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MAILLIS Business Case, Conceptualization and Evaluation Strategy

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1.0	Document Ready for Submission	Sophia Karagiorgou (UBITECH)

Reviewer

Name	Organisation
Marco Lewandowski	BIBA
Indah Lengkong	BIBA
Moritz von Stietencron	BIBA

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List of Abbreviations

EU	European Union
FMECA	Failure Mode, Effects and Criticality Analysis
GA	Grant Agreement
KGF	Kilogram-Force
KPI	Key Performance Indicators
MTBF	Mean Time Before Failure
OECD	Organisation for Economic Co-operation and Development
OEE	Overall Equipment Effectiveness
PLC	Programmable Logic Controller
RAG	Red, Amber, Green
UC	Underlying Challenges
UCIG	User Case Interest Group
UPTIME	Unified Predictive Maintenance System

Executive Summary

Deliverable D6.1 “MAILLIS Business Case, Conceptualization and Evaluation Strategy” reports the outcome of the work that has been conducted in the frame of Task 6.1 “Definition of the MAILLIS Business Case” and Task 6.2 “Requirements and MAILLIS System Conceptualisation” activities since the beginning of the project.

Task 6.1 delivers a definition of the scope of the MAILLIS Predictive Maintenance Business Case, the as-is-situation and the envisioned improvements related with the implementation of UPTIME at MAILLIS’s steel industry production line. Task 6.2 identified the individual system and technical requirements of the MAILLIS maintenance pilot in cold rolling mills line. To realize the adaptation of the UPTIME Predictive Maintenance model in the MAILLIS Business Case, we collected stakeholders’ requirements and closely collaborated with domain experts to draw a clear understanding of the several cases. Therefore, the initial requirements as specified in Deliverable D2.1a “Conceptual Architecture and System Specification” are further elaborated and instantiated in the case of MAILLIS, further extended to address the pilot specific system and technical requirements of the cold rolling mills maintenance.

This deliverable presents the current state-of-the-art modelling approaches and the to-be situation in the context of MAILLIS Business Case and is also aligned with the other UPTIME pilots (WP4 and WP5). The identification of the entire picture in the MAILLIS Business Case and the requirements collected by the stakeholders enable for the adaptation of the UPTIME Framework for this specific use case. The deliverable defines the datasets to be used evaluating the ease of use and integration and the experiments to be conducted for evaluation and validation purposes. Specifically, it describes multiple, heterogeneous datasets that will be used in the cold rolling mill lines scenarios and the means to validate the use case. It introduces how they support the different scenarios to ensure that the UPTIME components can be easily deployed and advance the current MAILLIS ICT infrastructure and maintenance operations. The customization and further deployment of the software components in Task 6.3 and Task 6.4 will based on the status of the specification as reported in this document.

1. Introduction

This document is the Deliverable 6.1 of the Work Package 6 (WP6) of the UPTIME project. It describes a steel industry operational use case for predictive maintenance in support to the UPTIME research and innovation objectives. It also serves as the basis for data collection and infrastructure setup (Deliverable 6.2), the deployment of UPTIME and integration with MAILLIS IT infrastructure (Deliverable 6.3) and the preparation of the experimentation activities, system evaluation, learning and improvement (Deliverable 6.4).

1.1. Purpose and Objectives

The UPTIME project aims at enabling manufacturing companies to fully exploit the availability of huge amounts of real-time (or near-real-time) and historical data with respect to the implementation of a predictive maintenance strategy. Thus, it will enable manufacturing companies to reach Gartner's level 4 of data analytics maturity (i.e. "optimized decision-making") with the aim to optimize in-service efficiency and contribute to increased accident mitigation capability by avoiding crucial breakdowns with significant consequences".

In the context of the MAILLIS Business Case which uses cold rolling mill lines to produce rolling products with the closest possible thickness tolerances and an excellent surface finish, this means to:

- Have a machine or a piece of equipment that can report its current health status along with the appropriate data analytics and metrics to identify the degree to which that status deviates from normal or healthy operational mode;
- Have predictions about equipment's future health as well as recommendations for future actions;
- Enable machines perform self-assessment based on which decision-making can be significantly followed to advance equipment maintenance and facilitate the entire products life cycle;
- Facilitate the development of a predictive maintenance strategy which permits increased productivity through transparency and traceability, lower maintenance and repair costs with higher machine availability and enables for cost efficiencies and better quality of products.

A new study released on the 24th of April 2018 highlights the importance of the European steel sector to the EU economy. As the steel sector is responsible for 320,000 direct jobs in the European Union (EU), the indirect and induced jobs add up to a further 2.137 million related positions across the continent – for a jobs total of almost 2.5 million and a multiplier of 7.7 [1]. In June 2013, the European Commission published an Action Plan for a competitive and sustainable steel industry in Europe that aims to meet several challenges, i.e. the right regulatory framework, the demand for steel, access to raw materials, energy, climate, resource and energy-efficiency policies, innovation, and the social dimension. In response, the European Parliament launched its own-initiative procedure 2013/2177 (INI) [2]. These *activities emphasize the importance of steel sector in Europe* and highlight the necessity for a new model able to embed digital transformation in its core to *boost productivity*, *enable better working conditions* and *develop control strategies* to *optimize the performance of systems*.

Effective predictive maintenance requires not only recording, detecting and classifying system's health state but also detecting, classifying and predicting their future state, which derives to detecting future maintenance needs and/or correlations among different components or systems. This challenging and crucial task is at the core of the compilation of the MAILLIS Business Case. In other words, UPTIME will support the decision-making in raising its level of situation awareness for an informed decision.

Roller mill maintenance can be broken down into four general areas; rolls, bearings, drives and auxiliaries. The use of a set of sensors mixing cooperative self-identification systems such as condition of assets, instruments inspections, interfaces with production control and maintenance information systems and non-cooperative systems such as maintenance history from digital inspection forms provide the necessary complementarity and redundancy of information to overcome the possible and quite common roller mill malfunctions while increasing the clarity and accuracy of the cold rolling mill state.

In fact, the new architecture, described in Deliverable D2.1a "Conceptual Architecture and System Specification", centralizes on diagnosis that can mine data from digital control systems and provide real-time insights for prognosis. To be precise, prognosis will give a perspective or foresight on what is going to happen when and with which probability by assessing the extent of deviation or degradation of a component or system from its expected normal operating conditions.

The main objectives of UPTIME are the development of highly scalable methods and methodologies for advancing predictive maintenance operations, sophisticated planning and scheduling using real-time data, systems that can self-optimize performance across interconnected components, self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes. This will be realized as follows:

- All analytics components can take full benefit of the computations of others, also taking advantage of interlinking between their results. Thus, the malfunction detection and predictive methods can benefit from events detected or predicted and vice-versa;
- Diagnosis and prognosis rely on efficient processing of data and mechanisms for data-driven Failure Mode, Effects and Criticality Analysis (FMECA) which support advanced planning and decision-making;
- Users can interact and explore data, via integrated data views, being supported for advanced decision-making.

The focus of the Deliverable 6.1 "MAILLIS Business Case, Conceptualization and Evaluation Strategy" of the Work Package 6 (WP6) resides in describing the MAILLIS Business Case in support to the UPTIME innovation objectives. This definition will serve as the basis for the preparation of the experimentation activities, the MAILLIS Pilot Data Aggregation Infrastructure and evaluation criteria (Deliverable 6.2) and corelates the current MAILLIS business processes with the business scenarios to be implemented (i.e. requirements, business case realization and evaluation) along with the business vision for predictive maintenance in the context of UPTIME.

1.2. Approach

This Business Case describes the interaction of a user with the UPTIME Framework, to achieve a specific goal or accomplish a specific task. The system and technical requirements can then be derived enabling the user to achieve his objectives in different scenarios. The term Actor is used to describe a person or an external system that interacts with the system to be designed. We will be using the term Actor interchangeably as the user or the operator of the UPTIME Framework.

The different scenarios defined within the MAILLIS Business Case illustrate different usages of the system, and eventually define success (if the goal is achieved) or failure (if the goal is not achieved). The UPTIME objectives describe general goals of the new digital, e-maintenance services and tools to be implemented. They involve several Underlying Challenges (UC) or would drive some innovation focus to exploit the full potential of a predictive maintenance strategy with the UPTIME Framework that may be specific to each partner. In collaboration with the other business case partners (FFT and

WHIRLPOOL), it is ensured that the Business Case described is operationally relevant. The Business Case describes the general context of use of the UPTIME methods. The detailed presentation of the MAILLIS Business Case is included in Section 4.1.

The MAILLIS Business Case will be supported by the appropriate datasets. From the initial list of datasets provided in the proposal, we will ensure that the data are usable, aligned in time and space, etc. The datasets have been identified and documented in Section 2.4. The performance criteria specify what the user expects and are given in Section 5. They also help to closely tie the Business Case evaluation to the use case development, resulting in an integrated product. The detailed description of the performance criteria will be the purpose of the Business Case evaluation, as they will be linked to the criteria identified in the Grant Agreement (GA). Through intensive and continuous communication within the entire consortium, it is ensured that the interfaces and knowledge remain transparent and that frequent knowledge transfer takes place.

1.3. Relation to UPTIME WPs and Tasks

Figure 1 describes the relation of the main components of the MAILLIS Business Case, their relations to the UPTIME Framework and the experimentation environment for the cold rolling mill lines. The MAILLIS Business Case comprises one or more alternative scenarios that describe how actors in the use case perform a set of operations to achieve a specific goal. Scenarios describe the current operations that will serve as a base for understanding and validating the UPTIME Framework, while demonstrating how it can be effectively used in the cold rolling mill lines (see Section 4). This deliverable is the outcome of the work conducted in the context of Task 6.1 Definition of the MAILLIS Business Case and Task 6.2 Requirements and MAILLIS System Conceptualisation.

In close cooperation with the other pilots (WP4 and WP5) as well as WP2 and WP3 the UPTIME architecture (defined in D2.1a Conceptual Architecture and System Specification) will be closely monitored to drive and realise the MAILLIS Business Case. The outcome of this activity brings the UPTIME partners very close in reaching the milestone MS2 “Availability of the UPTIME Business Cases Conceptualization” by the end of M9.

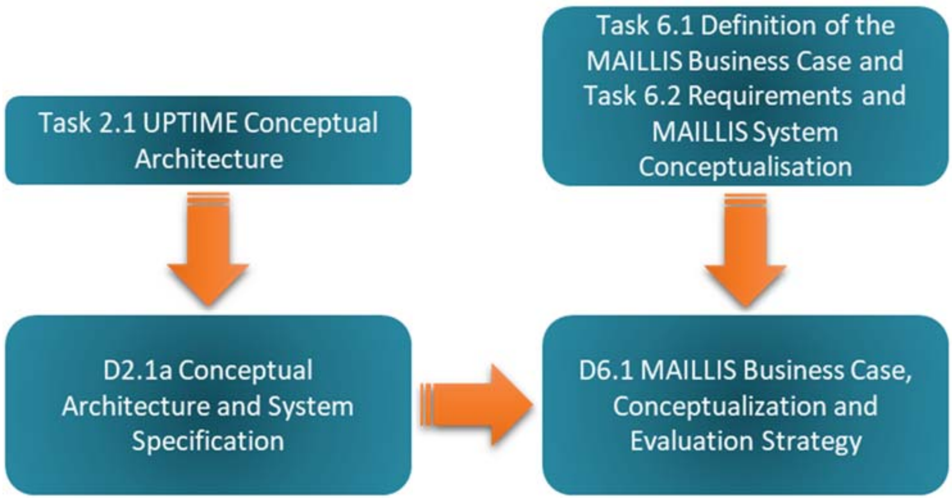

Figure 1. Relation of D6.1 with the related UPTIME WPs and Tasks

1.4. Structure of Deliverable

The remainder of this document is structured as follows.

In Section 2, we present the context of MAILLIS Business Case. This includes the vision for predictive maintenance, the definition of business scenarios, the as-is processes, the available data and the relevant IT systems.

In Section 3, we provide specific details regarding the business case requirements by classifying them in system and technical prerequisites, which will drive the development of the Business Case scenarios.

In Section 4, we present the adaptation of the UPTIME e-Maintenance Model to the MAILLIS Business Case Architecture and Infrastructure.

In Section 5, we provide methods to evaluate the MAILLIS Business Case.

In Section 6, we present the implementation roadmap for the realisation of the MAILLIS Business Case.

Finally, in Section 7 we conclude this deliverable and present an outline of the upcoming activities.

2. Business Case Context

This section presents the steel industry use case of UPTIME for predictive maintenance, which describes possible operational uses of UPTIME for steel industry production line optimization while focusing on relevant practical challenges, such as the data characteristics and operational questions.

2.1. Business Vision for Predictive Maintenance

Crucial to Predictive Maintenance in the steel industry is the compilation of the recognized steel industry picture from multiple and heterogeneous sources, its continuous monitoring and assessment against current and future business vision. This requires not only detecting, tracking and classifying sensor data but also detecting, classifying and predicting each component's and thus system's future behaviour based on a proven methodological framework.

2.1.1. Motivation for Steel Industry

The steel sector has been getting pressure from all sides in recent years as raw materials have become more expensive or difficult to source and growth has slowed to a crawl. Productivity growth for industrial companies in the European Union fell from an average of 2.9 percent over the 1996–2005 period to just 1.6 percent from 2006–2015, according to the Organisation for Economic Co-operation and Development (OECD) [3]. Digitization and process control is part of the 2030 Roadmap of the SPIRE cPPP. The current portfolio of running SPIRE projects related to ICT has an EC funding volume of about 85 Million Euro [4]. Predictive maintenance is vital in ensuring the health of technical systems like MAILLIS cold rolling facilities. However, the degradation of systems is a dynamic process, governed by changes in both the system and its environment. Currently, the interconnected lattice of the new smart factories can facilitate the steel sector to embed digital functionalities in its core along with advanced analytics for the diagnosis and prognosis of malfunctions resulting in sophisticated decision-making and cost efficiencies.

2.1.2. Steel Industry Operational Use of UPTIME

In the timeframe of the UPTIME project several activities will take place which will drive innovation and will facilitate its operational use in the MAILLIS Business Case and in the Steel Industry, in general.

MAILLIS offering combines high quality packaging materials and state-of-the-art technology, ensuring that metal producers enjoy reliable, durable, proven and high-speed strapping and wrapping technology at the optimal cost.

MAILLIS steel and PET strapping systems offer circumferential and through-the-eye strapping for coils as well as horizontal and vertical strapping for products with flat surfaces. Moreover, MAILLIS offering includes a complete range of manual, battery and pneumatic strapping tools for steel and plastic strap, allowing you to choose the most appropriate for your application. The equipment, in combination with high quality steel or PP/PET strap of superior strength and elongation, ensures product security throughout the supply chain. The offering also includes protective material for sensitive metal products thanks to a unique range of stretch wrapping systems (horizontal and vertical) that will ensure product protection from dust and humidity, reducing the risk of surface corrosion with the use of a comprehensive range of films. The valuable products can be also protected from mechanical damage with the additional use of edge boards where necessary.

The first step will be to identify the requirements to drive the conceptualization of the MAILLIS Business Case. This will facilitate the collection of system and technical characteristics which will be then adapted onto the UPTIME e-Maintenance Model, the Business Case Architecture and the required Infrastructure.

The second step will be to collect the required data in an efficient and flexible manner. While wireless communication in industrial environments is extremely challenging due to the high variability of the radio channel in terms of error rates, channel downtimes and error bursts caused by various equipment, one of the key challenges in deploying a wireless sensor network interconnected with Programmable Logic Controllers (PLC) is to introduce reliable and robust networking protocols able to support real-time capabilities.

The third step is the development of models, based on the physics of failure, to predict the critical failures in the system due to e.g. wear, fatigue, corrosion or creep. The collected data on usage, loads and environmental conditions will be used as input for diagnosis and prognosis.

The final step is to combine the data collection with the model development and demonstrate the integral concept on the MAILLIS production facilities.

The business vision for predictive maintenance after the UPTIME project completion will be to make available components able to predict the future behaviour (i.e. malfunctions, health state, etc.) of the milling rollers that are used in the milling processes. This way, MAILLIS partner and the steel industry related with the cold rolling will be able to save money and reduce downtimes via the optimization of the rollers’ change over time. It is also expected to advance the production lines and create better quality milled products, involving a much higher safety level on the final application. With respect to a continuous improvement approach getting information and estimations about the equipment status, the available data can be analysed to extract information, including:

- The equipment’s health state by maximizing its operation time;
- The improvement of Mean Time Before Failure (MTBF);
- The quality improvement of the created products;
- The efficient analysis of malfunction reasons to find effective solutions;
- The improvement of the Overall Equipment Effectiveness (OEE).

2.2. AS-IS Business Processes

In cold rolling mill production lines, MAILLIS uses cold rolling mills to produce rolling products with the closest possible thickness tolerances and an excellent surface finish. Given an entry steel coil of 4 tons weight and thickness of 2 mm, MAILLIS produces steel strips over the whole thickness spectrum until 0.4 mm. Figure 2 indicatively presents some of the existing MAILLIS AS-IS business processes in its production lines.

Figure 2. MAILLIS AS-IS Business Processes

Cold rolling is a process of reduction of the cross-sectional area or shaping a metal piece through the deformation caused by a pair of rotating in opposite directions metal rolls (cf. Figure 3). Cold rolling occurs with the metal below its recrystallization temperature. Figure 4 presents an existing mill in the current product line of MAILLIS (i.e. Roll Mill No2).

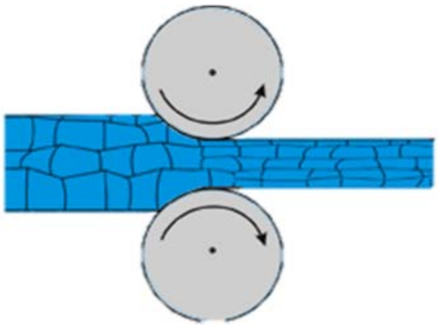

Figure 3. Deforming and Reducing the Grain Size

Figure 4. MAILLIS Roll Mill No2

Cold rolled steel strip is characterized by a cross-sectional reduction of at least 25%. In the stand we have one pair of back up rolls and one pair of work rolls. The deformation takes place through force of the rolls supported by adjustable strip tension in both coilers and de-coilers. These support the cold rolling process so that the setting force of the rolls can be reduced.

Lubricant mix of oil and water is applied during operation to better absorb produced heat and allow operation with increased speed. To achieve the final thickness, the MAILLIS personnel performs 3 to 5 reversing passes with about 30% thickness reduction on every pass and a maximum applied force of 90.000 kilogram-force (kgf). Some examples of a standing roll mill and working rolls are depicted in Figure 5 and Figure 6, respectively.

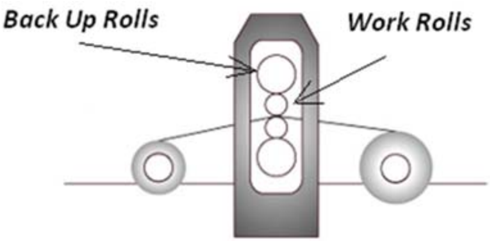

Figure 5. Roll Mill Stand

Figure 6. Working Rolls

2.2.1. Demonstration Site Overview

Roller mill maintenance can be broken down into four general areas; rolls, bearings, drives and auxiliaries. The materials processed influence the maintenance requirements of the roller mill system. When relatively clean or soft materials are processed, roll corrugation intervals can be extended and the machine operation can be smooth and trouble free (Figure 7).

Figure 7. MAILLIS Current Product Lines

Roll Maintenance

Over the life of the roll some wear will occur due to normal processing, and some wear will occur due to extraneous conditions. When this occurs, rolls are removed from the stand for grinding. This happens usually every eight hours for the work rolls and every week for the backup rolls. Each time the rolls are removed for grinding some roll diameter is lost. After several regrinding, the diameter of the roll become so small that the rolls are no longer useful. Factors affecting roll wear might be categorized as normal and abnormal operating conditions. Normal operating conditions would include such details as maintaining the parallel rolls and tram, uniform feeding end to end, and keeping the roll stops properly adjusted. Normal material characteristics would include the cleanliness of the grain or materials being processed, moisture, and test weight. Figure 8 illustrates a wear on a work roll.

Figure 8. Wear on Work Roll

Abnormal operating characteristics might be rolls operating out of parallel, uneven feeding from end to end and roll stops that are incorrectly set, allowing the rolls to touch metal to metal (Figure 9). Abnormal function might be also caused by excessive impurities, dirt, holes or material with uneven thickness from edge to edge.

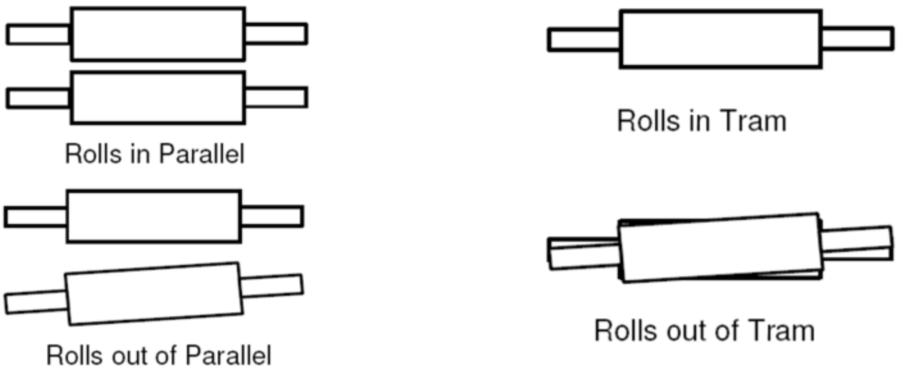

Figure 9. Roll Positioning Problems

Bearings

Bearing maintenance is critical to proper long-term roller mill operation. Normal maintenance would include frequent addition of small quantities of grease during operation. Whenever excessive amounts of grease are added to any bearing, some grease will naturally bleed from the seals. This excess grease is mixed with the oil-water emulsion effecting lubrication and cooling. Excessive amounts of grease do not improve bearing lubrication and may lead to bearing failures due to overheating of the bearing. When rolls are removed for service, MAILLIS removes the bearings and housings prior to grinding. Bearings used have tapered sleeve adapters, so it is critical that the bearings are properly set. This will involve measuring the internal clearance of the bearing with a feeler gauge and reducing the clearance by tightening the lock nut on the tapered adapter sleeve. If the bearing is too loose, the tapered sleeve may not grip the shaft and could cause the journal to slip or spin in the bearing damaging the bearing adapter and the roll shaft. If the bearing is too tight, it will certainly run hotter than normal and can fail prematurely due to frictional heating and improper lubrication.

Drives

Roller mill operates with dc motors (600Kw for the stand and 250Kw for the coiler & de-coiler) and gearboxes at less than motor RPM to ensure proper speed. Maintenance includes periodical check of brushes on the dc motors periodical addition of grease on the bearing and measurements of electrical characteristics of the motors. The motors are air-cooled, and the flow of the air is monitored to maintain operation below temperature limits. On the gear boxes, MAILLIS checks the level of lubrication oil the temperature of the oil and periodically, takes samples for chemical analysis to verify the condition of the lubricant and traces existence of metals indicating wear on the gears.

Auxiliaries

Auxiliaries among others include:

- Oil-water emulsion tank: We measure daily on the laboratory oil concentration, conductivity, ph. chlorides ions, iron ions, bacterial, fungi and yeast. The oil-water tank has a controlled temperature and filters for the removal of dirt;
- Hydraulic units: We check the level of the oil in the tank, the temperature of the oil and periodically we perform chemical analysis to verify the condition of the lubricant;
- Cooling systems: We use them for temperature control of oil water tank, hydraulic units and various equipment. We control the water temperature to achieve smooth operation of the equipment;
- Various motors – pumps: Maintenance includes periodical check of operation, vibrations leakages and overheating.

2.3. Business Scenarios – Steel Industry Assets

The steel industry is strategic in the EU economy. Steelmaking is a complex industrial process: the life-cycle of steel is long, from raw material extraction to coating of final products. Defects introduced in early stages have an economic impact in posteriors transformations, thus the sooner defects are detected, the sooner the process can be modified, redefining industrial routes.

In this scenario, the MAILLIS Business Case involves multiple and diverse parameters (e.g. temperature, vibration intensity, tension in the rollers, speed) that affect the final dimensional properties of the metal. Data is obtained in real-time from a sensor network. Predicting dimensional defects using the massive streaming real-time data is the main target. The use of advanced data analytics supports this objective, using scalable online machine learning for predictive analytics, together with advanced real-time visualization techniques.

MAILLIS manages diverse assets to support the several applications and offering specialized products such as hot rolled coils, cold rolled coils, electro-galvanised coils, etc. Indicatively, Figure 10 presents a strapping head for steel strap. This steel strapping head consists of a triple-notched jaw assembly for the gripping, the cutting and the notching of the strap. This design eliminates the need to use separate seals during the product strapping. The field of application covers mainly heavy industry. It is useful for various package types: slit-coils, jumbo-coils, sheet packs, profiles, tubes, wires, billets, etc.

Figure 10. Strapping Head for Steel Strap

The scope of the UPTIME project is to enable MAILLIS to predict the lifecycle of the milling rollers, in a way to choose the optimum time for replacing them, thus saving money and time. The MAILLIS Business Case has to do with the real-time monitoring of data relevant to operation, soap oil, and the material. It includes notifications being generated both by the front-end monitoring and by the backend of UPTIME. Specifically, this is to be achieved through the following approach:

- Operation variables are monitored and forwarded to UPTIME. The relevant sensors to monitor the mining rollers temperature, vibrations, bearings, the electrical motors' tension, the duration of the thickness reduction process and uneven operations have been installed and monitored in real-time;
- Soap oil variables are reported to UPTIME periodically. If UPTIME detects that soap oil needs to be renewed, an alert is generated. A group of sensors to adjust the proper oil characteristics have been installed and monitored in real-time;
- The material is monitored for impurities: If an impurity is detected, an alert is generated;
- In this pilot, the measuring devices include sensors, Programmable Logic Controllers (PLC), roller's pressure and vibration.

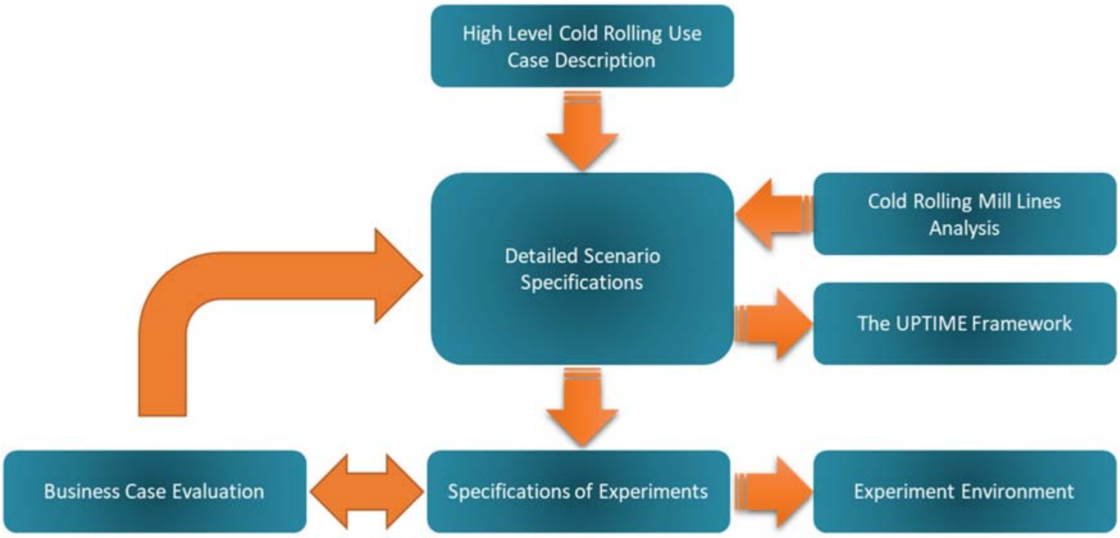

Figure 11. MAILLIS Business Case Components Graph

Figure 11 provides an overview of deployment of UPTIME to MAILLIS Business Case.

The expected outcome through the UPTIME Framework will be a set of ***recommendations*** in the form of alerts to MAILLIS engineers to proceed with a replacement of a roller or soap oil. Regarding soap oil, the difference between this case and the one occurring in the monitoring is that here the *entire roller system* is considered. More specifically, in the ***monitor system variables case***, the values are measured and are matched to base values. In the ***recommendation case***, the status of the rollers is also considered, and their function is projected with current soap oil values. Moreover, in the ***analysis of production data case***, the data collected within the production line lifecycle are analysed to identify the state that is needed to decrease the maintenance cost and thus the sum of corrective maintenance times, increase the Overall Equipment Effectiveness and thus the output Quality.

Besides, the UPTIME Framework is expected to contribute in the operational needs of the MAILLIS Business Case by ensuring:

- Scheduling optimization—What and When to produce is an important decision for any steel mill, and it's particularly critical when one of the most important inputs is electrical energy (for arc furnaces that melt scrap into molten steel). The UPTIME optimization models will try to maximize energy consumption at off-peak times and thus minimize energy costs.
- Production line optimization—All steel mills have unplanned events like breakouts (when molten steel breaks out during casting) and cobbles (when hot rolled steel escapes from rollers, often onto the mill floor). These events stop production and are both dangerous and costly. The machine learning models devised in the context of UPTIME can predict when they are most likely to happen and minimize their occurrence.
- Predictive maintenance—As with an increasing number of industrial machines, the UPTIME project will use machine learning models to identify the optimal times to maintain key machines and equipment.

The Key Performance Indicators (KPIs) to be reported are as follows:

- Utilization Ratio (Operational_time / (Operational_time + Maintanance_time + Replacement_time);
- Total DownTime (Maintanance_time + Replacement_time);

- Loss of Production;
- Cost Reduction due to UPTIME;
- Roller Mean Life or higher order moments of interest.

In a nutshell, the MAILLIS Business Case requires the identified datasets, predictive maintenance and operational needs coming from MAILLIS engineers and is driven by the UPTIME objectives, the underlying challenges and KPIs to be realized as presented in Figure 12.

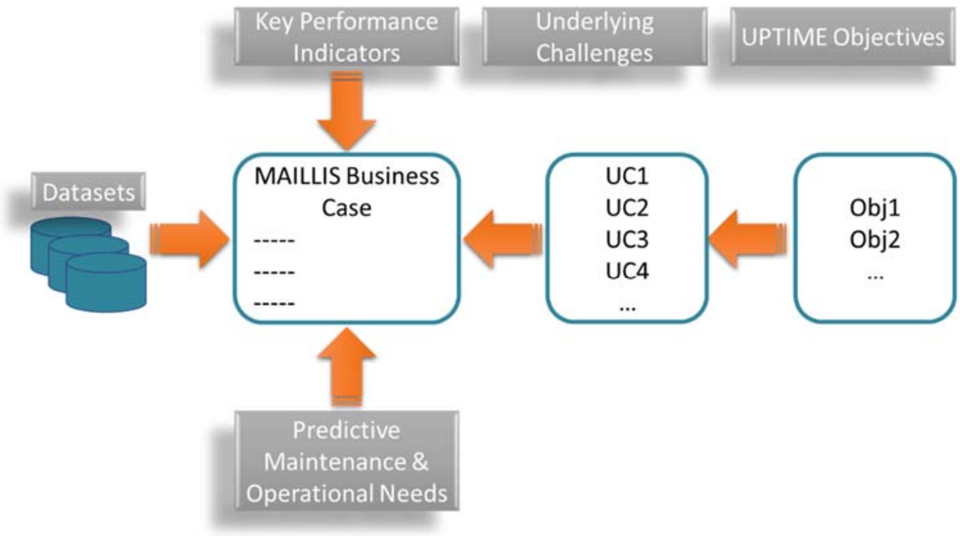

Figure 12. General Methodology for the MAILLIS Business Case Development

2.3.1. Stakeholders in the Steel Industry Chain

In addition to the real-time or near-real-time data monitoring and analysis, the system also has to consider and address the individual information needs of the different stakeholders in the value chain. To provide usable results for the different use cases each end user's business case has been carefully analysed during the first phase of the project. The most relevant users of the UPTIME system involve the following actors:

- The **Technical manager** is responsible for the entire production line and the interconnection of the maintenance with other operations in the steel industry, i.e. production, logistics, quality.
- The **Factory worker** plans and coordinates part of the production line. This actor informs the Technician about possible defects and is responsible for the good health of a system or subsystem. This actor also proposes continuous improvements and contributes to the Overall Equipment Effectiveness by decreasing the man-hours for maintenance.
- The **Technicians** are responsible for the inspection and repair of malfunctions. All the issues are recorded and fixed if it is possible immediately. Otherwise, if the repair is not possible the production line should be paused until the repair is completed.

2.3.2. Monitor System Variables

This business scenario 1 (Table 1) that shall be implemented by the MAILLIS Business Case aims at effectively monitoring system variables to improve activities related with assets maintenance. This scenario includes real-time and near-real-time monitoring of a set of variables regarding operational properties, soap oil and the condition of the materials. It targets to detect malfunctions, identify the need for soap oil corrections and generate alerts for material defects.

Table 1. Business Case Scenario 1

Business Scenario 1: Monitor System Variables	
Business Process 1.1	**Identification of variables, business processes, their characteristics and duration**
The system variables shall be monitored to identify how they affect the lifecycle of the production line. By exploiting sensor data through the UPTIME_SENSE module and historical data from past business processes, we will generate the appropriate input format to feed the UPTIME_DETECT module to detect conditions and correlations and the UPTIME_FMECA module to identify criticality. The result will feed the UPTIME_DETECT, UPTIME_PREDICT and UPTIME_DECIDE module to drive notifications for material defects, provide insights for soap oil corrections and feedback on operation properties.	
Business Process 1.2	**Deploy alternative production line plans**
The objective will be to select the set of system variables that best meets MAILLIS business processes. For example, if the objective function is to minimise failures or the threshold of the defective parts, we will explore alternative set of variables for each operation and will save the generated selections for future use.	
Business Process 1.3	**Validation of alternative sets of monitored variables; Monitoring & Evaluation of the respective KPIs (Total DownTime; Utilization Ratio).**
We will assess the alternative generated selections of variables set with respect to time and cost savings.	
Main Actors	(I) Technical manager; (II) Factory worker; (III) Technicians.
Benefits	**Challenges**
Transform the short-term production plan; Optimal utilisation of the available resources; Increase the mean time between failures; Decrease the threshold of the defective parts; Contribute to increasing the Overall Equipment Effectiveness.	Variables feasibility; Algorithm efficiency; Detection & prediction accuracy.

2.3.3. Recommendation

The business scenario 2 (Table 2) that shall be implemented by the MAILLIS Business Case aims at effectively optimising daily activities and the entire production line by creating a set of recommendations regarding the rollers estimated working cycle, the rollers estimated service life and the soap oil readjustment time.

Table 2. Business Case Scenario 2

Business Scenario 2: Recommendation	
Business Process 2.1	Identification of variables, business processes, their characteristics and duration
The critical variables shall be monitored to identify how they affect the lifecycle of the production line. By exploiting sensor data through the UPTIME_SENSE module and historical data from past business processes, we will generate the appropriate input format. End users feedback will be used in the UPTIME_DECIDE module regarding the assessment w.r.t the quality of products. The UPTIME_DECIDE module shall be able to provide recommendations for rollers replacement or early warnings for soap oil usage.	
Business Process 2.2	Deploy alternative production line plans along with quality metrics regarding the full system roller
The objective will be to select the scenario that best meets MAILLIS business processes. The UPTIME_DETECT & UPTIME_PREDICT modules will be used to detect rules and correlations. The result will feed the UPTIME_DECIDE module to drive recommendations.	
Business Process 2.3	Validation of alternative plans performed along with user's feedback; Monitoring & Evaluation of the respective KPIs (Loss of Production; Cost Assessment)
The recommendations from the decision-making module with respect to cost savings will be assessed.	
Main Actors	(I) Technical manager; (II) Factory worker; (III) Technicians.
Benefits	**Challenges**
Optimal utilisation of the available resources; Decrease the mean time to repair; Self-optimize output quality and performance across the production line; Better products quality.	Variables feasibility; Decision-making algorithm efficiency; Recommendations accuracy.

2.3.4. Analysis of Production Data

The business scenario 3 (Table 3) that shall be implemented by the MAILLIS Business Case aims at effectively transitioning from preventive maintenance to predictive maintenance. This will be realized through a set of analytics over production data which will facilitate the prompt detection and prediction of malfunctions of roller mills. The analysis of total downtime will facilitate the estimation of the total lost production volume. The analysis of utilization ratio can give insights on the impact of the production cost. Also, the rollers mean working cycle time and mean service life can optimize the utilization of the available resources and improve the quality and performance across the production line.

Table 3. Business Case Scenario 3

Business Scenario 3: Analysis of Production Data	
Business Process 3.1	**Identification of variables, business processes, their characteristics and duration**
We will identify the production data to be analysed which can improve the lifecycle of the production line. By exploiting sensor data through the UPTIME_SENSE module and historical data from past business processes, we will use the UPTIME_DETECT, UPTIME_ANALYSE & UPTIME_PREDICT modules to detect patterns/events/rules. The result will feed the UPTIME_DECIDE module to facilitate the recommendation engine provide alternative maintenance scenarios or give insights regarding the cost reduction in the production line or insights regarding the increase of rollers mean life.	
Business Process 3.2	**Deploy alternative algorithms to support predictive maintenance;** **Deploy mechanisms for decision-making.**
The objective will be to select the parameter setting, configuration and set of analytics of production data that best meets MAILLIS predictive maintenance processes.	
Business Process 3.3	**Validation of performance, efficiency and accuracy of predictive maintenance models;** **Monitoring & Evaluation of the respective KPIs (Optimal times to maintain key assets; Utilization Ratio; Total DownTime; Loss of Production; Cost Reduction; Roller Mean Life).**
The alternative generated analyses of production data with respect to time and cost savings will be assessed.	
Main Actors	(I) Technical manager; (II) Factory worker; (III) Technicians.
Benefits	**Challenges**
Transform the short-term/long-term maintenance plan; Increase the percentage of the predictive maintenance execution; Decrease the man-hours for maintenance; Optimal utilisation of the available resources; Cost reduction.	Variables feasibility; Algorithm efficiency; Analytics efficiency.

2.4. Data Availability

Considering the early development phase of the UPTIME Framework, the data availability is not fully confirmed yet in terms of what specific data is going to be recorded as well as its format, nevertheless a first identification of the potential stored variables took place with respect to the achievement of the main goal of the specific business case needs. To this end, an analysis of both the main objectives and the categorization of the data is defined.

The main objectives of the MAILLIS Business Case is to ensure and increase the lifespan of rollers, which are meaningful part of equipment for the process of rolled steel. The process consists of three parts which are the cutting, the deoxidation and the rolled of the material. Each one phase is important for the process but just in deoxidation and rolled of the material there is data availability and variables that could be captured to avoid potential damage during the production. These variables are divided into three categories based on their operation and the material they derive from and their description can be found in Table 4.

While Table 4 describes the categorization of the data, Table 5, Table 6 and Table 7 measure the importance of each variable with respect to the system as well as the feasibility of being captured by the sensors. Each one of these tables refer to a separate category of variables, as they are specified in Table 4. This correlation of values will result in grouping the data that will be used in the first development phase. For the case of the evaluation of the data significance the values **Low, Medium and High** are used, while for the feasibility of data capture the values **Hard, Medium and Easy** are used.

Table 4. Variables Categorisation

Category	Kind of Data
Operation Variables	Roll Vibration, Temperature (bearing), Temperature (roller), Current Intensity in Engine, Duration of unequal operation of rolls, Duration of operation for each thickness reduction
Soap Oil Variables	pH, Fe Concentration, Inductance, Concentration, Temperature, Cl concentration in water
Material Variables	Composition, Material defects, Strip width

Table 5. Operation Variables

Variable	Significance	Feasibility
Roll Vibration	High	Hard
Temperature (bearing)	Medium	Medium
Temperature (roller)	High	Hard
Current Intensity in Engine	Medium	Easy
Duration of unequal operation of rolls	Medium	Easy
Duration of operation for each thickness reduction	High	Easy

Table 6. Soap Oil Variables

Variable	Significance	Feasibility
pH	Medium	Medium
Fe Concentration	Medium	Hard
Inductance	Medium	Medium
Concentration	Medium	Medium
Temperature	Medium	Easy
Cl concentration in water	Low	Medium

Table 7. Material Variables

Variable	Significance	Feasibility
Composition	Medium	Easy
Material Defects	High	-
Strip Width	Low	Easy

2.5. Relevant IT Systems

For the MAILLIS Business Case the systems that are used for the Roller mill maintenance can be summarized to existing data storage systems where the data are stored and then these datasets are processed by the engineers to proceed to several actions per case, according to their experience. In the context of UPTIME, sensors for measuring different types of data and Programmable Logic Controller (PLC) for the transmission of the captured data will be installed and used.

A sensor is a device, whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor [5]. The specific types of the sensors that will be placed to MAILLIS production line can be summarized as follows:

- Current sensor;
- Temperature gauge;
- Motion detector;
- Vibration sensor;
- Inductance detector.

Sensors will capture the values of the variables and this kind of information will pass to Programmable Logic Controller (PLC) for further processing and the actual transmission of the data to the UPTIME system. PLC is an industrial digital computer which is responsible for the processing and the control of manufacturing processes, such as assembly lines, or robotic devices, or any activity that requires high reliability control and ease of programming and process fault diagnosis [6].

3. Business Case Requirements

In this section, the individual requirements of the MAILLIS Business Case in cold rolling mills line are analysed and documented. Emphasis is given on the ease of integration to make sure, that components of the UPTIME Framework can be easily deployed into the existing MAILLIS Infrastructure. The UPTIME Framework as documented in the Deliverable D2.1a "Conceptual Architecture and System Specification" is a flexible and modular system architecture able to facilitate the realization of scenarios of the MAILLIS Business Case. In close cooperation with the other Business Cases as well as tasks conducted in the context of WP2 and WP3, the system concept is specified by following an agile approach. In the following, the main stakeholders (workers, project coordinator, administrator) of the MAILLIS Business Case report on the system and technical requirements and components needed for this pilot.

3.1. Stakeholder Requirements

Table 8 provides an overview of the global stakeholder requirements – commonly also referred to as business requirements or high-level requirements – and their description, as defined in the Deliverable 2.1a. The stakeholder requirements will be used as a reference in the definition of system and technical requirements (Sections 3.2 and 3.3).

For traceability purposes, the stakeholder requirements have a unique ID that follows a specific pattern: G_STHR_I_number, where G indicates global stakeholder requirements, which are applicable for all three business cases; STHR stands for stakeholder requirement; I (or II) represents the release it was defined; and number is the number of the defined requirement.

Table 8. Stakeholder Requirements

Requirement ID	Requirement Description	Comments
G_STHR_I_2	The system shall contribute to increasing the Operational Availability	How long a system has been available to be used when compared with how long it should have been available to be used. {Tup/(Tup+Tdown)}
G_STHR_I_3	The system shall contribute to increasing the Performance	The speed at which the manufacturing runs as a percentage of its designed speed.{(Parts Produced*Ideal Cycle Time)/Tup}
G_STHR_I_4	The system shall contribute to increasing the output Quality	The amount of the Good Units produced as a percentage of the Total Units Started{(Parts Produced-Defective Parts)/Parts Produced}
G_STHR_I_5	The system shall decrease the Maintenance Cost	The costs associated with keeping the manufactured goods in good condition by regularly checking it and repairing it. {Σ(all costs)/(Man-hours for maintenance)}
G_STHR_I_6	The system shall contribute to decreasing all costs	Those include: spare parts, consumable unit cost, packaging, storage, handling, transportation, training cost for mainenance, disposal cost.
G_STHR_I_7	The system shall decrease the man-hours for Maintenance	The accumulated duration of the individual maintenance times used by all maintenance personnel for a given type of maintenance action or over a given time interval.
G_STHR_I_8	The system shall increase the Percentage of the Predictive Maintenance Execution	Number of maintenance actions avoiding failures/Number of total failures

Requirement ID	Requirement Description	Comments
G_STHR_I_9	The system shall increase the Number of the Maintenance Actions Avoiding Failures	
G_STHR_I_10	The system shall decrease the Number of Total Failures	
G_STHR_I_11	The system shall contribute to decreasing the Plant Power Consumption	Function of Tup and other parametres, depending on the plant typology
G_STHR_I_12	The system shall contribute to increasing the Production Volume	Function of Performance
G_STHR_I_13	The system shall decrease the threshhold of the Defective Parts	Quantitative reduction of the parameters that contribute to define a defective part.
G_STHR_I_14	The system shall contribute to preventing injuries due to failures	
G_STHR_I_15	The plant shall increase the mean time between Failures	$1/\lambda$; The predicted elapsed time between inherent failures of a system, during normal system operation.
G_STHR_I_16	The plant shall decrease the Total Failure Rate of the Equipment	λ; The frequency of failure for a unit of time.
G_STHR_I_17	The plant shall increase the mean time between Critical Failures	$1/\lambda c$
G_STHR_I_18	The plant shall decrease the Total Critical Failure Rate of the Equipment	λc; The frequency of critical failure for a unit of time. Critical Failure: A failure or combination of failures that prevents an item from performing a specified mission and as a result there is a loss of the required functions and causing the loss of the equipment mission.
G_STHR_I_19	The plant shall contribute to decreasing the mean time to Repair	Σ(corrective maintenance times)/Number of failures
G_STHR_I_20	The plant shall decrease the sum of the Corrective Maintenance Times	
G_STHR_I_21	The plant shall decrease the Number of falures	
G_STHR_I_22	The system shall provide recommendations for scheduling the predictive maintenance activities to legacy systems (e.g. SAP-PM)	
G_STHR_I_23	The system shall receive historical machine failures	

Requirement ID	Requirement Description	Comments
	from legacy systems (e.g. SAP-PM)	
G_STHR_I_24	The system shall receive energy consumption data streams from legacy systems (e.g. Whr EMS)	
G_STHR_I_25	The user should have a clear indication about the current health status of the machine under monitoring	
G_STHR_I_26	The system shall provide a clear prognosis indication about the machine health status in the near future	
G_STHR_I_27	The system shall inherit all the maintenance-related static information (e.g. equipment Ledger, failure classifications, etc) from legacy systems (i.e. SAP PM DB)	

3.2. System Requirements

The current section describes the system requirements which according to the requirement methodology that defined in *D2.1a: Conceptual Architecture and System Specification*, derive from the stakeholder requirements and are used to assess the system engineering design, processes and plans of the MAILLIS Business Case. These requirements should answer "what" is needed by the UPTIME Framework. More specifically, a definition of system requirements takes place in the following, referring to the specific behaviour and functionality that the UPTIME Framework should have. The set of system requirements documented in the present deliverable, is derived from the stakeholder requirements according to Section 2.2 and the MAILLIS Business Case scenario which is mapped to UPTIME Conceptual Architecture and defined in *D2.1a: Conceptual Architecture and System Specification.*

In the MAILLIS Business Case, the system should provide mechanisms for real-time monitoring of data relevant to operation, soap oil, and the material. Table 9 summarizes the list of system requirements concerning to the present business case. To facilitate the description of the system requirements, a categorization of functions (taxonomy) which are related to these requirements takes place and is summarized as:

- <u>Application:</u> What are the key functions to be supported by the selected component in the demonstrator;
- <u>User Interface (if any):</u> What are the characteristics of component's user interfaces (considering different types of devices) and associated requirements;
- <u>Data sources:</u> What are the requirement and constrains for required data (databases, data streams and data repositories). In this category are also included field devices (e.g. PLC) devoted to realizing floor monitoring;
- <u>Interfaces and Interoperability:</u> What are the requirements for integration and interoperability of the component (EAI, protocols, etc.)

It is also necessary to identify the rank, identifying relevance/priority of the requirement as: **High**, **Medium**, **Low**.

It needs to be noted that for traceability purposes, the system requirements have a unique ID that follows a specific pattern: BC3_SR_I_no where BC3 indicates it concerns Business Case 3 by MAILLIS, SR highlights that it is a system requirement, I (or II) represents the release it was defined, and *no* numbering.

Table 9 depicts the list of system requirements for the Cold Rolling Case. The "*Derives From"* column denotes the list of stakeholder requirements that the corresponding system requirement satisfies. The list of stakeholder requirements was defined in D2.1; in this deliverable a simplified numbering convention for the stakeholder requirements is followed.

Table 9. List of System Requirements

System Req. ID	Description	Taxonomy	Priority	Action	Derives From
BC3_SR_I_1	The system shall monitor mining rollers temperature	Data sources	High	If an irregular value is detected an alert is generated	G_STHR_I_1 G_STHR_I_2 G_STHR_I_25 G_STHR_I_26
BC3_SR_I_2	The system shall monitor mining rollers vibration	Data sources	High	If an irregular value is detected an alert is generated	G_STHR_I_1 G_STHR_I_2 G_STHR_I_25 G_STHR_I_26
BC3_SR_I_3	The system shall monitor mining rollers bearings temperature	Data sources	High	If an irregular value is detected an alert is generated	G_STHR_I_1 G_STHR_I_2 G_STHR_I_25 G_STHR_I_26
BC3_SR_I_4	The system shall monitor soap oil variables	Data sources	Medium	An alert is generated, and soap oil needs to be renewed	G_STHR_I_1 G_STHR_I_2 G_STHR_I_25 G_STHR_I_26
BC3_SR_I_5	The system shall monitor measure of electrical motors' tension	Data sources	Medium	If an irregular value is detected an alert is generated	G_STHR_I_1 G_STHR_I_2 G_STHR_I_3 G_STHR_I_25 G_STHR_I_26
BC3_SR_I_6	The system shall monitor measure of duration of the thickness reduction process	Data sources	High	If an irregular value is detected an alert is generated	G_STHR_I_1 G_STHR_I_2 G_STHR_I_4 G_STHR_I_25 G_STHR_I_26
BC3_SR_I_7	The system shall monitor material defects	Data sources	High	An alert is generated if an impurity is detected	G_STHR_I_1 G_STHR_I_2 G_STHR_I_5 G_STHR_I_6 G_STHR_I_25 G_STHR_I_26
BC3_SR_I_8	The system shall monitor material composition	Data sources	Medium	An alert is generated if an impurity is detected	G_STHR_I_1 G_STHR_I_2 G_STHR_I_12 G_STHR_I_15 G_STHR_I_16 G_STHR_I_17 G_STHR_I_18 G_STHR_I_25 G_STHR_I_26
BC3_SR_I_9	The system shall monitor material composition strip width	Data sources	Low	An alert is generated if an impurity is detected	G_STHR_I_1 G_STHR_I_2 G_STHR_I_4 G_STHR_I_25 G_STHR_I_26

System Req. ID	Description	Taxonomy	Priority	Action	Derives From
BC3_SR_I_10	The system should provide recommendations to decrease the temperature	Application	High	The decision-making module should contribute to increase the temperature	G_STHR_I_1 G_STHR_I_2
BC3_SR_I_11	The system should provide recommendations to decrease the vibrations	Application	High	The decision-making module should contribute to decrease the temperature	G_STHR_I_1 G_STHR_I_2
BC3_SR_I_12	The system should provide recommendations to decrease the temperature of bearings	Application	High	The decision-making module should contribute to decrease the temperature of bearings	G_STHR_I_1 G_STHR_I_2
BC3_SR_I_13	The system should perform analysis of historical data to calculate risks and identify criticalities in the production line	Application	High	The risk analysis engine should perform analysis of historical data to calculate risks and identify criticalities in the production line	G_STHR_I_1 G_STHR_I_2 G_STHR_I_5 G_STHR_I_6 G_STHR_I_9 G_STHR_I_10 G_STHR_I_15 G_STHR_I_16 G_STHR_I_17 G_STHR_I_18
BC3_SR_I_14	The system should predict and assess risks of future failure(s) per machine	Application	High	Along with the definition of risk patterns, the risk analysis engine should be able to predict and assess risks of future failure(s) per machine	G_STHR_I_1 G_STHR_I_2 G_STHR_I_5 G_STHR_I_6 G_STHR_I_10 G_STHR_I_15 G_STHR_I_16 G_STHR_I_17 G_STHR_I_18
BC3_SR_I_15	The system should be easily configurable regarding the processes about decision-making	User Interface	High	The system users (managers) should be able to configure the processes about decision-making	G_STHR_I_7 G_STHR_I_8
BC3_SR_I_16	The system should be easily configurable regarding the definition of sample maintenance action related parameters	User Interface	High	The system users (managers) should be able to define some sample maintenance action related parameters	G_STHR_I_7 G_STHR_I_8

System Req. ID	Description	Taxonomy	Priority	Action	Derives From
BC3_SR_I_17	The system should provide notifications about optimal maintenance actions	User Interface	High	The system users (managers) should receive notifications about optimal maintenance actions and the system shall decrease the threshold of the defective parts	G_STHR_I_1 G_STHR_I_2 G_STHR_I_3 G_STHR_I_4 G_STHR_I_7 G_STHR_I_9 G_STHR_I_10 G_STHR_I_12 G_STHR_I_15 G_STHR_I_16 G_STHR_I_17 G_STHR_I_18
BC3_SR_I_18	The system should provide recommendations about the maintenance actions to be performed	User Interface	High	The system users (factory workers, technicians) should be able to get recommendations about the maintenance actions to be performed and the system shall decrease the man-hours for maintenance and thus the sum of the corrective maintenance times	G_STHR_I_1 G_STHR_I_2 G_STHR_I_3 G_STHR_I_4 G_STHR_I_5 G_STHR_I_6 G_STHR_I_10
BC3_SR_I_19	The system should provide recommendations/ suggestions for predictive maintenance actions	User Interface	High	Recommendations/ suggestions for predictive maintenance actions through GUI	G_STHR_I_1 G_STHR_I_2 G_STHR_I_3 G_STHR_I_4 G_STHR_I_5 G_STHR_I_7 G_STHR_I_12 G_STHR_I_15 G_STHR_I_16 G_STHR_I_17 G_STHR_I_18
BC3_SR_I_20	The system should be easily configurable towards users, events triggered by the production line or generated by the analytic processes	User Interface	High	System administrator (managers) can configure users, events, analytics processes through the UI	G_STHR_I_7 G_STHR_I_8 G_STHR_I_26

3.3. Technical Requirements

The system requirements described in Section 3.1 feed the technical requirements that are presented in this section and specify the technical implementation parameters of the system. As the primary scope of these requirements is to document implementation requirements as well as some constraints that derive from the development infrastructure following an agile methodology, the analysis will take the form of the definition of technical requirements. Table 10 presents the high-level taxonomy of technical requirements along with a short description of each category type and the priority level, while Table 11 gives the description of the technical requirements for the MAILLIS Business Case. Some of the technical requirements are very generic in the sense that they cover non-functional parts of the system. For these requirements, the *ALL* keyword in the *"Derives From"* column denotes that the particular technical requirement derives from all the *System* requirements. A technical requirement may also be derived from another technical requirement. If this is the case, the corresponding technical requirement also appears in the *"Derives From"* column.

Table 10. High-level Analysis of Technical Requirements

Technical Requirements	Description	Priority Level
Accuracy	The levels of accuracy on produced results	Medium
Communication	A system design principle where the implementation takes future growth into consideration	High
Interfaces	The presentation of project results in a visually appealing way	Medium
Performance	The level of time and resources needed for the delivery of the framework	High
Security/Privacy	Addressing security and privacy aspects	High
System	The capability of a system, network, or process to handle a growing amount of work, or its potential to be enlarged to accommodate that growth	High
User	User is position in the centre of usability aiming to facilitate the ease of use and learnability of the application	Medium

It needs to be noted that for traceability purposes, the technical requirements have a unique ID that follows a specific pattern: BC3_TR_I_no where BC3 indicates it concerns Business Case 3 by MAILLIS, TR highlights that it is a technical requirement, I (or II) represents the release it was defined, and *no* the numbering.

Table 11. List of Technical Requirements

Technical Req. ID	Description	Taxonomy	Priority	Action	Derives From
BC3_TR_I_1	The sensors shall capture real-time measurements to enable monitoring of system variables	Accuracy	High	Decision of what and when to produce	BC3_SR_I_1 BC3_SR_I_2 BC3_SR_I_3 BC3_SR_I_4 BC3_SR_I_5 BC3_SR_I_6 BC3_SR_I_7 BC3_SR_I_8 BC3_SR_I_9
BC3_TR_I_2	The product functions shall enable to optimise the production line	Performance	High	The UPTIME system shall minimize the occurrence of unplanned events by using machine learning models for prediction, decrease the threshold of the defective parts and the mean time to repair	BC3_SR_I_10 BC3_SR_I_11 BC3_SR_I_12 BC3_SR_I_13 BC3_SR_I_14 BC3_SR_I_15 BC3_SR_I_16 BC3_SR_I_17 BC3_SR_I_18 BC3_SR_I_19 BC3_SR_I_20
BC3_TR_I_3	The software shall conduct predictive maintenance tasks	Accuracy/ System	High	Use machine learning models to identify the optimal times to maintain key machines and equipment, increase the Overall Equipment Effectiveness and the mean time between failures	BC3_SR_I_14 BC3_SR_I_17 BC3_SR_I_18
BC3_TR_I_4	The interfaces shall provide formal language of the deployment country	Interfaces/ User	High	User Interfaces shall be in the formal language of the deployment country	BC3_TR_I_5 BC3_TR_I_6 ALL
BC3_TR_I_5	The interfaces shall provide simple and intuitive User Interface	Interfaces/ User	High	The User Interface shall be simple and intuitive for the end users and contribute to increasing the output quality	BC3_TR_I_6 ALL
BC3_TR_I_6	The interfaces shall provide clear and easy to understand recommendations	User	High	The recommendations provided by the system shall be clear and easy to understand	BC3_SR_I_18 BC3_SR_I_19

Technical Req. ID	Description	Taxonomy	Priority	Action	Derives From
BC3_TR_I_7	The system should be continuously operational	Performance	High	The platform and applications shall be 24/7 operational	ALL
BC3_TR_I_8	The system should be able to handle large number of request with short response time and without any downtime	Performance	High	To handle large number of request with short response time and without any downtime, having this feature would be beneficial	ALL
BC3_TR_I_9	The system shall be able to run without data corruption and underperformance	Performance	High	The system shall be able to run for long periods of time without data corruption and underperformance	ALL
BC3_TR_I_10	The software shall provide accurate detection of incidents and events	Accuracy/Interfaces	High	The platform should provide accurate detection of incidents and events (prognosis and decision-making)	BC3_SR_I_17
BC3_TR_I_11	The product functions shall provide accurate data analysis by monitoring historical and real-time system variables	Accuracy	High	The platform should provide accurate analytics (patterns/rules/risks identification)	BC3_SR_I_13
BC3_TR_I_12	The system shall provide platform independent communication among its components	Communication	High	Communication among UPTIME components shall be platform independent	ALL
BC3_TR_I_13	The communications shall be conducted in a common format for exchanged and stored information	Communication	High	All information exchanged and stored within UPTIME components shall be in a common format understandable from all components	ALL

4. Business Case Conceptualization

Following the Business Case Context in Section 2 where the whole process of rolled steel is described, the business case requirements that were identified and reported in Section 3 and the conceptual architecture that is documented in *D2.1a: Conceptual Architecture and System Specification,* the overall business case architecture is defined in terms of what components shall be involved and how they are going to interact with each other to fulfil the specific business case needs. At first, the UML use case diagram of MAILLIS Business Case is presented, the overall business case architecture along with the adaptation of the e-Maintenance model is described and in continuation to this, the infrastructure to support the whole architectural definition is presented.

4.1. MAILLIS Business Case

In this Section, we present the MAILLIS Business Case expressed in a UML use case diagram (Figure 13). The use case diagram covers three (3) scenario for the MAILLIS Business Case, namely **monitor system variables**, **recommendation** and **analysis of production data**.

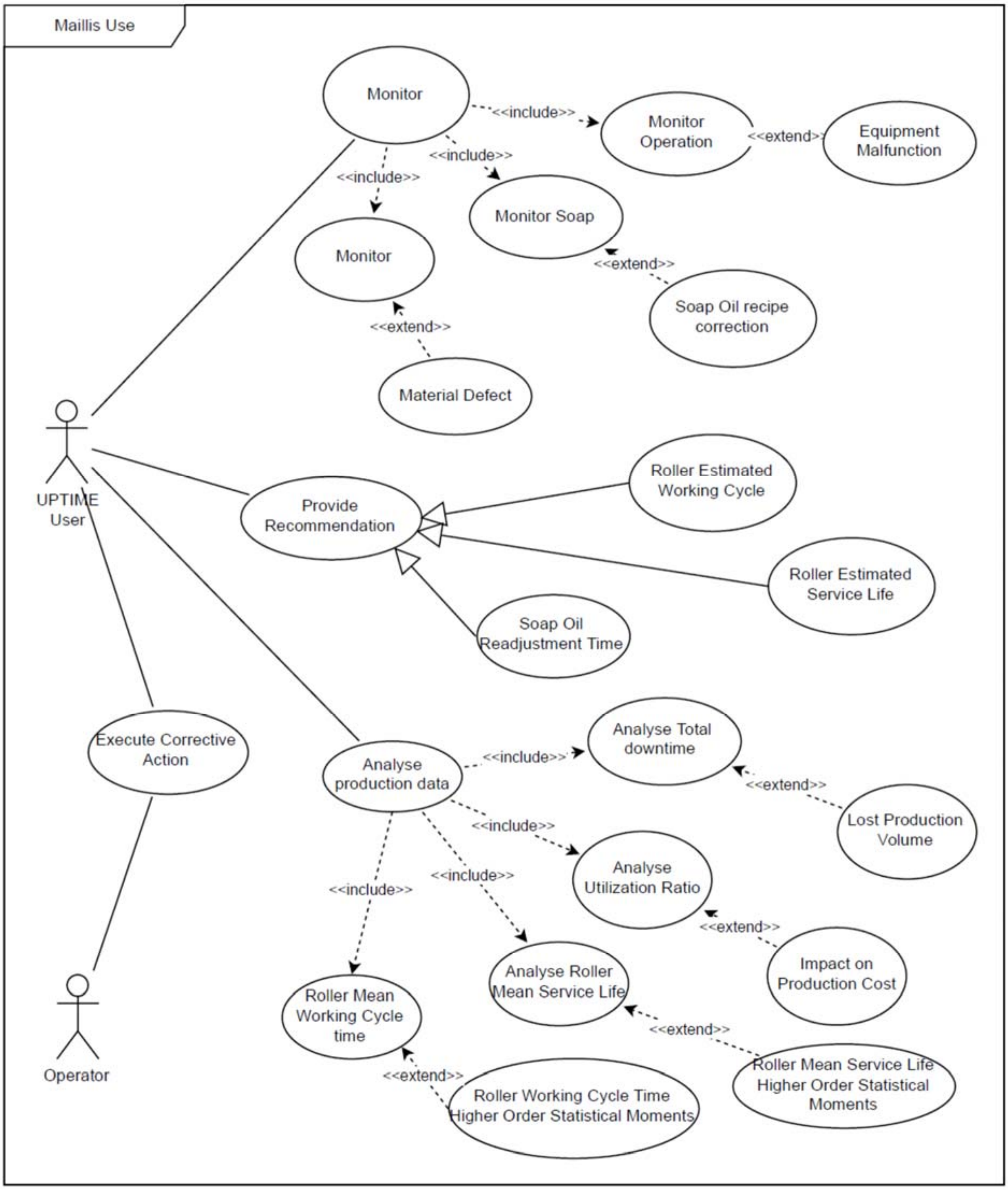

Figure 13. UML Use Case Diagram for the MAILLIS Business Case

4.1.1. Monitor System Variables

This use case deals with the real-time monitoring of data relevant to operation, soap oil, and the material. It includes notifications being generated both by the front-end monitoring and by the backend of UPTIME. The variables to be monitored include Operation Variables, Soap Oil Variables and variables related to the condition of the materials.

4.1.2. Recommendation

This use case alerts MAILLIS personnel (i.e. Factory workers and/or Technicians) to proceed to a replacement of a Mil Roller or Soap Oil. Regarding Soap Oil, the difference between this case and the one occurring in the monitoring is that here the entire roller system is taken into account. More specifically, in the monitor case, the values are measured and are matched to base values. In the recommendation case, the status of the rollers is taken into account and their function is projected with current soap oil values.

4.1.3. Analysis of Production Data

This use case includes a set of analytics over production data provided in the form of interventions/feedback to MAILLIS personnel. This set of analytics enable the tracking of the defined KPIs (cf. Section 2.3) and permit to report based on a Red, Amber, Green (RAG) reporting the status of the respective indicators.

4.2. Adaptation of the UPTIME e-Maintenance Model

The UPTIME Framework aims to satisfy the MAILLIS Business Case requirements and project requirements by the adaptation of the UPTIME e-Maintenance Model as depicted in Figure 14. To this end, UPTIME e-Maintenance model should fulfil the specific business case needs by addressing the business case requirements that were specified in Section 3 on the one hand, and on the other hand as a unified platform, should cover the project requirements by taking into account the heterogeneous fields in industry.

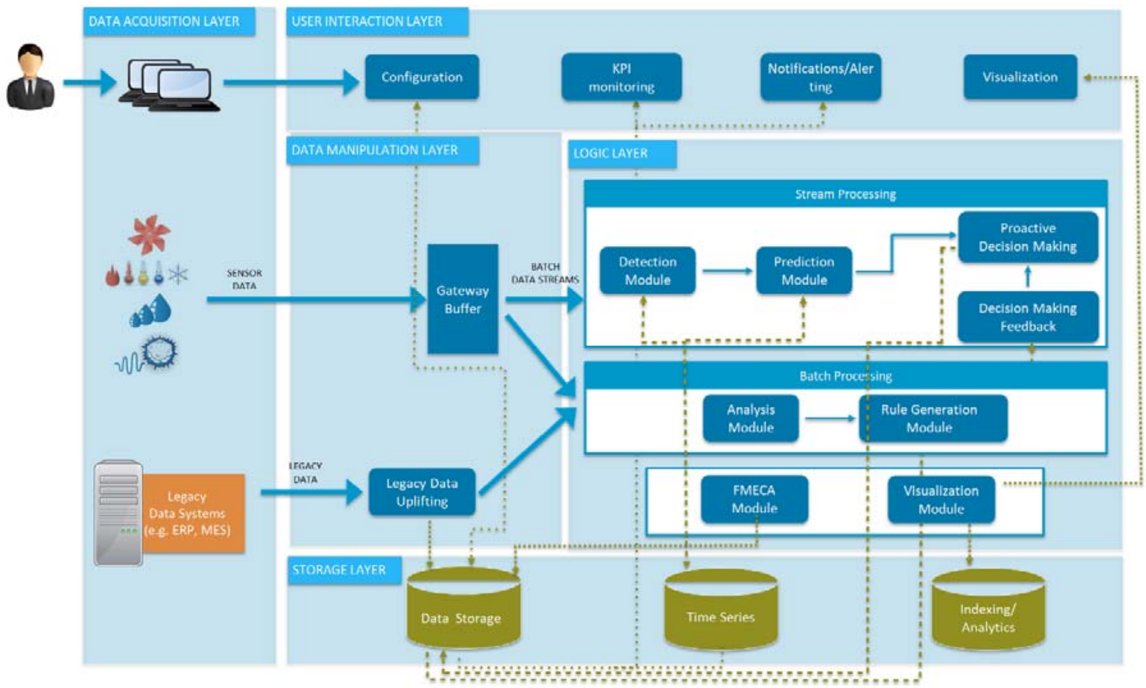

Figure 14. Adaptation of UPTIME e-Maintenance Architecture

For the technical deployment in MAILLIS Business Case the UPTIME modules of each UPTIME phase cover the respective functionalities and provide a structural relationship among them. These modules of the technical view of the conceptual architecture as well as their functionalities that meet the specific business case requirements are summarized in Table 12.

Table 12. UPTIME e-Maintenance Model and Business Case Conceptualisation

Process / Action	Functionality	Module(s)
The user installs the sensors for monitoring the real time operational data.	Data Acquisition	IoT Gateway
The user installs the sensors for monitoring material data	Data Acquisition	IoT Gateway
The user stores the reported soap oil values to the PLC	Data Acquisition	IoT Gateway
Rounding filters are set to all variables that are transmitted as numbers	Data Handling	IoT Gateway
Categorization filters are set to all variables that are transmitted as categorical.	Data Handling	IoT Gateway
Data gathered at the on-site PLC are transmitted through the channel	Data Transmission	IoT Gateway
Brokers apply in real time the filters set by the user	Data Transmission	Broker
Apply time intervals for any measured operation variable streams	Connecting to sensor data	Flows Engineering
Define alert thresholds for material variables	Definition of queries on sensor data streams	Flows Engineering
Define alert thresholds for operation variables	Definition of queries on sensor data streams	Flows Engineering
Set query to obtain correlations of operation alerts and operational variables	Definition and engineering of calculation flows	Flows Engineering
Apply monitoring queries to highly correlated operational variables	Instantiation of calculation flows	Flows Engineering
Output estimated time until failure of each roller	Deployment and monitoring of calculation flows	Prediction Flows Calculation
Output projected performance level for each roller assuming no maintenance.	Deployment and monitoring of calculation flows	Prediction Flows Calculation
Output recommendation time for roller maintenance	Proactive recommendations	Proactive Decision-Making

Process / Action	Functionality	Module(s)
Output recommendation for roller replacement	Proactive recommendations	Proactive Decision-Making
Identify critical components and increase detectability by improving the sensor network sensitivity.	Incorporating FMECA results	Decision-Making Feedback
Store past excel records to databases	Data Preparation	Legacy Data Uplifting
Apply filters, normalization and categorization to stored data	Data Pre-processing	Legacy Data Analysis
Obtain correlations of roller failure times and recorded operational variables	Data analysis	Legacy Data Analysis
Encode the correlations to rules: each significant combination of operational variables shall generate rules for roller maintenance and replacement	Rule Generation	Rule Generation
Encode significant correlations between trends of operational variables and roller maintenance failure times to patterns	Pattern recognition models	Legacy Data Analysis
Recognized patterns of trends shall be exposed for UPTIME PREDICT	Pattern recognition models	Legacy Data Analysis
Identify critical component of the production line	FMECA parameters update	FMECA Feedback
For each component calculate the total risk. Aggregate results for the whole production line	Risk calculation	FMECA Analysis
Predict possible modes of failures for all the identified components	Risk prediction	FMECA Analysis
Calculate the propagated risk between any combination of critical components	Fault Tree Analysis	FMECA Analysis

4.3. Business Case Architecture

In this section the architecture of MAILLIS Business Case in the context of UPTIME is presented. More specifically, the parts that shall compose the whole architecture of the present business case shall be described focusing on the *correlation of the sensor network infrastructure to the UPTIME phases*. To this end by taking into account the business case context of Section 2, the architecture of the current business case should follow a programmable sensor networking approach conducted by PLC device which collects the data from implemented sensor networks. A sensor network consists of sensors that collect the environmental variables and pass the information to PLC. Then, the stored data are accessible by the UPTIME system for the UPTIME_SENSE phase which subsequently shall feed the modules of the UPTIME system as well. Figure 15 depicts the business case architecture which complies to the general conceptual architecture from the technical point of view.

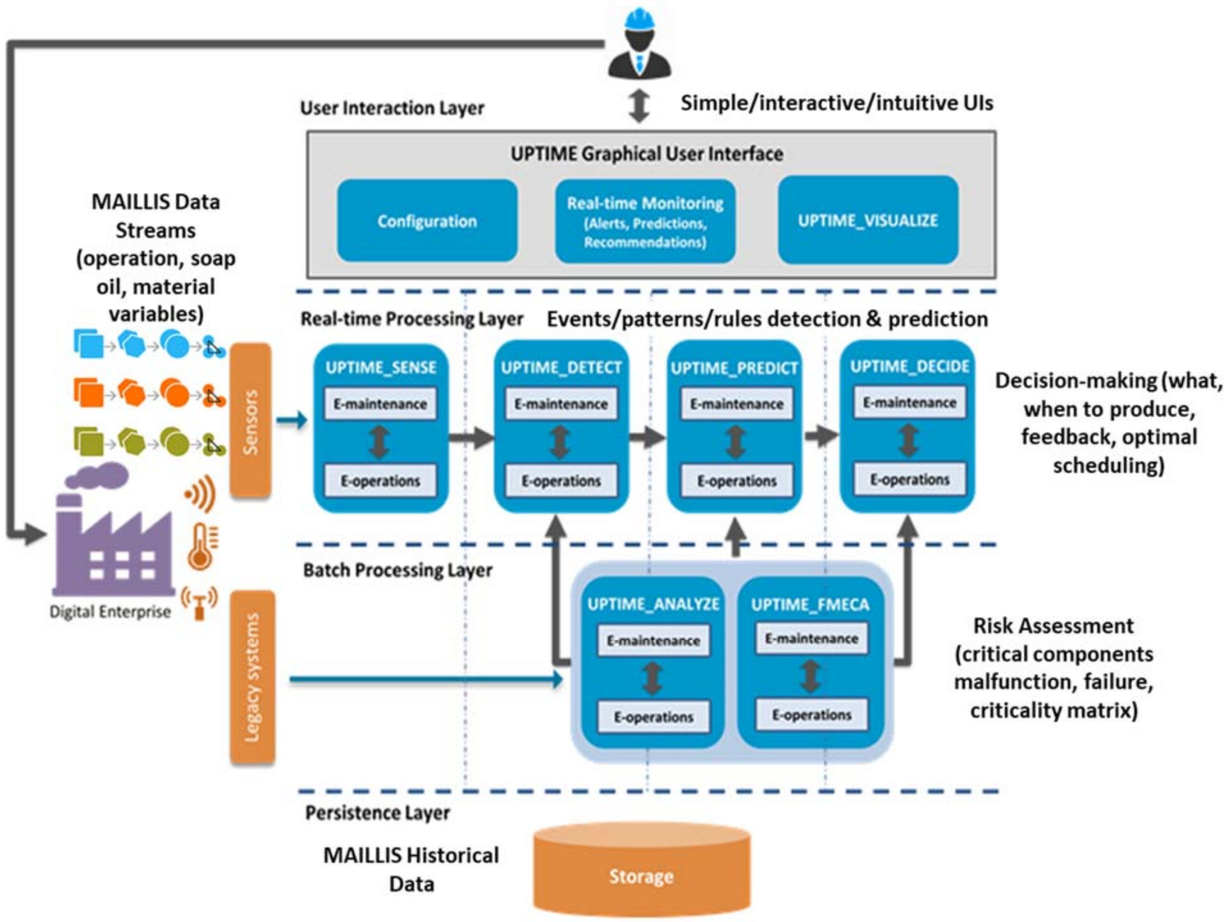

Figure 15. MAILLIS Business Case Architecture

In addition to the general approach of the architecture definition, the role of core modules that constitute the architecture with respect to the specific business case needs of MAILLIS can be summarized per phase from the conceptual architecture perspective.

UPTIME_SENSE: In this phase the modules aim to provide real-time monitoring of the state of each variable (operation, soap oil, material) and to ensure that the gathered data at the on-site PLC are transmitted through the communication channel.

UPTIME_DETECT: The definition of alert thresholds as well as a set of queries to obtain correlations of operation alerts and operational variables will be provided.

UPTIME_PREDICT: The calculation of prediction flows will result the estimated time until the failure of each roller. This covers the starting point of the main objective which is to extend the lifespan of rollers.

UPTIME_DECIDE: This phase includes the recommendations that UPTIME system should provide according to the results of UPTIME_SENSE and UPTIME_PREDICT, with respect to the operational and material variables.

UPTIME_ANALYZE: In this phase, after the migration/storage of past excel records to databases, the main analysis of these data and pattern recognition of trends will be implemented.

UPTIME_FMECA: FMECA phase aims to identify critical components and failures in the context of MAILLIS Business Case, that derive from a risk matrix per case. In this matrix the criticality of the components and failures is reported and is available to the UPTIME system.

UPTIME_VISUALIZE: This module is responsible for the aggregation of the results which will be available to the user and will report the results of the whole production line.

4.4. Existing Business Case Infrastructure

The existing infrastructure complies to the business case needs in terms of historical data persistence from existing data storage systems as well as the sensor networking approach that was described in Section 4.2 and is depicted in Figure 16. The historical data are the results of the current maintenance approach in the four general areas rolls, bearings, drives and auxiliaries as they were described in Section 2.3 and they are stored in a local data storage for further analysis and actions regarding the process of rolled steel. In the context of UPTIME, a SIEMENS S7-1500 Programmable Logic Controllers (PLC) is already installed, which runs on Siemens SIMATIC Industrial PCs completely independently of the operating system, a fact that gives significant performance advantages as soon as the controller is started. In addition to the high performance, the SIMATIC S7-1500 Software Controller is the only software controller with integrated safety functions [7]. Moreover, a connection from PLC to a client which acquires the data from the controller is set up and is conducted by Ethernet. Apart from the client for the data acquisition, a connection among PLC and the sensors shall be implemented as soon as they are ready for capturing and measuring the environmental variables.

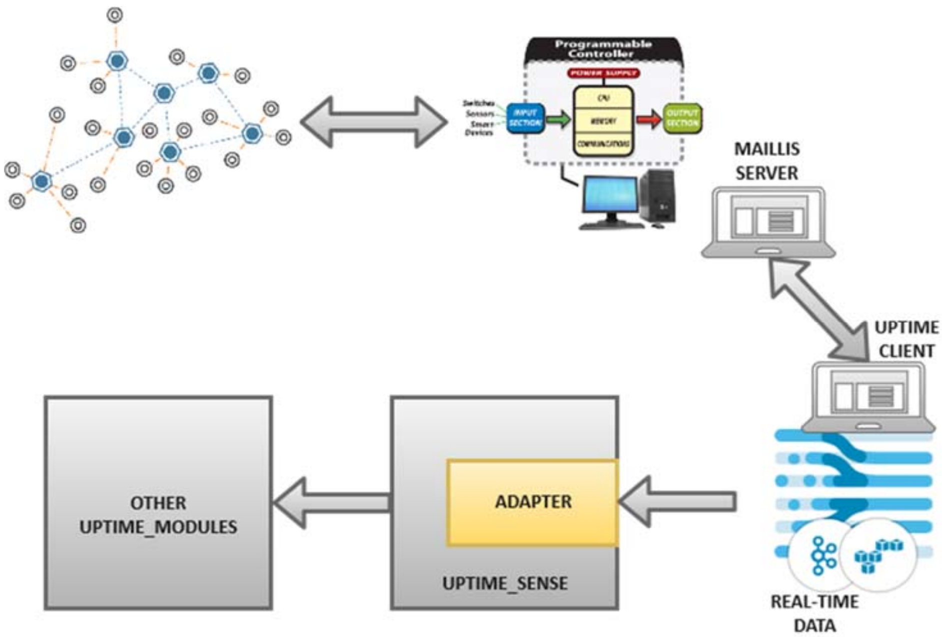

Figure 16. Existing Business Case Infrastructure

5. Business Case Evaluation

5.1. Evaluation Methodology

In this section we describe the methodological approach to evaluate the Business Case of the UPTIME Framework in the cold rolling mill lines. The MAILLIS Business Case is organized in health system assessment and predictive maintenance scenarios addressing secure and sustainable operations in the cold rolling domain. The Business Scenarios will serve as framework for the experimental set-up, addressing project outcomes through the project requirements and objectives.

A user centred approach will be adopted to assess the benefits and the impact of the adoption of the UPTIME approach in the cold rolling domain. The users participating in the experimental evaluation will be expert users, such as technician, engineers, operators and specialists with experience in the scenarios described in Section 2.2. Focus of the UPTIME experiments for the cold rolling case will be on the assessment of the developed models, functionalities and their efficiency. However, testing will evaluate also the usability of the integrated UPTIME Framework. The functionalities of the predictive maintenance in the cold rolling case will be evaluated against quality criteria, including the performance criteria (KPIs as presented in Section 2.2) derived from the evaluation of the UPTIME Architecture as introduced in Deliverable D2.1a Conceptual Architecture and System Specification. Additional technical criteria assessing the performance gain in the use of resources will also be included. The performance criteria defined for the validation of the UPTIME approach and framework against project requirements and objectives will be integrated in the MAILLIS Business Case.

The assessment of the UPTIME functionalities will be multi-level, because the UPTIME Framework will be evaluated against minimal functionalities of interest for the cold rolling use case, i.e., KPIs in Section 2.2. Moreover, through controlled degradation of the input datasets, the experimental evaluation will assess the capability of the UPTIME Framework to cope with the quality and variety of data.

Usability testing will include experts review of the prototype design and development and a focus group evaluation in a simulated operational setting reproducing the situations described in the scenarios, to assess qualitatively the experience of the user in typical working situations and accomplishing tasks common to their daily activities. Questionnaires and semi-structured interviews will be used to collect the data necessary to usability testing and evaluation. Similar data collection tools will be used for operational criteria.

Furthermore, additional data for quantitative performance criteria (such as processing time) will be collected automatically. The results of the evaluation will be disseminated in Deliverable D6.4 MAILLIS System Performance Evaluation. Formative testing will be run involving the users in the development cycle to identify and fix issues at an earlier stage, making the developers aware of insight of user evaluation and driving the development (e.g., of user interaction components). Summative testing will be also run to validate whether the UPTIME Framework satisfies the MAILLIS Business Case and project requirements, validating the final developments.

Other points that may be developed:

- Scope of the experiments and of the evaluation (and what is not in scope);
- Quality principles of evaluation and ethical considerations;
- Limitation, Risks, Constraints.

5.2. Benefits and Impact

The use case definition provides a tool for UPTIME to address different aspects of a large innovation problem, describing users' needs, operational problems and underlying challenges. Illustrating innovation implications on a common use case, sharing the same datasets, and utilizing outputs from other teams are all benefits of having an integrated picture of the general problem.

As such, the MAILIS Business Case should:

- UC Req. 1 Address challenging problems deemed of interest for the cold rolling mills operational community in general;
- UC Req. 2 Be aligned with the European Union initiatives and needs regarding the steel sector;
- UC Req. 3 Be aligned with UPTIME 's innovation objectives and expected outcomes such that the use case challenges the UPTIME's technical solutions to be developed, while accommodating the innovation interests of the different partners;
- UC Req. 4 Describe the problem in a simple way as a kind of _skeleton_, flexible enough to allow further evolution and developments as possibly requested by partners' interests;
- UC Req. 5 Provide the necessary information to understand the user's goal, from which the corresponding sub-goals, associated levels of granularity required, the information needs, and the desired output quality can be deduced;
- UC Req. 6 Act as an _integrator_ for the different aspects to be pursued so that teams can illustrate their findings within a common story;
- UC Req. 7 Provide a background and support for close interactions between the different work packages and teams involved with the team in charge of the MAILLIS Business Case;
- UC Req. 8 Rely on the available datasets (unclassified, shareable) among the teams and others of interest in the relevant community (e.g. e, sensor data, historical maintenance datasets, databases of past events, intelligence reports, etc).

These requirements may also be used as qualitative system performance metrics, while, at the implementation level, they may act as result validation measures.

More specifically, the main role of the MAILLIS Business Case is to act as a guide for innovation and development. It focuses on relevant practical challenges and operational questions. It describes possible operational uses of the UPTIME Framework. In the second step, it will help to validate innovation findings from an end-user point of view and will provide common examples and illustrations of results.

The goal of the MAILLIS Business Case is thus to stimulate ideas, define new solutions and improve theoretical findings based on practical considerations. It should thus drive innovation activities. The adoption of a reliable Preventive Maintenance system may help the cold rolling mills production lines to improve its main KPIs. Table 13 presents the TO-BE values of the different KPIs envisioned in M21 and M36.

Table 13. UPTIME Business Case 3: Business KPIs Target Values

Key Performance Indicator	TO-BE Value (M21)	TO-BE Value (M36)
Maximisation of Utilization Ratio	5%	10%
MTBF reduction	10%	20%
Quality improvement of the created products	5%	10%
OEE average improvement	80%	85%
Reduction of total maintenance cost	10%	15%
Reduction of Production Loss	3%	5%
Maximisation of Rollers' Mean Life	5%	10%

The consortium being composed of complementary and sometimes overlapping expertise, unifying the individual contributions may be hard beside any good willingness, fruitful meetings and frequent interactions. If each team takes care of positioning its technological contribution within the MAILLIS Business Case in a meaningful way and relatively to the other members' contribution, the final product will de facto be unified.

However, the MAILLIS Business Case does not provide specific values for source performances or prior probabilities, for instance. The latter should be simulated, retrieved through real data, elicited or even invented where needed. Each team has thus the freedom (and even the duty) to develop any missing part useful for its needs and adapt it to the use case. Neither the use case suggests an internal structure for the system nor a design solution, to avoid putting extra constraint on the system's designer [8].

5.3. Business Implications and Future Trends

Current business implications appear to not adequately reflect the importance of ICT and e-maintenance for the steel industry. In the context of the UPTIME project, we aim to:

- Support ICT skills development and transfer of knowledge in the steel industry;
- Foster value chains and promote e-maintenance use;
- Promote ICT use and ease of access to services for saving resources and energy.

The demonstration of the MAILLIS Business Case will be held in two iterations, following the agile principles adopted in the project. This time plan is realized by means of a Gantt chart for the implementation of the different activities. In the following period, we will follow the implementation roadmap which includes a list of tasks, experimentation and evaluation activities to be performed in each iteration.

6. Implementation Roadmap

The demonstration of the MAILLIS Business Case will be held in two iterations, following an agile methodology. In the following sections, we report the list of detailed tasks and activities to be performed in each phase of the project. We also take into consideration the respective experimentation and evaluation activities to validate the UPTIME results.

6.1. Planning of 1st Iteration

The 1st iteration of the MAILLIS Business Case and implementation plan is organized over **4 quarters** (**12 months**) as presented in Table 14. In the following, we present the tasks and the respective activities on more details.

Review of existing MAILLIS infrastructure and assets

This task has already started to identify the current infrastructure and assets of MAILLIS. It has been currently realised either as bilateral visits and teleconferences to determine the available ICT systems, data and control mechanisms to finalise the technical requirements (M12).

Finalisation of MAILLIS attributes and variables

This task has already started to identify the available data and variables to be monitored in the context of the MAILLIS Business Case, minor updates may apply once we proceed with the development of the integrations with the data sources and existing legacy systems. The outcome of this task will be to finalise the data attributes (real-time and batch) and variables by M15.

Mechanisms for data collection and ICT infrastructure setup

In parallel execution with the previous task, this task includes the development of mechanisms which will integrate the UPTIME Framework with the sensors and the legacy systems of MAILLIS. This task deals with setting up the necessary modules and infrastructure to initiate the UPTIME e-maintenance services and tools for the MAILLIS Business Case and is expected to be realised by M15.

Early prototype of e-Maintenance modules for MAILLIS Business Case

This task includes the early prototype of the different services and tools that consist the UPTIME solution for the MAILLIS Business Case. The deployment of the services is dependent on the availability of the different extended components as developed in WP3 (Task 3.2 Diagnosis and Prognosis, Task 3.3 Maintenance Decision Making and Actions Planning, Task 3.4 Industrial Operations Management Dashboard, Task 3.5 Data-driven FMECA Mechanisms) with an early version to be expected in M18.

Usability Testing

This task aims to record observations from the end users interacting with the early prototype of UPTIME in the context of the MAILLIS Business Case. We will specify and give concrete goals to the end users with the ambition to explore how they interact with the prototype without having given them specific instructions. The outcome of this task is expected by M18.

Risks & Constraints Monitoring

This task includes monitoring and recording potential risks and constraints coming from users' interaction with the early UPTIME prototype or during the 1st iteration of the implementation phase. The outcome of this task is expected by M18.

Experimentation, KPIs, Business Case Evaluation

The data collection process will be quickly initiated to validate that the infrastructure works according to the expectations. The as-is values for the KPIs (defined above) will be measured to have the baseline measurements to assess the real-life benefits and impact of the UPTIME solution when deployed in the MAILLIS Business Case in T6.5. The outcome of this task is expected by M18.

Results Review of 1st Iteration

This task aims to review the results of the 1st iteration, assess its outcomes and drive potential improvements to be incorporated in the updated prototype of e-Maintenance modules for MAILLIS Business Case. The outcome of this task is expected by M21. The milestones for this early deployment coincide with the official WP6 deliverables, namely D6.2 on M15, D6.3a on M18 and D6.4a on M21, as reported in the UPTIME DoA.

Table 14. Gantt chart of the 1st iteration of the MAILLIS Business Case

Activity Descriptive Title	Year 1				Year 2			
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Businesss Case 3: Cold Rolling - 1st Iteration								
Review of existing MAILLIS infrastructure and assets								
Finalisation of MAILLIS attributes and variables								
Mechanisms for data collection and ICT infrastructure setup								
Early prototype of e-Maintenance modules for MAILLIS Business Case								
Usability Testing								
Risks & Constraints Monitoring								
Experimentation, KPIs, Business Case Evaluation								
Results Review of 1st Iteration								

6.2. Planning of 2nd Iteration

The 2nd iteration of the MAILLIS Business Case and implementation plan is organized over **5 quarters** (**15 months**) as presented in Table 15.

Updated prototype of e-Maintenance modules for MAILLIS Business Case

This task applies to the different system components of the UPTIME Framework, including Data gathering, Diagnosis and Prognosis, Maintenance Decision Making and Actions Planning, Industrial Operations Management Dashboard & Data-driven FMECA Mechanisms. Along with the development of the different modules, continuous Integration and refinement of the UPTIME Framework will take in parallel. The outcome of this task will be the final version of the e-Maintenance services related with the MAILLIS Business Case and is expected by M24.

UPTIME deployment and integration with MAILLIS infrastructure

This task is responsible for the deployment of the UPTIME e-maintenance platform in the MAILLIS Business Case (in line with the other pilots realized through WP4 and WP5). The interoperability interfaces with the relevant MAILLIS systems have been defined, specified and developed and specific verification and technical validation tests (as defined in this document) will be executed to ensure seamless integration according to the requirements and design specifications. The outcome of this task is expected by M30.

Usability Testing

Workshops will take place to gather the feedback from the business stakeholders, following their day to day interaction with the UPTIME Framework. Along with the extensive testing of the framework, lessons learnt will be recorded as the result of this task expected by M30.

Experimentation, KPIs, Business Case Evaluation and Knowledge Transfer

During the 2nd iteration, data will be continuously collected to assess the performance and efficiency of the UPTIME Framework. The identified KPIs (defined above) will be measured to have the baseline measurements to assess the real-life benefits and impact of the UPTIME solution in the MAILLIS Business Case. Recommendations for next steps will be extracted to support the exploitation and commercialization of the different modules of the UPTIME as an end to end Predictive Maintenance platform. The outcome of this task is expected by M36.

Results Review of 2nd Iteration

This task aims to review the results of the 2nd iteration and assess its outcomes with respect to usability and user acceptance of the updated prototype of e-Maintenance modules for MAILLIS Business Case. The outcome of this task is expected by M36. The milestones for this deployment coincide with the official WP6 deliverables, namely D6.3b on M30 and D6.4b on M36, as reported in the UPTIME DoA.

Table 15. Gantt chart of the 2nd iteration of the MAILLIS Business Case

Activity Descriptive Title	Year 2				Year 3			
	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Businesss Case 3: Cold Rolling - 2nd Iteration								
Updated prototype of e-Maintenance modules for MAILLIS Business Case								
UPTIME deployment and integration with MAILLIS infrastructure								
Usability Testing								
Experimentation, KPIs, Business Case Evaluation and Knowledge Transfer								
Results Review of 2nd Iteration								

6.3. Experimentation Boundaries and Constraints

In the MAILLIS Business Case implementation roadmap, we have allocated a specific task monitoring the progress of the pilot and identifying potential risks or constraints. The early identification of risks and constraints that may affect the prompt demonstration of the framework in premise will be a continuous activity in the course of the pilot. Close collaboration with the partners, prompt communication means (workshops, tele-conferences, meeting) will enable to timely identify and generate alerts in case of potential risks. Along with the definition of risks, a mitigation plan is defined to continuously monitor the status of deployment and presented in Table 16.

Table 16. Risk assessment of MAILLIS Business Case

Risk ID	Risk Description	Contingency Plan
R1	Tight schedule for the UPTIME Framework	WP2 consolidates all the tasks needed for the project to advance, including support from the entire consortium. Additional resources will be allocated if needed.
R2	Unexpected delay delivering software modules	Regular monitoring of the project to ensure the early development and deployment of solution.
R3	Lack of models' accuracy	Initial datasets will be available from partners to ensure that the models will be available on due time.
R4	Limited functionality or inadequate integration with the UPTIME Framework	The project workplan includes two tight cycles of development, integration and demonstration of the several components (WP2-WP6). An overlap is in place between implementation and integration, as well as the continuous participation of the same partners. Strong horizontal technical coordination of WP2-WP6 will also be in place.
R5	UPTIME facing technology replacement issues	The UPTIME project will be engaged in a continual technology watch effort, which will last till the very end of the project. The consortium will deliver concepts that are going to be easily adopted and reused by stakeholders and other initiatives, and to be built on existing standards to effectively face potential technology replacement issues.
R6	MAILLIS Business Case deployment constraints and poor quality of data	MAILLIS will ensure that the data gathered in a prompt way as defined by the technical partners.
R7	Unavailability of concrete datasets	Pilot partners will ensure the prompt access on the datasets as defined in D6.1.
R8	Limited time for analytics/baseline	The time allocated for training/baseline is enough to get accurate results.
R9	Limited acceptance by the end-users	Well defined user requirements to be incorporated in the platform; agile methodology to ensure the active enrolment of the users.

7. Conclusions and Next Steps

This document proposes a description of the "MAILLIS Business Case, Conceptualization and Evaluation Strategy" as well as several relevant scenarios addressing challenging problems for the steel industry community. The Business Case initially depicted in Task 6.1 Definition of the MAILLIS Business Case and Task 6.2 Requirements and MAILLIS System Conceptualisation and documented in Deliverable 6.1 "MAILLIS Business Case, Conceptualization and Evaluation Strategy".

A particular attention has been drawn around the following topics: which data will be used, how to use these data, which format should be used to manage them, how to put in communication the different tools in the UPTIME Framework and with the external tools.

- A meeting in M15 is planned which would serve as a second-round validation of the MAILLIS Business Case along with the other UPTIME Business Cases with the help of the User Case Interest Group (UCIG);
- The list of KPIs is an initial proposal issued from the survey of several national and EU workshops aiming at capturing the operational information needs for cold rolling mill lines. However, it is expected that the list or structure may evolve during the project;
- Equivalently, the list of scenarios proposed may be enlarged or refined during the project to eventually reflect specific operational needs or interests. However, this should not affect the generic scientific work to be performed within.

This will be a proof of the methodology applicability in a real context of the benefits that it can generate in the companies and of the flexibility allowed by the UPTIME Framework that do not require the exploitation of all its tools to generate new value for the company.

In this deliverable, the MAILLIS Business Case has been described using this structure:

- Detailed description of the scenarios composing the Business Case;
- The workflow representing how the MAILLIS Business Case is using the UPTIME functionalities along its design process;
- Detailed description of MAILLIS Infrastructure to clearly understand how UPTIME is implemented and connected with the existing companies' tools and processes. Connected to this a description of the available data and the actions required for their integration has been provided.

In conclusion, the development and testing of Early and Full Prototype confirmed for the three companies the targeted added values as specified at start of project, such as:

- Significant reduction of time for information penetration from the market to actors in value/production chain to allow fast adaptation of products and services as well as new business models and workflows;
- Systematic and automated analysis of market reaction based on defined mutually agreed criteria to receive objective market information.

As a next step of the work performed, the conceptualization of the UPTIME conceptual model is undertaken to reflect how the predictive maintenance model is adapted and adopted for the MAILLIS

Business Case. The business case specific architecture is also defined addressing the main functionalities and deployment considerations in respect to the requirements expressed.

Finally, the evaluation methodology for the MAILLIS Business Case was elaborated on the basis of the UPTIME needs. Such an evaluation framework spans over the technical and business aspects with the involvement of appropriate stakeholders and well-acknowledged techniques. The detailed time plan for the implementation of the demonstration and validation activities in the business case is also explained in order to anticipate the activities in the 2nd releases of the business case.

The linkage of this work with the rest of the tasks in WP6, namely Task 6.3 about “Data Collection and Infrastructure Setup”, Task 6.4 for the “Deployment of UPTIME and Integration with MAILLIS IT Infrastructure” and Task 6.5 about “System Evaluation, Learning and Improvement” is obviously tight.

D6.1 is overall considered as a living document acting as the specifications manual for the implementation of the demonstration activities in the MAILLIS Business Case for the remaining project period.

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