SIA

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1 Executive Summary

This document is the first issue of Deliverable D9.2 the “Development and Delivery of the Exploitation Plan” document in the framework of the project titled “System for vehicle-infrastructure Interaction Assets health status monitoring” (Project Acronym: SIA; Grant Agreement No 776402).

This document has been drafted to provide an exploitation plan for the SIA project. This exploitation plan will identify how the project partners envisage their implementations, analyses, deliverables and other project outputs being exploited, either by themselves or by others, but particularly those who are targeted as part of the dissemination activities. Practical exploitation has been a key objective for all the implementation activities and the aim has been for exploitation to continue after the formal end of the project.

Within this document it is noted that there are several different exploitation routes available for the SIA system and the services available. This includes joint exploitation and individual partner exploitation opportunities. Firstly in this document the exploitable results from the project are explained in relation to how the various subsystems have been implemented in the available SIA services. It is noted that some further modifications are required to the developed system in order for the services to be at TRL9 and configured to specific rail operator requirements within their respective countries. This includes modification to the SIA DH (SIA Data Hub) and SIA POS (SIA Positioning) subsystems.

Positively, additional joint and individual exploitation opportunities have arisen due to the results produced and the completion of this project. This includes the MainRail venture started by INYCOM (sister company of INGECONTROL (SIA consortium partner)) and CEIT which will commercialise a software platform for the management of railway infrastructure maintenance. The new features of the visualization platform (SIA_VP) could be integrated in the platform, as well as SIA on-board components, to enable the monitoring capabilities of the SIA system.

In addition, there could be scope to use the business model outlined in the SIA Grant Agreement however before this is to be completed further modification would be needed for the SIA services to be at TRL9 and some configuration would be needed to specific end user requirements.

With regards to individual exploitation, there are several activities to be completed by each partner to utilise the results of the project. It is expected that technologies developed by SIA will be used in further research and development activities (outside of the action).

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3 Abbreviations and Acronyms

Abbreviation / Acronyms	Description
CDM	Component Degradation Model
COTS	Commercial Off The Shelf
DF	Dual Frequency
EGNOS	European Geostationary Navigation Overlay Service
EU	European Union
EUSPA	European Union Agency for the Space Programme
GA	Grant Agreement
GLONASS	GLObalnaya NAvigatsionnaya Sputnikovaya Sistema
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IM	Infrastructure Manager
IMU	Inertial Measurement Unit
NSL	Nottingham Scientific Limited (now GMV NSL Limited)
GMV NSL	Grupo Mecanica de Vuelo Nottingham Scientific Limited
OCW	Overhead Contact Wire
PNT	Position Navigation Timing
SIA-ABA	SIA Wheel-rail Interaction Monitoring System
SIA-CDM	SIA Component Degradation Model
SIA-DH	SIA Data Hub
SIA-PANT	SIA Pantograph-catenary interaction monitoring system
SIA-POS	SIA Positioning System
SIA-VP	SIA Visualisation Platform
SME	Small Medium Enterprise
TBC	To be confirmed
TBD	To be decided
UK	United Kingdom

Table 1: Acronyms

4 Introduction

This document has been created to provide a clear exploitation plan for the SIA project. This exploitation plan will identify how the project partners envisage their implementations, analyses, deliverables and other project outputs may be exploited, either by themselves or by others, but particularly those who have been targeted as part of dissemination activities. Practical exploitation has been a key objective for all the implementation activities and the aim is that exploitation continues long after the formal end of the project.

Throughout the project, the Dissemination, Communication and Results Exploitation Work Package (WP9) drives the dissemination and communication of project information, particularly for the purpose of ensuring future exploitation and the collaboration with other projects. The planning of exploitation activities is vital to ensure the sustainable, profitable and the wide scale exploitation of project results.

4.1 Background

The main goal of the SIA project is to develop four 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, at the points of the interaction between the vehicle and the infrastructure (wheelset, pantograph, rail and catenary).

4.2 Applicability to Other Deliverables and Work Packages

The final version of the system has delivered six subsystems as follows.

- SIA_PANT
- SIA_ABA
- SIA-DH
- SIA-POS
- SIA-VP
- SIA-CDM

The following table correlates the subsystems to the Work Packages that worked on the subsystem and the associated deliverables.

Subsystem	Technical Work Package	Deliverable(s)
SIA-PANT	WP2, WP4, WP5, WP6, WP7, WP8	D2.1, D2.2, D4.1, D4.2, D4.3, D5.1, D5.2, D5.3, D5.4, D5.5, D6.1, D6.2, D7.1, D8.1, D8.2

(Pantograph to catenary interaction monitoring system)		
SIA-ABA (Wheel-rail Interaction Monitoring System)	WP2, WP4, WP5, WP8	D2.1, D2.2, D4.1, D4.2, D4.3, D5.1, D5.2, D5.3, D5.4, D5.5, D8.1, D8.2
SIA-DH (SIA Data Hub)	WP2, WP3, WP4, WP5, WP6, WP7, WP8	D2.1, D2.2, D3.1, D3.2, D3.3, D4.1, D4.2, D4.3, D5.1, D5.2, D5.3, D5.4, D5.5, D6.1, D6.2, D7.1, D8.1, D8.2
SIA-POS (SIA Positioning System)	WP2, WP3, WP4, WP8	D2.1, D2.2, D3.1, D3.2, D3.3, D4.1, D4.2, D4.3, D8.1, D8.2
SIA-VP (SIA Visualisation Platform)	WP2, WP6, WP7, WP8	D2.1, D2.2, D6.1, D6.2, D7.1, D8.1, D8.2
SIA-CDM (SIA Component degradation model)	WP2, WP5, WP8	D2.1, D2.2, D5.1, D5.2, D5.3, D5.4, D5.5, D8.1, D8.2

Table 2: Correlation between each work package, deliverable and delivered subsystem

4.3 Management of Foreground

The management of IPR within the SIA project is discussed within deliverable D1.2 [1], the Intellectual Property Rights Controls Agreement deliverable. This activity has been coordinated by CEIT's IPO (Intellectual Property Officer), who has circulated throughout the duration of the project several templates in which all partners have included their exploitable results.

5 Exploitable Results

The developed SIA system is composed of six subsystems that enable the deployment of 4 end-to-end services (iCatMon, iPantMon, iWheelMon and iRailMon). A simplified version of the system architecture described in deliverable D2.2 [3] is shown in Figure 1. As described in deliverable D1.2 [1], this architecture is used to reference the exploitable results of the project.

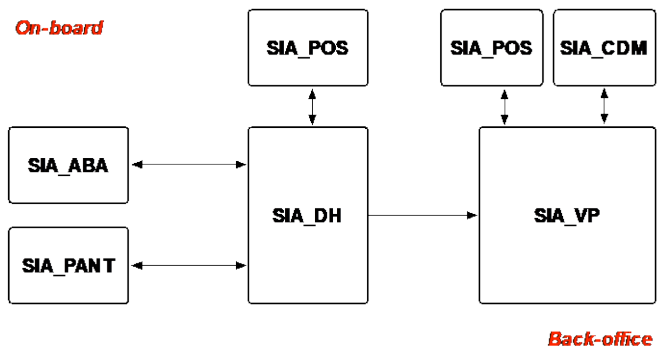

Figure 1: Simplified architecture of SIA system used for reference

With reference to figure 1, table 2 below describes the interaction between the SIA subsystems and the four new SIA end-to-end services available.

	SIA Subsystems	SIA Services			
		IWheelMon (A)	IPantMon (B)	IRailMon (C)	ICatMon (D)
1	**SIA_PANT**		X		X
2	**SIA_ABA**	X		X	
3	**SIA_DH**	X	X	X	X
4	**SIA_POS**			X	X
5	**SIA_VP**	X	X	X	X
6	**SIA_CDM**	X	X	X	X

Table 3: SIA subsystems to services

With the exploitable results described above in mind, according to the Grant Agreement, each beneficiary must take measures aiming to ensure exploitation of its results (directly or indirectly), in particular through transfer or licensing, by:

- Using them in further research activities (outside the action).
- Developing, creating or marketing a product or process.
- Creating and providing a service.
- Using them in standardisation activities.
- Others (Joint Venture, spin-off, etc.).

The available exploitation routes for the SIA developments are described in this deliverable document and are broken down between joint consortium exploitation activities and exploitation activities that will be completed individually by each partner on their own.

6 Investment Plan

It has been identified that it will be necessary to optimize some hardware and software components of the SIA system for it to be commercially ready based on the requirements of the end user and for the rail market for the domain and its application. The list of necessary optimisations required are noted in the following sections of this chapter.

6.1 SIA Data Hub (SIA-DH)

One of the main technical objectives of SIA is the development of the data hub (SIA_DH), this subsystem collects on-board information, provides accurate positioning and time stamping with high availability, and transmits the information to a trackside visualization platform. This on-board data integration platform and train-track communication hub integrates information from SIA_POS, the positioning platform, and the different sensing nodes (SIA_ABA and SIA_PANT) and transmits it to the back-office by means of the train-track communication hub. It also synchronizes the data from the different sensing nodes using the precise time reference available from the GNSS component.

The design of the SIA_DH is described in detail in deliverable D4.3 [5]. It is composed by a set of COTS components that are compliant with relevant standards for railway on-board electronic systems, according to our system requirements (D2.1 [2]). These components are integrated and protected by a 19” rack enclosure in accordance with the installation requirements and constraints of the pilot demonstrators of the project.

Two prototype units of the SIA_DH have been assembled and validated up to TRL7 in operational environments (3 pilot scenarios, as described in D8.1 [9]). However, some actions are still required to reach TRL9 for a commercially ready system:

1. **Redesign of the enclosure**. The actual enclosure of the system has been adapted to the particular needs of the end-users of the consortium. However, for a more attractive commercial solution, further exploration is required to design a more universal enclosure that enables
   a) Simpler installation with the lowest form-factor.
   b) It includes connectors for all the interfaces of the different modules (not used in SIA).
   c) It is cost-effective while contributing to the compliance of the system with railway standards.
2. **Certification**. Certification tests and compliancy with railway standards as specified in D2.1 shall be assessed by a notified body.
3. **Extensive field tests**. To reach TRL9, extensive tests in real operation conditions to assess the reliability of the system will be needed.

6.1.1 SIA Positioning System

The current version of the SIA POS unit/system is designed to be integrated into the SIA system and to be able to demonstrate the provision of precise real-time position and heading information in the railway environment. It is not currently a saleable product – as a stand-alone product or as part of the SIA system – but was intended as a solution to support the demonstration of the system to create multiple services. The status of the unit, and a preliminary list of changes that would be required to turn it to a saleable product, are described below.

6.1.1.1 Current Hardware Overview

For the SIA POS system the following components have been used:

- COTs Components:
    - Antonics Rail Certified GNSS antenna and cable
    - Septentrio AsteRx4 Rx card
    - IMU – UM7
    - CPU
    - PSU
    - Fans
    - Power Terminal Clock
    - Screws, cables, LEDs etc.

- Bespoke Components:
    - Bespoke enclosure to house all of the components
    - Internet connection via the SIA Data Hub

With these components the approximate hardware cost is €7000. This is based on the production of one demonstrator unit, if we using the same components for the production of a product we would expect to get discounts for bulk purchases.

6.1.1.2 Current Software Overview

- Provide real-time precise position and heading
    - PPP
        - Convergence: 15 minutes for 2 metres
        - Position accuracy: 2 metres (95% of the time – OBB testing)
- Currently we are using Novatel Inertial Explorer to process data from the PwrPak7D E2 SPAN. The SPAN wouldn't be part of an operational system or commercial product. It is just used at the current development phase in order to enable a ground truth solution to be derived (by post-processing SPAN measurements with Inertial Explorer) and therefore enable us to analyse the positioning performance of the SIA solution.

6.1.1.3 Known Limitations and Changes Required for Commercialisation

There are some limitations that have been identified for the current developed system taking into consideration if it were to be used as a product. The following changes are definitely required:

- Improvement required to software efficiency and processing time
  - Why?
    - To allow GNSS updates at 10Hz to help relative localisation and navigation
    - To reduce CPU loading – allow lower spec CPU (lower cost) and to reduce power draw
  - How?
    - Further software implementation optimisation
    - For this, effort and time is required (GMV NSL)

- Improved robustness of software
  - Why?
    - So that will run routinely without unforeseen problems
  - How?
    - Increased robustness in code
    - Much more testing than has been possible in the project so far
    - For this, effort and time is required (GMV NSL, plus support from rail operators

- Improved robustness of hardware
  - Why?
    - Poor performance of current IMU – better quality IMU required
    - To prevent damage when transporting
    - To protect against vibrations from usage
  - How?
    - IMU prices vary according to quality. For better performance and also for commercial purposes, it would be more beneficial to select a high quality IMU but this would come at greater cost.
    - Review / redesign inside connections and connectors
    - Weatherproof enclosure
    - Fire proof enclosure (according to the requirement of the railway)
    - For this, effort, time and some HW costs required (GMV NSL)

- Alternative precise products provider
  - Why?
    - Outages in corrections from current source have been experienced (it is a free service mainly for R&D)
  - How?
    - Look for alternative providers with better reliability (with some service level agreement would be ideal), and with equivalent (or better) accuracy performance
    - For this, effort and time required (GMV NSL). If a commercial provider is used, there may also be some ongoing service costs.

        - Consider Galileo High Accuracy Service (free of charge, expected to provide initial services in 2022 and reach full service operational capability in 2024).
        - Consider use of GMV precise products (https://magicgnss.gmv.com/magicGNSS_Correction_and_Product_EN.pdf), in order to provide an end-to-end service and product with GMV group level control and potential for improved performance.

The following list includes some possible improvements to optimise the system:

- Reduced convergence time
    - Why?
        - Having a reduced convergence time means you can start tests or operations much quicker – less wasted time.
    - How?
        - Better tuning
        - New algorithms (e.g. PPP ambiguity resolution)
        - Look at new / alternative precise products
    - For this, effort and time is required (GMV NSL)
    - Possibility of service costs if alternative precise products were to be used

- Reduce size of the SIA POS hardware unit
    - Why?
        - Having smaller (and lighter) unit would make it possible to use on more rail platforms – easier to fit into available spaces
    - How?
        - For this, effort, time and hardware costs are required (GMV NSL)

6.1.1.4 Standalone Version

The absolute localisation unit could also be a separate product in its own right. Many different applications require precise positioning and so this could serve those. As well as changes / improvements identified above, the following additional ones are required if this is to be a stand-alone product.

- Required
    - Approvals for the unit
        - EMC testing to get CE marking (or equivalent)
            - Would certainly need this if wanting to sell as stand-alone product. May also need it if is sold part of a SIA solution.
        - Some one-off effort and cost depending if the work is subcontracted
    - The unit will need its own internet connection
        - Could be inbuilt 4G modem?
        - Wi-Fi likely to be needed for applications
        - Could connect external one (if have correct connections)
        - Some one-off effort and cost to look at options.
    - Need to be able to do a reference trajectory solution
    - Need to improve interface for setting up and for getting data

        - Currently designed to go through SIA DH
        - Need easy to use interface for configuring, logging and retrieving files, getting outputs in real-time, etc.

- Nice to have elements:
    - Internal battery
        - Would be a useful option to have internal power for the unit when external power not available from a train.
        - Needs effort to redesign, plus there will then be additional hardware cost for each unit.

6.1.1.5 Rail Standard Approval Required

Furthermore, the SIA POS hardware would be a need to meet requirements on a national basis. In the UK these are normally driven by the Train Operator (e.g. East Midlands Railway) and/or the ROSCO (Rolling Stock Company) which owns the vehicles. The hardware installed would need to meet several railway standards such as the following in the UK (based on a 2012 engineering Railway Group Standards Analysis):

- GE/RT8015 - EMC Compatibility between Railway Infrastructure and Trains
- GM/RT2100 - Structural Requirements for rail Vehicles
- GM/RT2130 - Fire, Safety and Evacuation
- GM/RT2149 - Requirements for defining and maintaining the size of Railway Vehicles
- GM/RT2304 - Equipotential Bonding of Rail Vehicles to Running Rail Potential

<u>Summary of approximate cost to make required changes for commercialisation</u>

A ROM cost for these changes would be between €500,000 to €1,000,000 Euros.

6.2 Pantograph-catenary interaction monitoring system (SIA-PANT)

The SIA_PANT sub-system provides data acquisition of pantograph-to-catenary dynamic interaction, which will be used for condition monitoring of the catenary (i.e. Overhead Contact Wire) and the pantograph. Specifically, on the one hand, PANT data can be linked to OCW irregularities, such as wear, height and stagger. One the other hand, failure mechanisms associated to the pantograph, such as the wearing of the contact strips.

The design of SIA_PANT has been described in detail in deliverable D4.1 [4]. The core of the SIA_PANT sub-system is a set of sensors to assess the dynamic interaction of the catenary-pantograph system. The data need to undergo certain pre-processing, such as band-pass filtering, before reaching SIA_DH for real-time feature extraction, before they are sent to the visualization platform (SIA_VP).

A prototype unit of SIA_DH have been assembled and validated up to TRL7 in operational environments (2 pilot scenarios, as described in D8.1 [9]). However, some actions are still required to reach TRL9 for a commercially ready system:

1. **More field tests with prototype**. The duration of the field tests to validate SIA_PANT system has been shorter than initially planned. Plus, the pantograph/catenary interaction has been assessed only for a unique use case. Therefore, further field tests in other scenarios (e.g. light rail, metro, etc.) for longer durations (to evaluate trends in the data) are needed to enable more features in terms of its monitoring capabilities.
2. **Redesign of the enclosure**. The actual enclosure of the system has been adapted to the particular needs of the end-users of the consortium for a given model of a pantograph. However, for a more attractive commercial solution, further exploration is required to design a more universal enclosure that enables
    a) Simpler installation with the lowest form-factor.
    b) It is cost-effective while contributing to the compliance of the system with railway standards.
3. **Redesign of HW components**. The energy consumption of the system shall be reduced for an autonomous (and longer) operation by designing ad-hoc modules, instead of using COTS.
4. **Enhancing the energy autonomy of the system**. Further exploration in energy harvesting devices is required to reach higher energy levels to supply SIA_PANT components.
5. **Certification**. Certification tests and compliancy with railway standards as specified in D2.1 [2] shall be assessed by a notified body.
6. **Extensive field tests**. To reach TRL9, extensive tests in real operation conditions (and different scenarios, e.g. light rail, metro, etc.) to assess the reliability of the system will be needed.

6.3 Wheel-rail Interaction Monitoring System (SIA-ABA)

The SIA-ABA sub-system comprises sensors and processing capabilities for the collection and analysis of axle-box acceleration (ABA) data. Together with SIA-POS, SIA-ABA provides the data basis for the services iRailMon and iWheelMon that provide the monitoring of the railway tracks and the vehicle wheels, respectively. The SIA-ABA sub-system also provides the data basis for the component degradation models (SIA-CDM) concerned with wheels and rails. The SIA-ABA sub-system has been in pilot operation on an OBB in-service train since November 2020. The data provided by SIA-ABA are complemented with position and time information from SIA-POS in SIA-DH.

Hardware overview

The SIA-ABA sub-system hardware is described in detail in Deliverable D4.1 [4]. It comprises axle-box accelerometers for the recording of high-bandwidths high-range vibration data. The current set-up has two 3D accelerometers installed, one on each side of the train. The analogue ABA sensors provide a continuous electrical signal as output, which is converted by an analogue-to-digital converter (ADC). The processing hardware in the SIA architecture shared with the SIA-DH processing hardware in the form of a rail-certified industrial-PC.

Software overview

The software used for recording the ABA data, online analysis of ABA signals, event message generation for user feedback, and interfacing SIA-DH is implemented in the framework Robot Operating System (ROS). Several ROS modules have been developed and tested. The code is written in Python and C++.

Known limitations and required steps for commercialisation

The SIA-ABA sub-system has been successfully operated in pilot a pilot phase on an OBB in-service train since November 2020. Still, there are limitations to be addressed for commercialisation.

Thus far, only a single unit has been designed and tested with SIA-ABA. For a commercial product one next step would be a small series of devices running on in-service trains. This requires a commercial hardware partner and a train / infrastructure operator that commits to carrying the units.

The SIA unit in the OBB pilot is a solid basis and has shown the system operation on TRL7 (SIA-ABA components validated in application environment). With the COVID-related restrictions, however, the installation and performance of tests were delayed. In order to further advance SIA-ABA, longer tests and more time to analyse the gathered data would be beneficial.

The SIA-ABA sub-system comprises several hardware components. The employed ADC is a relatively expensive device. Further commercialisation requires the test of less expensive alternatives to possible facilitate a cheaper overall system. This ambition is in conflict with the requirement to employ rail-certified hardware. Hence, future commercialisation would also require further certification efforts by a dedicated hardware partner.

The SIA-ABA sub-system comprises several components that can be arranged in different housing solutions. That concerns mainly the ADC and industrial-PC, the ABA sensors are mounted on the axles after all. For commercialisation a tighter integration with a range of dedicated pilot vehicles would be beneficial. Here, rack solutions for the in-cabin hardware could be one option but would also limit the range of vehicles for retro-fitting and testing.

6.4 SIA Component Degradation Model (SIA-CDM)

SIA-CDM is concerned with the analysis of monitoring data (as provided by SIA-ABA and SIA-PANT) that is enriched with position and time information (as provided by SIA-POS). SIA-CDM is related to the four SIA services iWheelMon, iRailMon, iPantMon and iCatMon in the sense that it employs mathematical models, data, and algorithms to gather information about the respective assets from the ABA and PANT data.

Methods overview

Several model - and data-driven analysis strategies were investigated within SIA. A detailed review is given in Deliverables D5.4 [6] and D5.5 [7].

Methods on the PANT data include:

- Developing a virtual framework for the simulation of pantograph-catenary interaction, in compliance with EN50318 [11] to generate synthetic data to train machine learning algorithms. This framework utilizes different (parametrizable) models of the pantograph and the catenary.

- Modelling and data from sensors to determine the height of the overhead line.
- Modelling and data from sensors to determine the stagger of the overhead line.
- Modelling and data from sensors to determine the contact force.
- Modelling and data from sensors to determine the wear of the overhead line.
- Online functionalities that analyse the collected PANT data on-board and flag events such as larger shocks in the PANT data.

Methods on the ABA data include:

- Power spectrum analysis of the ABA data to monitor the wheel diameter. Here, EGNSS velocity information as provided by SIA-POS is relevant.
- The track-dependent analysis of georeferenced roughness indices that are derived from ABA data. Roughness indices have been chosen as KPI that relate to rail faults of different wavelengths. Here, position information from SIA-POS is relevant. With recorded data from several passes over the same tracks and the accurate track-selective offline position data, the temporal evolution of the different roughness indices can be monitored.
- Online functionalities that analyse the collected ABA data on-board and flag events such as larger shocks in the ABA data.

Software overview

- The SIA-CDM software has been implemented in different ways including ROS-modules (Python, C++) for online processing, as well as Python software for the analysis of georeferenced monitoring data (ABA and PANT data that is enriched with position, velocity and timing information).

Known limitations

- The methods and software developed within SIA-CDM are a solid basis for future work.
- In order to be incorporated into commercial products, the testing phase must be extended to include 1) further units for data collection to address the possible variance in the ABA and PANT data, and 2) more auscultation or maintenance data provided for the respective vehicle and infrastructure assets, and 3) the possibility to perform tests on controlled asset faults.

6.5 SIA Visualisation Platform (SIA-VP)

SIA_VP component is mostly ready for commercialization. Only some minor improvements are envisioned to foster sales in target markets after SIA project finishes:

- Multilingualism: Currently iCatMon, iPantMon, iWheelMon and iRailMon are only available in Spanish and English. System should be translated to German and French to enhance demos. Other languages would be available upon request by customers after purchase commitment.
- Client customization: Apart from language, client customization in terms of logos, user interfaces look & feel, metric system… would be a nice to have feature.

On the other hand, testing SIA system in WP8 has provided interesting insights for future product evolution based on operational and usability issues. This, together with technology landscape changes monitoring, enables partners to create a product backlog to include in future SIA versions:

- Merging iCatMon with iPantMon and iWheelMon with iRailMon: Monitoring data for iCatMon and iPantMon comes from SIA_PANT on-board equipment, and monitoring data for iRailMon and iWheelMon comes from SIA_ABA on-board equipment. This makes that the only difference between each pair of applications are the assets they deal with. So, user interfaces could be merged to facilitate maintenance operations. Depending on customer SIA purchase, different maintenance algorithms could be enabled to display the expected information to the users.
- Refactoring JavaScript web interfaces from Polymer to Angular: Angular is now much more widely used than 2 years ago compared to Polymer. Migrating the code to Angular would make software maintenance and hiring skilled developers easier. Nevertheless, this would be a large critical project whose benefits, risks and costs should be carefully assessed. In any case, this task will not start before knowing market response to SIA and several sales have been secured within the first 2 years.

Finally, the following issues need to be addressed to commercialize SIA system in a Software as a Service basis, where we also have to provision and operate for our customer's infrastructure and platform apart from SIA software, as well as provide support to users:

- Maintain bigger cloud resources: Running commercial operations will require much bigger resources than those used in SIA testing, where only several lines of 2 end users have been tested for a few months. Cloud resources are elastic, but their operation and charging to customers will need planning and even a dedicated platform team.
- SIA System performance monitoring: Aligned with previous item, commercial operation of SIA system needs the deployment and integration with supervisory software to monitor infrastructure and performance, guarantee quality of service and a quick response to prevent or solve unexpected events that may threaten the service availability. Connectivity with on-board equipment and latency are also included in this topic. There are many options, from commercial SIEMs (Security Information and Event Management) as Splunk to open source infrastructure/network monitoring such as Nagios or Zabbix.
- Service Desk: SIA commercialization will also require setting up a Service Desk to support customer's requests. The Service Desk would have different support levels such as a contact centre (first level), a second level of skilled technicians and a third level with domain experts to solve the most difficult issues and provide fixes to bugs. Every technology provider in SIA will have to participate at least in the Second level of Support. A ticketing system such as JIRA (open source) to track the reported issues life cycle will have to be deployed as well. INGECONTROL has a wide experience establishing and running User support services based on ITIL standards and could lead the Service Desk.

7 Market Analysis (GNSS in Rail)

7.1 Introduction

The aim of the SIA project is to provide 4 ready to use services for railway maintenance. Therefore within the market analysis below, we have focussed on the areas of rail infrastructure and vehicle maintenance and the differentiator in the SIA system, the use of EU GNSS in the system in the context of the rail industry.

7.2 Rail Infrastructure Monitoring

There are 3 broad areas where GNSS is (or has potential to be) used in rail, fleet management and tracking, monitoring and inspection, and train control.

For monitoring and inspection there are many different applications, including monitoring/survey of communications coverage, automated inspection of track condition, surveying of infrastructure, etc. These applications may involve all trains, or dedicated engineering / maintenance trains, travelling on the rail network and logging various information of interest as well as the position information. The position may not necessarily be required in real-time, but reasonable accuracy is required and as there may be difficult GNSS conditions to cater for.

This area is the target for the SIA system/service in particular the automated inspection of infrastructure and asset health status monitoring with EGNSS. The type of potential users for the four SIA services iWheelMon, iRailMon, iPantMon and iCatMon include:

- Integrated operators
- Infrastructure managers
- Train operating companies
- Maintenance subcontractors

With regards to the European railway market, in 2021 a final version of the seventh monitoring report on the development of the rail market was completed and delivered by the Commission to the European Parliament and The Council under Article 15(4) of Directive 2012/34/EU [RD 2]. The main findings and trends were covered for 2015 to 2018/2019 (in some areas), therefore excluding the implications of the COVID-19 pandemic on the industry. Also since the United Kingdom was a Member State until 31 January 2020, the report also provides totals and averages for the EU28.

The main findings and trends for 2015-2018 in EU27 (with the exception of the length of the high-speed network, for which the comparison is with 2019) applicable to rail infrastructure asset monitoring were that:

- Rail traffic increased annually by 2.5% for passengers and by 4.1% for freight;
- The length of the high-speed network increased by 17% between 2015 and 2019;
- The total length of tracks that were declared to be congested more than doubled;
- The average market share of competitors to national incumbents in 2018 was:

- 42% of rail freight markets (an increase of 8 percentage points);
- 10% of commercial passenger markets (an increase of 2 percentage points);
- 16.2% of public service obligation (PSO) passenger markets (a decrease of 0.5 percentage points).

Furthermore with specific reference to key market figures and statistics for rail infrastructure monitoring, a large proportion of infrastructure manager's revenues are for track access charges (more than 80%) in the EU27 in 2018 (84% from freight trains and 88% from passenger trains). Furthermore, track access charges for high-speed rail were higher than other passenger charges, with the highest charges in 2018 occurring in the United Kingdom (EUR 18 per train kilometre) and Belgium (EUR 10.6 per train kilometre)[12].

These specific statistics are of importance as they what has been discussed is where SIA service would provide specific cost benefit.

7.3 GNSS in Rail

GNSS is becoming more widely used in the Rail industry in safety and non-safety-critical applications, although perhaps not yet to the same extent as some other sectors. Partly this is due to the rail environment having sky obstructions meaning that GNSS performance can be degraded. Nevertheless, there are 3 broad key areas for the use of GNSS in rail including, fleet management, monitoring, surveying and inspection and train control. Some example applications that fit into these areas include:

- Main Line Command & Control Systems
- Low-Density Line Command and Control Systems
- Asset Management
- Passenger Information Systems
- Driver Advisory Systems (DAS)
- Predictive Maintenance
- Trackside Personal Protection [10]

8 Exploitation Routes

8.1 Overview

For the exploitation of the developments within the SIA project, the system may be utilised and exploited in two methods in use of the results of the project by individual partners and as a consortium in which there are different options for such a pathway.

8.2 Joint Consortium Exploitation Plan Options

The following options are available to the SIA consortium for the joint exploitation of a SIA system for use by end users:

- It could be an option to still utilise the business model suggested in the Grant Agreement however but there would be limitations to the actual implementation of this including all consortium members in the business. This is due to some consortium members being non for profit research organisations.
- INYCOM (INGECONTROL's sister company) and CEIT have created the company 'MainRail'. MainRail commercializes a Software Platform for the management of railway infrastructure maintenance. The new features of the visualization platform (SIA_VP) could be integrated in the platform, as well as SIA on-board components, to enable the monitoring capabilities of SIA system.

It is noted that the flexible offline option described in D7.1 [8] to import/export files will always be available. Nevertheless, as for example we are going to demonstrate the online integration with VIAS maintenance software during project extension through MainRail, this type of integration with new software systems can be easily implemented for a few thousand euros which is marginal compared to the total cost of the ownership that SIA will have.

8.3 Individual Partner Exploitation Plans

8.3.1 CEIT Exploitation Plan

CEIT is a private non-profit research centre, whose mission is to contribute to improving the competitiveness of the business community, through applied research projects that generate advanced solutions based on scientific and technological excellence. Likewise, CEIT pretends to contribute to the training of young researchers who will lead the necessary changes to bring companies to the first level of international competitiveness.

In the project, CEIT has been working in all activities of the project that have a relation to the pantograph-catenary ecosystem. In particular, CEIT has developed SIA_PANT and SIA_DH, contributed significantly to SIA_CDM and SIA_VP, and to SIA_POS with a lower dedication.

CEIT plans exploiting the results of SIA (according to section 4.3) as follows:

- **Know-how for new projects**. The know-how gained in the project will be further exploited in new R+D project proposals, at regional, national and European level. In this sense, as a Candidate Funding Member (CFM) of Europe's Rail Joint Undertaking (ERJU), CEIT will continue the research carried out in SIA to build new technology.
- **Know-how for consulting services**. The know-how gained about the pantograph-catenary interaction will be used for consulting services with OEMs, TOCs and IMs in two possible ways: firstly, by simulating the quality of the contact between the pantograph and catenary for given specific conditions. Secondly, by obtaining the monitoring data of the health status of these assets by installing SIA_PANT.
- **Publications**. Disseminating the results of the projects with publications in JCR Journals and International Conferences it in the DNA of CEIT. During the project (and after its conclusion) CEIT will contribute with international scientific publication and keynote presentations in relation with the results of SIA.
- **New service offering**. Using the pantograph-catenary interaction model (that has been validated in compliance with EN50318:2018 standard), CEIT plans offering to OEMs, TOCs and IMs a new service consisting on a comprehensive assessment of the pantograph/catenary interaction for different conditions (e.g. for the inclusion of new running gear, new materials/geometries of the catenary, electrification of existing lines, etc.)
- **Development of new product**. CEIT plans to develop a new SW tool to support the design of new electrification systems based on the pantograph-catenary interaction model developed in SIA.
- **Development of new product**. With the combination of SIA_PANT and SIA_DH, CEIT plans developing a new product for the auscultation of railway infrastructure.
- **Commercialization of new product**. CEIT plans commercializing a new product developed during the project: an energy harvesting device that will enable digitalization applications in freight wagons.
- **License technology**. CEIT has created a spin-off company with INYCOM (INGECONTROL sister company) for the management of the maintenance of railway infrastructure. MainRail commercializes a SW tool, whose features will be enhanced with the applications developed in SIA for the (infrastructure-related) services (iCatMon/iRailMon). In this sense, CEIT will license to MainRail new features developed in the project (i.e. communications, data structure, etc.).
- **Another sector**. CEIT is currently exploring the utilization of SIA technology in the automotive sector, to contribute to an auscultation system and supporting SW for the management of road infrastructures.

8.3.2 GMV NSL Exploitation Plan

The following options are under consideration at GMV NSL for exploitation of the outcomes from the SIA project:

- Collaboration with Main Rail to exploit the SIA system as a whole or individual components of it (including SIA_POS).

- Application of SIA_POS within commercial opportunities related to applications in the railway domain that require high accuracy and high availability train positioning, e.g. remote condition monitoring, 'rough ride' monitoring. Potential clients are likely to be infrastructure managers (IM) or engineering companies that provide services to IMs.
- Exploitation of SIA_POS technology within other markets that require high accuracy and high availability positioning e.g. automotive, unmanned aerial vehicles (UAVs), robotics.
- Further development of SIA_POS technology within institutional research and development projects.

It is also of note that a license will be available for the SIA_POS technology to be exploited by other companies within the GMV group, with internal knowledge transfer and training provided by GMV NSL as required. The GMV group is a world leader in high precision GNSS technology via its GAP (GNSS Algorithms, Products and Services) division within the GNSS business unit.

8.3.3 INGECONTROL Exploitation Plan

INGECONTROL foresees the following individual exploitation plans:

- **Technology licence:** INGECONTROL is planning to grant a license of its technology developed in SIA to INYCOM, a company to whom it has a strategic partnership. As aforementioned, INYCOM and CEIT have a start-up called MainRail dedicated to commercializing software for maintenance operations in railway sector. INYCOM would yield the license to MainRail, who could be interested in improving its products and services using functionalities developed in SIA by INGECONTROL for asset maintenance in iCatMon and iRailMon. These functionalities could be the visualization platform, the railway domain ontology, the database model and the communications with on-board monitoring equipment.
- **New business applications:** In other business sectors, such as logistics, INGECONTROL could use SIA_POS EGNSS receiver in applications where a very accurate geo-positioning is mission critical. Cost effectiveness will be a key factor for adoption.
- **New R&D foundations:** The last exploitation path envisioned by INGECONTROL would be applying to new R&D public funded projects to further improve the technological achievements of SIA and test and implement new cutting-edge products and services. R&D programs such as Horizon2020 and the new Horizon Europe, are paramount for INGECONTROL and other innovative SMEs to keep track of emerging technologies and market trends.

8.3.4 UIC Exploitation Plan

UIC, in existence since 1922, is the worldwide international organisation of the railway sector including some 200 members across all five continents. UIC members include integrated railway companies, infrastructure managers, railway and combined transport operators, rolling stock and traction-leasing company service providers. The UIC mission is to promote rail transport at world level and meet the challenges of mobility and sustainable development.

Being a non-profit association, UIC's contribution to exploitation actions should therefore be understood as the potential use of SIA outcomes by UIC members and, more generally, by the railway community. One fundamental aim of UIC, since its foundation in 1922, is the spreading of industry standards and codes of practice, to which SIA is expected to provide fresh inputs.

More specifically UIC is participating in the consolidation of best practice guidelines (deliverable D9.4 "Guidelines for SIA implementation") targeting both decision makers and technicians.

More and more UIC members, both RUs and IMs, are focusing on making better use of their assets: increasing availability and reducing maintenance costs. Therefore, predictive maintenance should be implemented wherever possible.

For rolling stock, this is done while each vehicle must have an entity in charge of its maintenance. (2019/779). The added value of the UIC is to help its members SIA services in a good way, with the end-user's point of view and by promoting this methodology to its members.

After the project end, UIC will go on presenting SIA results in appropriate UIC groups, such as asset management, rolling stock and track expert groups and in relevant international conferences organised by UIC.

8.3.5 TELICE Exploitation Plan

TELICE, as a company, prides itself in providing infrastructure managers with top-of-the-line services, know-how and professionals to ensure the best possible execution in OLE (Overhead Line Equipment) and traction substations projects, both for new constructions and deployments, as for renewal or maintenance works.

A fully deployed SIA system will be able to be fed with catenary measurement data created with TELICE’s tCat® measurement trolley. tCat® can record, in real-time and on-site, key geometrical parameters of the railroad environment, focusing on those related to the OLE. The measured parameters are:

- OLE height and stagger.
- Cant/super elevation level of the track.
- Travelled distance.
- GNSS position.
- Tunnel cross section.
- Pole offset/ R.E.F.O.S.
- Clearance to railway equipment (platforms, trenches, transformer boxes, etc.).
- Electrical clearance survey (e.g., distance requirements verification at insulated/air gap overlaps).

A tCat® survey session generates a survey report which can be exported as Excel (.xlsx) or CSV worksheets. These worksheets can therefore be imported into SIA's iCatMon interface to create data baselines for the appraisal of the OLE system.

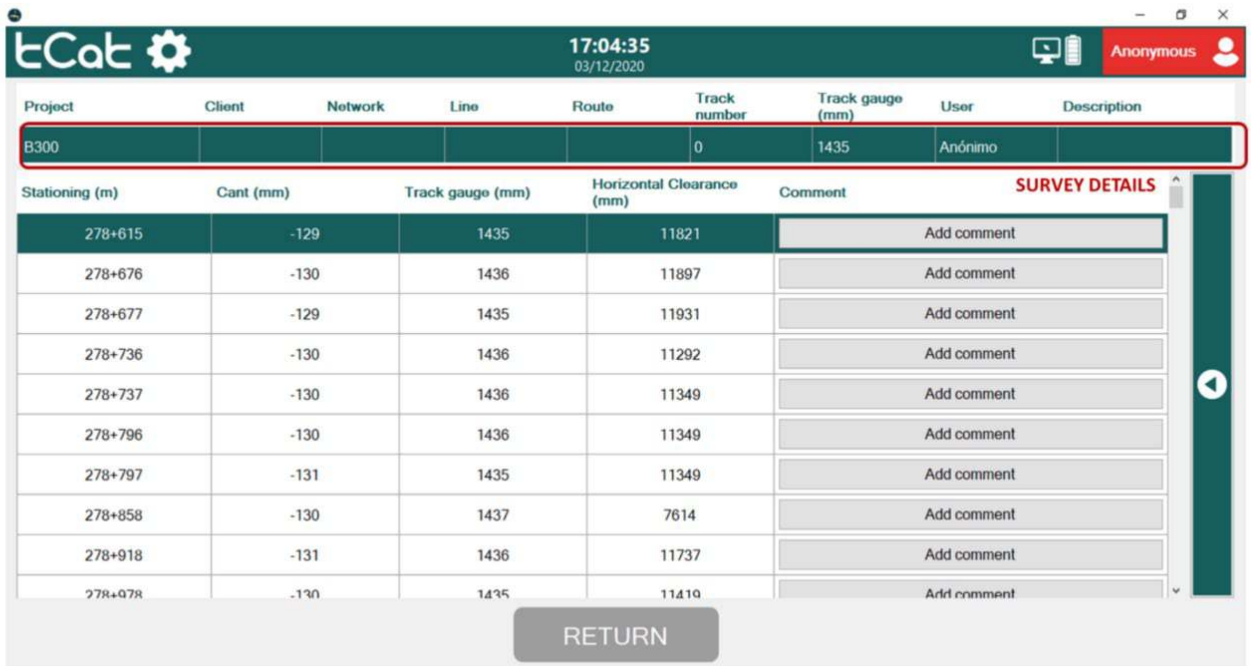

Figure 2: tCat® survey analysis workbook example

TELICE exploitation intent with respect to SIA will follow the lines of offering our tCat® compatible service to allow infrastructure managers and other railway undertakings to populate SIA databases with accurate geometry figures for the whole extent of the monitored OLE, which can be renewed in regular intervals to act as reference data contrasts with respect to the SIA pantograph-based sensor platform.

8.3.6 OBB Exploitation Plan

OBB has the role as an end-user in this project. For future SIA services OBB as an infrastructure manager will be a potential customer. Considerations on the benefit and the added value of future SIA modules and services have to be done on the basis of the R&D strategy road map of OBB-Infrastructure, comprising the most challenging thematic issues within the next years to reach some basic goals like e.g.

- increasing train capacities on the network,
- increasing availability of the infrastructure or
- reducing maintenance costs.

Within this R&D strategy there are two streams where we see that the SIA project can have a benefit; the potential of integration into our systems and processes must be evaluated later after further development of the system and services.

Here is a short summary of the two thematic streams of the strategy road map describing the needs of infrastructure managers:

8.3.6.1 Key components of the infrastructure

The goal is to develop scientifically proven foundations for the construction and provision of innovative track, catenary and control & safety technology components as well as for intelligent bridges and tunnels both for the core network and in particular for regional railway lines in order to

- simplify the technical design of these components,
- to enable an optimization of construction time, service life & sustainability,
- to make the digitization of the infrastructure usable for smart asset management
- and thus to reduce the costs of infrastructure construction and maintenance activities.

8.3.6.2 Condition Based & Predictive Maintenance

The goal is to provide scientifically proven methods, models and evaluation procedures for future condition-dependent or predictive and, where possible, automated or autonomous maintenance methods in order to

- optimize the use of human resources and costs,
- to reduce or completely avoid the effects of maintenance work on train operation,
- to make the advantages of digitization usable, especially by means of robotics
- and thus to reduce the effort for maintenance activities and costs for the re-construction of infrastructure components.

8.3.7 DLR Exploitation Plan

DLR is a German research institute that is, to some extent, publicly funded. DLR has the mandate to perform research and advance technologies from ideas to prototypes. DLR can support in the technology transfer but has no mandate to develop and market own products. These facts determine the exploitation of the SIA results.

DLR will pursue further collaboration in research projects with partners from the SIA consortium. This includes further collection of ABA data with the OBB SIA pilot system.

DLR will perform further research based on the achieved SIA results by DLR including the contributions to SIA-POS, SIA-ABA, and SIA-CDM etc. Specific focus is put on multi-sensor-systems using ROS, EGNSS- and map-supported positioning algorithms, and the analysis of ABA data. The involvement is SIA has revealed further research topics that will be addressed by DLR.

DLR has gathered a rich data base from the SIA experiments and pilot operation. It is intended to further use these data for future research purposes.

DLR has written scientific publications within the SIA project and will continue to do so based on the achieved results. The scientific publications concern several aspects and may include algorithms and mathematical concepts, actual data (with consent of relevant SIA partners if required, ÖBB pilot and infrastructure details), and software (with or without companion papers).

8.3.8 FGC Exploitation Plan

FGC as a public railway operator and infrastructure administrator does not have individual exploitation plans. FGC act as the end-user of the developed outcomes of the project, and do not envisage to claim any kind of property.

8.3.9 VIAS Exploitation Plan

In the project VIAS has been working in the activities related with the rail, participating in the integration and validation phases. VIAS plans exploiting the results of SIA as follows:

- VIAS as a construction company that maintain railway tracks, will offer SIA to clients in future tenders in case that the client wants to install SIA, VIAS will arrange the terms with the developers of the different solutions.
- VIAS will use the know-how gained in the project in new R+D proposals (on a national and international basis)

9 SIA Business Plan

Within the SIA Grant Agreement (section B2.2.2.2) the proposed business plan was outlined for iWheelMon, iRailMon, iPantMon and iCatMon, this being an end-to-end service for four different type of clients with a joint venture created by GMV NSL and INGECONTROL. The business model remains a viable option for the future although during the project duration it has been identified that some modification would be required to the hardware and software that would require additional investment would be needed for an end-to-end SIA service to be ready for end users.

9.1 Description of the Target Market

Within the project, four new end-to-end services, iWheelMon, iRailMon, iPantMon and iCatMon, have been developed. The exploitable results and solution developed within the project is further details in Chapter 6 of this document.

Due to the capability of the SIA services, the target market sector for iWheelMon, iRailMon, iPantMon and iCatMon is railway maintenance. More specifically, the companies and organizations that implement the maintenance work schedule to maintain the infrastructure and vehicles.

With this target market in mind key figures and statistics that are applicable to SIA are maintenance expenditure and the cost benefit that SIA can provide. SIA services will target a reduction in maintenance costs due to efficient monitoring. In 2018 the total maintenance and renewal expenditure reported for the EU27 countries was EUR 20.6 billion, i.e. 53% of total expenditure (EUR 25.8 billion and 54% for the EU28), with significant variations between different countries. National budgets accounted for 72.3% of total expenditure and investment for infrastructure, EU co-financing accounted for 8.3% and 19.4% came from other sources, including loans, equity financing and charges [RD 2].

9.2 Description of Potential End-users

For a future SIA system the end user would be a railway maintenance operator, of which there are different types. The end user would be in charge of maintenance schedules, have the responsibility for railway infrastructure and therefore maintain that infrastructure and the vehicles that use it. A description of potential end users are discussed below:

- Integrated Operators
- Infrastructure Managers
- Train Operating Companies
- Maintenance Subcontractors

Within the project, we had a target to complete 20 interviews with potential end users, further information on this is described in D2.1 [2] to gather user requirements and through our dissemination and exploitation plans. Specifically, the following table was created:

End-user profile	**Potential end-users**
Integrated Operators	Spain: FGC, Metro Madrid, Metro Barcelona, Metro Bilbao, Metro Tenerife, Metro Sevilla, Ferrocarrils Majorca UK: NET (Nottingham Express Transit), Metrolink, Edinburgh Trams France: Compagnie des Omnibus et tramways de Lyon (OTL), RATP Switzerland: Verkehrsbetriebe Zürich (VBZ)
Infrastructure Managers	Spain: ADIF, ETS Austria: ÖBB-Infrastruktur France: SNCF Réseau UK: Network Rail Sweden: Trafikverket Norway: Bane NOR Germany: DB Netze Italy: Rete Ferroviaria Italiana
Train Operating Companies	Spain: Renfe, Euskotren France: SNCF Italy: Trenitalia Austria: OBB Germany: Deutsche Bahn Norway: NSB Gjøvikbanen Sweden: SJ, Tågkompaniet, Snälltåget, MTR Express and Inlandsbanan UK (29): some include: CrossCountry, East Midlands Railway, TransPennine Express (TPE), London North Eastern Railway (LNER) (Nationalised)
Maintenance Subcontractors	Spain: Telice, VIAS, COPASA, Cemosa

Table 4. Potential end-users of SIA system and services

9.3 Assessment of the Competition

The objective of this section of the document is to provide a description of similar solutions to SIA that are currently in the market place and the main technologies that are being developed by competitors. In the following section, competitors are briefly discussed:

- InnoTamp
- Bentley (Assetwise)
- ZEDAS (Zedasasset)
- IBM (Maximo)
- CARL Software (CARL Source Transport)

9.3.1 InnoTamp

Currently, accurate geodetic information for track maintenance is only used for high speed lines to ensure optimal ride and safety; the former is not only passenger comfort but low dynamic forces on track and rolling stock, which also reduce their wear and tear. For non-high speed lines it is deemed too expensive and cumbersome (due to safety precautions) to geodetically survey and analyse tracks at regular intervals (monthly/bimonthly). Fugro, in collaboration with Network Rail, proposes InnoTamp: an innovative, cost-effective and safe survey methodology for maintaining positional track geometry (adjusting both rails to the required optimum alignment) even for non-high speed rail lines. Studies have shown that track maintenance cost savings of up to 30% are achievable when accurate geodetic data are regularly utilised. The use of InnoTamp will therefore lead to improved environmental sustainability and customer experience, optimised railway operations as well as optimised and cost-effective track maintenance for Network Rail and other track owners in future. InnoTamp extends the capabilities of Fugro's RILA technology, which has been used by Network Rail since 2013 to generate geodetic data for projects such as electrification and track renewals. This survey system neither requires personnel on track, not a dedicated measurement train. It makes use of regular timetabled revenue earning trains and has proven to be very cost effective. InnoTamp focuses on applying the collected geodetic track data such that track maintenance can be executed efficiently for all lines. It includes e.g. identifying where maintenance is required; for those areas, computing the best alignment and corresponding required track adjustments; checking and proving whether the computed adjustments are practically feasible; uploading the approved adjustments in the computers of on-track maintenance equipment; and finally checking and proving the track changes are implemented correctly. Fugro seeks funding to transition InnoTamp from an R&D concept through to prototype and proving in the areas of cloud computing, algorithm development, machine learning, process automation and application interfaces [16].

9.3.2 Bentley (Assetwise)

AssetWise Linear Analytics is a railway decision support system that enables proactive management and decision support for linear railway assets. AssetWise Linear Analytics is designed to help you turn railway data into actionable information, enabling better decisions about track and other maintenance assets. Track managers can confidently determine what work needs to be done, where to focus the work, and when to perform the work.

Data Analysis and Rules Engine

AssetWise Linear Analytics has a library of more than 200 linear network-aware data processing rules and commands that can be applied to extract actionable information. These rules can find clusters of defects, trend track degradation to plan surfacing, filter spikes and flat lines from measurement data, and much more.

Big Data and the Internet of Things

Data collection systems such as track geometry vehicles, ground penetrating radar, laser scanners, video recorders, track walkers, and more can produce many gigabytes of data in a day. AssetWise Linear Analytics efficiently stores, links to, and correlates this data for rapid access and analysis, enabling you to make timely and accurate maintenance decisions.

Data Visualization

Data visualization is critical for transforming vast quantities of complex linear data into actionable information that users can readily access, understand, and utilize. Straight line diagram visualization features provide you with instant access to an informative representation of any combination of configured data types at any location on the railroad network.

Improving Rail Maintenance Strategies

Railways can do more with less resources if they can better manage rail information and harness the vast amount of existing rail corridor data in a prioritized plan, assign the work, and monitor the execution and results with technology applications.

The AssetWise Linear Analytics solution can help you perform analysis and data trend forecasting that enables your engineers to make better-informed decisions about maintenance and renewals [13].

9.3.3 ZEDAS (zedas®asset)

Zedas®asset continuously supports you with the management of inspections, maintenance planning and monitoring of rail infrastructure. Incidents and faults are recorded to the exact change (metre/kilometre) and/or GPS coordinates. All basic asset information of linear- or non-linear infrastructure objects (Rails, Catenary, Switches, Signalling, etc.), measured data as well as results from sight inspections are used in zedas®asset to analyse and evaluate the current condition of your infrastructure at any time, taking into account all influential stress factors. These information is the basis for calculating, planning, managing and monitoring of maintenance processes according to regulations and based on the up-to-date condition.

All recorded data is historicised (e.g. incidents, corrective- or preventive maintenance, component changes, meter readings, etc.). This data is available to the operator for the entire maintenance cycle without any additional input effort and can be accessed on-site using our mobile solution zedas®smart.

The zedas®asset functionality allows monitoring of entire infrastructure systems: tracks, catenary, third rail, switches, signalling control systems, rail power supply, bridges, buildings, stops, stations, escalators or any other related technical asset. The system manages assets of railway infrastructure by:

- Integration of operating data (tonnage, run overs, etc.) or measured data (gauge, cant, twist, etc.)
- Analysis of recorded data for detailed condition assessments and asset weak point detection
- Visualisation of networks and non-linear objects (incl. asset basic data, history or condition)
- Track Analyser (analysis of attributes and measured data for linear assets)
- Tracking of incidents (defects, faults, etc.)
- Recording of asset- and event position (metre, kilometre or GPS position)
- Automatic schedule/due date planning (based on time, loads or condition)
- Management of inspections and maintenance activities linear-/non-linear infrastructure
- Monitoring of warranties down to component level or track metre
- Mobile support on-site (zedas®mobile for maintenance, measurements and inspections)
- Railway terminology and nomenclature
- Extensive reporting functionality (validation of existing business processes) [14].

9.3.4 IBM (Maximo)

IBM's Maximo asset management solution is currently used by some of the biggest railways to manage their day to day operations. IBM Maximo asset management solution's rich functionalities allow managing all types of enterprise assets, such as organisation facilities (office buildings), warehouses, transportation fleets and utility assets. On top of this IBM Maximo comes with industry specific solutions. Maximo for transportation is specifically designed keeping in mind the requirements of railways. Below are some of the key features of Maximo for Transportation:

- One solution to support all types of assets such as Locomotives, passenger cars, freight cars, stations, tracks, communication equipment, bridges etc. Maximo Asset management solution as well as industry add-ons such as Maximo for Transportation, Maximo Asset Configuration Manager, Maximo Linear Asset Manager, Maximo Scheduler is the perfect combination to handle such complex organisational infrastructure.
- Configuration Management allows defining as designed and as maintenance configuration by defining models of each configuration items such as locomotive or power plant etc. System will regularly check the actual asset i.e. locomotive configuration with reference to model

configuration. It will also validate the parts fitted to various positions and change the status of the asset to unavailable in case any of the mandatory position is empty.
- Complete Rail Hierarchical graphical view of planned and forecasted work through fleet planning and maintenance forecasting.
- Graphically planning of the rail maintenance work to ensure that the workshops used to full capacity.
- Maximo Anywhere Application allows maintenance technicians and support staff to work in either online or offline mode, review task details, report labour actuals and maintain log. Also, then can use bar code scanning or voice to enter data and view a map of their work orders and get directions to selected items.
- Warranty Tracking & Recovery features send alerts prior to the due date of warranty expiration. System will generate claims against warranty items and manage reimbursement in money, replacement parts, credit and other conditions. You can also create and track OEM, extended and After Market warranties by Item and Manufacturer [15].

9.3.5 CARL Software (CARL Source Transport)

CARL Software, European leader in Maintenance Management (CMMS) and Equipment Management (EAM) has been active in the transport sector since 2008. The company has 3 agencies in Europe and relies on an international network of partners' distributors and experts in the conduct of CMMS projects using CARL Source Transport. The publisher presents CARL Source Transport dedicated to the management of rolling stock, fixed and linear assets including:

- Maintenance work process adapted to your organisation: (rolling stock, fixed and linear installations): qualification, preparation, planning, execution, and acceptance of work (signature).
- CARL Source Transport also takes incidents, vandalism, standard exchanges, parts taken from other equipment, and other specific aspects of your field into account.
- Automation of the implementation of preventive and regulatory maintenance: technical control, certification, etc. optimized programming of preventive maintenance.
- Data from the IoT platform integrated into CARL Source is considered.
- Programming of interventions and multi-year works (macro planning, alerts).
- Graphical and interactive view of the work order schedule
- Automatic integration of reports from inspection bodies.
- Management of the specific features of linear assets (tracks & sections, etc.)[17].

9.4 Value Proposition

iWheelMon, iRailMon, iPantMon and iCatMon will provide prognostic health monitoring of critical assets responsible for the 40% of the maintenance and 60% of the unscheduled unavailability. This feature is an opportunity since it is directly targeting at cost reductions (estimated in a 15%) and potential clients are eager of such services.

- Reliable predictions since are using combination of physical models with data stream with accurate positioning and time stamping based on EGNSS and other complementary positioning systems

- SIA constituents employ the same technology for infrastructure and vehicle maintenance subsectors, which doubles the number of potential clients.

- IWheelMon, iRailMon, iPantMon and iCatMon will be commercialized as end-to-end services. This is an opportunity since clients do not have to worry about installation, maintenance or renewal or complex hardware or software. Moreover, it is not an investment requiring important budget but a service contract and SIA services do not require personnel on the track and a dedicated measurement train wouldn't be needed this would be of financial benefit to any end user.

9.5 Proposed Business Model

With reference to the preliminary business plan identified in the Grant Agreement, the following figure shows the proposed business model for a consolidated SIA system with the 4 services. This preliminary business model, summarized in the following figure, provides the arguments to believe that iWheelMon, iRailMon, iPantMon and iCatMon could be a very interesting business in a high-tech niche market.

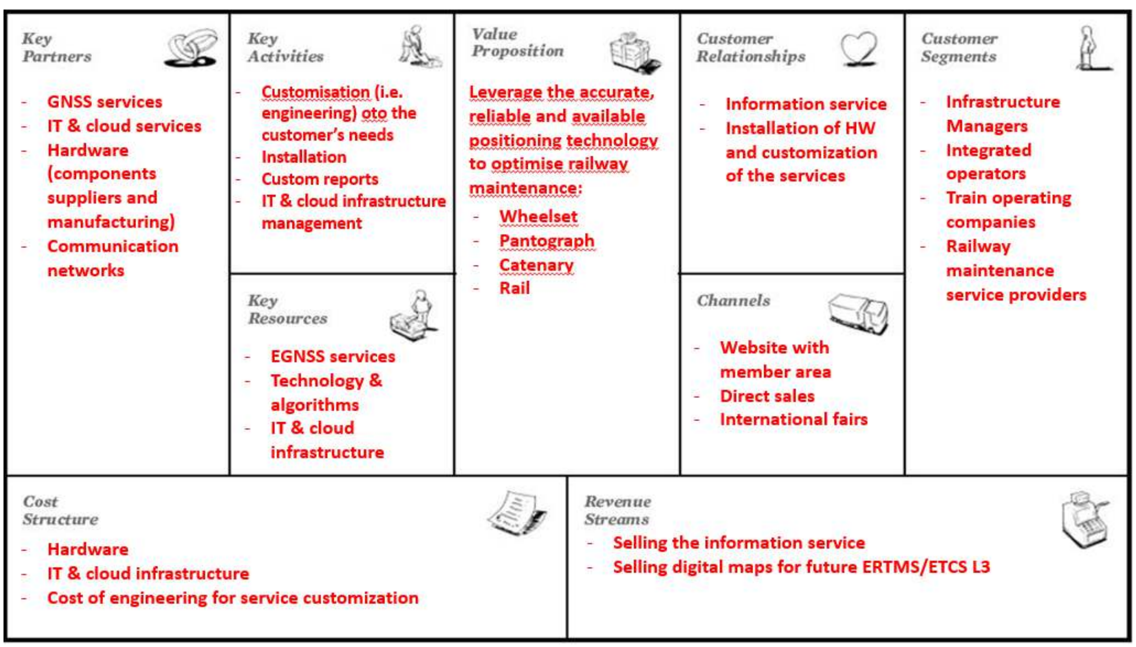

Figure 3: SIA Joint Exploitation Plan Business Model Canvas

9.6 Distribution, Sales & Marketing

There would not be a properly structured distribution chain for the SIA service, products are directly sold to the end users (infrastructure managers, integrated operators, train operating companies and maintenance subcontractors). A marketing strategy should be created however due to the custom nature of the application, these campaigns would not be detailed. Furthermore, from the SIA project dissemination and communication preliminary relationships have been built with potential clients therefore a rigorous marketing campaign wouldn't necessarily be required depending on the timing of the launch.

A factor that would also need to be taken into consideration for sales is the geographical dispersion of potential customers which could make marketing and engineering adaptations very expensive.

As described in previous sections and the Grant Agreement, the sale strategy shall be based on selling a service with monthly payment not a product, which will be much easier due to the accountability system of public organizations and their decision processes.

9.7 Cost Benefit Analysis & Revenue Streams

A cost-benefit analysis has been developed to evaluate, in a preliminary way, the potential business that *iWheelMon, iRailMon, iPantMon* and *iCatMon* would bring. This analysis is based on the following points:

- Reference sales unit is a railway system transporting 40 million passengers per year (mppy)
- The cost of maintenance and renewal has been estimated conservatively in 1M€ per million passengers per year. Thus 40M€ per year for 40mppy.
- The price of the service is 0.75% of maintenance and renewal costs (300,000€ per year per unit) during 5 years. Since *iWheelMon, iRailMon, iPantMon* or *iCatMon* will bring 15% reduction of maintenance costs and 25% in unscheduled unavailability, the value captured by the client is 14.25%.
- The size of the market has been estimated more than 10 trillion passengers per year in 330 entities for Europe and over 50 trillion passengers per year and 1500 entities for the world. Assuming 10 years of amortization for IT services technological products, this means an average of 33 and 150 entities renewing the IT services per year.
- The number of sales after the project starts from 2 units reaching 32 units (1,200Mppy) in the fifth year (accumulated less than 0.1% of world unit annual sales).
- The initial cost per unit sale of the required for engineering, HW and installation is 260,000€. There are also recurrent costs such as cloud services, wireless communication services, and indirect costs reaching
- Marketing (commercial tools, visit to potential customers, trade fairs, etc..) will increase from 50,000€ to 800,000€ during the period of analysis
- Indirect costs (without marketing) are 15,000€ per unit sale.

- Operational expenses will be paid with a loan with an interest rate of the 3% and the internal return rate k is 5%.
- Tax rate is 25%
- Investment for developing parts of the SIA system up to TRL9 (to the requirements for operational service on a railway) is estimated to be a further 3,000,000€.

With the previous assumptions, the analysis reveals that the **gross margin is roughly 45%** (without taxes and financial cost), the **accumulated turnover in 5 years is over 34M€**, **incomes acquired rights** for the next years **58M€** and the **return of investment in the central scenario is 123%**.

Revenue Streams

The above mentioned cost benefit analysis would provide a revenue stream for a business model utilizing the 4 SIA services. There are also other revenue streams available from other ventures made available to the SIA consortium during the duration of the project as described in section 8.2.

10 Conclusions

The aim of this report has been to present the exploitation routes available for the SIA project. The main conclusions are summarised below:

- There are several different exploitation routes available for the SIA system and services for the system developed. This includes joint exploitation and individual partner exploitation opportunities.
- It is noted that some further modifications are required to the developed system in order for the services to be at TRL9 and configured to specific rail operator requirements and for operational requirements within their respective countries.
- During the project, joint and individual exploitation opportunities have arisen due to the results produced and the completion of this project. This includes the MainRail venture started by INYCOM (INGECONTROL's sister company (SIA consortium partner)) and CEIT.
- There could be scope to use the business model outlined in the SIA Grant Agreement however before this is to be completed further modification would be needed for the SIA services to be at TRL9 and some configuration would be needed to specific end user requirements (with approximate further investment of 3,000,000 Euros).

The Next Steps

The SIA partners will continue to review the business potential for the joint exploitation of SIA services where possible. Each partner has developed IP during the project but really a combined effort is needed to provide a real-time service for all 4 SIA services.

Being still at pre-commercial phase aspects of SIA will also be used for additional research, test-beds and educational purposes, which can make the case stronger for commercialisation in the years to come.

Pricing models and financial analysis can be further developed in detail and other options can be explored, once the decision to go to market is taken. The number of cities and exactly which ones to be involved in the further launch of the services should also be reviewed and challenged. The partners through general enquiries will monitor interest and assess potential for a SIA setup.

11 References

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