SIA_DH in real time)

SIA_VP_DASH and SIA_VP_CONFIG are the only components with user views, which are described in Chapter 7 SIA_VP Subsystem: User Interfaces of this document. The rest are supporting components.

4.2 SIA_VP Interfaces

In Figure 3-1 and Figure 4-1, SIA_VP interfaces are displayed at both system and subsystem level respectively. They are classified next in 2 types as external and internal.

4.2.1 Internal Interfaces

Internal interfaces allow for communication between the SIA_VP subsystem and other SIA subsystems:

- IF_DH_VP: Through this interface, SIA_VP receives monitoring data from SIA on-board sensors (SIA_ABA, SIA_PANT and SIA_POS) via the data hub (SIA_DH). These data have two different recipients:
  - SIA_VP_IN: Raw data files are received in asynchronous delivery via SFTP (Secure File Transfer Protocol)
  - SIA_VP_WARN: Synchronous delivery reception via MQTT messages - using Apache Nifi - of events detected by on-board sensors, which are immediately displayed to users in SIA_VP_DASH.
- IF_CDM_VP: Additionally, SIA_VP passes the raw data files to SIA_CDM through this interface for an offline processing to generate the KPIs of the four SIA services, degradation forecasts and detect additional events (warnings) which are sent back to SIA_VP via IF_CDM_VP again. Then they are stored in SIA_VP_DB and displayed in SIA_VP_DASH.

4.2.2 External Interfaces

External interfaces exchange information, inputs or outputs, between SIA_VP and end users or external applications.

Input:

- IF0.4: Configuration parameters and SIA_VP parametrization by means of SIA_VP_CONFIG described in Chapter 7.
- IF1.1.1: GIS map of the line(s).
- IF1.1.2: Composition of the infrastructure (e.g. sections, curvature, switches and crossings, tunnels, components, materials, etc.)
- IF2: Maintenance procedures.

- IF3: Auscultation raw data.
- IF4: Inspection raw data.

Output interfaces provided by SIA_VP_DASH described in Chapter 7:

- IF7: Asset Status
- IF8: Early detection of component failure
- IF9: Maintenance recommendations
- IF10: External interfaces.

4.3 SIA_VP Subsystem Requirements

This section details in different categories the requirements that SIA_VP has to fulfil. Some requirements will be addressed by other WPs. The requirements described will assist in the following chapters to show how they have transformed into a software architecture and the components from the previous conceptual design.

4.3.1 Functional Requirements

Req_ID	Description	System Req_ID
SIA_DH_FR_1	Manage assets, failure modes, maintenance actions and inspection and monitoring data and KPIs.	SIA_F1_001 SIA_F2_001 SIA_F3_001
SIA_DH_FR_2	Receive data from on-board equipment (SIA_ABA, SIA_PANT and SIA_POS)	SIA_F4_003 SIA_F5_002
SIA_ DH_FR_3	Forecast future evolution of assets health status.	SIA_F6_001 SIA_F6_003 SIA_F6_004
SIA_ DH_FR_4	Display in a GIS assets and past, present and future monitoring data and KPIs.	SIA_F4_001 SIA_F5_001 SIA_F5_003

Req_ID	Description	System Req_ID
SIA_ DH_FR_5	Display past, present and future monitoring data and KPIs in charts.	SIA_F4_001 SIA_F5_001 SIA_F5_003
SIA_ DH_FR_6	Generate alerts on current and future assets health.	SIA_F5_003 SIA_F6_002 SIA_F6_005
SIA_ DH_FR_7	Suggest maintenance actions to solve/prevent	SIA_F7_001

Table 4-1: SIA_VP functional requirements

4.3.2 Software Requirements

Req_ID	Description	System Req_ID
SIA_DH_SR_1	Opensource: The software platform used to develop SIA-VP shall be opensource to promote reusability, maintainability, interoperability and avoid vendor locking.	New SIA_SW_003
SIA_DH_SR_2	Security: Access to the system shall require a valid username and password. Passwords shall be robust using at least 8 characters mixing upper and lower case letters and numbers. It shall be cancelled after 5 consecutive mistakes introducing it.	New SIA_SW_004
SIA_ DH_SR_3	Multiplatform: SIA-VP shall be supported by different types of end user's platforms and devices. If designed as a web-based system, it will be supported by any device with a web browser (Chrome, Firefox, Edge).	New SIA_SW_005
SIA_ DH_SR_4	Responsiveness: SIA-VP shall be responsive, to be properly displayed in different devices resolutions.	New SIA_SW_006

Req_ID	Description	System Req_ID
SIA_ DH_SR_5	Communications: Secure communication protocols shall be used (HTTPS, FTPS).	New SIA_SW_007

Table 4-2: SIA_VP Software requirements

4.3.3 Performance Requirements

Req_ID	Description	System Req_ID
SIA_DH_PR_1	Rapidity: SIA_VP shall display data as soon as possible. GIS representations shall take no longer than 10 seconds to display the information.	New SIA_PF_007
SIA_DH_PR_2	Data management: System shall be able to cope with huge amount of data. As at least data from last 2 years should be available in the system, a minimum storage of 2 terabytes per year shall be foreseen.	New SIA_PF_008
SIA_ DH_PR_3	Scalability: System shall be hosted in a Cloud based infrastructure to be easily scalable to support the monitoring and maintenance of different sizes of railway infrastructures and vehicles.	New SIA_PF_009

Table 4-3: SIA_VP Performance requirements

4.3.4 Operational Requirements

Req_ID	Description	System Req_ID
SIA_DH_OR_1	Ubiquitous interface: System shall be accessible from many different places. A web-based interface will address this requirement.	New SIA_OP_013

Req_ID	Description	System Req_ID
SIA_DH_OR_2	Availability: As an application to manage critical infrastructures, it shall be resilient and available 24/7. The system architecture and software platform shall enable high availability measures such as redundancy, fault tolerance and disaster recovery to prevent and minimize downtime.	New SIA_OP_014
SIA_ DH_OR_3	Interoperability: The system shall be able to import data from other end-user current information systems. WP 7 will address this requirement.	New SIA_OP_015
SIA_ DH_OR_4	Users management: There shall be different types of user profiles with different privileges granted to access railway networks, SIA Services (iCatMon…) and manage configuration.	New SIA_OP_016

Table 4-4: SIA_VP Operational requirement

5 SIA_VP Subsystem: Software Architecture

5.1 Visualisation Platform Architecture

The visualization system that has been developed is a web-based platform with a client-server architecture with three layers, as designed in D2.2 and displayed in the following Figure 5-1. The applications web server and the database can be hosted in the same physical server, if it is powerful enough.

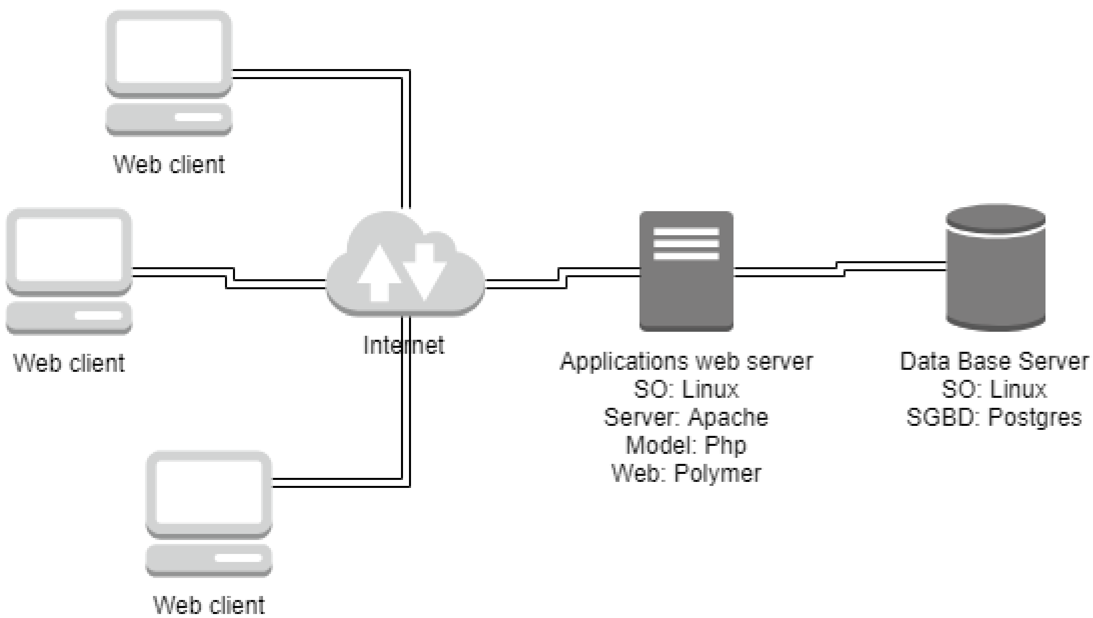


Figure 5-1: Visualization Platform IT Architecture

The three layers description is:

<u>Web Client</u>: Any device (i.e.: PC, laptop, Tablet…) with Internet access and a web browser to load the web app interface.

<u>Applications Web Server</u>: Linux Ubuntu OS server hosting an Apache Web server with:

- Database connection interface implemented in PHP to retrieve from the Data Base Server the data to be displayed.
- Web app, with the business logic implemented in JavaScript using the Polymer library for web components

<u>Data Base Server</u>: stores efficiently, based on visualization requirements, the data to be displayed coming from the rest of SIA subsystems.

The physical infrastructure required will depend on the system load based mainly on size of the railway infrastructure and rolling stock managed, and in the number of users., It is not strictly required to maintain physical servers as they can be virtualized and/or deployed in a cloud-based provider, granting higher flexibility when facing system load fluctuations scaling up and down the resources quickly if needed. In Section 6, an estimation of a minimum infrastructure is given based on the development and testing during SIA project.

5.2 Web Information Architecture

The way in which information is organized, structured and tagged in software development is very important in terms of effectiveness, usability and sustainability, particularly in web applications such as SIA. The goal is to help users find information and complete tasks considering their needs, context and business goals.

Firstly, SIA-VP will have a login screen requiring a valid username/password. Once logged in, a homepage will be displayed from where users will be able to access to the four different applications (Figure 5-2): iCatMon, iPantMon, IRailMon and iWheelMon. Thus, the back-office database will be common, but the four SIA services will have their own independent screens and application flows.

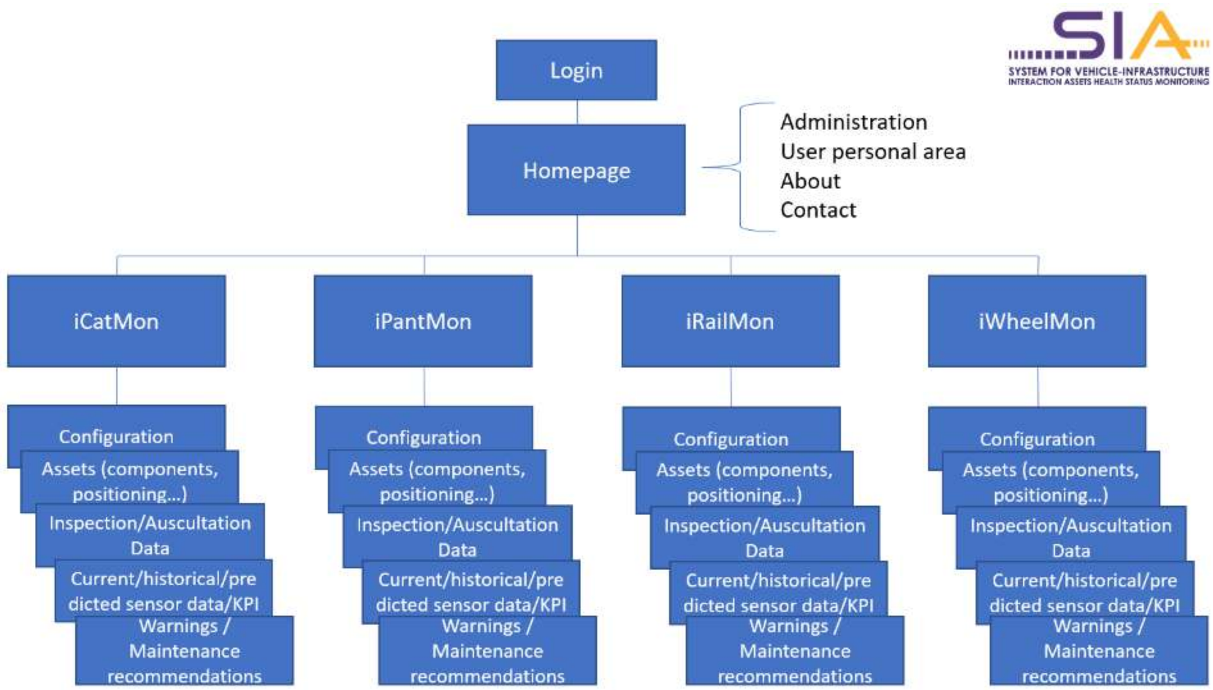


Figure 5-2: High level SIA Web Information Architecture

Then, selecting a specific service, the user will have access to the different screens enabling the functionalities and tasks described in section 3. For example, for iRailMon (Figure 5-3), with the same structure for the others:

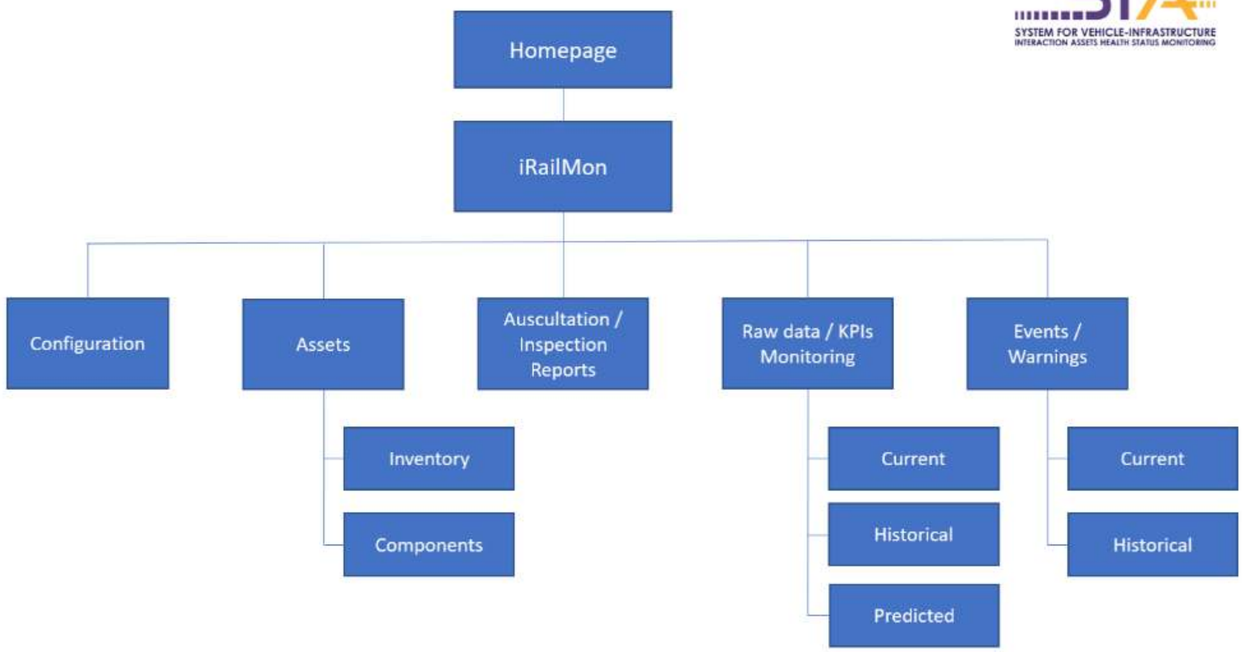


Figure 5-3: iRailMon Website Map and User Interfaces (similar for iCatMon, iRailMon, iWheelMon)

The previous two figures are updates to those in deliverable D2.2 with the final SIA system implemented. Each box in Figure 5-3 corresponds to a different screen in iRailMon.

6 SIA_VP Subsystem: Software / Hardware Description

One of the objectives of Work Package 6 is to establish a software framework to support the development of the user interfaces for a railway specific infrastructure and vehicle maintenance application as the one envisioned in SIA. One of the main requirements established by the partners for this framework is that it is based on open source technologies. This way the maintenance solution implemented is reusable and doesn't depend on proprietary software by any of the partners nor third parties, which may hinder the application evolution in the future.

While describing the SIA system architecture in the previous Chapter (Figure 5-1) some of the software technologies used have been already disclosed, but in this Section we will go deeper describing the selection of the specific domain components enabling the management of georeferenced data supplied by GNSS.

Although using open source software brings advantages in terms of lower cost and the avoidance of vendor locking, there are threats which have to be carefully assessed. The most important one is not selecting emerging technologies which may disappear in a few years or initiatives lacking the support of the community for maintenance and evolution, nevertheless how promising they are.

In this sense, the core open source technologies selected by the consortium partners are mature enough after many years of contributions by flourishing communities and the development of a huge number of thousands of commercial projects and applications. As mentioned in the previous chapter, they are Linux Ubuntu 18.04 "Bionic Beaver" LTS [8] as Operating System and Apache Web Server [9] to host the SIA system developed in PHP and JavaScript, so a very standard and widely used development environment to which we have to add the specific GIS components described next.

6.1 SIA_VP Database

The SIA_VP database is the central information repository of the whole SIA system. It receives data from the other SIA subsystems and from the end users via the SIA_VP user interface. It has to cope with a huge amount of data coming from on-board sensors growing quickly with time, but it also has to be able to display those data in maps and charts to end users.

Therefore, the database selected must have strong read and write data capabilities simultaneously. An open source SQL database such as MySQL [10] or PostgreSQL [11] seems to be a promising option if using an efficient design of Key/Value tables for monitoring data. An example of fields for fast access Key/Value tables agreed with SIA_ABA and SIA_PANT developers in WP4 and WP5 is:

- Parameter_id / KPI_id -> Parameter_id for field measurement, KPI_id for processed data
- Sensor_id
- Timestamp
- GNSS coordinates (UTM)

- Value

To implement the geo-referencing functionalities and datatypes supplied by GNSS, some research was done to support in the database that information. The best option and compatible with a SQL database was installing PostGIS [12] package, a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing location queries to be run in SQL. Partners carried out successfully load tests to confirm the performance of the PostgreSQL database, and thus it was selected as SIA system database.

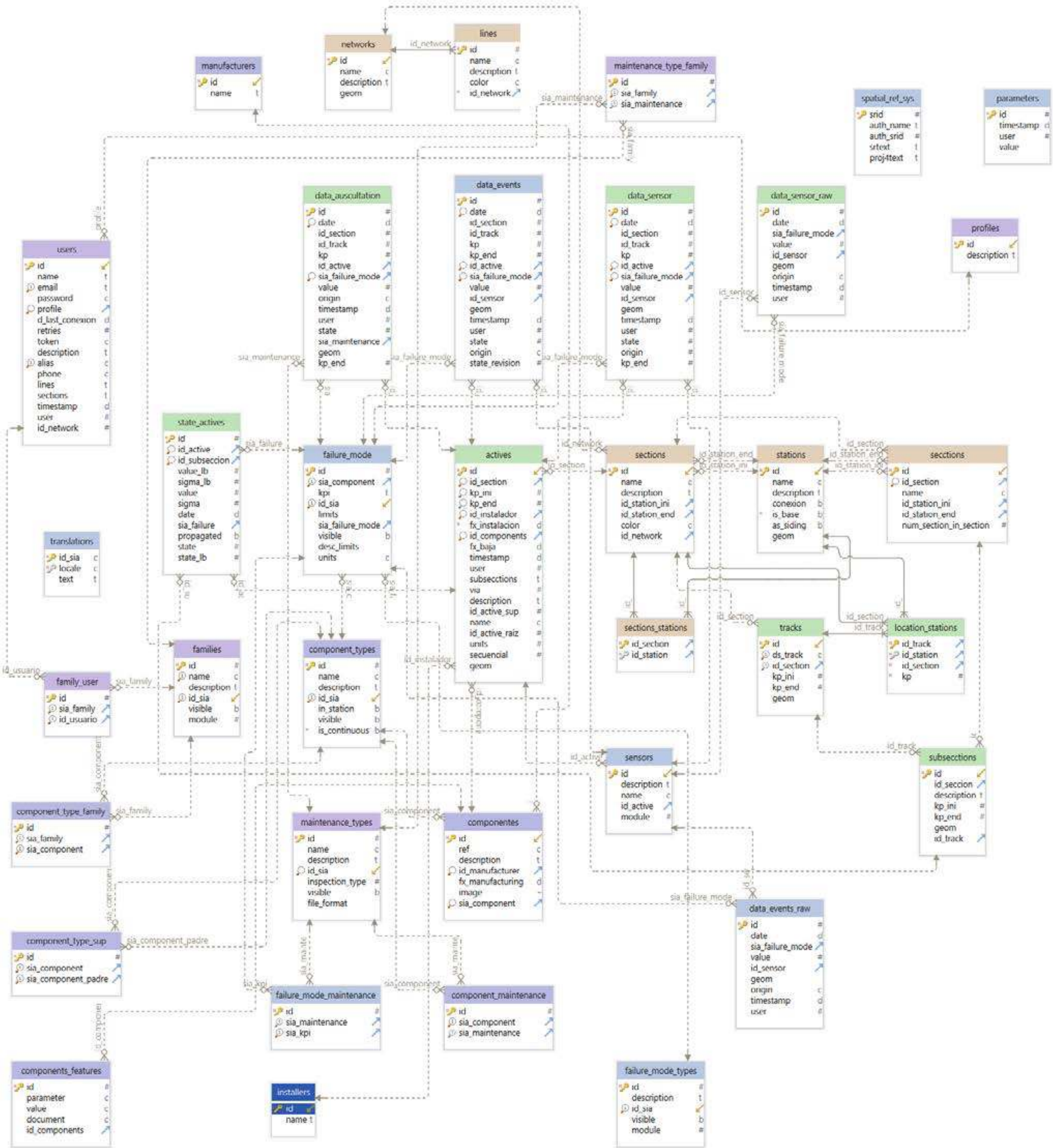


Figure 6-1: SIA_VP Database schema

6.2 SIA_VP Mapping Framework

Similarly to the work described in Section 6.1 for SIA_VP database, in WP6 research was also carried out to find the most suitable framework for map representation in SIA. Different options were tested such as map repositories (e.g. Google Maps or OpenStreetMap), and JavaScript libraries to create applications using the maps as OpenLayers, Leaflet and Arc GIS API. The final solution selected has been using OpenStreetMap [13] with Leaflet [14] (Figure 6-2), which are both open source.

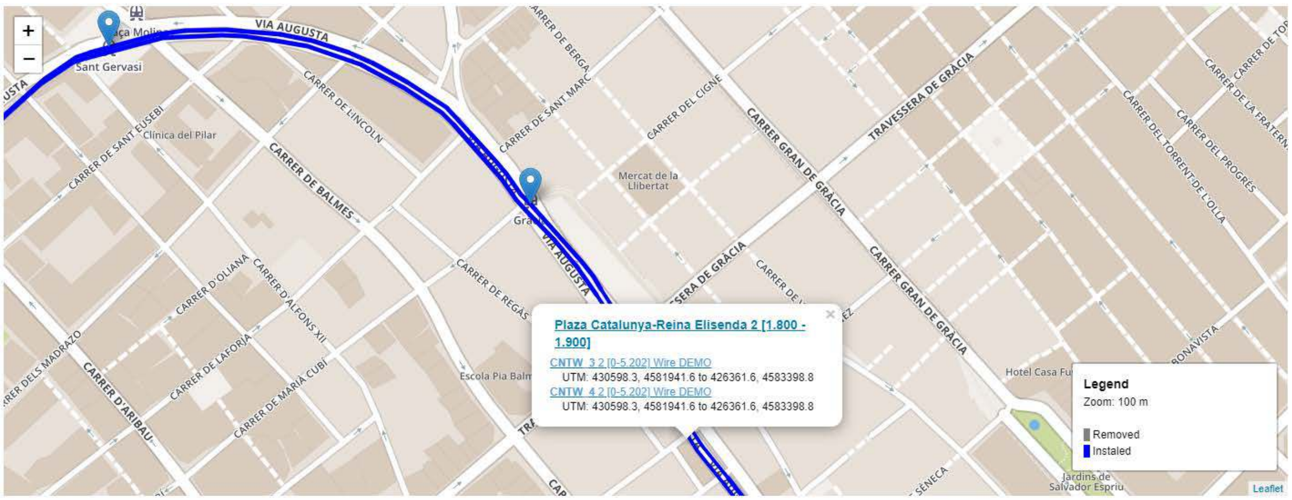


Figure 6-2: Assets map representation in iCatMon using Leaflet and OpenStreetMap

With the database and mapping solution described in the previous paragraphs, SIA becomes a powerful GIS solution supported by well-established open source technologies, not depending, for example, on the tariffs fixed by Google to use Google Maps, which have increased dramatically recently.

6.3 SIA_VP Hardware Configuration

INGECONTROL has provisioned the hardware infrastructure needed for the development and testing of the SIA_VP applications, deploying the software architecture and components described in this and previous sections. Currently, the Applications web server and database servers displayed in Figure 5-1 are hosted in the same cloud server with the following characteristics:

Hard drive	2 Terabytes
Processor	Intel i3-2130
CPU	8GB DDR3 1333 MHz

Table 6-1: SIA minimum on premise/cloud hardware requirements

This configuration is estimated enough to run the tests envisioned in SIA in one line of FGC and one line of OBB for one year at least. This server will also host the SIA_CDM displayed in Figure 5-1. In there are any performance issues during testing in WP8, this environment could be migrated to another one with more resources.

In any case, this is minimum set of requirements to run the SIA system, and in a future commercial deployment, the hardware infrastructure required should be sized accordingly to the client's assets to be monitored and maintained. This can be easily assessed based on the relative size to the current tests carried out in SIA. Additionally, as SIA will be a critical system for infrastructure managers and operators, it should be run in a cluster instead of as a stand-alone server. This way SIA performance and availability would be ensured thanks to parallel processing, load balancing and fault tolerance.

6.4 SIA_VP Software Framework

The following table, Table 6-2 summarizes the software components of the SIA_VP framework described in previous sections. As mentioned, they are open source, mature and widely used by software developers, which in any case can substitute each of them by similar ones seamlessly.

	Operating System: **Linux Ubuntu** 18.04 "Bionic Beaver" LTS [8]
	Applications Web Server: **HTTP** Apache Server [9]
	Database: **PostgreSQL** [11] with PostGIS package [12]
	Database connection interface: **PHP** [15]

	Web app: **JavaScript using Polymer** [16] library
	Javascript library to create map applications: **Leaflet** [14]
	Maps repository: **OpenStreetMaps** [13]

Table 6-2: SIA_VP Framework Components

7 SIA_VP Subsystem: User Interfaces

In this chapter, we detail the different web user interfaces developed using the software framework and prototypes described in previous chapters. First, we present how to access the portal, then the Administration and Configuration options (SIA_VP_CONFIG) and afterwards the four SIA Services (SIA_VP_DASH):

- iCatMon
- iRailMon
- iPantMon
- iWheelMon

The structure and screens of the four applications are very similar. In the case of iRailMon and iCatMon, both assets and field data are georeferenced, but for iPantMon and iWheelMon assets are not georeferenced, so they are not displayed in a map. On the other hand, measurements coming from onboard sensors for these iPantMon and iWheelMon are still georeferenced, so they are displayed in a map as in iCatMon and iRailMon.

When a user tries to access the SIA system, the browser loads a landing page SIA requesting valid credentials (Figure 7-1):

Figure 7-1. SIA Landing page

The password must be at least eight characters long and contain upper and lower case letters and numbers. After 5 errors introducing the password, the account is blocked for 24 hours (unless there is a password reset) and a notification email is sent to the user.

After login-in, there is a home page (Figure 7-2) enabling the user to select which of the four SIA applications the user wants to work with. The administration and configuration menu is available in the top left part of the web page, next to the SIA logo:

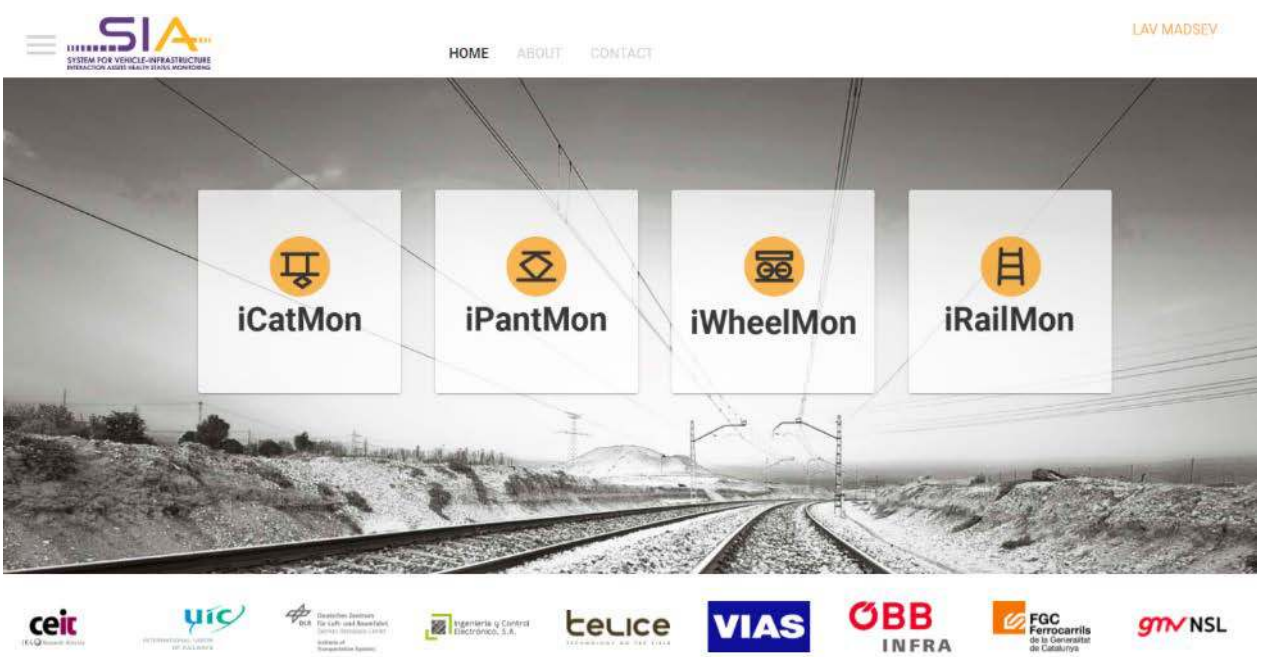


Figure 7-2. SIA Home page

7.1 Administration/Configuration

These views correspond to SIA_VP_CONFIG. As said, from the homepage, the administration menu is available (it is common for the four services). Depending on the user permissions and profile, the end user can change the system and model parameters. The menu is also available inside each one of the four services, but then it only allows the user to manage the setup of the respective applications. The administration menu is displayed in the left part of the next screenshot (Figure 7-3):

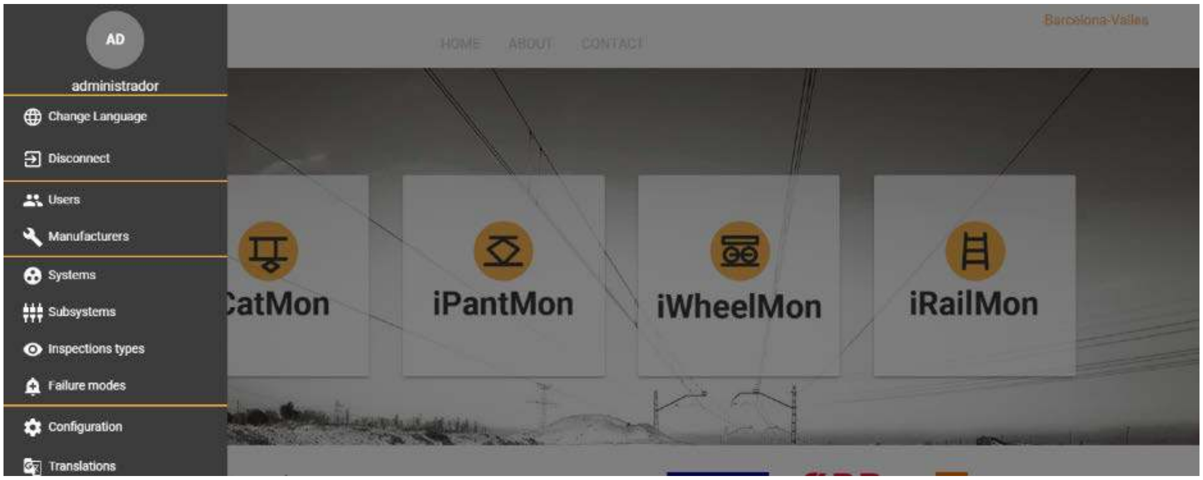


Figure 7-3. SIA Administration Menu

Specifically for users management, there are different types of user profiles, and permissions can be granted to access to each of the four SIA Services and a particular railway network (Figure 7-4). Currently, there are three user profiles, but new ones can be easily configured:

- Administrator: Total control of the system and Administration menu in all SIA Services and Networks
- Project Manager: Is able to access to Administration menu to modify configuration in the Network and SIA Services enabled to him.
- Operation Manager: Can`t access to any configuration in Administration Menu and can only manage the SIA Services and Networks assigned to him.

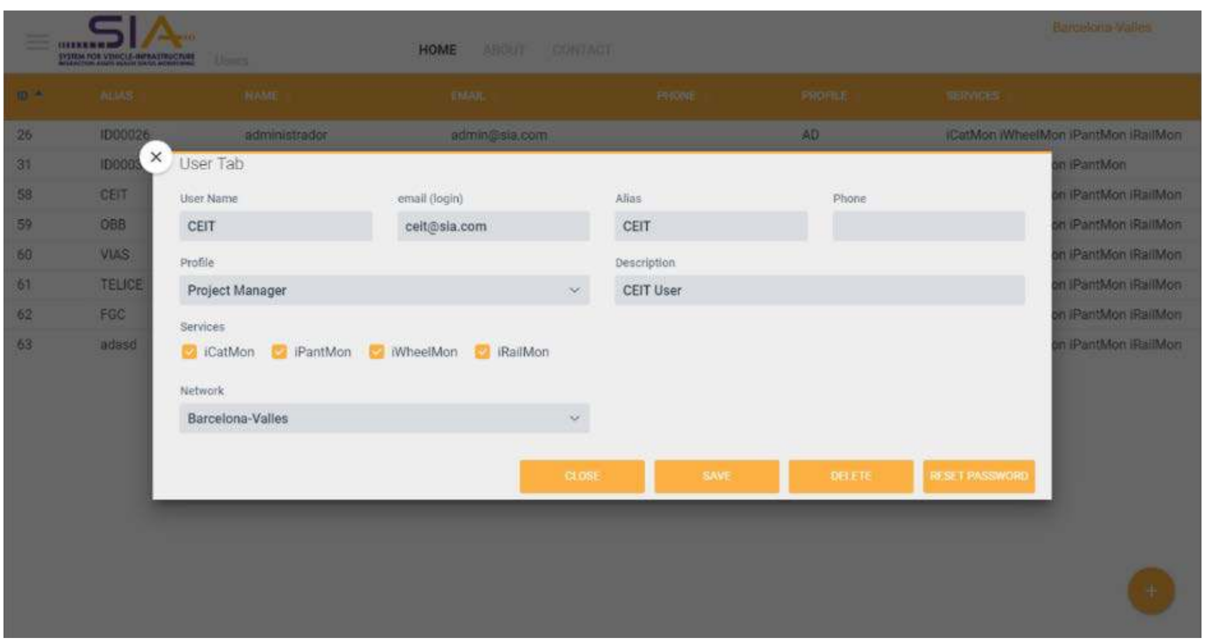


Figure 7-4: User management tab

Apart from users, suppliers and multilingualism management, the administration menu enables the configuration in the SIA system of assets' systems and subsystems classification, failures modes and maintenance inspection types. Based on the component descriptions, failure modes and use cases compiled in Deliverable D2.1, partners have defined in WP6 railway domain ontology to organize these categories. For example, the types of assets defined for iPantMon are distributed in a two levels structure according to Table 7-1:

Service	System	Subsystem
iPantMon	HEAD Pantograph Head	CNTS Contact strip
		HORN Horn
		PHSU Pantograph head support unit
		OTHE Other components
	FRAM Frame and base frame	INSU Insulators
		JUNC Junctions
		OPPO Operating positions
		ELCO Electrical connections
		OTHE Other components
	DRIV Drive system	ADDV Automatic dropping device
		CFRE Contact force regulation
		OTHE Other components

Table 7-1: iPantMon assets ontology

This ontology has been used to design and implement the PostgreSQL database of SIA introduced in section 6.1 of this document. The screens in the Administration menu allow end users to manage this ontology. For example, the system option displays a table with the System families defined in SIA (Figure 7-5):

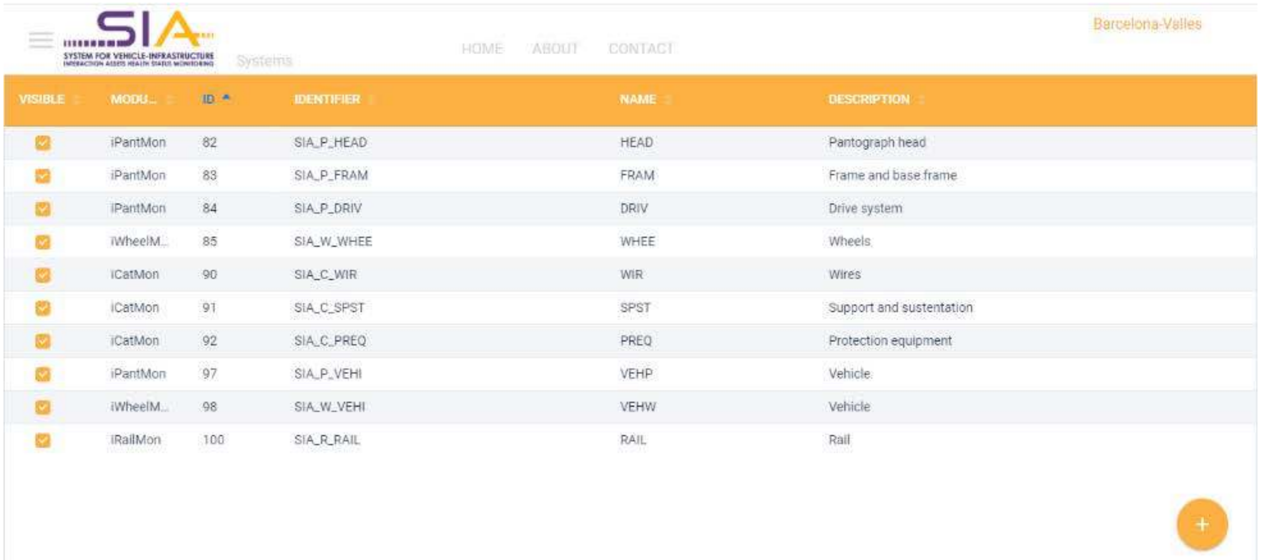


Figure 7-5: SIA Systems Administration Screen

Double clicking in each system in the table, a new screen pops up enabling end user to modify the category. Additionally, by means of the **+** button in the bottom right part of previous Figure 7-5, new items can be created (Figure 7-6) in the same form as to edit them:

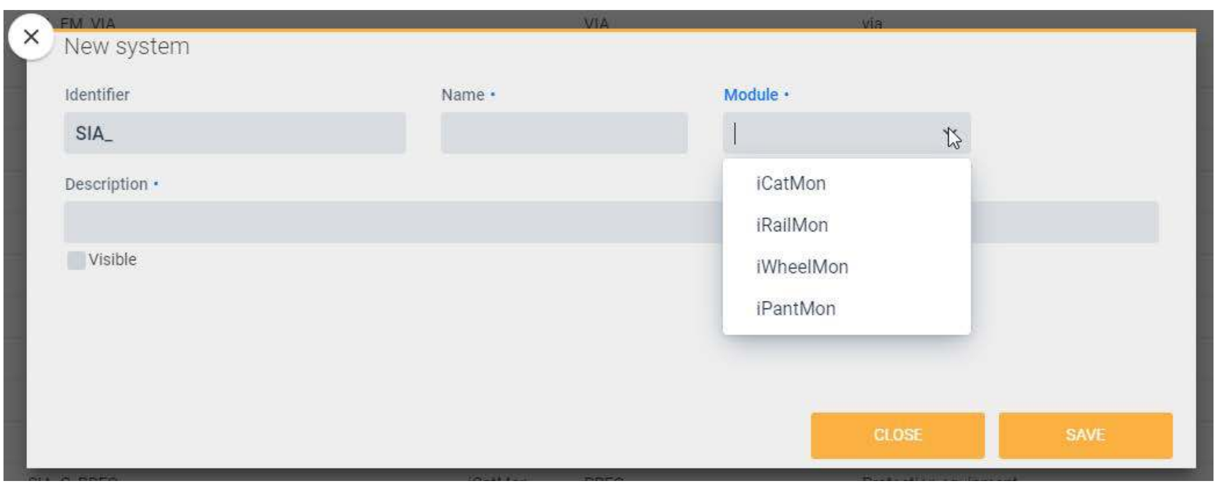
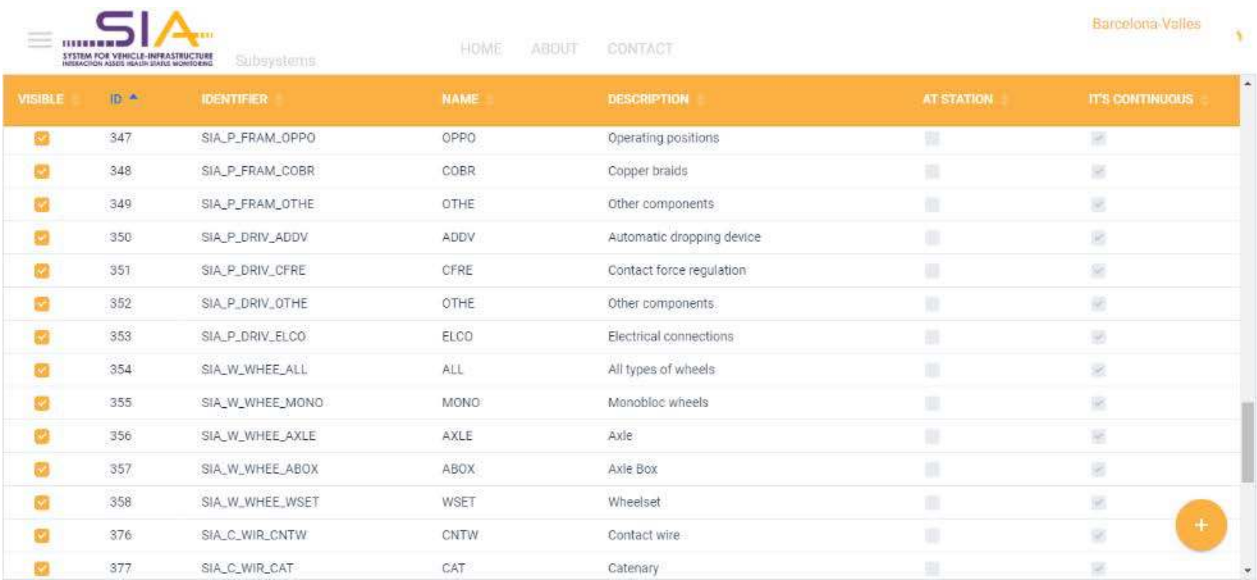


Figure 7-6: SIA new systems creation or editing screen

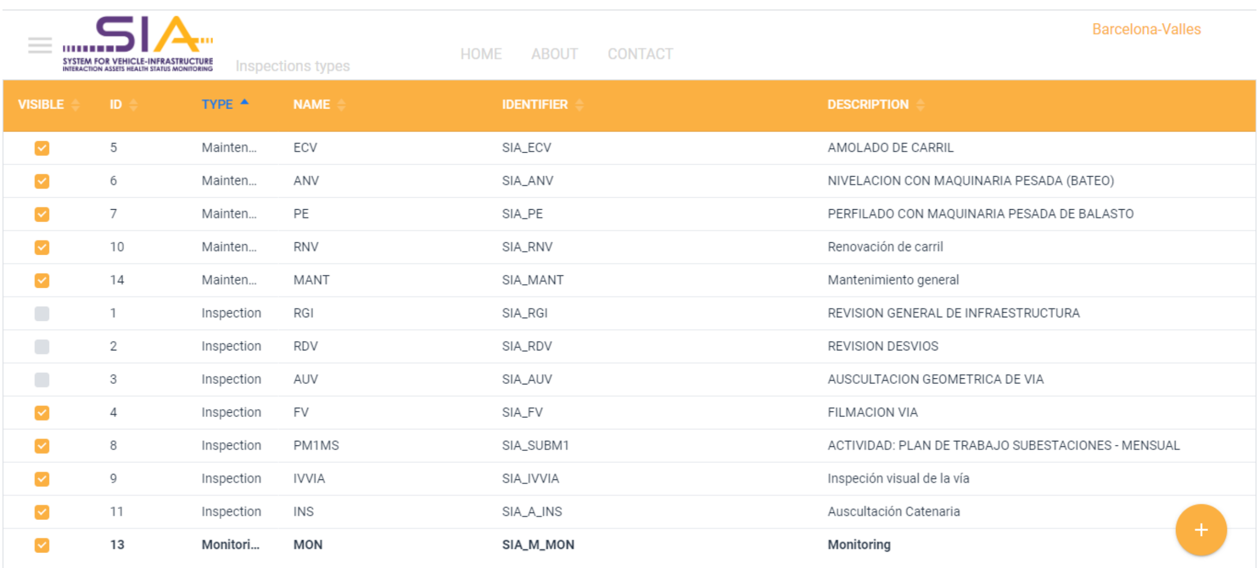
Similar options are available in the sub-systems menu option for the second level in the components ontology (Figure 7-7):



VISIBLE	ID	IDENTIFIER	NAME	DESCRIPTION	AT STATION	IT'S CONTINUOUS
☑	347	SIA_P_FRAM_OPPO	OPPO	Operating positions	☐	☑
☑	348	SIA_P_FRAM_COBR	COBR	Copper braids	☐	☑
☑	349	SIA_P_FRAM_OTHE	OTHE	Other components	☐	☑
☑	350	SIA_P_DRIV_ADDV	ADDV	Automatic dropping device	☐	☑
☑	351	SIA_P_DRIV_CFRE	CFRE	Contact force regulation	☐	☑
☑	352	SIA_P_DRIV_OTHE	OTHE	Other components	☐	☑
☑	353	SIA_P_DRIV_ELCO	ELCO	Electrical connections	☐	☑
☑	354	SIA_W_WHEE_ALL	ALL	All types of wheels	☐	☑
☑	355	SIA_W_WHEE_MONO	MONO	Monobloc wheels	☐	☑
☑	356	SIA_W_WHEE_AXLE	AXLE	Axle	☐	☑
☑	357	SIA_W_WHEE_ABOX	ABOX	Axle Box	☐	☑
☑	358	SIA_W_WHEE_WSET	WSET	Wheelset	☐	☑
☑	376	SIA_C_WIR_CNTW	CNTW	Contact wire	☐	☑
☑	377	SIA_C_WIR_CAT	CAT	Catenary	☐	☑

Figure 7-7: Subsystems administration screen

In the Inspection types menu option, users can create different types of inspection and auscultation reports of the assets, as well as maintenance actions (Figure 7-8):



VISIBLE	ID	TYPE	NAME	IDENTIFIER	DESCRIPTION
☑	5	Mainten...	ECV	SIA_ECV	AMOLADO DE CARRIL
☑	6	Mainten...	ANV	SIA_ANV	NIVELACION CON MAQUINARIA PESADA (BATEO)
☑	7	Mainten...	PE	SIA_PE	PERFILADO CON MAQUINARIA PESADA DE BALASTO
☑	10	Mainten...	RNV	SIA_RNV	Renovación de carril
☑	14	Mainten...	MANT	SIA_MANT	Mantenimiento general
☐	1	Inspection	RGI	SIA_RGI	REVISION GENERAL DE INFRAESTRUCTURA
☐	2	Inspection	RDV	SIA_RDV	REVISION DESVIOS
☐	3	Inspection	AUV	SIA_AUV	AUSCULTACION GEOMETRICA DE VIA
☑	4	Inspection	FV	SIA_FV	FILMACION VIA
☑	8	Inspection	PM1MS	SIA_SUBM1	ACTIVIDAD: PLAN DE TRABAJO SUBESTACIONES - MENSUAL
☑	9	Inspection	IVVIA	SIA_IVVIA	Inspeción visual de la vía
☑	11	Inspection	INS	SIA_A_INS	Auscultación Catenaria
☑	**13**	**Monitori...**	**MON**	**SIA_M_MON**	**Monitoring**

Figure 7-8: Inspection types screen

Finally, the Failure modes defined in D2.1 for each of the assets can be managed by means of the Failure modes administration screen (Figure 7-9):

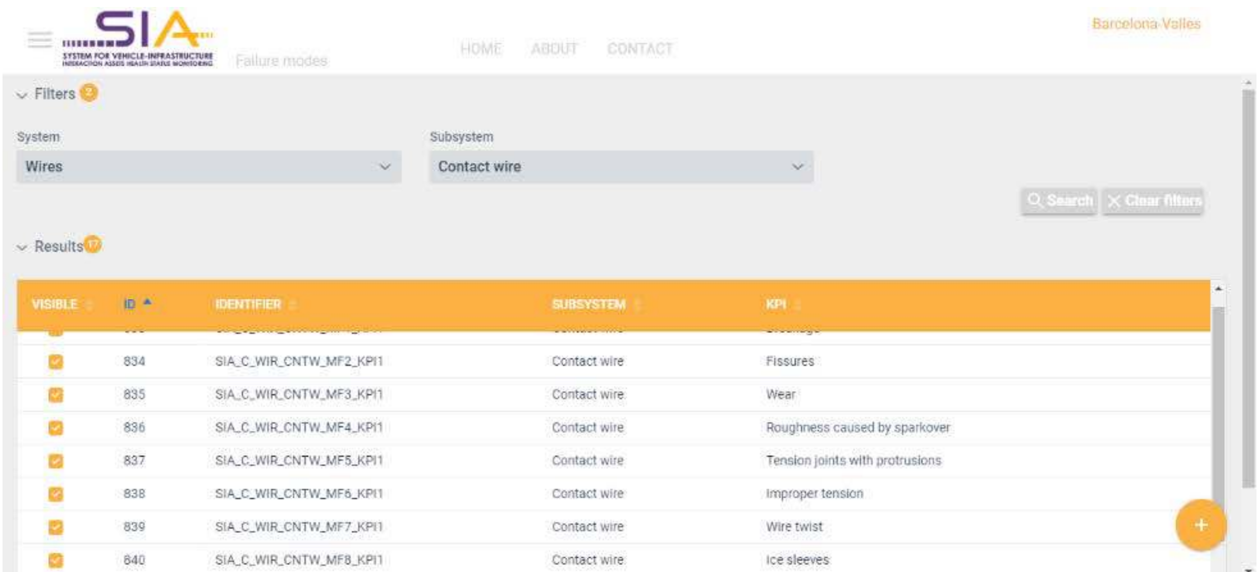


Figure 7-9: SIA Failure modes administration screen

The user can edit one of the failure modes double clicking on it or create a new one by means of the **+** button in the bottom right. In both cases a pop-up will come up (Figure 7-10) and the user will be able, for example, to set the limits associated to the KPI of that failure mode. These thresholds will be used by the system to raise maintenance warnings and alarms in the user interfaces.

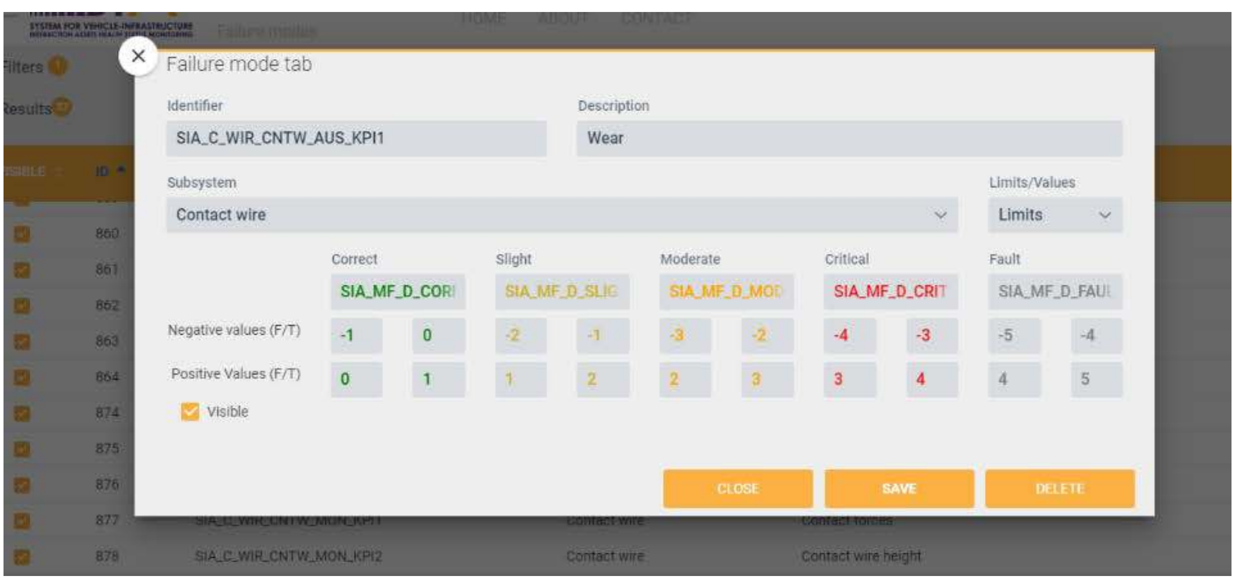


Figure 7-10: Failure mode administration pop-up window

7.2 iCatMon

By clicking on the iCatMon icon in the SIA Home Page (Figure 7-2), the user can access the corresponding application. By default, the iCatMon Inventory screen in the Assets menu option is shown with the menu on the top part of it to access other functionalities included in the site map in Figure 5-3.

The Inventory screen (Figure 7-11) has a map where the catenary assets are displayed as well as some filtering options. User can zoom in and out and moving over the map with the mouse will pop up description boxes with information on the components placed there (Figure 7-12).

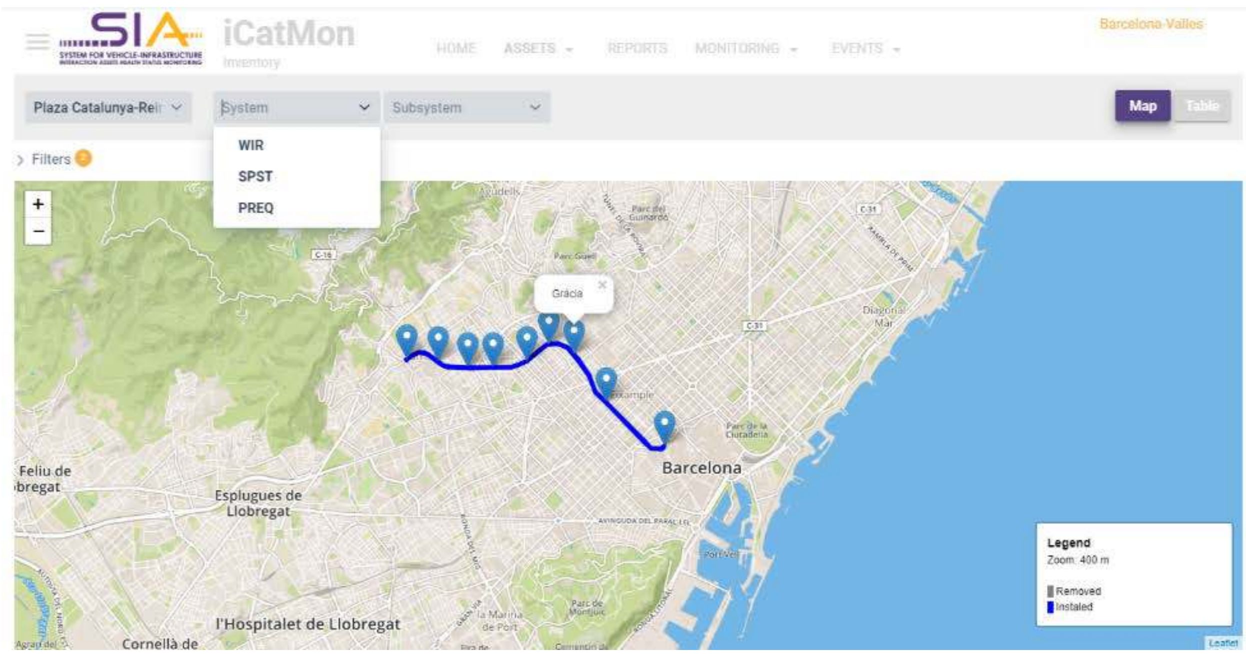


Figure 7-11: iCatMon assets inventory map representation

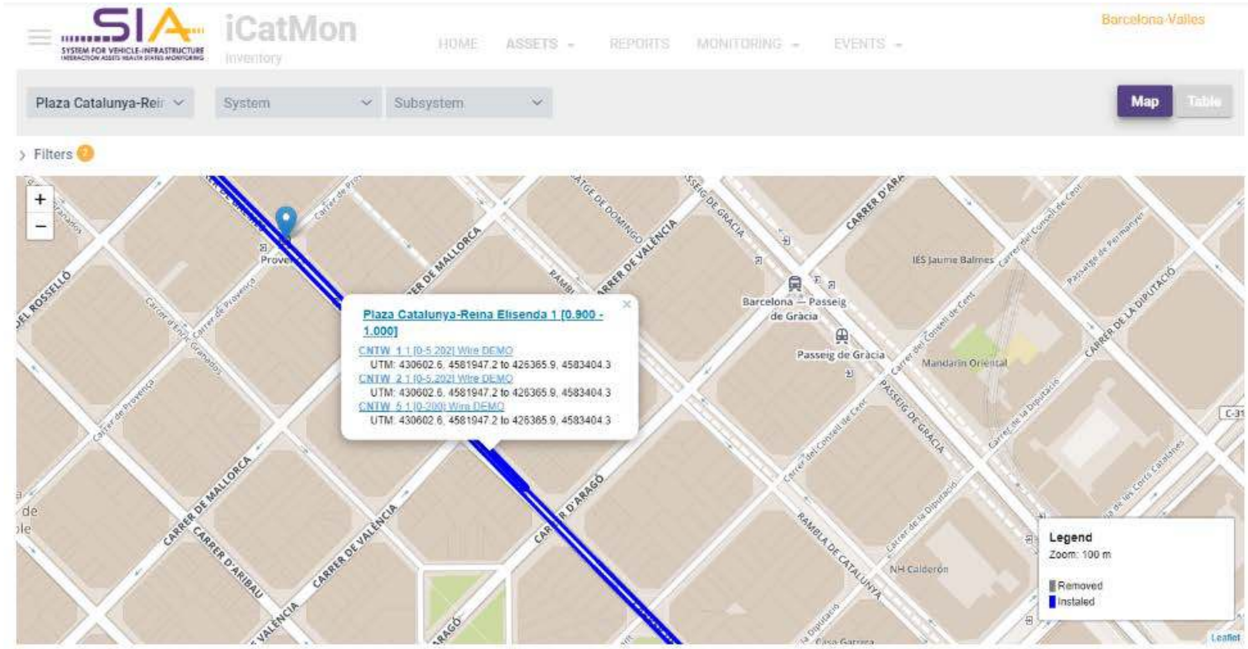


Figure 7-12: iCatMon assets inventory map representation with high details after zooming in

Clicking on an element in the description box in Figure 7-12 will open the asset information form we are going to see below (Figure 7-14). Additionally, there is a table button on the top right part of the screen, which changes the view to a table with the assets instead of a map and filtering options (Figure 7-13).

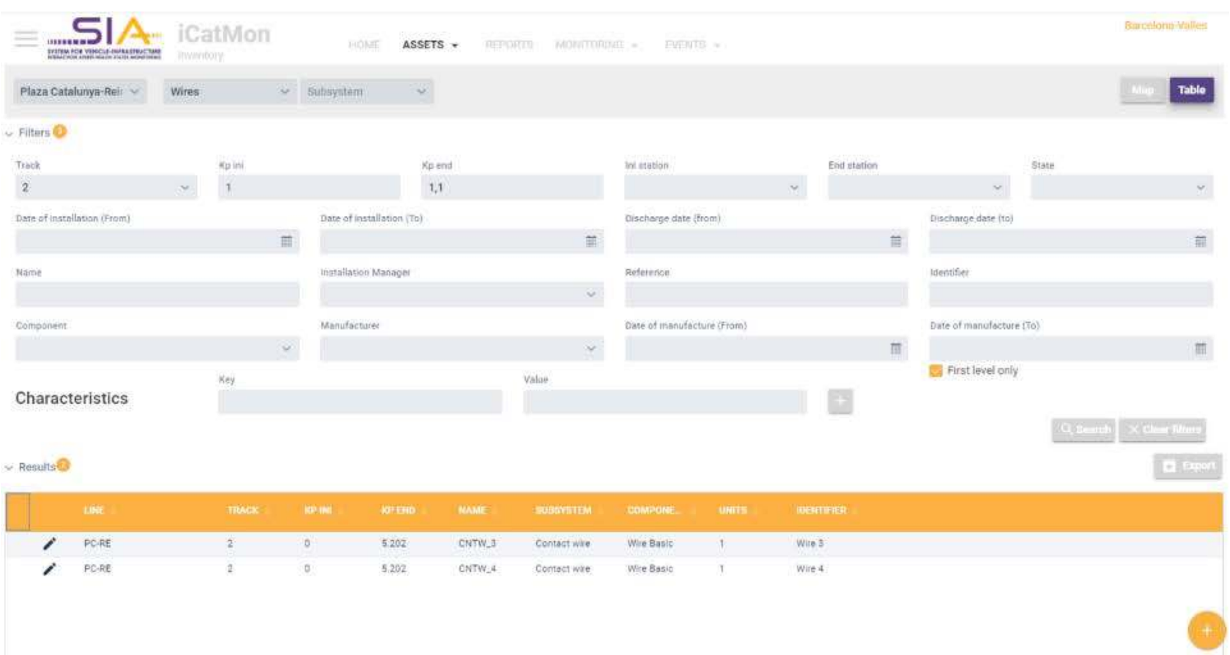


Figure 7-13: iCatMon assets inventory table representation

Clicking on the pencil on one of the assets or by means of the + button in the bottom right, a user with permissions can access to a pop-up form to edit or create new assets (Figure 7-14) based on the existing types of components, which we will address next from the Assets menu also. Double clicking on an asset in the table allows to see the details in the form, but not to change them. All these types of screens are common to iPantMon, iRailMon and iWheelMon as well:

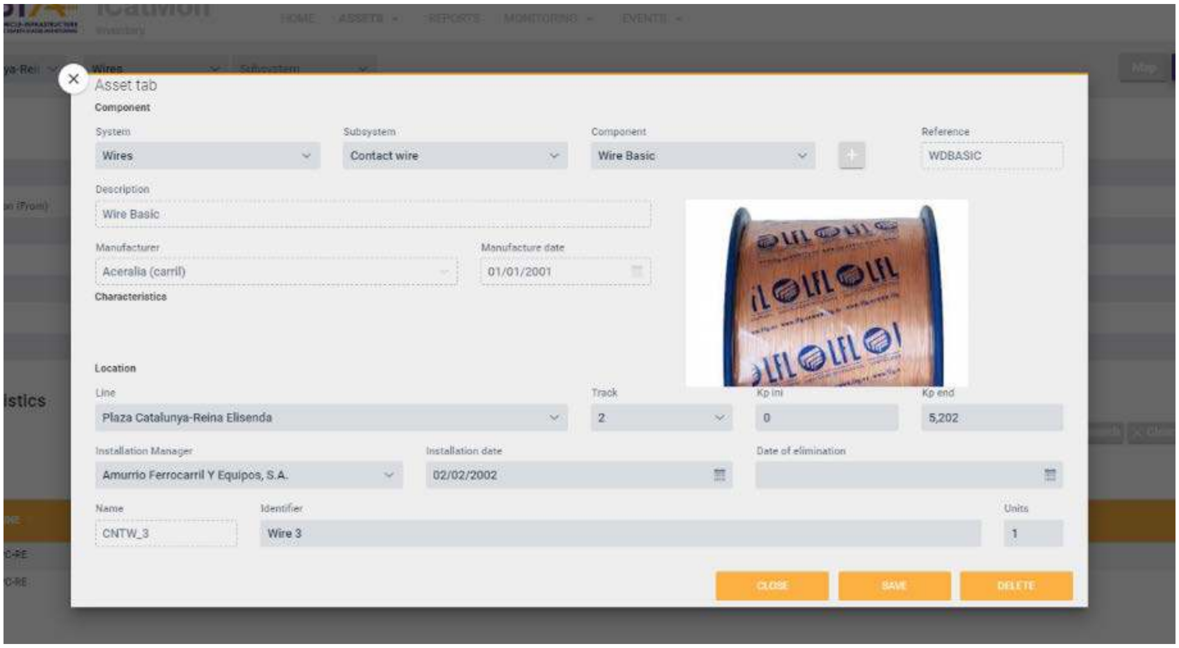


Figure 7-14: New asset form

Next option in Assets Menu is Components (Figure 7-15). In components screen, users can manage the different types of elements that may be present in their infrastructure. For example, in Components there could be a type of feeder supplied by a manufacturer, an in the Inventory users could create the thousands of feeders of that particular type of component in their infrastructure.

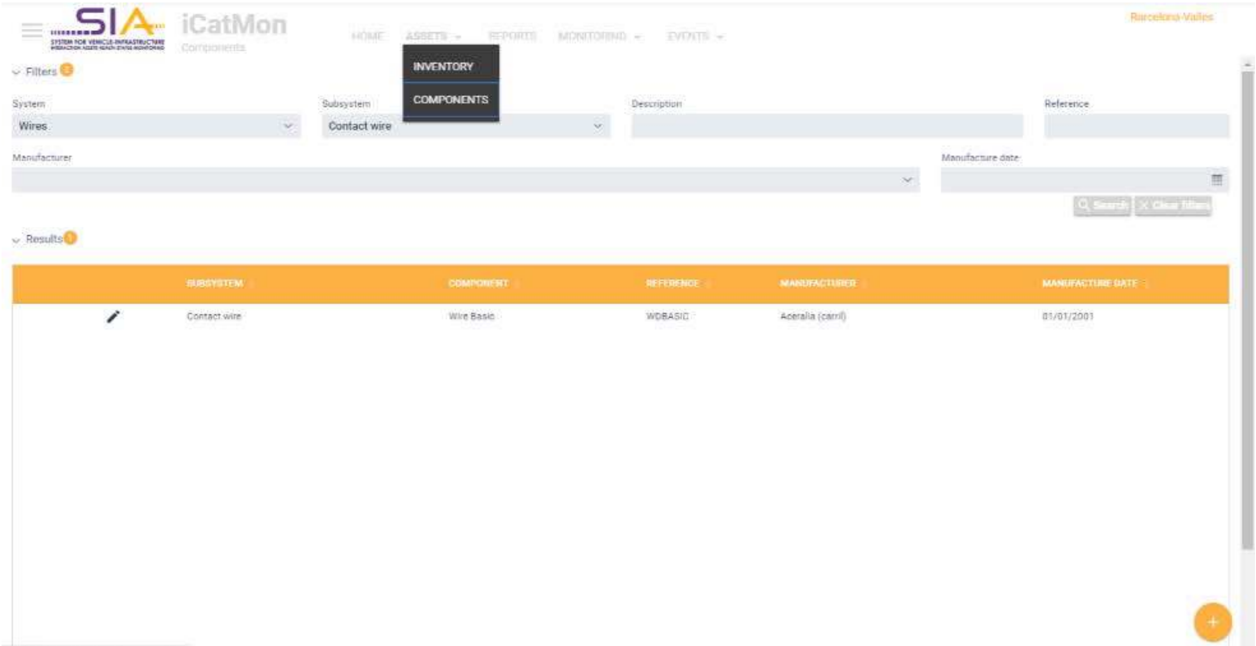


Figure 7-15: Components management screen

Similarly to inventory screen, user can create or edit a component by means of the pencil or the **+** button to access New Component Form (Figure 7-16).

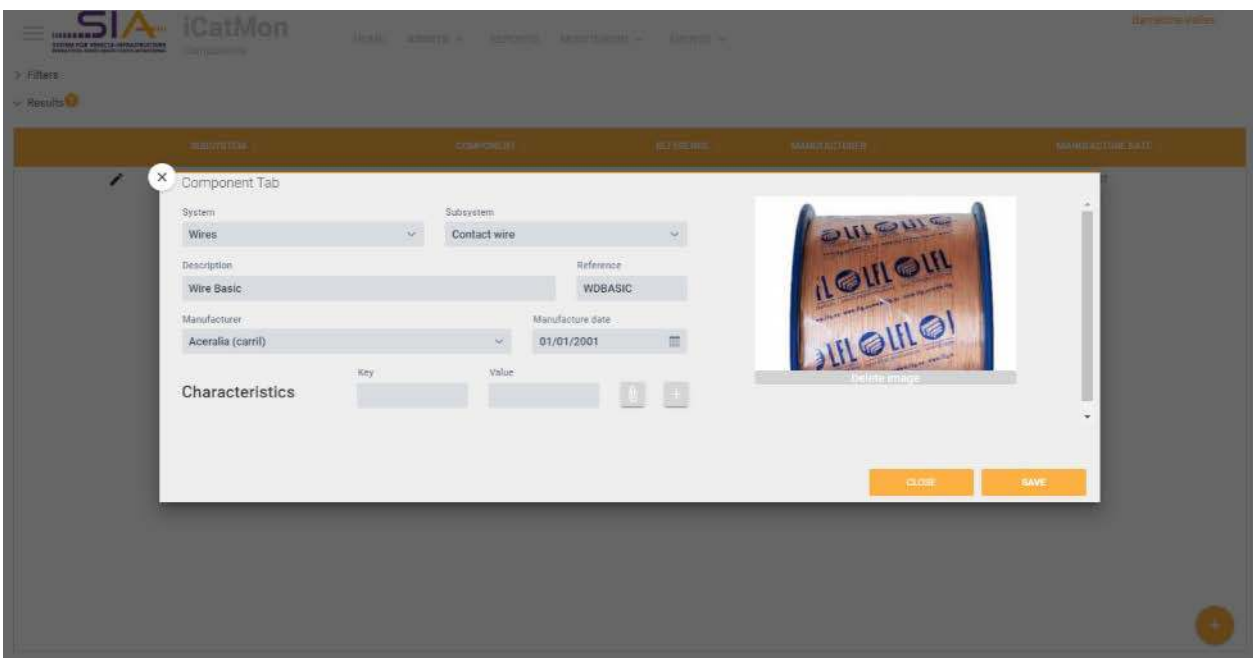


Figure 7-16: Component create/edit screen

The next option in iCatMon menu is Reports where data from the different inspection types created for iCatMon in Administration are shown. The information displayed here is georeferenced information not coming from SIA onboard sensors, which is displayed in Monitoring Menu, but from offline asynchronous reports uploaded to SIA, such as catenary auscultation/inspection reports. The default view is a map (Figure 7-17 and Figure 7-18), where users can zoom in and out and moving the mouse over they can see the data on each point. Each measurement point is highlighted with a different colour based on the thresholds established for KPIs in failures modes screen in Administration. This color code warns users about networks assets that may require a maintenance action. On the top right of the screen user can change to table or chart view of the data selected.

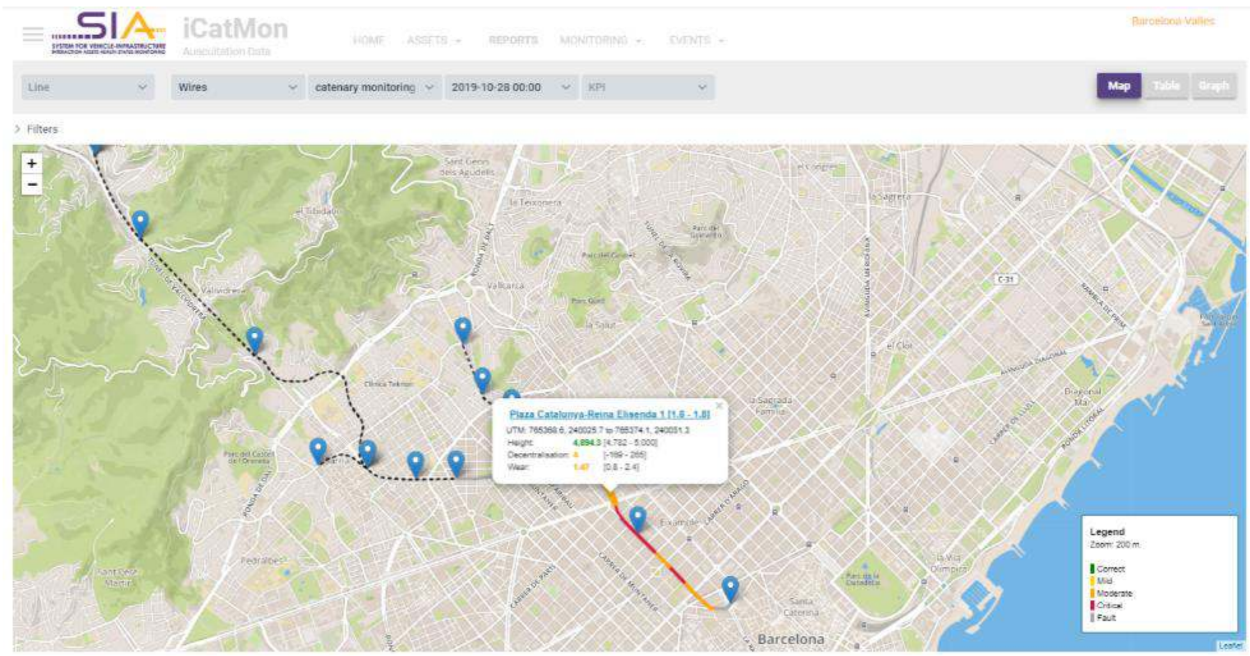


Figure 7-17: iCatMon catenary auscultation data displayed in a map in Reports screen

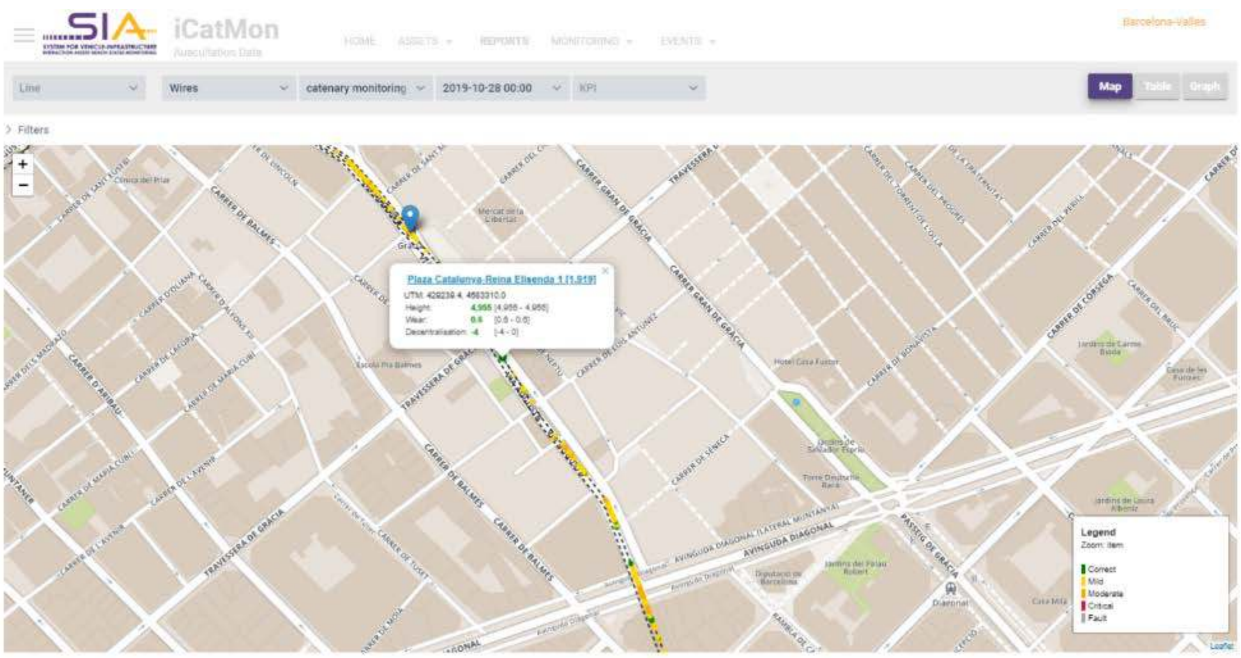
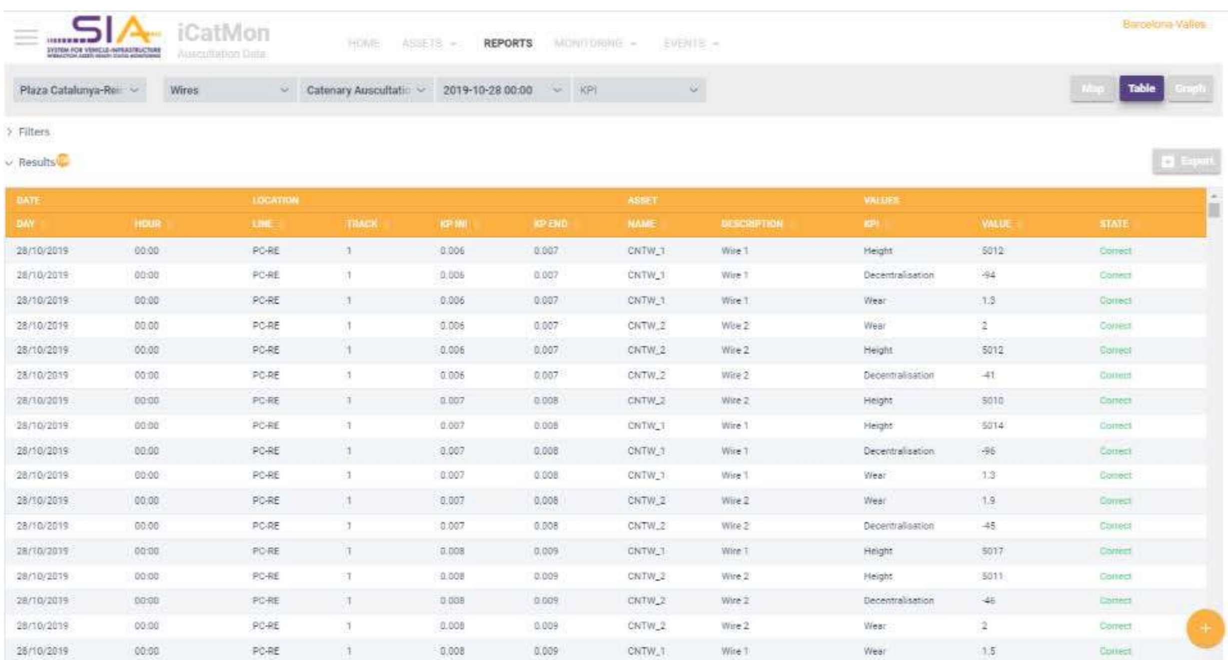


Figure 7-18: iCatMon catenary auscultation data displayed with high zoom in Reports screen

The catenary auscultation data can be also displayed in a table instead (Figure 7-19):



DATE		LOCATION				ASSET		VALUES		
DAY	HOUR	LINE	TRACK	KP INI	KP END	NAME	DESCRIPTION	KPI	VALUE	STATE
28/10/2019	00:00	PC-RE	1	0.006	0.007	CNTW_1	Wire 1	Height	5012	Correct
28/10/2019	00:00	PC-RE	1	0.006	0.007	CNTW_1	Wire 1	Decentralisation	-94	Correct
28/10/2019	00:00	PC-RE	1	0.006	0.007	CNTW_1	Wire 1	Wear	1.3	Correct
28/10/2019	00:00	PC-RE	1	0.006	0.007	CNTW_2	Wire 2	Wear	2	Correct
28/10/2019	00:00	PC-RE	1	0.006	0.007	CNTW_2	Wire 2	Height	5012	Correct
28/10/2019	00:00	PC-RE	1	0.006	0.007	CNTW_2	Wire 2	Decentralisation	-41	Correct
28/10/2019	00:00	PC-RE	1	0.007	0.008	CNTW_2	Wire 2	Height	5010	Correct
28/10/2019	00:00	PC-RE	1	0.007	0.008	CNTW_1	Wire 1	Height	5014	Correct
28/10/2019	00:00	PC-RE	1	0.007	0.008	CNTW_1	Wire 1	Decentralisation	-96	Correct
28/10/2019	00:00	PC-RE	1	0.007	0.008	CNTW_1	Wire 1	Wear	1.3	Correct
28/10/2019	00:00	PC-RE	1	0.007	0.008	CNTW_2	Wire 2	Wear	1.9	Correct
28/10/2019	00:00	PC-RE	1	0.007	0.008	CNTW_2	Wire 2	Decentralisation	-45	Correct
28/10/2019	00:00	PC-RE	1	0.008	0.009	CNTW_1	Wire 1	Height	5017	Correct
28/10/2019	00:00	PC-RE	1	0.008	0.009	CNTW_2	Wire 2	Height	5011	Correct
28/10/2019	00:00	PC-RE	1	0.008	0.009	CNTW_2	Wire 2	Decentralisation	-46	Correct
28/10/2019	00:00	PC-RE	1	0.008	0.009	CNTW_2	Wire 2	Wear	2	Correct
28/10/2019	00:00	PC-RE	1	0.008	0.009	CNTW_1	Wire 1	Wear	1.5	Correct

Figure 7-19: iCatMon catenary auscultation data displayed in a table in Reports screen

Alternatively, in interactive charts (Figure 7-20):

Figure 7-20: iCatMon catenary auscultation data displayed in a Chart in Reports screen

The next option in the menu is Monitoring, which displays screens similar to the Report's one for current, historical and predicted values of KPIs calculated by means of sensors developed in SIA. If we select Current the most recent data in SIA will be displayed (Figure 7-21) in a similar fashion to Reports screen:

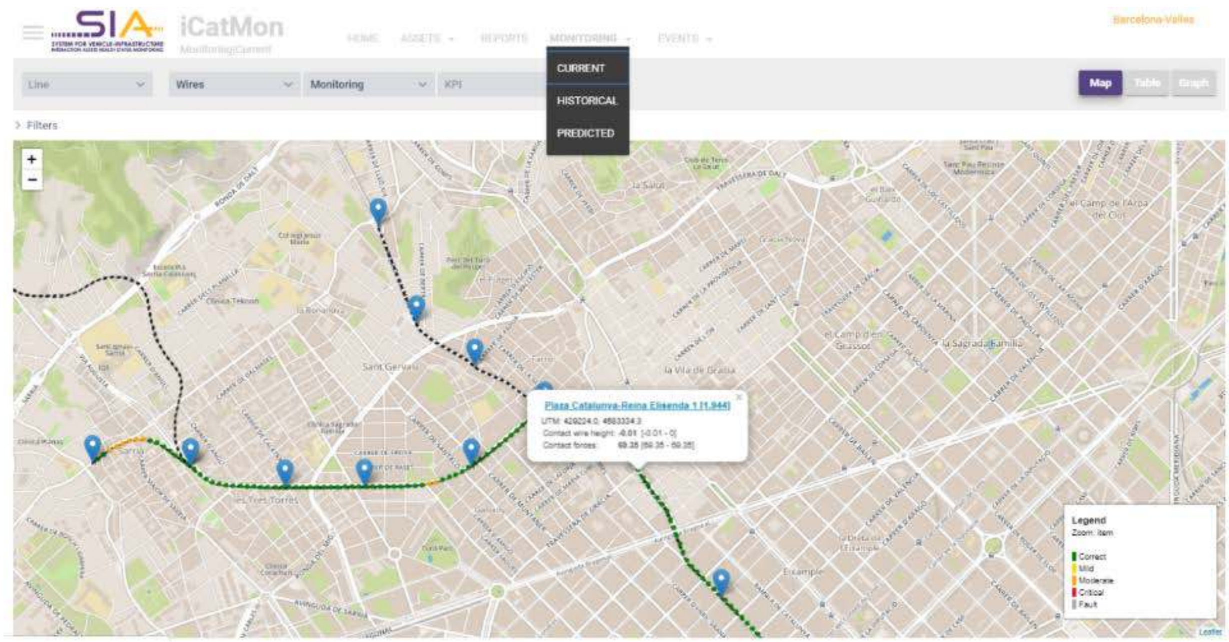


Figure 7-21: Current (latest) monitoring values displayed in map

Colour code, established in System administration, in Figure 7-21 alerts users on places where assets may require a maintenance action. Data can also be displayed in a table or in charts (Figure 7-22) in the same way as in Reports:

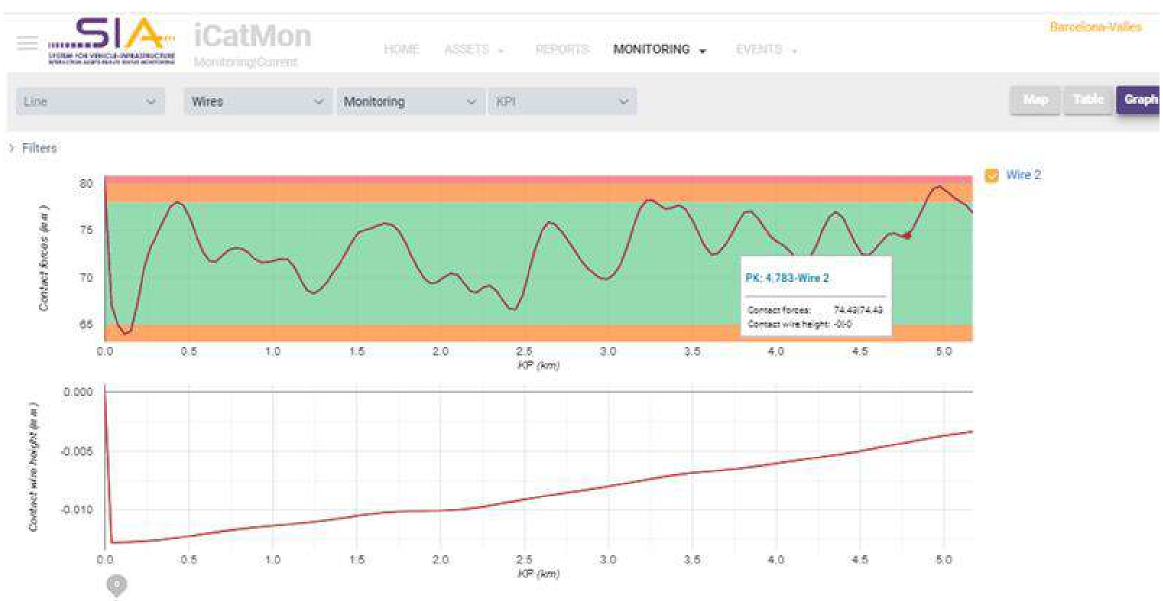


Figure 7-22: Current monitoring values displayed in charts

If instead of selecting Current the user selects Historical or Predicted, a similar screen will come up (Figure 7-23) but with the option of selecting a past or future date:

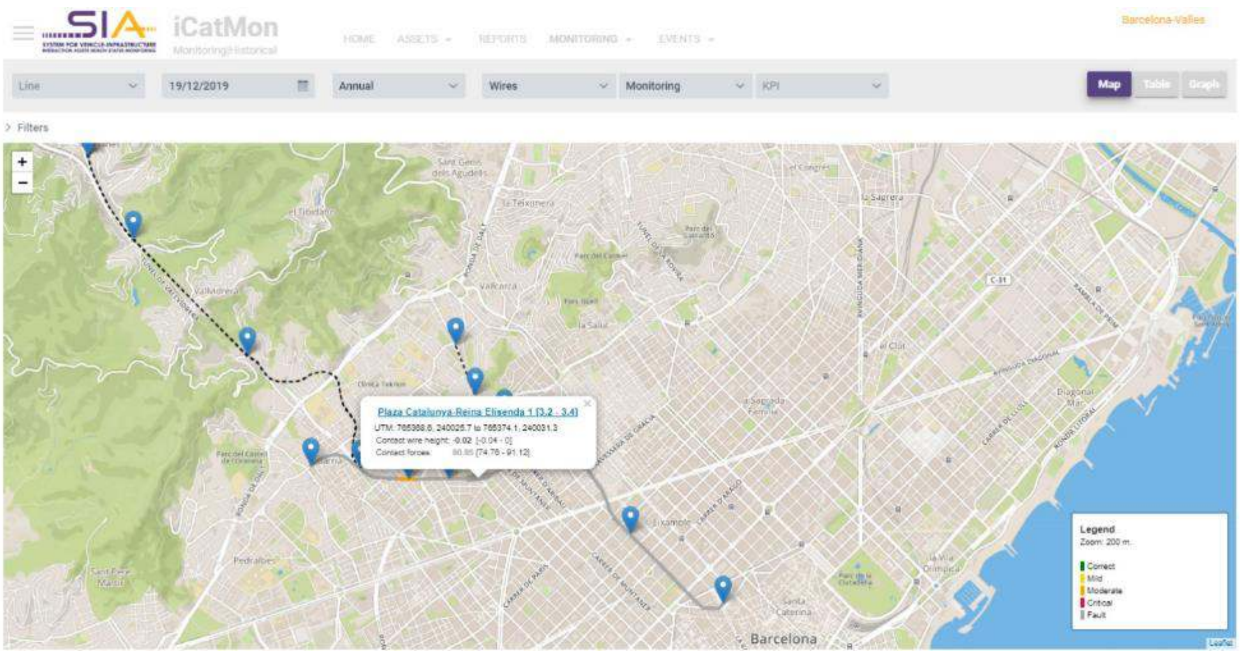


Figure 7-23: Historical on-board sensors calculated KPIs

In addition, the last option to the right in the iCatMon menu is events, where the application displays the abnormal events (warnings) detected monitoring the assets (Figure 7-24). It enables acknowledging the information and displaying it in table or map format. Double clicking on an element in the table, it changes to map view (Figure 7-25) locating the event raised on it and **the system suggests a recommended action to sort out the issue.** This table pops-up every time a new event is raised by the system, so the users connected to SIA are immediately notified.

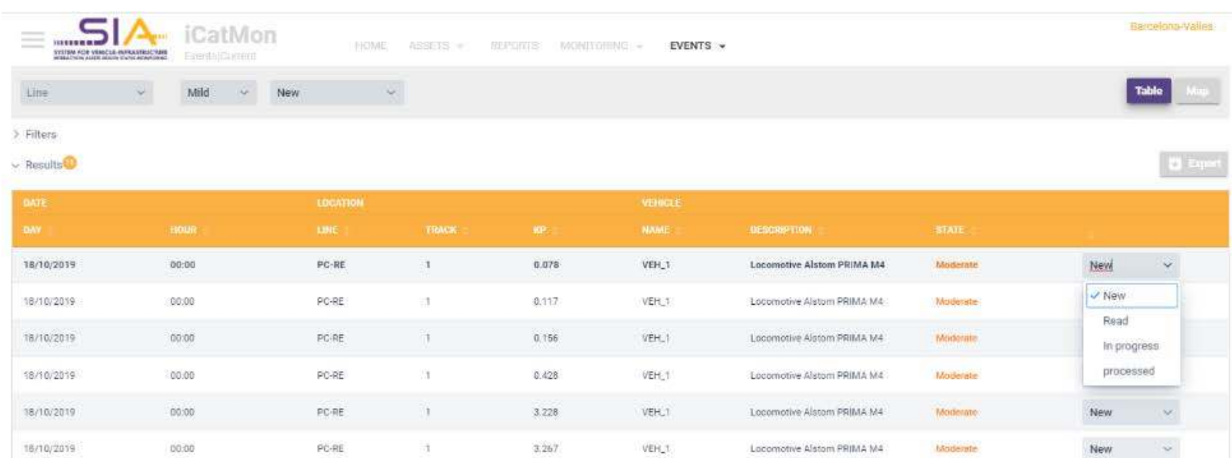


Figure 7-24: iCatMon current events raised by SIA

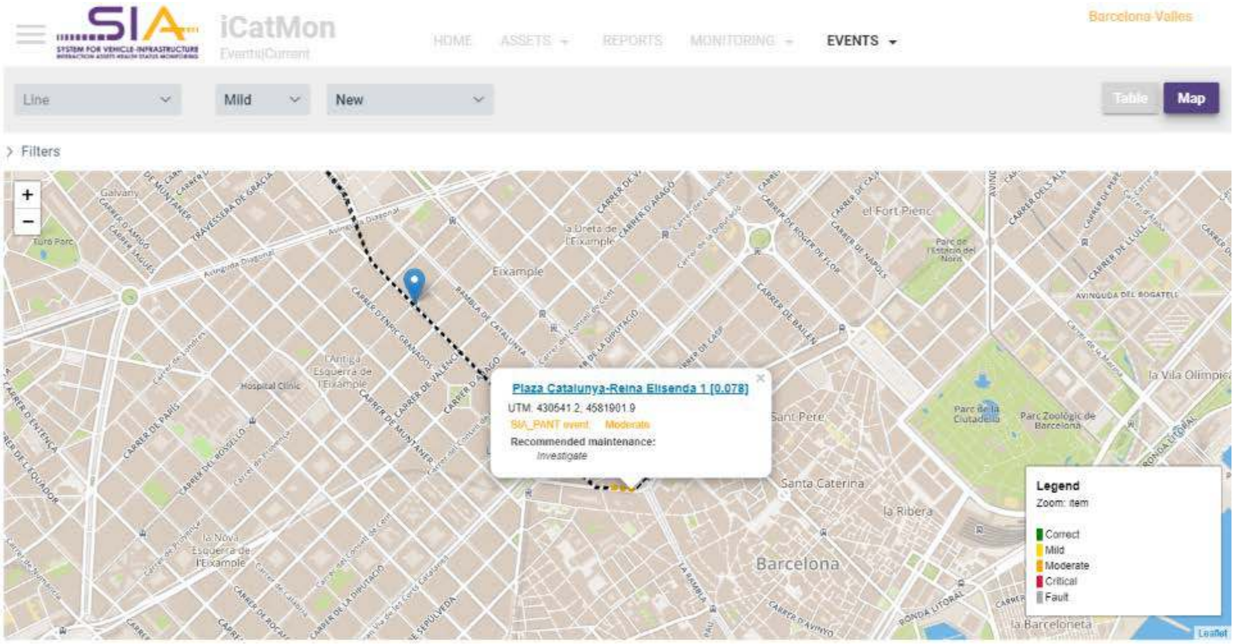


Figure 7-25: Events information in map format

7.3 iRailMon

Similarly to iCatMon, by clicking on the corresponding icon in the SIA Home Page (Figure 7-2), the user can access to iRailMon. As in all the services, the Inventory screen in the Assets menu option is shown by default with the menu on the top part of it to access other functionalities included in the site map in Figure 5-3. The menu options, screen and functionalities as the same as in iCatMon, but displaying data related to infrastructure rails (Figure 7-26 to Figure 7-28).

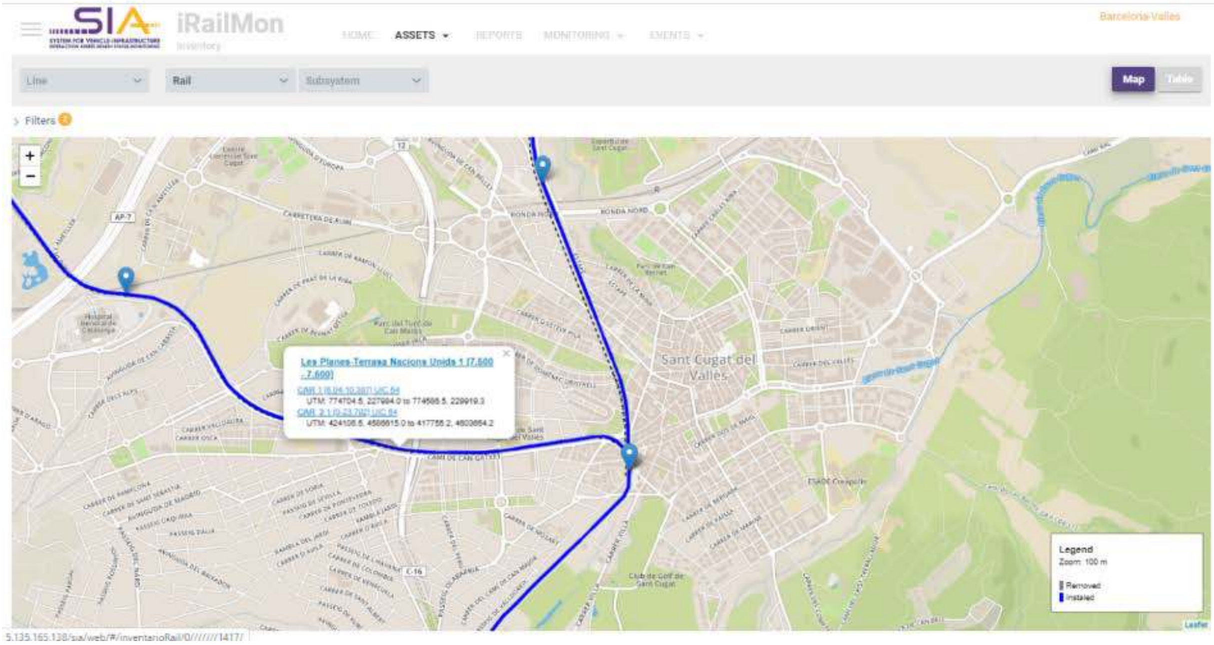


Figure 7-26: iRailMon assets inventory map representation with high details after zooming in

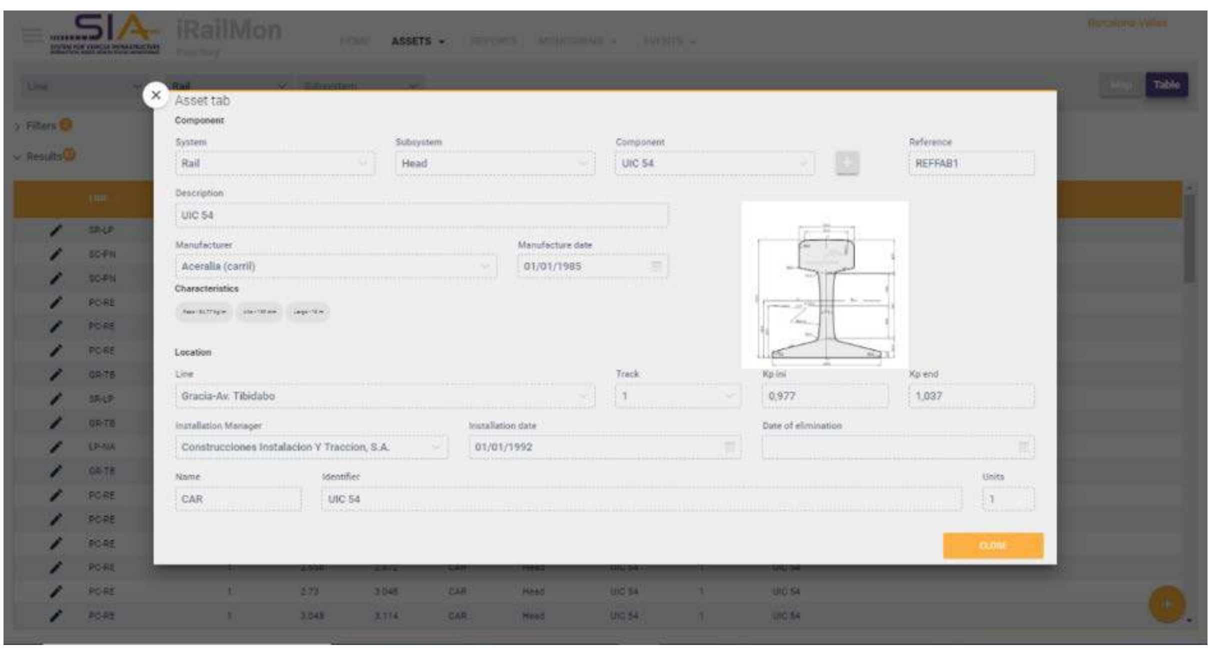


Figure 7-27: iRailMon New/Edit asset form

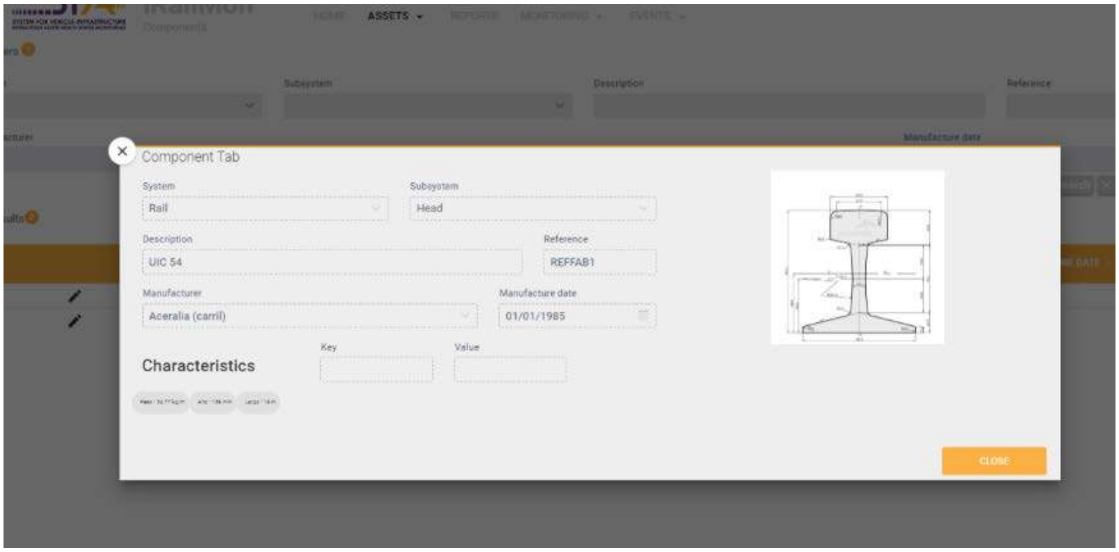


Figure 7-28: Component create/edit form in Components screen

Then, going through other menu options user can access Reports and Monitoring data, displaying the information in map, table and chart format for analysis (Figure 7-29 and Figure 7-30).

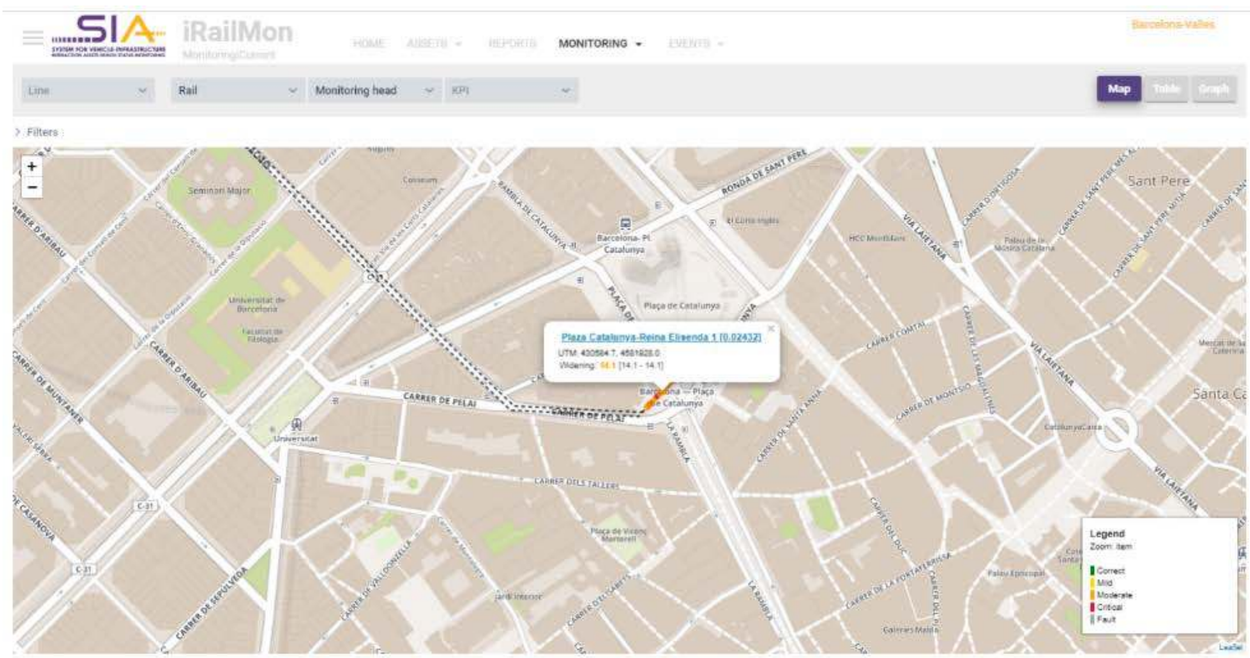


Figure 7-29: iRailMon Rail Head data displayed in map format Current Monitoring Screen

Figure 7-30: iRailMon Rail Head data displayed in chart format Current Monitoring Screen

An in the last menu option to the right, Events, user can check events raised by SIA, acknowledge them and take actions based on recommendations provided by the system (Figure 7-31).

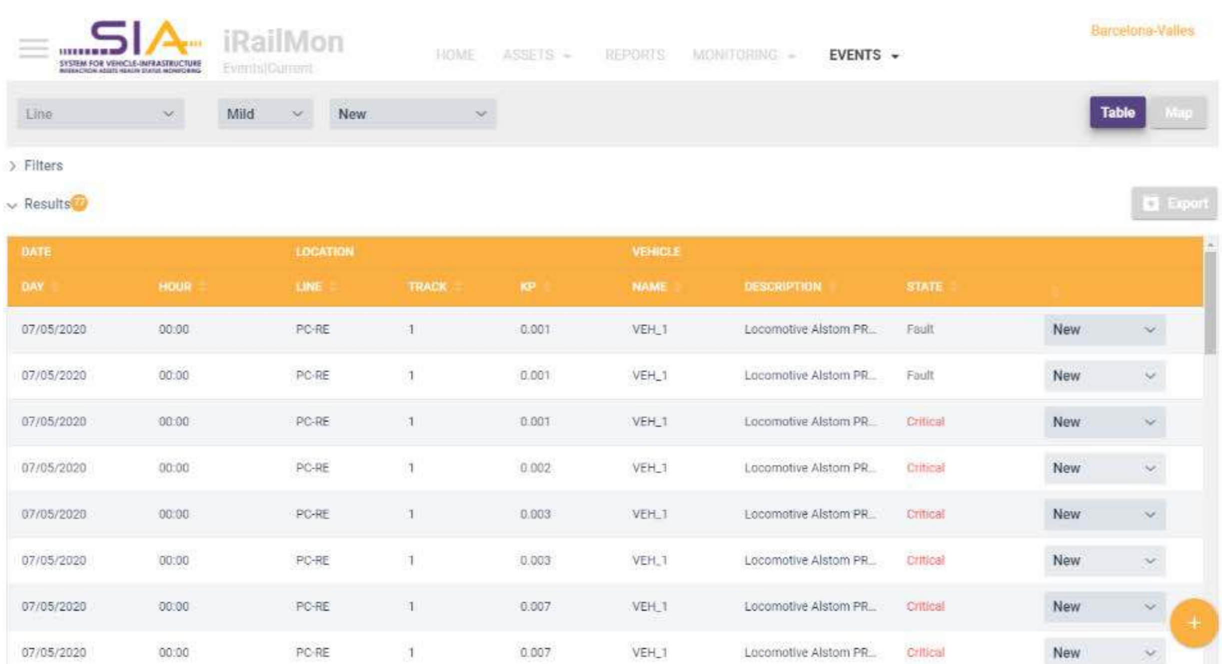


Figure 7-31: iRailMon latest system warning events Current Events Screen

And if the user double clicks on any of them, the view changes to map where the event is located and **a recommended maintenance action is suggested** (Figure 7-32).

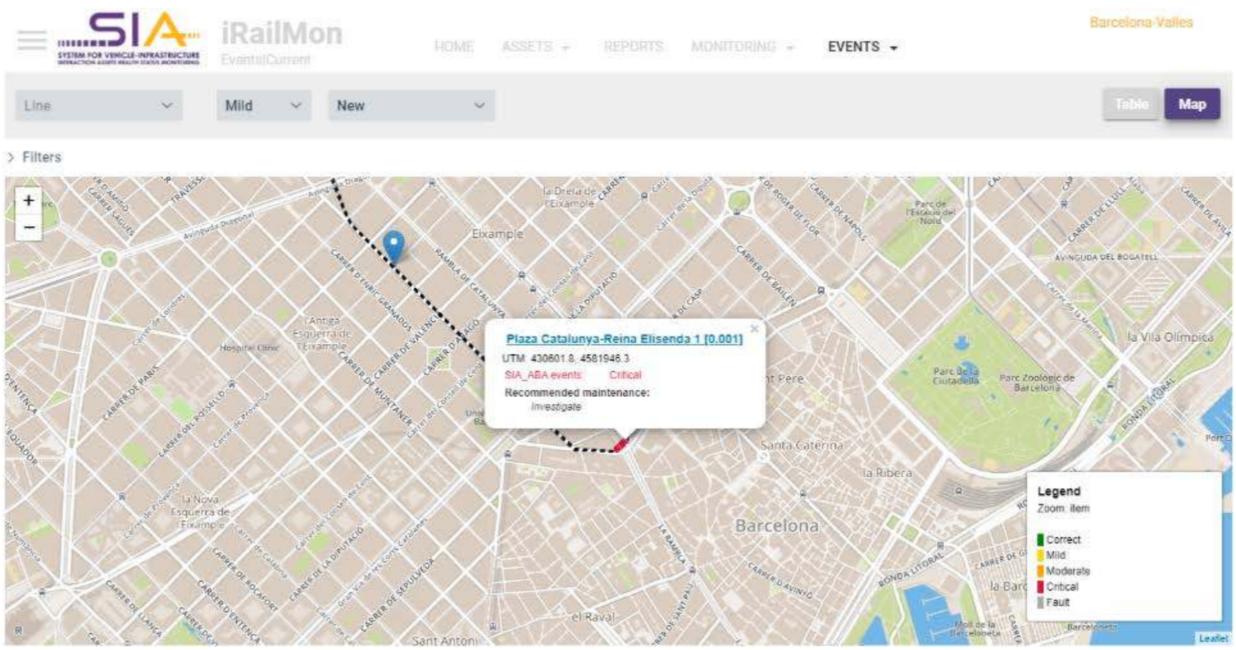


Figure 7-32: iRailMon current event information placed in map and suggested action

7.4 iPantMon

From SIA home page, clicking on the iPantMon icon user can access to iPantMon. Once again, the Assets Inventory screen is displayed first by default. As already mentioned, there is no map representation for assets in iPantMon and iWheelMon. On the other hand, pantograph assets are linked to a particular vehicle carrying them (Figure 7-33).

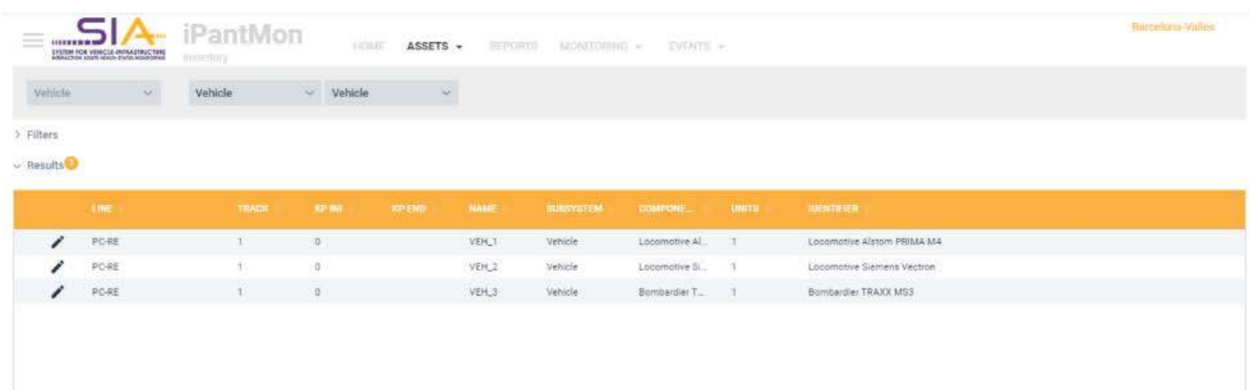


Figure 7-33: iPantMon assets inventory screen

In all of the SIA services, in the assets inventory screen existing components (manages in corresponding Components screen in Assets menu) in the Database are displayed. For each of these components there can be many different elements mounted in different vehicles. Using the **+** button in these screens new elements and types of components can be created (and edited).

The next option in the menu is Reports, where health status data (not collected by SIA sensors) can be uploaded and displayed. In the case of the pantograph it will be typically not georeferenced visual inspections and manual measurements carried out in maintenance workshops.

The next option in the iPantMon menu (Monitoring), displays monitoring data and the health-related KPIs (current and historical) as well as the predicted values by SIA algorithms. These data are collected by on-board sensors during operation, so they are georeferenced and displayed in map, table and graph formats as in iCatMon and iRailMon.

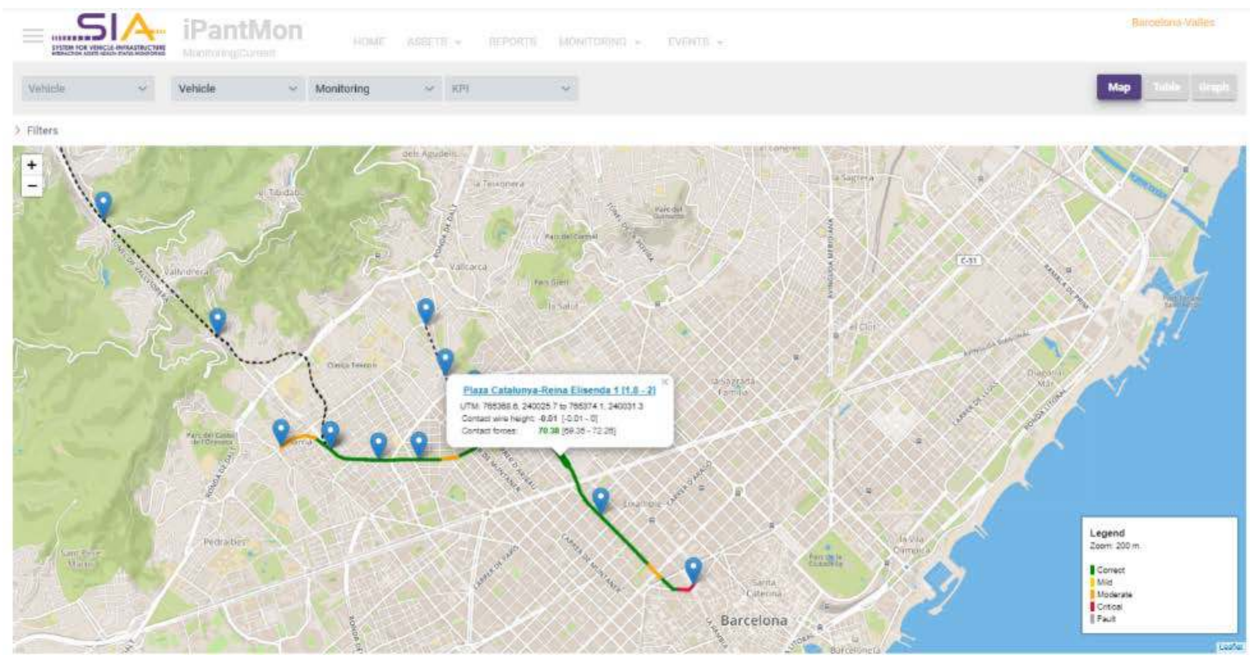


Figure 7-34: iPantMon current monitoring screen

Finally, in the Current and Historical Events menu options, user could check pending and past events related to pantographs maintenance raised by SIA.

7.5 iWheelMon

iWheelMon SIA service functionalities and user interfaces are very much similar to those of the other three services, specially to iPantMon ones, as assets are neither georeferenced. iWheelMon assets are installed on-board vehicles moving all over the railway network. On the other hand, measurements collected by SIA to monitor and assess health of wheelset assets are still georeferenced, so for Reports and Monitoring sections of the web application there is a map representation using EGNSS data.

Clicking on the corresponding icon in SIA home page, user can access iWheelMon, where the first screen displayed is Assets Inventory (Figure 7-35):

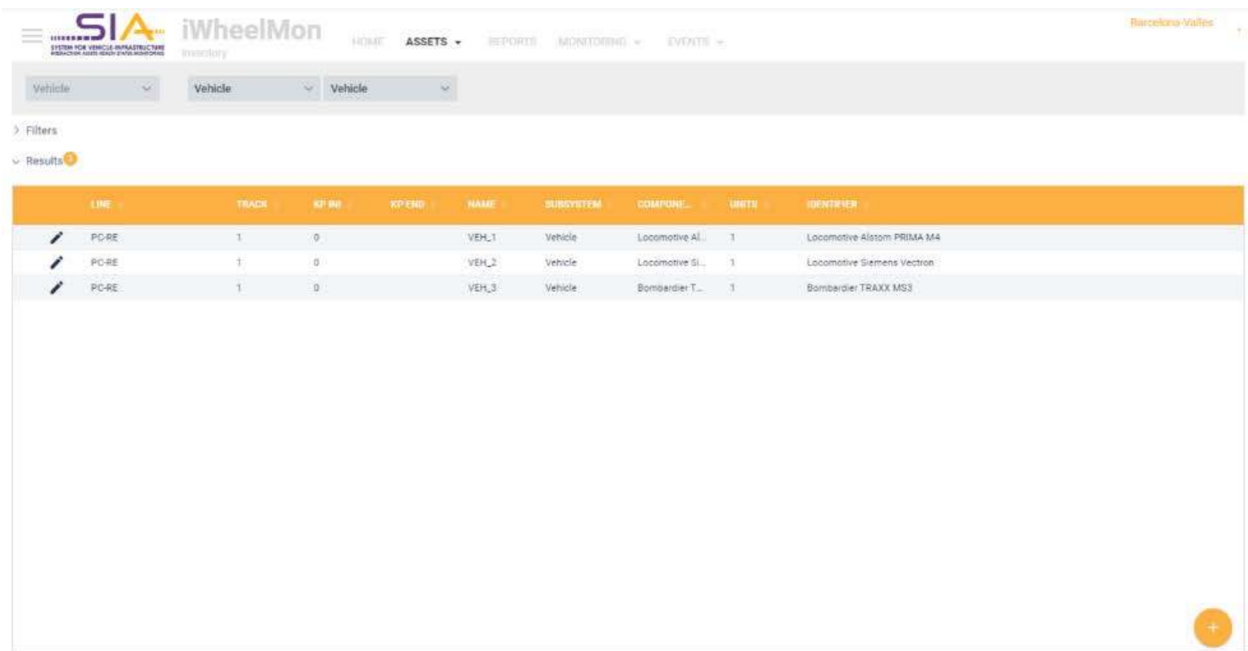


Figure 7-35: iWheelMon assets inventory screen

Clicking on the pencil to edit a vehicle type component, a form will pop up enabling the user to edit vehicle characteristics, and also to add wheelset type components (axle, axle box, monobloc wheels…) to the vehicle by means of the Add subcomponent button (Figure 7-36). A new asset tab will pop up to create wheelset components associated to the current vehicle. This could be done similarly in iPantMon to add pantograph components to the vehicles.

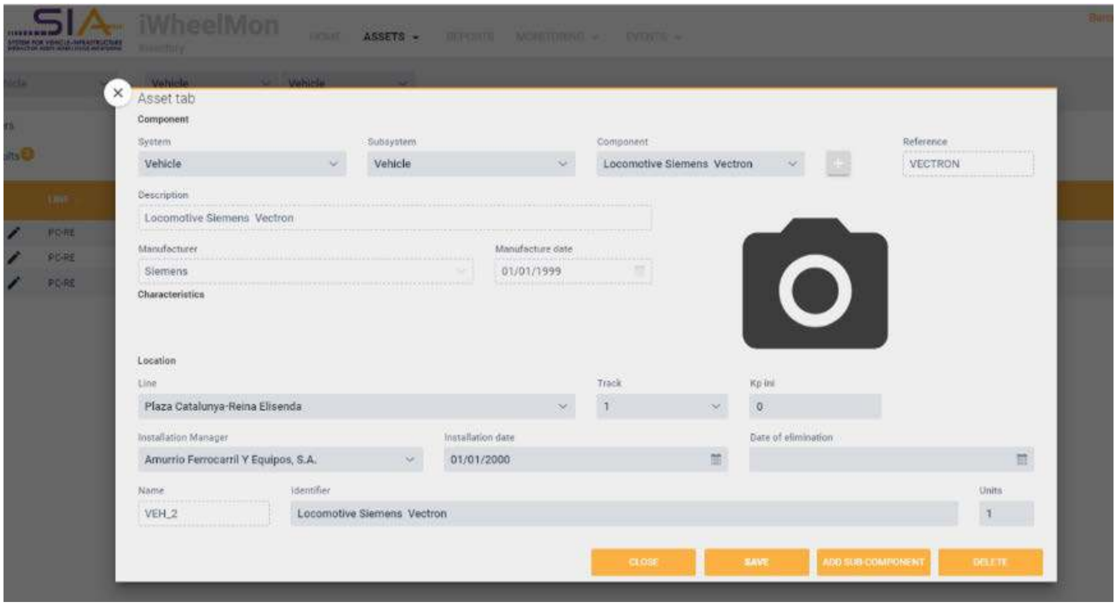


Figure 7-36: iWheelMon New/edit asset tab

The rest of iWheelMon menu options (Reports, Monitoring and Assets) look and behave in the same fashion as in the rest of SIA services explained in previous sections.

8 SIA_VP Subsystem Verification

8.1 Functional Requirements Verification

Req_ID	Description	Verification
SIA_DH_FR_1	Manage assets, failure modes, maintenance actions and inspection and monitoring data and KPIs.	Chapter 7
SIA_DH_FR_2	Receive data from on-board equipment (SIA_ABA, SIA_PANT and SIA_POS)	Section 4.2, Chapter 7
SIA_ DH_FR_3	Forecast future evolution of assets health status.	Chapter 7
SIA_ DH_FR_4	Display in a GIS assets and past, present and future monitoring data and KPIs.	Section 6.2, Chapter 7
SIA_ DH_FR_5	Display past, present and future monitoring data and KPIs in charts.	Chapter 7
SIA_ DH_FR_6	Generate alerts on current and future assets health.	Chapter 7
SIA_ DH_FR_7	Suggest maintenance actions to solve/prevent	Chapter 7

Table 8-1: SIA_VP Functional requirements verification

8.2 Software Requirements Verification

Req_ID	Description	Verification
SIA_DH_SR_1	Opensource: The software platform used to develop SIA-VP shall be opensource to promote reusability, maintainability, interoperability and avoid vendor locking.	Section 6.4
SIA_DH_SR_2	Security: Access to the system shall require a valid username and password. Passwords shall be robust using at least 8 characters mixing upper and lower case	Figure 7.1

Req_ID	Description	Verification
	letters and numbers. It shall be cancelled after 5 consecutive mistakes introducing it.	
SIA_ DH_SR_3	Multiplatform: SIA-VP shall be supported by different types of end user's platforms and devices. If designed as a web-based system, it will be supported by any device with a web browser (Chrome, Firefox, Edge).	Section 5.1, Chapter 7
SIA_ DH_SR_4	Responsiveness: SIA-VP shall be responsive, to be properly displayed in different devices resolutions.	Section 5.1, Chapter 7
SIA_ DH_SR_5	Communications: Secure communication protocols shall be used (HTTPS, FTPS).	Section 4.2

Table 8-2: SIA_VP Software requirements verification

8.3 Performance Requirements Verification

Req_ID	Description	Verification
SIA_DH_PR_1	Rapidity: SIA_VP shall display data as soon as possible. GIS representations shall take no longer than 10 seconds to display the information.	Open Map representation in Assets, Reports and Monitoring checking it takes less than 10 seconds to show data
SIA_DH_PR_2	Data management: System shall be able to cope with huge amount of data. As at least data from last 2 years should be available in the system, a minimum storage of 2 terabytes per year shall be foreseen.	Section 6.1, Section 6.3
SIA_ DH_PR_3	Scalability: System shall be hosted in a Cloud based infrastructure to be easily scalable to support the monitoring and maintenance of different sizes of railway infrastructures and vehicles.	Section 5.1, Section 6.3

Table 8-3: SIA_VP Performance requirements verification

8.4 Operational Requirements Verification

Req_ID	Description	Verification
SIA_DH_OR_1	Ubiquitous interface: System shall be accessible from many different places. A web-based interface will address this requirement.	Section 5.1 Chapter 7
SIA_DH_OR_2	Availability: As an application to manage critical infrastructures, it shall be resilient and available 24/7. The system architecture and software platform shall enable high availability measures such as redundancy, fault tolerance and disaster recovery to prevent and minimize downtime.	Section 6.3
SIA_ DH_OR_3	Interoperability: The system shall be able to import data from other end-user current information systems. WP 7 will address this requirement.	Section 4.2, Deliverable D7.1
SIA_ DH_OR_4	Users management: There shall be different types of user profiles with different privileges granted to access railway networks, SIA Services (iCatMon…) and manage configuration.	Section 7.1

Table 8-4: SIA_VP Operational requirements verification

9 Conclusions

The aim of this document is to provide an overview of the work done in WP6 and present the results achieved, namely the open source framework selected for georeferenced railway maintenance applications, and the SIA visualization user interfaces implemented with it. This framework and iCatMon, iRailMon, iWheelMon and iPantMon screens developed meet the technical and functional requirements defined in WP 2 at the beginning of the project.

There were no deviations in WP6 from the project work programme/Annex I (DOW). As a result, no efforts have been required to manage deviations, although now with field testing of the four SIA services it's sure that some adjustments and modifications will have to be done in terms of functionality and UX based on end user's feedback operating with the SIA_VP. INGECONTROL will analyse this feedback, implement it if so agreed with partners and update and extend this document accordingly until the end of the SIA project. Besides, the work reflected in these deliverables has been produced using historical and/or fake data, so although they were fine to assess functionality and performance, sample screenshots will also be substituted with real results from field testing in FGC and OBB railway networks in WP 8 "Test setup preparation and validation".

To summarize, the consortium believes the objectives for WP6 have been successfully achieved, but visualization interfaces are the cornerstone to ensure the market uptake and wide adoption by users of an application. Therefore, this is a living document that will be updated and extended based on the results obtained in other WPs as the SIA project progresses and the user interfaces developed are tested and improved. Specifically, this document will be revised and updated based on the final contents of D7.1 "Integration of SIA with end-user information systems" and D8.2 "Validation of SIA", when those documents are approved (presumably in September-2020 and March-2021 respectively).

10 References

[1] D2.2. SIA deliverable: SIA Architecture (approved version SIA_Architecture_and_Verification_Plan_v4.0)

[2] D2.1. SIA deliverable: End user requirements of SIA and validation plan (approved version SIA_Deliverable_D2.1_v5.0)

[3] Marvel - Software UI prototyping tool (https://marvelapp.com)

[4] ISO 1005-8. Railway rolling stock material

[5] EN50405. Railway applications. Current collection systems. Pantographs, testing methods for contact strips

[6] ISO 5003:2016. Flat bottom (Vignole) railway rails 43 kg/m and above

[7] EN50119. Railway applications - Fixed installations - Electric traction overhead contact lines

[8] Linux Ubuntu 18.04 "Bionic Beaver" LTS (https://wiki.ubuntu.com/BionicBeaver/ReleaseNotes)

[9] Apache Web Server (https://httpd.apache.org/)

[10] MySQL Database (https://www.mysql.com/)

[11] PostgreSQL Database (https://www.postgresql.org/)

[12] PostGIS - Spatial and Geographic objects for PostgreSQL (https://postgis.net/)

[13] OpenStreetMap https://www.openstreetmap.org/

[14] Leaflet - JavaScript library for interactive maps (https://leafletjs.com/)

[15] PHP Scripting language (https://www.php.net/manual/es/intro-whatis.php)

[16] Polymer Javascript library (https://www.polymer-project.org/)