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Deliverable 5.1
Whirlpool Business Case, Conceptualization and Evaluation Strategy

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Versioning and contribution history

Version	Description	Contributions
0.1	Deliverable Table of Contents	WHR, SUITE5
0.2	Review of existing premises	WHR
0.3	Business scenarios definition for deployment (Section 2)	WHR, SUITE5
0.4	Business and Technical requirements (Section 2 and 3)	WHR, SUITE5
0.5	Update of the demonstration premises description (Sections 2.3, 4.3)	WHR
0.6	Business Case Conceptualization - Adaptation of the UPTIME model and architecture (Section 4)	SUITE5
0.7	Evaluation Activities and Time plan (Sections 5, 6)	SUITE5
0.8	Document Ready for Internal Review	WHR
0.9	Review of the document	UBITECH
1.0	Update on requirements tables and final formatting	WHR, SUITE5, BIBA

Reviewer

Name	Organisation
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List of Abbreviations

AM	Autonomous Maintenance
CILR	Cleaning Inspecting Lubricating Refastening
DB	Database
EEM	Early Equipment Management
FMECA	Failure Mode, Effects, and Criticality Analysis
ICT	Information Communication Technologies
KPI	Key Performance Indicator
MTBF	Mean Time between Failures
MTTR	Mean Time to Repair
OEE	Overall Equipment Effectiveness
PLC	Programmable Logic Controller
PM	Professional Maintenance
PM	Preventive Maintenance
SAP DEP	SAP Digital Enterprise Platform
SAP ERP	SAP Enterprise Resource Planning
SAP PM	SAP Plant Maintenance
SCADA	Supervisory Control and Data Acquisition
UML	Unified Modelling Language
UPTIME	Unified Predictive Maintenance System
WCM	Whirlpool Production System
WHR	Whirlpool

Executive Summary

The scope of D5.1 “Whirlpool Business Case, Conceptualization and Evaluation Strategy” is to report the work performed in the context of T5.1 “Definition of the Whirlpool Business Case” and T5.2 “Requirements and Whirlpool System Conceptualisation” activities, providing the outline and the plan of the WHR business case in the white goods / home appliances industry towards the demonstration of the UPTIME predictive maintenance framework.

With regard to T5.1, the overall context of the Whirlpool Business Case is provided by describing in detail the as-is processes, the data and the IT systems in which the proposed predictive maintenance framework will be applied. Two business scenarios, namely Maintenance Planning in the Production Line and Maintenance Execution, aim at effectively transitioning from preventive maintenance to predictive maintenance in the complex automatic production line to produce drums for the dryer. To this direction, insights into the business vision of WHR for predictive maintenance along the World Class Manufacturing strategy were gained, the current situation was evaluated in order to understand how the generic UPTIME predictive maintenance model (with a detailed overview on the basis of “why, what, how and who” are involved in the process) may be adapted for the automatic drum line, and the underlying business need (for Whirlpool and generally for the white goods sector), the expected benefits and impact for e-maintenance processes were effectively conveyed (through concrete KPIs).

In order to perform the UPTIME predictive maintenance model adaptation in the WHR industry, a clear understanding of the end users’ requirements is also a prerequisite. Therefore, the initial stakeholder requirements as specified in D2.1a “Conceptual Architecture and System Specification” are further elaborated in the case of Whirlpool, and further extended into 26 system and 16 technical requirements for the UPTIME predictive maintenance platform in order to be effectively deployed for the purposes and needs of the automatic drum line.

Upon obtaining the overall picture of the business case from a business perspective, the UPTIME predictive maintenance conceptual model (defined in D2.1a) is also adapted to reflect the specificities of the WHR business case. While the details of the technical architecture are specified in WP2, emphasis is laid on how the different phases are applicable in the WHR business case to ensure that the UPTIME platform can be easily deployed into the existing WHR ICT-infrastructure, and on the mapping of the functionalities of the different components with the WHR-specific system and technical requirements.

Building on successful past V&V (verification and validation) method applications, the blueprints of the evaluation methodology for this business case are documented. Such a methodology aims at ensuring that: (a) the UPTIME platform is being built according to the requirements and design specifications as expressed by WHR, and (b) the UPTIME platform actually meets the WHR end users’ needs, its business case-specific specifications were correct in the first place and it fulfils its intended use for predictive maintenance when placed in the WHR demonstration site. Two core steps, spanning over both the technical and the business perspectives, have been effectively defined, while the stakeholders to be involved, the techniques to be applied and indicative KPIs have been provided. Finally, the time plan for the demonstration activities in the 1st and 2nd releases is explained in detail.

Overall, D5.1 documents the pilot preparation activities conducted in the first months of the UPTIME project implementation and is envisaged as a live reference document that acts as the specifications manual for the demonstration activities in the WHR business case for the remaining project period.

1. Introduction

1.1. Purpose and Objectives

In D5.1 "Whirlpool Business Case, Conceptualization and Evaluation Strategy", the context of the Whirlpool Business case in White Goods / Home Appliances is provided by describing in detail the as-is processes, data and systems in which the UPTIME predictive maintenance strategy will be applied. In parallel, the individual requirements of the WHR business case in the predictive maintenance of the automatic drum line are analyzed and documented in a traceable manner.

In more detail, the purpose of this document is:

- To **examine the current situation in the pilot site** and further define the vision for the Whirlpool Business Case.
- To **elaborate on how the generic UPTIME predictive maintenance model** (as specified in D2.1 "Conceptual Architecture and System Specification") **can be adopted for the WHR business case** by concretely identifying "why, what, how and who" are involved in order to convey the underlying business vision.
- To **elicit the business case-specific requirements** at system and technical level expanding and further instantiating the initial stakeholders requirements (as specified in D2.1) to address the specific requirements of predictive maintenance at the WHR premises.
- To **adapt the UPTIME platform architecture for the specific business case**, providing the overall picture of the business case and liking it to the requirements to ensure that the UPTIME platform will be easily deployed into the existing WHR ICT-infrastructure;
- To **provide the early version of the evaluation framework** along with the definition of the **time-plan for the implementation** of the demonstration activities in the Whirlpool Business Case.

Overall, the aim in this document is to screen the landscape for the adaptation of the UPTIME approach in the white goods industry and to appropriately document the pilot preparation activities.

D5.1 is released in the context of T5.1 "Definition of the Whirlpool Business Case" and T5.2 "Requirements and Whirlpool System Conceptualisation" and will be treated as a live reference document for the business case that stands at the heart of the transition from the conceptualization and the specification phase to the business specific development, deployment, demonstration and evaluation activities.

1.2. Approach

Towards the definition of UPTIME system specifications for the Whirlpool demonstration site, a user-centric, agile approach was adopted to ensure the active participation of end users in the overall process. More specifically, the main actors involved in the maintenance activities are actively engaged in the different phases of this process through brainstorming sessions, including:

- Contribution at the early phase to the definition of the current situation in Whirlpool premises. Status as-is, tools and processes are defined by the end users to further enable the appropriate mapping of the maintenance processes in UPTIME;
- Collaboration of the IT support partners with the business stakeholders for the extraction of end user requirements for this specific business case.

By acquiring the overall picture of the end users' needs and requirements, the technical partners proceed with the definition of how the UPTIME predictive maintenance conceptual model will be practically applied in the Whirlpool demonstration site. Once the first blueprint of the UPTIME architecture was ready in WP2, further discussions were held with the end users and all stakeholders involved in the drum production line to review the current infrastructure, understand how UPTIME will be integrated to it and elicit the business case specific system and technical functionalities. Comments and recommendations are further considered towards the delivery of the adapted UPTIME architecture in the demonstration site.

With regard to the modeling process for the UPTIME specifications, typical Unified Modelling Language (UML) principles have been adopted following the definition of the UPTIME overall architecture in WP2.

1.3. Relation to UPTIME WPs and Tasks

In order to put the WHR business case into the appropriate UPTIME context, the developments in WP1 "UPTIME Predictive Maintenance Methodology" and WP2 "UPTIME e-Maintenance Platform" have been closely followed. In particular the system overview and specifications as defined in the early stage of the project and documented in D2.1 "Conceptual Architecture and System Specification" have been taken into account. Active participation on the brainstorming sessions for the "UPTIME Predictive Maintenance Management Model & MVP" in Task 1.2 that were performed during the plenary meetings has ensured that the business case conceptualization is in line with the overall predictive maintenance model. Complementary, the ongoing state-of-the art analysis and definition of different analytics techniques in Task 1.3 "Multi-Source Data Acquisition, Harmonisation and Processing Patterns" and T1.4 "Diagnosis, Prognosis and Decision Making Algorithms" are also considered to better frame the specifications and the functionalities to be supported by the UPTIME platform instantiation in the WHR business case.

On the other hand, the definition of the context and the specificities regarding the WHR business case deployment will further trigger the work for the extension of the system components in WP3 and the integration of the UPTIME platform in WP2. The proper conceptualization and requirements analysis for the WHR business case in a concrete manner also prepares the ground and facilitates the deployment of the UPTIME solution in the WHR demonstration premises (in T5.3 "Data Collection and Infrastructure Setup" and T5.4 "Deployment of UPTIME and Integration with Whirlpool IT Infrastructure") and further the validation of the overall framework (in Task 5.5 "System Evaluation, Learning and Improvement").

The overall analysis performed in this document is in line with the presentation of the other UPTIME business cases in WP4 "Business Case 1: Construction of Production Systems" and WP6 "Business Case 3: Cold Rolling", respectively.

1.4. Structure of Deliverable

The structure of the deliverable is as follows:

- Section 1 provides an overview of this document.
- Section 2 reports the business case for the White Goods / Home Appliances industry and the vision for the UPTIME demonstration.
- Section 3 provides a detailed analysis of the business case specific requirements.
- Section 4 consolidates the first conceptual view of the adapted UPTIME framework to the needs of the White Goods / Home Appliances business case in Section 4.
- Section 5 presents the evaluation methodology to be applied at business and technical level, as well as the expected benefits and impact of the to-be predictive maintenance processes.
- Section 6 follows with the detailed time-plan for the implementation of the piloting activities in the WHR business case.
- A summary of the work with the final remarks and next steps is reported in Section 7.

2. Business Case Context

In order to effectively apply the UPTIME predictive maintenance model in the White Goods - Home Appliances business case, the current situation needs to be thoroughly understood and the vision for the business case needs to be properly reflected following a user-centered design approach. To this direction, this section evaluates the current situation (the as-is processes and the available data and systems regarding the automatic drum line in the WHR premises where the UPTIME predictive maintenance strategy will be applied), and defines the underlying business vision, the business need (for Whirlpool and generally for the white goods sector), the expected benefits and impact of the to-be e-maintenance processes.

2.1. Business Vision for Predictive Maintenance

Whirlpool EMEA has embraced World Class Manufacturing as the global production system framework (Figure 2-1). WCM is a continuous improvement approach that helps guide where to work and how to work for all parts of the transformation process and focus on reduction of wastes, defects, breakdowns and inventory.

Figure 2-1: WCM framework

WCM is based on 10 technical pillars and 10 managerial pillars as shown in Figure 2-2.

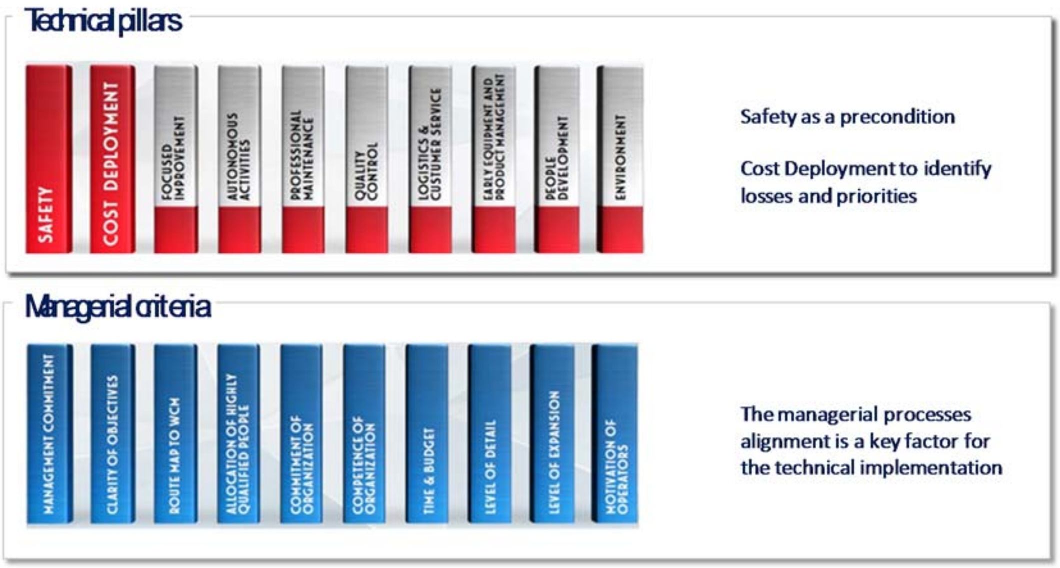


Figure 2-2: The 10 + 10 pillars of WCM

The plant maintenance policy in Whirlpool EMEA so far is based on the WCM (Whirlpool, 2018a) strategy, where the dedicated PM (professional maintenance), AM (autonomous maintenance), and Early Equipment Management (EEM) pillars outline the steps to counteract the maintenance and to manage the implementation of the system with minimal lead time and minimal downtime. The type of maintenance could be classified as shown Figure 2-3 below.

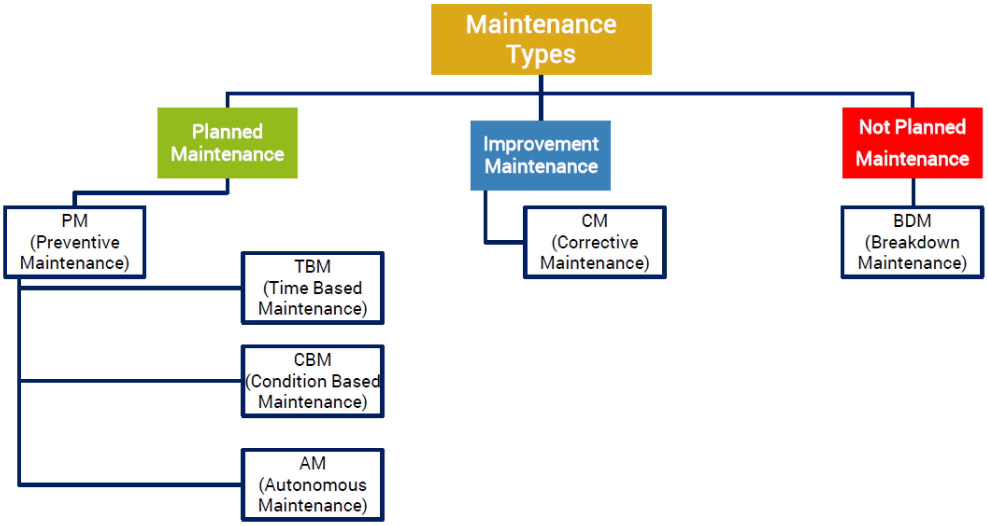


Figure 2-3: Production Maintenance Types

The Professional maintenance pillar actually covers seven steps as presented in the following Figure 2-4. The first three steps involve reactive based maintenance where the aim is to stabilize Mean Time Between Failures (MTBF) and Mean Time to Repair (MTTR). Steps 4 (Countermeasures against weak points of the machine and lengthened equipment life) and 5 (Build a periodic maintenance system – TBM) form the preventive phase and aim at maximizing the component lifespan and restore deterioration periodically and decrease to Mean Time to Repair (MTTR).

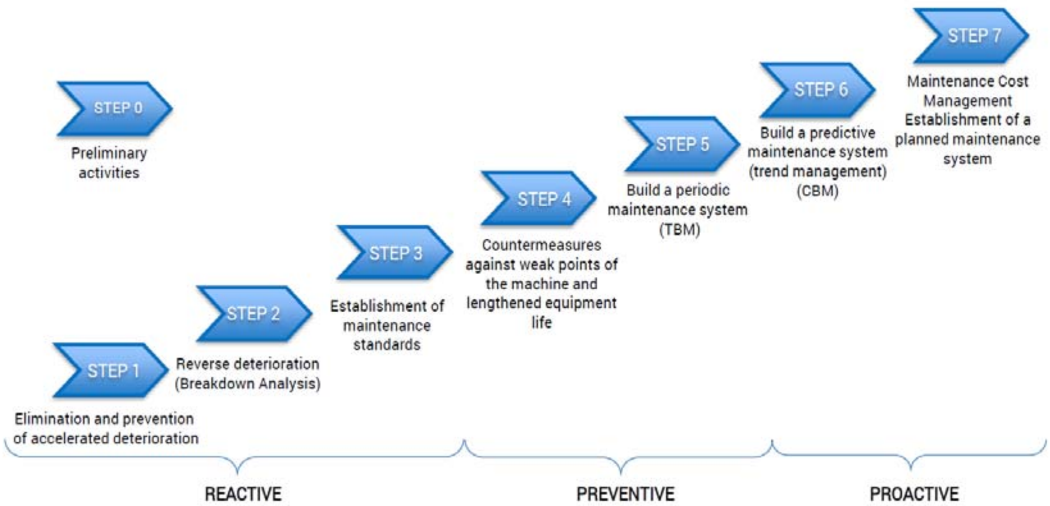


Figure 2-4: Professional maintenance pillars

Currently, the professional maintenance in WHR EMEA is based on a **preventive structure** and **the WHR vision is to move in step 6 (Build a predictive maintenance system – trend management, CBM) and beyond towards incorporating innovative predictive maintenance techniques as proposed by UPTIME** as part of the overall maintenance process.

In parallel, the AM pillar stands for **Autonomous Maintenance** and aims to prevent breakdowns that occur due to the lack of basic conditions of the machines, through a systematic approach to manage autonomously inspection, control, restoration of the basic conditions and to eliminate the sources of contamination activities with the help of strict application and continuous improvement of the standards. The main objective of this pillar is to have zero breakdowns of each machinery which will eventually maximize equipment reliability and availability with less costs while increasing the operators' ability to see, analyze and eliminate losses.

In general, Autonomous Maintenance requires strong commitment and competence of the operators (i.e. factory workers) in order to bring them close to the machinery and early discover problems and sources of contamination. Indicatively, the need for active enrolment of the operators in the process is highlighted through some typical examples: during the cleaning & inspection phase, the operators become aware that keeping machines clean is one of their tasks; the contaminated lubricants must be frequently checked and changed as lubrication is one of the most important parameters to ensure the machines' basic conditions and availability; all unnecessary objects close to the machine must be removed. The AM activities are eventually needed to be carried out mainly by the production line operators as they are the people who interact with machines in a daily basis.

The schematic representation of the AM typical process is presented in the following Figure 2-5.

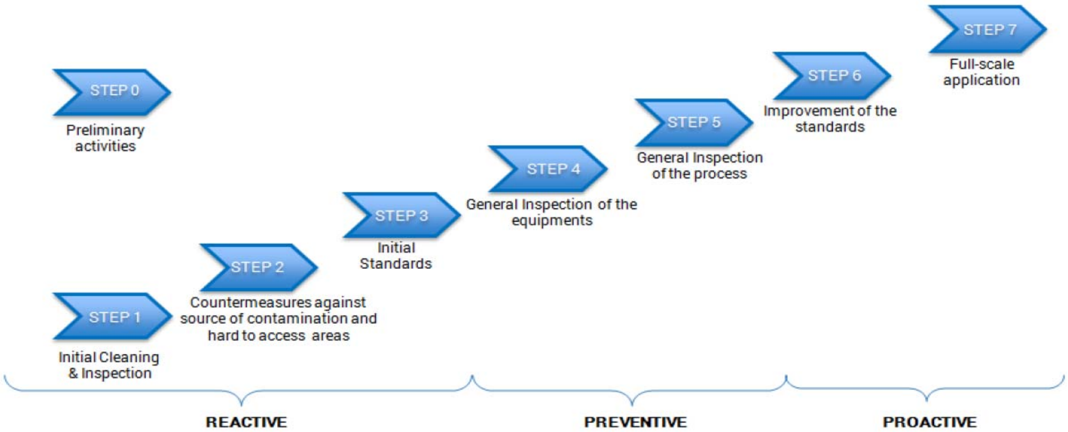


Figure 2-5: Autonomous maintenance pillars

So far, Whirlpool focuses on Steps 2 (Countermeasures against source of contamination and hard to access areas) and 3 (Initial standards) as part of the internal process management. Step 0 (Preliminary activities) comprises of machine classification and team definition whereas Step 1 (Initial cleaning & inspection) involves people in the maintenance activities as the preliminary step towards cleaning and inspection.

Step 2 practically involves some general countermeasures against the potential sources of contamination with the recorded list to contain the map of source of contamination (S.o.C.) and the map of hard to access areas (H.A.A.). In step 3, the operator defines through a standardized approach the time, the frequency and the method of performing different on-site activities e.g. lubrication, inspection, and cleaning. The main objective through this step is to increase the efficiency of cleaning, inspection and lubrication activities, while reducing in parallel the CILR (Cleaning, Inspecting, Lubricating and Refastening) times, and to optimize the lubrication system performance.

Currently, the autonomous maintenance in WHR EMEA is based on a **standardized approach (Step 3)** and **the WHR vision is to move to steps 4** (General inspection of the equipments), **5** (General inspection of the process) **and beyond towards proactive autonomous maintenance in step 6** (Improvement of the standards) **by incorporating the innovative UPTIME predictive maintenance techniques** as part of the overall maintenance process.

Finally, the very last pillar of the holistic maintenance framework is about **Early Equipment Management** (**EEM**) and focuses on the implementation of new products and processes with vertical ramp up and minimised development lead time; the goal is to introduce a loss and defect free process so that equipment downtime is minimal (zero breakdowns), and the maintenance costs are all considered and optimised.

Overall, the **Early Product Management** (**EPM**) aims to shorten development lead times, with teams working on simultaneous activities so that vertical start up can be achieved with zero quality loss (zero defects). The four phases of EEM are shown in Figure 2-6 below.

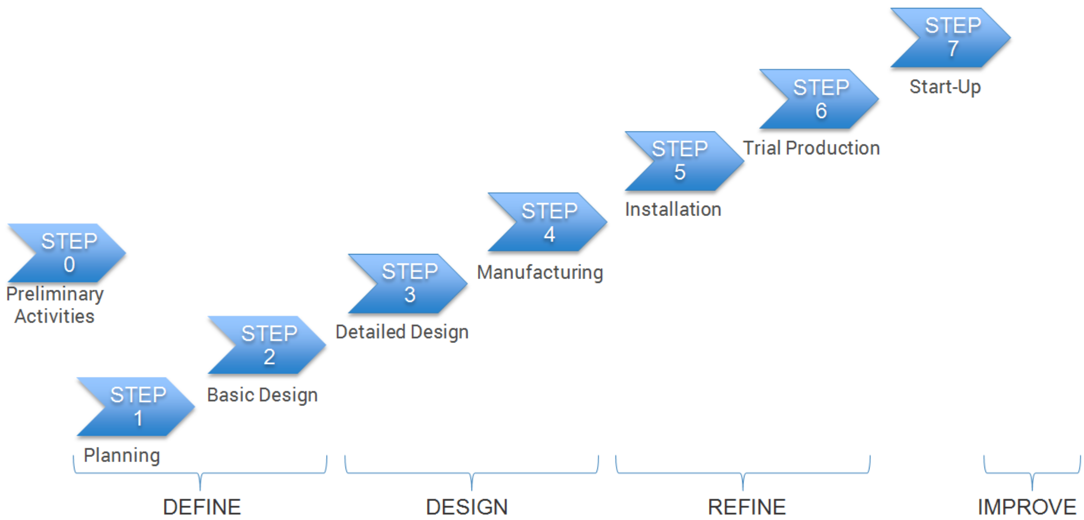


Figure 2-6: Early Product Management Pillar

The design goals of the EEM pillar should have the following characteristics:

- Safety and Environmental – High (Fail safe operation);
- Reliability – High;
- Operability – Easy;
- Maintainability – Easy;
- Diagnosis – Easy check.

2.2. Demonstration Site Overview

The White Good appliance business case will be based on a complex automatic production line to produce drums for dryer. The product is basically a carbon steel cylinder used to keep and rotating clothes during drying stage.

The schematics of the product selected for analysis is presented in the following Figure 2-7.

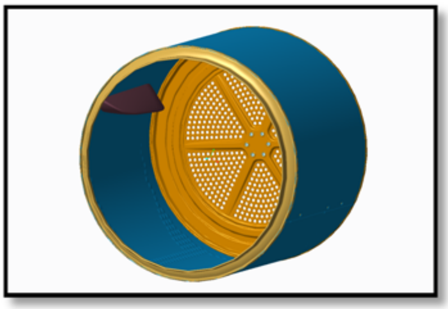


Figure 2-7: Dryer drum schematics

The Plant layout of the drum line in the Lodz facility where the UPTIME demonstration will take place is shown in the following Figure 2-8 with some images from the actual installation in premises (Figure 2-9).

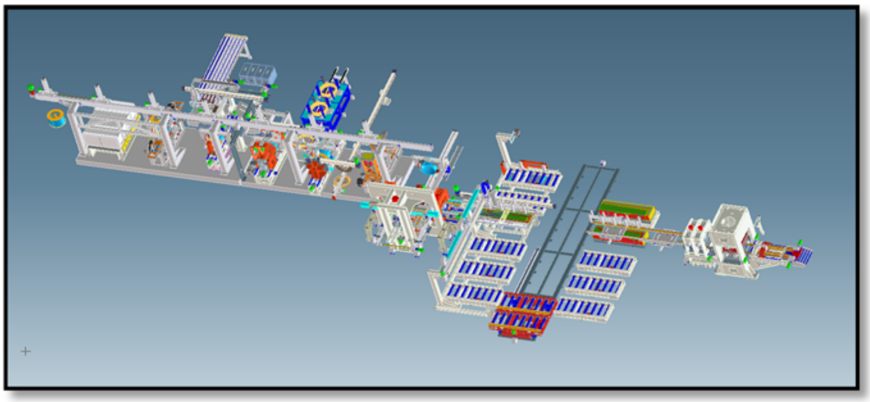


Figure 2-8: Plant layout of the drum line

Figure 2-9: Plant images of the drum line

The production process is basically a sequence of different steps involving many operations and requiring the synchronized action of mechanical, electrical, hydraulic and pneumatic tools and moving parts as depicted in the following Figure 2-10.

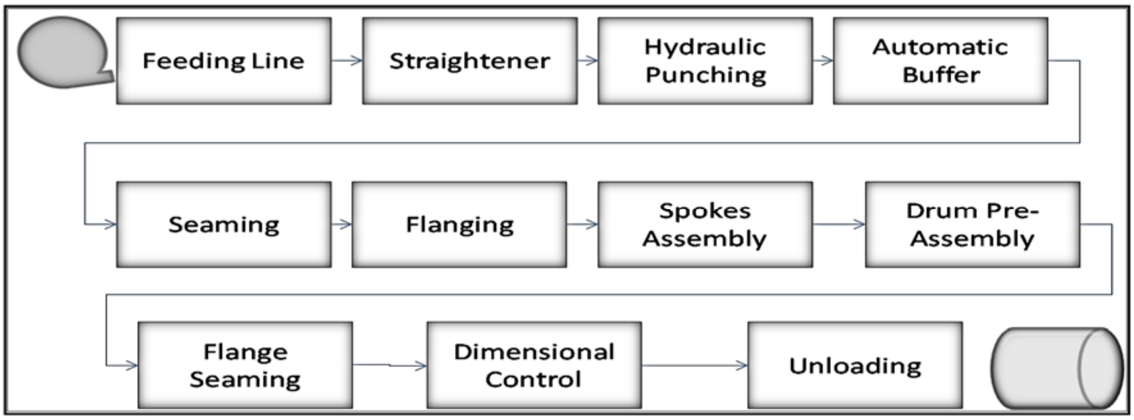


Figure 2-10: Dryer drum production process

The feeding line uncoils the steel and feeds the straightener that eliminates the curvature of the sheet and reports it in a plane. In the Hydraulic Punching, the sheet is cut at dimension and holes and patterns are produced: these parts are then stored temporarily in the buffer. In the Seaming and Flanging stations, the sheet edges are pre-formed through mechanical dies and rollers, and then the sheet is assembled (screwing and seaming) with external parts (plastic lifters, front and rear flanges) in the Spoke Assembly station. The sheet is now ready to be formed to a cylinder shape in the Pre-assembly station and then is coupled with the back side that is produced externally, through a mechanical seaming operation. As a final step, the part is measured to ensure its quality, marked with a QR code for traceability and finally unloaded through a conveyor belt.

The main reasons for the selection of this process (from the production line) to evaluate the UPTIME predictive maintenance approach are:

- The process is the very first step for producing a dryer and has to guarantee a high overall efficiency.
- Several examples of failures may occur spanning from wearing or mechanical tools (punchers, stoppers, welding rollers), pneumatic failures of moving parts (pressure drops, valve or pumps not working), parts misplaced, and lubrication absence.
- The maintenance plan is usually suggested by the supplier based on the equipment ledger. From this statement, a preventive maintenance plan is created and used to.
- Currently only preventive and reactive maintenance are implemented and thus there is a requirement to expand the list of maintenance activities performed.

2.3. AS-IS Business Processes

Professional Maintenance based on Equipment Ledger

The maintenance processes are conducted according to the Professional Maintenance pillar of World Class Manufacturing as explained in section 2.1. Whirlpool is currently implementing two BP’s: Reactive Maintenance (RM) and Preventive Maintenance (PM).

The RM is based on the ANDON concept: when the operator recognizes a state of the equipment which is deviating from the normal behaviour and puts safety, part quality or production performances at risk, he or she starts an escalation of the problem through signalling it to the maintenance department (usually through a phone call to a specified telephone number). The Maintenance Department is then tracking the process using SAP-PM, the CMMS software currently implemented in all Whirlpool EMEA Factories.

The PM is a set of planned activities which are put in place to keep the initial state of equipment through basic tasks (CILR: Clean, Inspect, Lubricate, Refasten) or complex tasks such as substitute component and subsystems, performed at specified time intervals. The final scope of PM is to reduce the breakdowns as much as possible and ensure that both Quality, Performances and Availability components of OEE (Overall Equipment Efficiency) are maximized. The PM is defined according to a Machine Ledger, a living document initially compiled with a strong intervention of the machine producer, which is specifying the recommended preventive actions for all the components of an equipment (Figure 2-11).

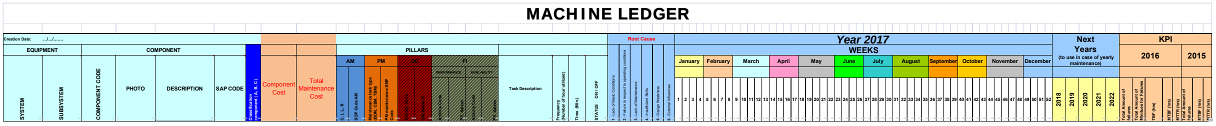


Figure 2-11: Machine Ledger Document

The actual PM plan is managed by the Maintenance Department with the help of CMMS SAP-PM.

Weaknesses & Bottlenecks

Both approaches, RM and PM, although needed, exhibit many drawbacks. RM is, by definition a reactive approach and implies that it is performed during production time, causing either a stop of the production or a degradation of it. The main objective of RM is to bring the equipment back to its operational status at the shortest time possible. This implies that the organization is set to react very fast and with a high availability of resources and competences in location. The main parameter used to evaluate RM is Mean-Time-to-Repair.

In order to reduce as much as possible the unwanted breakdowns, preventive maintenance has the objective of limiting the probability of ruptures, interruptions and so on, through a set of activities involving a lot of economical and human resources. An effective PM requires the components to be checked well before their apparent degradation and substitution of component without regards of their real degree of wear. PM is able to reduce breakdowns, and thus to influence Mean Time Between Failures, MTBF), but can be very expensive, impacting on the Total Cost of Maintenance (TCM).

2.4. Business Scenarios

The business scenario that shall be implemented by the white goods business case aims at effectively transitioning from preventive maintenance to predictive maintenance in the ***complex automatic production line to produce drums for dryer***.

To this direction, the following Table 2-1 presents the business scenarios that have been elaborated with the end users of the WHR business case. Business Scenario 1 deals with maintenance planning in the production line and business scenario 2 deals with the maintenance execution process.

Both scenarios are formulated on the basis of the stakeholders' requirements documented in D2.1, e.g. StR_ 16 The system shall decrease the Maintenance Cost; StR_17 The system shall decrease the Number of Total Failures; StR_18 The system shall decrease the man-hours for Maintenance.

Table 2-1: WHR Business Scenarios

Business Scenario 1.	**Maintenance Planning in the Production Line**	
Business Process 1.1	Generation of Predictive Maintenance Order	**Business Process Prerequisites**
Predictive Maintenance Orders are specific orders of preventive maintenance that are generated through a CBM system.		• The order for Maintenance generated by the Prediction Module has to be compatible in format with legacy CMMs system • The order generation must have a very high degree of accuracy (very low false alarm generation)
Business Process 1.2	On-time scheduling of professional maintenance actions	**Business Process Prerequisites**
This process generates a sequence of time-based maintenance orders containing all the information to perform maintenance activities.		• The schedule needs to optimize resource usage and reduce unavailability of the equipment
Related Stakeholders Requirements[1]		G_STHR_I_8, G_STHR_I_9, G_STHR_I_10, G_STHR_I_15, G_STHR_I_21-27
Main Actors	Maintenance manager	
Benefits		**Challenges in UPTIME**
Maintenance Planning allows for the optimized use of resources and influences positively the main maintenance indicators (MTBF, MTTR, TCM).		Data availability & quality; Algorithms efficiency; Maintenance decision making reliability

Business Scenario 2.	**Maintenance Execution**	
Business Process 2.1	Early detection of autonomous maintenance actions	**Business Process Prerequisites**
Generation of early warnings to suggest Autonomous Activities to factory workers.		• The generation of a warning should be communicated to workers through mobile devices or on-board devices.

[1] Refer to UPTIME D2.1 (2018) for a detailed analysis

Business Process 2.2	Validation of maintenance actions performed	**Business Process Prerequisites**
The closure of any maintenance activity requires reporting of the relevant data (i.e. time, results, cost)		• The maintenance activity closure must be associated to a Maintenance Order or to an Early Warning.
Related Stakeholders Requirements[2]		G_STHR_I_5, G_STHR_I_7, G_STHR_I_9, G_STHR_I_10, G_STHR_I_13, G_STHR_I_15-20
Main Actors	Factory worker, Professional maintenance technician	
Benefits		**Challenges in UPTIME**
Maintenance execution is the core process to keep (or bring back) equipment to an optimal working condition and thus reduce breakdowns and influence positively other indicators (OEE, MTBF, MTTR).		Maintenance recommendations accuracy and timeliness; Correlation between Recommended vs Actual Maintenance actions

2.5. Data Availability

The preliminary data analysis conducted in the WHR business case premises covers two different viewpoints: **sensorial data and data from legacy/operational systems.**

Starting with the **sensor data**, the collection is based on a proprietary tool (called OEE Data Collection) to gather the main output from the equipment. PLC, the Programmable Logic Controller is a Siemens PLC handling for the drum, side panel line, heat pump, assembly line and sorter. Data gathered at present state are typically related to equipment status (operative / non-operative) and number of shots (usually of last operation); further stored in a SQL2000 database acting as the SCADA database/gateway in premises. The current architecture for data gathering in premises is presented in the following Figure 2-12, where we highlight the components of interest for the demonstration of UPTIME framework in the project:

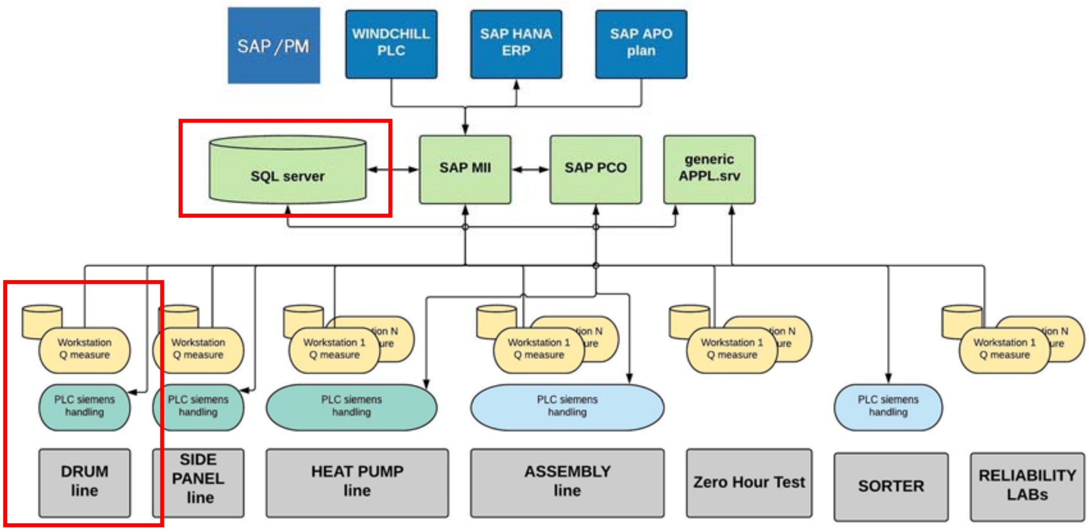


Figure 2-12: Sensorial Data Management Architecture

[2] Refer to UPTIME D2. 1 (2018) for a detailed analysis

The equipment ledger (SQL2000 database) may be further managed through web services to allow data input and output, e.g. show spare part availability and location, list details of operations and gather feedback on activities.

The list of data attributes available through the database are presented in the following Table 2-2 and Table 2-3.

Table 2-2: WHR Sensorial Data High-level Profiling - I

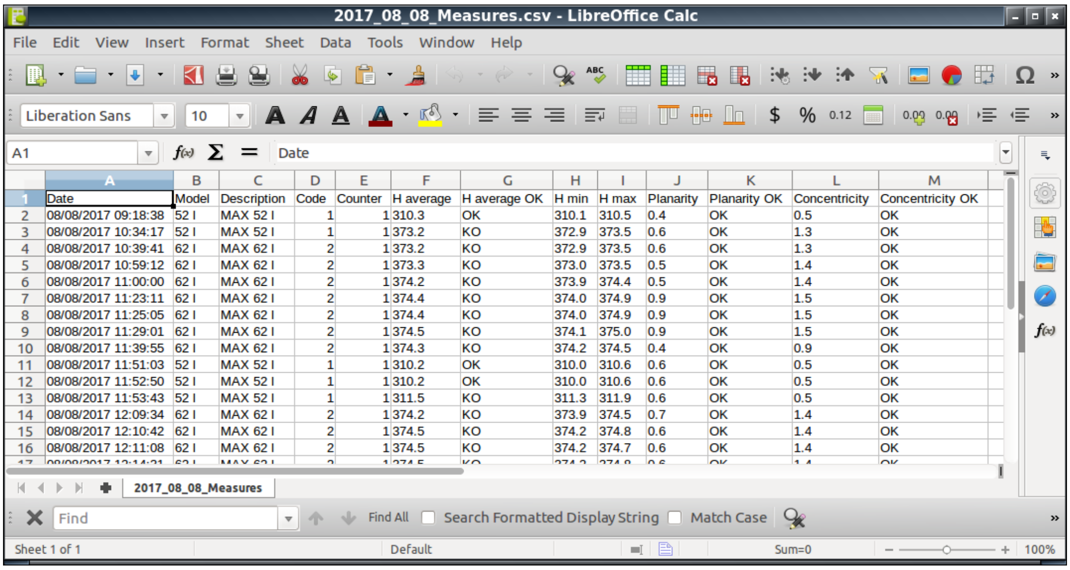
Dataset title	Part Gauge
Origin	Equipment – Quality Station / Drum Preassembly Station
Device sensor	Various
Sensor type	Gauge
Physical world measurements	Height, Planarity, Concentricity, Torque, PreTorque, Angle, Depth
Measurement purpose	Part quality
Sensor reporting frequency	12sec
Data stream rate	5 KB/minute

In general, it is expected that there will be used sensors to monitor the component wear status (welding seaming wheels, hemming heads) and punching areas on the product (e.g. deviation on the punched profiles indicates wear or damages to punchers), temperature sensors on spinning parts indicate lubrication problems or wear, pressure sensors on hydraulic units (punchers and embossing) giving indication on problem on pumps or valves. In addition, general electrical measure (current, voltage) will be used to establish operative and health status of welding rollers. However, the exact sensors to be deployed with be decided in conjunction with the FMECA analysis that is ongoing at the moment.

Table 2-3: WHR Sensorial Data High-level Profiling - II

Dataset title	Equipment Gauge
Origin	Equipment
Device sensor	Various
Sensor type	gauge
Physical world measurements	TBD after FMECA
Measurement purpose	Component health status
Sensor reporting frequency	12sec
Data stream rate	TBD

A screenshot of measurements as stored in the database is presented in the following Figure 2-13.



Date	Model	Description	Code	Counter	H average	H average OK	H min	H max	Planarity	Planarity OK	Concentricity	Concentricity OK
08/08/2017 09:18:38	52 I	MAX 52 I	1	1	310.3	OK	310.1	310.5	0.4	OK	0.5	OK
08/08/2017 10:34:17	52 I	MAX 52 I	1	1	373.2	KO	372.9	373.5	0.6	OK	1.3	OK
08/08/2017 10:39:41	62 I	MAX 62 I	2	1	373.2	KO	372.9	373.5	0.6	OK	1.3	OK
08/08/2017 10:59:12	62 I	MAX 62 I	2	1	373.3	KO	373.0	373.5	0.5	OK	1.4	OK
08/08/2017 11:00:00	62 I	MAX 62 I	2	1	374.2	KO	373.9	374.4	0.5	OK	1.4	OK
08/08/2017 11:23:11	62 I	MAX 62 I	2	1	374.4	KO	374.0	374.9	0.9	OK	1.5	OK
08/08/2017 11:25:05	62 I	MAX 62 I	2	1	374.4	KO	374.0	374.9	0.9	OK	1.5	OK
08/08/2017 11:29:01	62 I	MAX 62 I	2	1	374.5	KO	374.1	375.0	0.9	OK	1.5	OK
08/08/2017 11:39:55	62 I	MAX 62 I	2	1	374.3	KO	374.2	374.5	0.4	OK	0.9	OK
08/08/2017 11:51:03	52 I	MAX 52 I	1	1	310.2	OK	310.0	310.6	0.6	OK	0.5	OK
08/08/2017 11:52:50	52 I	MAX 52 I	1	1	310.2	OK	310.0	310.6	0.6	OK	0.5	OK
08/08/2017 11:53:43	52 I	MAX 52 I	1	1	311.5	KO	311.3	311.9	0.6	OK	0.5	OK
08/08/2017 12:09:34	62 I	MAX 62 I	2	1	374.2	KO	373.9	374.5	0.7	OK	1.4	OK
08/08/2017 12:10:42	62 I	MAX 62 I	2	1	374.5	KO	374.2	374.8	0.6	OK	1.4	OK
08/08/2017 12:11:08	62 I	MAX 62 I	2	1	374.5	KO	374.2	374.7	0.6	OK	1.4	OK

Figure 2-13: SQL2000 database snapshot

It needs to be noted that all info coming from parts monitoring will be correlated with critical dimensions and failure modes on equipment with FMECA, while the maintenance activities will be scheduled in conjunction with logistics management considering that spare parts warehouse will be managed by standard processes according to SAP PM.

Additional sources of data that are at the disposal of the UPTIME project include: (a) the **maintenance ledger**, (b) the **maintenance historical data that are available from the Yate and Amiens plants**.

2.6. Relevant IT Systems

The information system related to plant maintenance that is put into use in the WHR demonstration site is the SAP Plant Maintenance (SAP-PM).

Structure of SAP Plant Maintenance in Whirlpool case (Whirlpool, 2018b)

SAP Plant Maintenance platform is an add-on to the overall SAP enterprise management tool installed in premises. An overview of the generic enterprise's organizational structure as the basis of all master data and business processes is presented in the following Figure 2-14

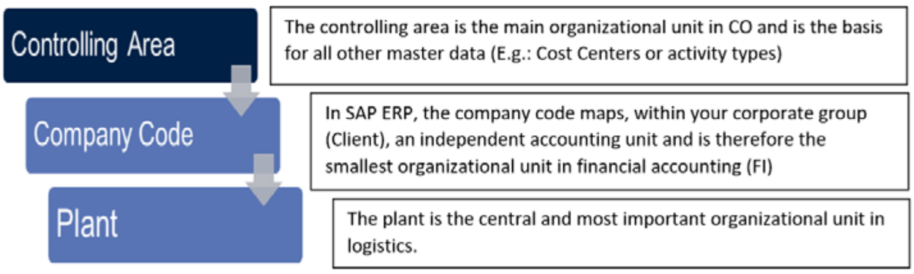


Figure 2-14: SAP ERP organizational structure

The "plant" attribute is, without doubt, the most important organizational unit for plant maintenance. It contains the maintenance functions as defined in the platform: maintenance planning plant (plant in which the maintenance tasks for a technical object are planned and prepared) and the maintenance execution plant (the plant at which a technical object is installed). This Organizational Structure is depicted in the following Figure 2-15:

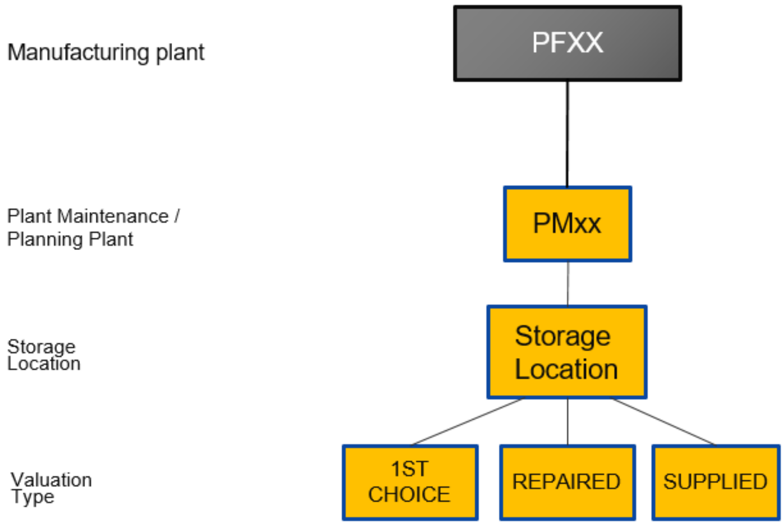


Figure 2-15: SAP PM organizational structure

The core concepts and naming conventions that are included in the SAP-PM feature:

- **Spare parts** represent the single components used by maintenance people to repair the equipment.
- **Functional Location** represents the areas of a system at which objects can be installed according to functional and spatial criteria, as it usually represents immovable, functional units.
- **Equipment** consists of individual objects that are to be regarded as autonomous units and connected to a specific Functional Location. Examples include machines, pumps, engines, Production Resources/Tools (PRTs) and IT inventories. Equipment categories that are moved infrequently (e.g., pumps) are intended to be installed on functional locations. Other equipment categories (e.g., fleet objects) are not installed on functional locations, due to their constant movement.
- **Work Centers** are responsible for carrying out the maintenance activities and consist of people and group of skilled workers.
- **Task List**: list of activities to be done for preventive maintenance.
- **Maintenance strategies**: define the rule for the sequence of planned maintenance works. It contains general scheduling information and can therefore be assigned to as many maintenance task lists (PM task lists) and maintenance plans as required.

A visual representation of SAP PM naming convention structure is presented in the following Figure 2-16.

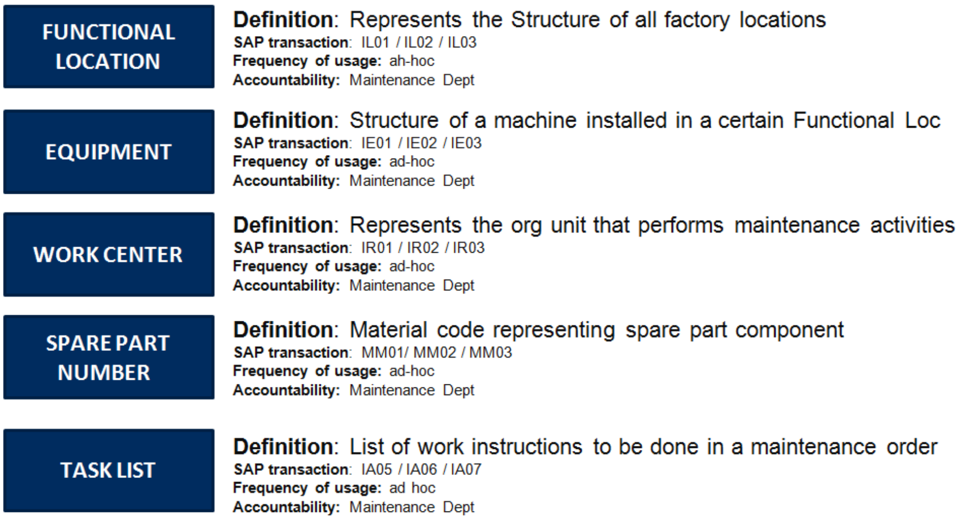


Figure 2-16: SAP PM Naming Conventions

A more detailed description of the aforementioned attributes in the SAP-PM following in the next paragraphs.

The **Functional Location Structure** Indicator proposed is as follows (Figure 2-17):

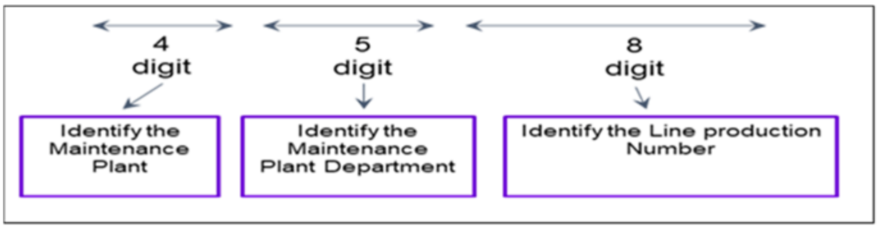


Figure 2-17: SAP PM Functional Location

The user can generally insert and maintain the different master data view of a functional location. It is also possible to view a structure list of the different levels of functional locations and the equipment installed. An indicative hierarchy of functional hierarchies in association with the rest of the system elements is depicted in the following Figure 2-18:

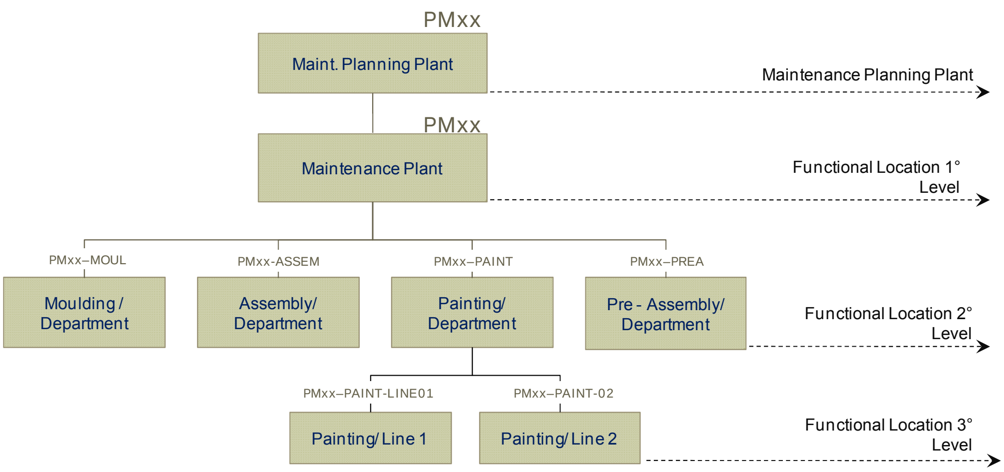


Figure 2-18: SAP PM Functional Hierarchy

The **Equipment** attribute is linked with the last level of the created Functional Location. The request is to have max 3 equipment hierarchical levels:

- The first level identifies the machine or the equipment section/ part;
- The second level identifies the components or the group of components;
- The third level identifies additional components or group of components under second level.

It is evident that the Functional Location is directly linked with the list of equipment. The AS-IS model to manage tools is to code it in SAP as a functional location of type W and one or more equipment linked with equipment category P.

Work Centers are responsible for carrying out maintenance activities and consist of people and groups of skilled workers. Each Work center is identified with a unique person – Maintenance specialist. For each Work center the following parameters must be defined:

- Maintenance person;
- Belonging to a plant;
- Name and surname of the person;
- The main skills (electrician, mechanic, manager and so on);
- Disposable time;
- Cost center collecting the resource's cost.

The Work Center is also used for the assessment of the KPIs: MTTR and MTBF. In that case, the WORK CENTER has to be defined with additional std and assigned to all the equipment belonging in this scheduling rule.

Finally, the **Task List** contains the list of work instructions to be done in a Preventive Maintenance order. Task list can be:

- General Maintenance Task list;
- Equipment Task list;
- Functional Location Task list.

Along with the definition of static data attributes (workers, equipment etc…), the structure for order management is also defined. There are different rules defined to set the notifications/ orders process (Figure 2-19):

Notification Management	- **Notification** can be initiated through phone call to Maintenance team or directly into SAP Plant Maintenance environment . - **Notification** can be initiated by Maintenance team member, Production team member, other Whirlpool authorized people. - Creation of **Notification** into SAP PM environment through std **SAP transaction** or through **SAP-MII front-end**, providing information about start Date/Time of the event. - Closure of **Notification** within Order closure or in case of not Order creation, simple closure of **Notification.**
Order Management	- Creation of **Order** into Plant Maintenance environment through std **SAP transaction,** through **SAP-MII frontend** or following time schedule defined by Maintenance team/group leader - **Order** can be initiated by Maintenance team member. - Execution of **Order** by Maintenance team member into SAP PM environment through std **SAP transaction** or through **SAP-MII front-end**. - Assignment of **Order** by Maintenance team member into SAP PM environment to Maintenance team member through std **SAP transaction** or through **SAP-MII front-end**. - Update of **Order** into SAP PM environment by Maintenance team member through std **SAP transaction** or through **SAP-MII front-end** providing all info regarding order execution: intervention start date/time, repair start date/time, repair end date/time, intervention end date/time. - If Spare Parts required, update of **Order** into SAP PM Environment by Maintenance team member through std **SAP transaction** or through **SAP-MII front-end** providing all info regarding Spare Parts consumption. - Closure of **Order** into SAP PM environment by Maintenance team member through std **SAP transaction** or through **SAP-MII front-end** - Costing of **Order (Confirmation)** into SAP PM environment by Maintenance team/group leader through std **SAP transaction** and Spare parts management.

Figure 2-19: Order Management in SAP PM

The different types of orders supported by the SAP-PM include:

- BREAKDOWN: Unplanned maintenance, initiated by the Production Department, to request restoring of equipment that is broken. Equipment could be completed stopped or working in degraded way. In SAP PM, it is defined as EM.
- MANUAL PREVENTIVE: Unplanned maintenance, initiated by the Maintenance Department, to execute maintenance on equipment in order to prevent malfunctions or future breakdown. It can be triggered by an awareness coming from the Production Department on irregular functionality of the equipment. If a Manual Preventive will be triggered following a determined time interval, the Manual preventive could become Preventive following a time interval rule. In SAP PM, it is defined as MP.
- GENERAL SERVICES: Unplanned maintenance, initiated by the Non Production Department, to request to execute maintenance not on a production equipment but on facilities, building, etc. In SAP PM, it is defined as GS.
- PREVENTIVE MAINTENANCE: Planned maintenance, initiated by the SAP PM, to execute maintenance on equipment to prevent malfunction, future breakdown or following vendor recommendation. Set-up and maintenance of the Preventive Maintenance is owned by the Maintenance Department that has to maintain SAP PM objects as Task list, Maintenance strategies, Maintenance planning. In SAP PM, it is defined as PM.
- CHANGE OVER: Unplanned maintenance, initiated by the Maintenance Department, to execute maintenance on equipment to change set-up of an equipment. In SAP PM, it is defined as CO.
- CORRECTIVE: Unplanned maintenance, initiated by the Maintenance Department, to execute maintenance on equipment to correct a technical issue/design that after study generates a corrective action. In SAP PM, it is defined as CR.

The aforementioned analysis illustrated the data attributes available from the operational systems installed in premise to provide the valuable information required in the UPTIME project.

3. Business Case Requirements

By clearly defining the business vision for the demonstration of the UPTIME framework in Section 2, the list of requirements is subsequently extracted at business and technical levels. The individual requirements for predictive maintenance in the automatic drum line as expressed during brainstorming sessions are analyzed in detail and are documented in a traceable manner following state-of-the-art modelling approaches. In practice, such an analysis builds on and moves beyond the requirements analysis already performed in WP2.

Overall, UPTIME shall contribute to improving various KPI metrics which are crucial to the drum-line production as specified in the following stakeholders requirements: G_STHR_I_18 The plant shall contribute to decreasing the mean time to Repair; G_STHR_I_10 The plant shall decrease the Number of failures; G_STHR_I_16 The plant shall decrease the Total Failure Rate of the Equipment; G_STHR_I_20 The plant shall decrease the sum of the Corrective Maintenance Times; G_STHR_I_17 The plant shall increase the mean time between Critical Failures; G_STHR_I_15 The plant shall increase the mean time between Failures.

Such objectives are actually the driving force behind the requirements analysis performed in the WHR business case. Following up on the work conducted in D2.1a "Conceptual Architecture and System Specification" for capturing and generalizing the stakeholders' requirements and in alignment with the UPTIME Requirements Engineering Process, the system and technical requirements will be elicited in the following sections. As defined in D2.1, the system requirements should state "what" is needed in terms of requirements while the technical requirements specify the technical implementation parameters for the system including hardware and software limitations and constraints.

It needs to be noted that such requirements list only reflects the initial visibility of the business case and an evolutionary process shall be effectively supported through an iterative agile approach, in order to continuously adapt to the emerging needs.

3.1. System Requirements

The UPTIME system requirements as extracted from the WHR business case and listed in the following Table 3-1 are practically related with the actual functions that the UPTIME platform is expected and requested to execute. To facilitate the consolidation of such requirements and ensure their completeness, they are classified into 4 core categories, namely:

- *Application*: What are the key functionalities to be supported by the UPTIME platform at application level?
- *User Interface* (if any): What are the key characteristics of the user interfaces (also considering different types of devices)?
- *Data sources*: What are the requirement and constrains for the required data (at batch level as stored in legacy databases or operational data repositories, and at real-time stream level as captured by field sensors and controls in the shop-floor)?
- *Interfaces and Interoperability*: What are the requirements for integration and interoperability with other systems (particularly legacy systems in the business case)?

In order to assess the importance and criticality of the requirements for implementation, a preliminary assessment has been performed at the business case level, identifying priority of each 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: BC2_SR_I_no where BC2 indicates it concerns Business Case 2 by WHR, SR highlights it is a system requirement, I (or II) represents the release it was defined, and no: numbering.

Table 3-1: UPTIME System Requirements – Business Case 2: WHR

System Req. ID	Description	Related Requirements Derives from	Type	Priority
BC2_SR_I_1	The UPTIME platform shall retrieve the relevant sensor data collected at the shop-floor, at batch level.	BC2_SR_I_8	Data Sources	High
BC2_SR_I_2	The sensor data readings that are collected should be filtered, normalized and transformed (prior to or right after their retrieval by the UPTIME platform).	BC2_SR_I_1	Data Sources	Medium
BC2_SR_I_3	The UPTIME platform shall gather different maintenance-related data (e.g. the equipment ledger, historical machine failures, the maintenance actions history and maintenance-related operational data), at batch level.	G_STHR_I_23, G_STHR_I_24, G_STHR_I_27	Data Sources	High
BC2_SR_I_4	The UPTIME shall connect to middleware of the factory's IT infrastructure to access the calibrated sensor readings.	BC2_SR_I_1	Interfaces and Interope-rability	High
BC2_SR_I_5	The UPTIME platform shall bi-directionally communicate with the factory's operational systems (SAP-PM) via APIs.	BC2_SR_I_3, G_STHR_I_22	Interfaces and Interope-rability	Medium
BC2_SR_I_6	The UPTIME platform shall provide interfaces to upload data extracted from the factory's legacy and operational systems.	BC2_SR_I_3, BC2_SR_I_5	Interfaces and Interope-rability	High
BC2_SR_I_7	The UPTIME user should configure the data retrieval settings in an intuitive manner.	BC2_SR_I_1	Application	High
BC2_SR_I_8	The UPTIME user shall configure and, whenever needed, train the different algorithms for predictive maintenance and health detection of the machinery in the production line.	G_STHR_I_25, G_STHR_I_26, G_STHR_I_8	Application	High
BC2_SR_I_9	The UPTIME user shall experiment with different algorithms for predictive maintenance and health detection of the machinery in the production line.	BC2_SR_I_8	Application	High
BC2_SR_I_10	The UPTIME user shall experiment with different algorithms for analyzing the legacy/operational data, e.g. in order to correlate failure times intervals with machine maintenance actions.	BC2_SR_I_8	Application	High
BC2_SR_I_11	The UPTIME user shall provide feedback to the rules and patterns extracted regarding the machinery from the analysis of the factory's legacy and operational systems.	BC2_SR_I_10	Application	High
BC2_SR_I_12	The UPTIME user shall configure the maintenance actions parameters per machine.	BC2_SR_I_18	Application	High
BC2_SR_I_13	The UPTIME user shall directly receive email/mobile notifications regarding recommendations for predictive maintenance actions.	G_STHR_I_9, BC2_SR_I_25	Application	High
BC2_SR_I_14	The UPTIME user shall directly receive mobile notifications regarding recommendations for autonomous maintenance actions upon approval by the WHR maintenance manager.	G_STHR_I_9, G_STHR_I_22, BC2_SR_I_25	Application	Low

System Req. ID	Description	Related Requirements Derives from	Type	Priority
BC2_SR_I_15	The UPTIME user shall "personalize" the notifications he/she wishes to receive.	BC2_SR_I_13, BC2_SR_I_14	Application	Medium
BC2_SR_I_16	The UPTIME user shall report on the autonomous maintenance actions performed.	BC2_SR_I_12	Application	High
BC2_SR_I_17	The UPTIME system should be able to correlate the recommended maintenance actions with the maintenance actions that were actually performed.	BC2_SR_I_13, BC2_SR_I_14, BC2_SR_I_16	Application	Medium
BC2_SR_I_18	The UPTIME user shall model the equipment of the shopfloor in the UPTIME platform, at appropriate granularity levels in accordance with the UPTIME model.	G_STHR_I_27	User Interface	High
BC2_SR_I_19	The UPTIME platform shall support performing the FMECA analysis in an intuitive manner.	BC2_SR_I_18	User Interface	High
BC2_SR_I_20	The UPTIME user shall visualize all analytics results at different levels (e.g. for the time dimension: per day, per month, forever) and save or export them as reports.	BC2_SR_I_9, BC2_SR_I_10	User Interface	High
BC2_SR_I_21	The UPTIME user shall gain near real-time insights in the health status of each machinery and the KPIs of interest.	G_STHR_I_25	User Interface	High
BC2_SR_I_22	The user interfaces and dashboards of the UPTIME platform shall be attractive and visually appealing.	BC2_SR_I_20	User Interface	High
BC2_SR_I_23	The user interfaces and dashboards of the UPTIME platform shall be preconfigured depending on the user role.	BC2_SR_I_20	User Interface	Medium
BC2_SR_I_24	The UPTIME user should be able to configure the UPTIME user interfaces and dashboards according to his/her needs and preferences.	BC2_SR_I_23	User Interface	Low
BC2_SR_I_25	The UPTIME platform shall provide accurate and credible recommendations for maintenance actions after the initial training period.	BC2_SR_I_10, BC2_SR_I_11	User Interface	High
BC2_SR_I_26	The UPTIME platform shall provide accurate and actionable analytics related to predictive maintenance at the shop-floor.	BC2_SR_I_8, BC2_SR_I_11, BC2_SR_I_13, BC2_SR_I_14	User Interface	High

3.2. Technical Requirements

Taking into account the system requirements as elaborated for the White Goods business case in the previous section, a set of technical requirements are derived and discussed at the business case level (Table 3-2). Such technical requirements eventually serve a dual purpose: to externalize the non-functional requirements of the business case (classified into the look & feel, the usability, the performance, the management, the scalability, the security & privacy and interoperability aspects), and to better understand the necessary hardware and software requirements that need to be met as a precondition for the UPTIME platform.

As in the case of the system requirements, an indication of the importance and criticality of the requirements is provided through the priority of each requirement assessed as High / Medium / Low. The technical requirements on their behalf also have a unique ID that follows a specific pattern for traceability purposes: BC2_TR_I_no where BC2 indicates it concerns Business Case 2 by WHR, TR highlights it is a technical requirement, I (or II) represents the release it was defined, and no: numbering.

Table 3-2: UPTIME Technical Requirements – Business Case 2: WHR

Technical Req. ID	Description	Related Requirements Derives from	Type	Priority
BC2_TR_I_1	The user interfaces and dashboards of the UPTIME platform should be responsive (for desktop, tablet and mobile)	BC2_SR_I_22	Look & Feel	Medium
BC2_TR_I_2	The user interfaces and dashboards of the UPTIME platform shall be in English.	BC2_SR_I_22	Usability	High
BC2_TR_I_3	The user interfaces and dashboards of the UPTIME platform should support the formal language of the deployment country.	BC2_SR_I_22	Usability	Medium
BC2_TR_I_4	The user interfaces and dashboards of the UPTIME platform shall be simple and intuitive.	BC2_SR_I_7, BC2_SR_I_12, BC2_SR_I_19, BC2_SR_I_26	Usability	High
BC2_TR_I_5	The recommendations provided by the UPTIME platform shall be clear and easy to understand.	BC2_SR_I_13, BC2_SR_I_14	Usability	High
BC2_TR_I_6	The notifications spread by the UPTIME platform should be non-intrusive and clear for the targeted user.	BC2_TR_I_5	Usability	High
BC2_TR_I_7	The UX design by the UPTIME platform should correspond to the profiles and digital skills of the actual users.	BC2_SR_I_23, BC2_SR_I_24	Usability	Medium
BC2_TR_I_8	The UPTIME platform should not restrict the factory's or the workers' autonomy.	BC2_SR_I_14, BC2_SR_I_16	Usability	High
BC2_TR_I_9	The UPTIME platform shall be 24/7 operational, with short response time (<1 sec) and without any downtimes (that disrupt the data ingestion processes).	BC2_SR_I_3, BC2_SR_I_4, BC2_SR_I_26	Perfor-mance	High
BC2_TR_I_10	The UPTIME platform shall be able to effectively handle and process massive amounts of data (to cover potential future big data needs).	BC2_SR_I_1, BC2_SR_I_6	Scalability	High
BC2_TR_I_11	The UPTIME platform shall be able to easily scale to include for additional data sources, i.e. sensors.	BC2_SR_I_1	Scalability	High
BC2_TR_I_12	The communication of the factory's operational systems with the UPTIME platform should be platform-independent, through APIs.	BC2_SR_I_5	Interope-rability	High
BC2_TR_I_13	Access to the factory's data will be granted via VPN upon assessment in accordance with the WHR security and privacy policies.	BC2_SR_I_4	Privacy/ Security	High
BC2_TR_I_14	Processing and storage of the business case's data will be performed in a dedicated instance of the UPTIME platform.	BC2_SR_I_13, BC2_SR_I_15	Privacy/ Security	High
BC2_TR_I_15	The WHR policies and the local legislation of the countries where the pilot sites are placed should be considered towards handling data captured from factory premises.	BC2_SR_I_4	Privacy/ Security	Medium
BC2_TR_I_16	The sensor topology should be in place and accurately defined in the UPTIME platform.	BC2_SR_I_1	Hardware	High

4. Business Case Conceptualization

Taking into account the business scenarios and the business case-specific requirements that have been elaborated on the previous sections, as well as the draft UPTIME e-Maintenance Model and the architecture documented in the UPTIME Deliverable D2.1, the conceptualization of the business case is performed primarily along three axes concerning: (a) the necessary adaptation of the UPTIME e-Maintenance Model for adoption in the WHR business case, (b) the preliminary, flexible pilot-specific architecture that shall be deployed in the WHR demonstration site to meet the specific business objectives, and (c) the underlying infrastructure on top of which the UPTIME solution shall be deployed. It needs to be noted that such a specification and conceptualization is once again realized in a user-driven manner taking into account the information captured top-down, in collaboration with the involved stakeholders at the business case premises (mainly workers and managers).

4.1. Adaptation of the UPTIME e-Maintenance Model

As defined in D2.1, the UPTIME e-Maintenance model for Predictive Maintenance features 6 core phases, namely UPTIME_SENSE, UPTIME_DETECT, UPTIME_PREDICT, UPTIME_DECIDE, UPTIME_ANALYZE and UPTIME_FMECA, to address the complete prognostic lifecycle in a holistic manner, linking maintenance with other industrial operations. Figure 4-1depicts the UML use case diagram of the WHR business case that was initially presented in D2.1.

The WHR business case involves 3 types of actors, namely the Maintenance Manager, the Factory Worker and the Maintenance Technician who leverage different functionalities of the UPTIME platform as follows:

- The Maintenance Manager is able to monitor the machines' health status, to assess the risk of future failure(s) per machine, to get recommendations for optimal maintenance actions, to monitor maintenance cost, to optimize the maintenance time, to decide on maintenance action(s) to be performed and to calculate and monitor maintenance-related KPIs.
- A factory worker may model the equipment in a factory, define the maintenance action(s) per machine, monitor the machines' health status, receive notifications for performing autonomous maintenance action(s), report on the autonomous maintenance action(s) performed on his end, and provide feedback on maintenance actions performed on the machine.
- A maintenance technician may define the maintenance action(s) per machine and report on the professional maintenance action(s) performed on his end.

There are also certain use cases that are interrelated in terms of including many other use cases as preconditions (i.e. Get recommendations for optimal maintenance actions) or extending existing use cases (e.g. Decide on maintenance action(s) to be performed).

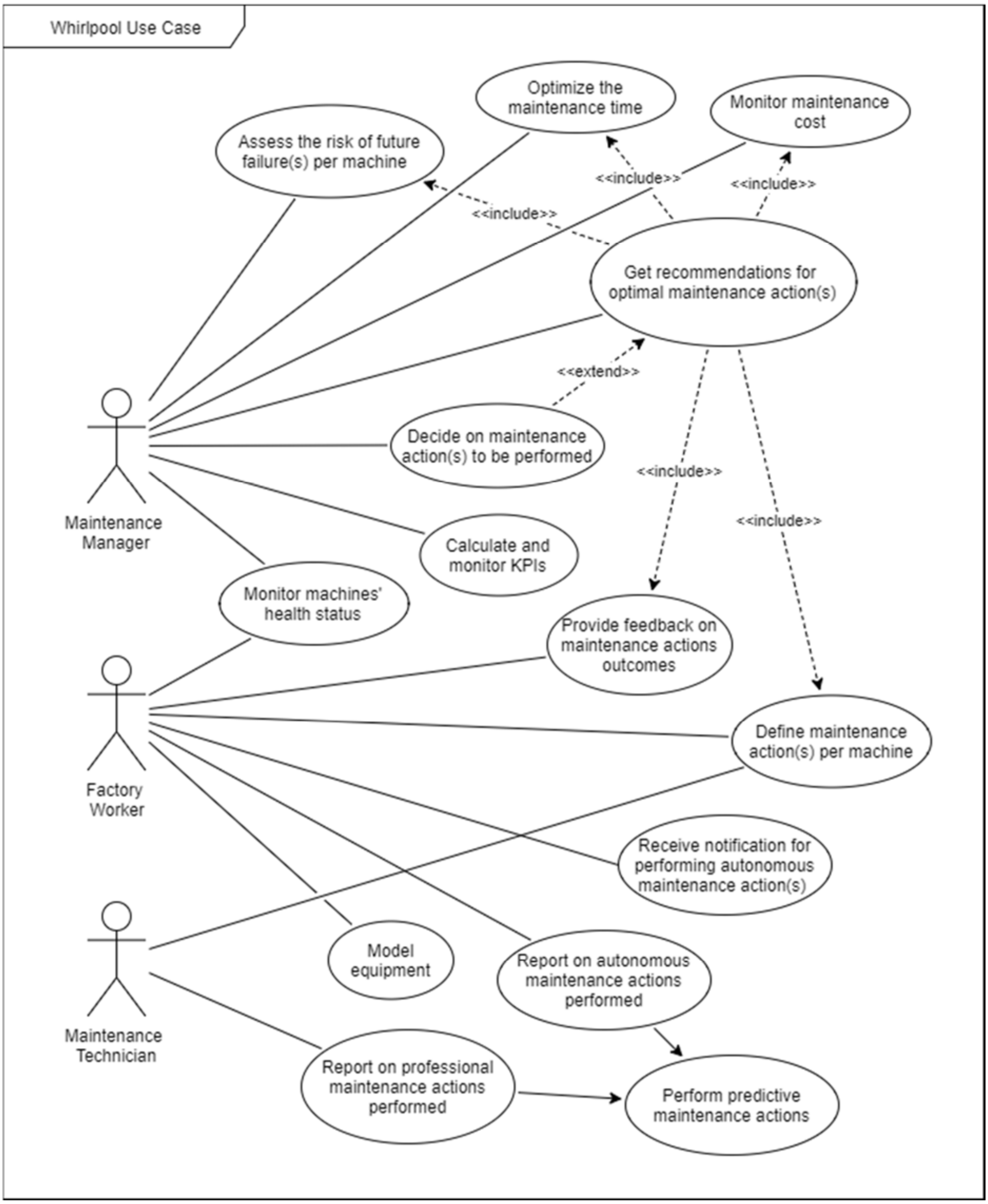


Figure 4-1: UML Use Case Diagram of WHR Business Case[3]

Figure 4-2 depicts the initial adaptation that is performed to the conceptual UPTIME e-Maintenance Model to highlight the following aspects:

[3] Source: UPTIME D2.1 (2018)

- *The different actors in the WHR business case*, i.e. the maintenance manager, the factory worker (responsible for autonomous maintenance actions), the maintenance technician (responsible for professional maintenance actions).
- *The deviation from the real-time access to sensor data through an IoT middleware*: Sensorial data will be periodically retrieved from a central database (as presented in Section 4.3) and access will be thus granted on data batches rather than data streams via a secure private network. The option for data streams to be processed through the UPTIME_SENSE phase will be investigated in the 2nd iteration.
- *The retrieval of batch data from both legacy and operational systems* (e.g. SAP Plant Maintenance-PM) as well as of legacy data related to maintenance (e.g. the maintenance ledger). Such a retrieval shall be performed either through extracts of the data (as downloadable files) or / and via APIs.
- *The availability of the UPTIME predictive maintenance results in machine-readable format via an UPTIME API* so as to be directly imported in the WHR operational systems.
- *The importance of timely (desktop / tablet / mobile) notifications delivery* as an alternative method for receiving recommendations for optimal maintenance actions. Such a notification engine shall be employed in the User Interaction Layer.

The rest of the deployment of the conceptual architecture remains largely the same, appropriately addressing in this way the project requirement for a unified UPTIME architecture that fits in different, heterogeneous business cases.

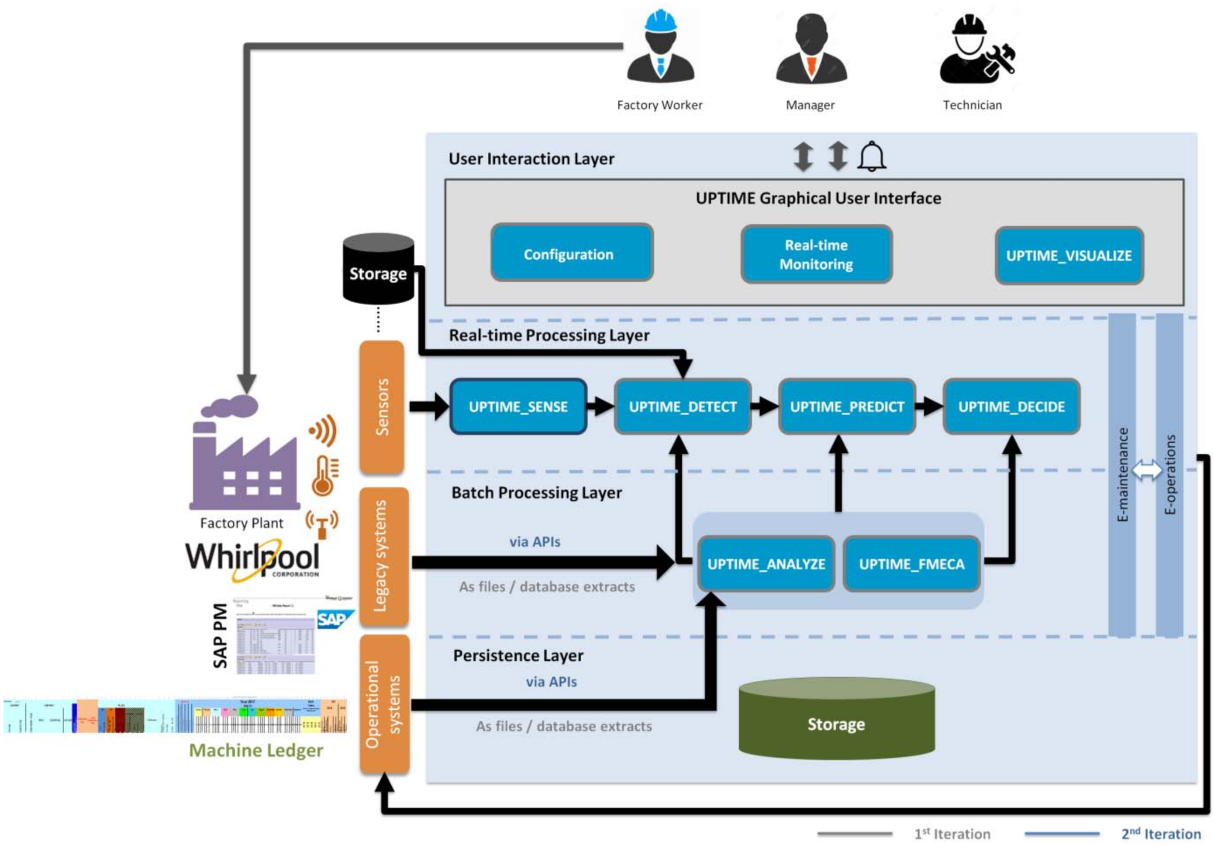


Figure 4-2: Adaptation of the UPTIME conceptual architecture (D2.1) for the WHR Business Case

A more detailed analysis of the different phases, focusing on the business case-specific perspective follows in the next paragraphs:

- **UPTIME_SENSE,** reflecting the sensorial data ingestion process, that includes the collection, aggregation and manipulation of sensor data from selected, critical machinery in the drum production line. Whenever not already performed at the shop-floor, pre-processing tasks will take place focusing mainly on the normalization, aggregation and filtering of raw data and raw readings to provide meaningful data at the rest of the UPTIME phases. These results are also appropriately stored to the Storage Layer for persistency reasons.
- **UPTIME_DETECT** concerning the state detection and health assessment of the machinery included in the drumline in the WHR premises in order to provide an accurate and reliable diagnostic output. Such an analysis is carried out by different algorithms to facilitate the recognition of any directly or progressively unusual (and potentially hazardous) state of a machine (e.g. measuring indicators of degradation and quality performance metrics), with respect to the expected model of 'normal' behaviour. UPTIME_DETECT continuously learns from the equipment behaviour by updating and improving the incorporated diagnostic model and the detection algorithms while an early baseline estimation of the "typical" behavior based on historical data is provided with the help of UPTIME_ANALYZE (although it has certain restrictions due to the lack of availability of historical sensor data).
- **UPTIME_PREDICT** that constitutes the backbone of predictive maintenance and provides (near) real-time state prediction for the machinery in the drum production line across different dimensions, e.g. prediction about the time-to-failure, the probability distribution function of the failure occurrence. The predictions are the outcome of different prognostic algorithms through the definition of calculation flows which require extensive experimentation and training with appropriate datasets to provide credible outcomes.
- **UPTIME_DECIDE** providing recommendations ahead of time in a proactive manner taking into account the accumulated prognostic information and the information/ knowledge deriving from experts (e.g. maintenance engineers) or from further data analysis of the operational processes and data. On the basis of the (near) real-time predictions from UPTIME_PREDICT, the optimal mitigating maintenance actions and the optimal times for their implementation are recommended considering the WHR-specific need to address both professional and autonomous maintenance activities. It needs to be noted that a user-oriented framework will be established with the users of the UPTIME platform in order to be able to report about the autonomous and professional maintenance activities performed and provide feedback on the maintenance activities outcomes.
- **UPTIME_ANALYZE** performing analysis of legacy and historical data available from WHR, as well as of operational data regarding the plant maintenance, in order to gain insights into the latent maintenance-related knowledge that can be extracted and effectively support predictive maintenance. More specifically, analytics over historical legacy data can lead to finding patterns of downtimes and to clustering/classifying the failures of the machinery in the drum production line based on similar characteristics while the exploitation of the operational data can lead to predictive maintenance tasks (in UPTIME_PREDICT and UPTIME_DECIDE) that effectively take into account the current preventive plans and operations. The role of UPTIME_ANALYZE is highlighted in the WHR business case because of the availability of historical and legacy data from multiple sources (whose collection was promptly initiated since M3), and the concurrent lack of sensorial historical data from the demonstration site.
- **UPTIME_FMECA** representing the bottom-up data-driven process that performs failure mode, effects and criticality analysis and is instrumental for predictive maintenance. UPTIME_FMECA started early (from M4) for the WHR business case in an "offline" manner in order to identify in a solid and informed manner which are the machineries in which the placement of sensors would have the most significant impact to predict failures.

- **UPTIME_VISUALIZE** which is responsible for the intuitive and uninterrupted human-machine interaction. The user interfaces, including the analytics dashboards and the notification engine, shall be customized or further developed in full accordance with the end-users of the WHR business case.

In summary, by combining the experts' knowledge with insights from data gathered from the machines and legacy/operational systems in the WHR demonstration site, the UPTIME phases will enable a smooth transition from Reactive Maintenance and Preventive Maintenance to Predictive Maintenance for the WHR business case.

4.2. Business Case-Specific Architecture

From a more technical perspective, the dedicated architecture that builds on the generic UPTIME architecture and takes into account the WHR business case specificities is drafted and illustrated in Figure 4-3. Such an architecture is consistent with the scenarios and the requirements of the business case as elicited in sections 2 and 3. As presented in Figure 4-2, the deployment of the UPTIME platform will be planned for 2 iterations in an agile manner (in section 6) in accordance with the system and technical requirements while the different modules specified in the UPTIME technical architecture shall be leveraged with different criticality and priority.

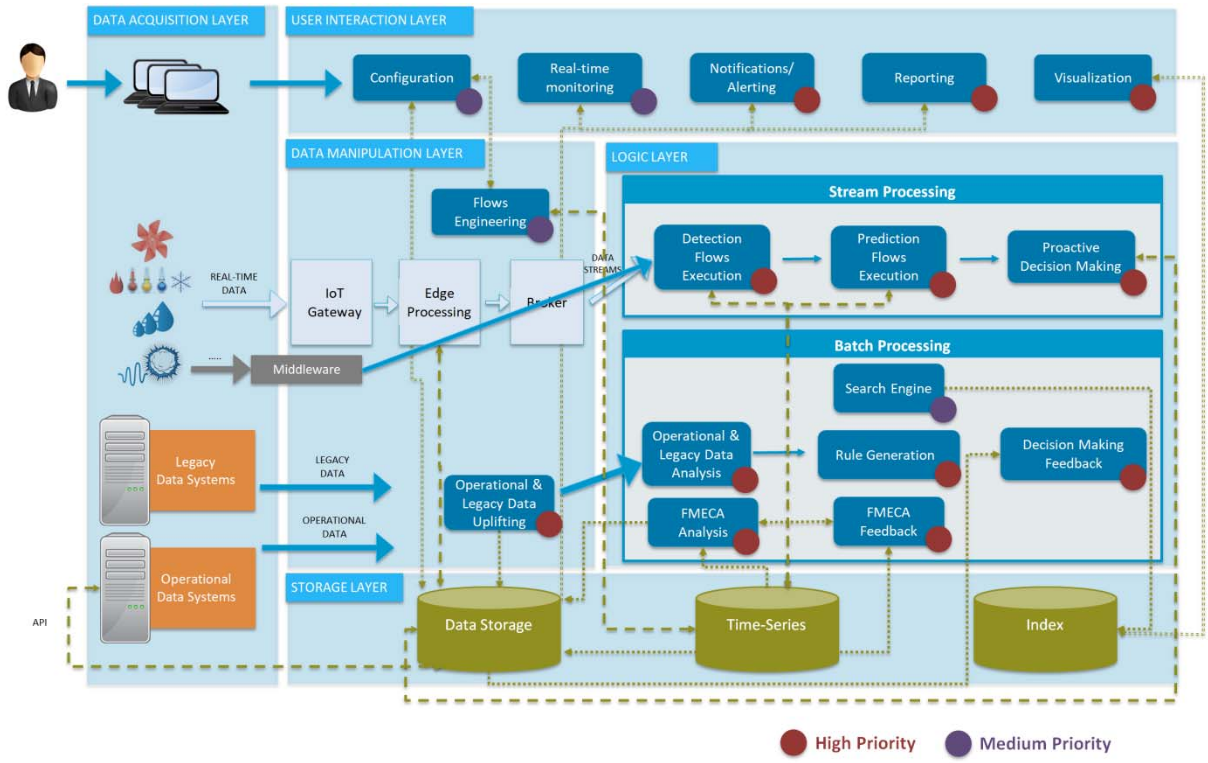


Figure 4-3: UPTIME Technical Architecture (D2.1) adopted in the WHR Business Case

The following Table 4-1 recalls the functionality of each technical module that is relevant to the WHR business case as documented in D2.1 and associates it with the system requirements that were identified in section 3.

Table 4-1: UPTIME BC2 Requirements in the UPTIME Architecture

	Technical Module in UPTIME Architecture	Functionality identified in D2.1	Relevant BC2 Requirements
UPTIME _SENSE	Broker	• Use or adaptation of interfaces and middleware for PLC data retrieval in a secure manner • Definition of parameters (e.g. time intervals) for data batches retrieval	BC2_SR_I_1, BC2_SR_I_2, BC2_SR_I_4
UPTIME_DETECT & UPTIME_PREDICT	Detection Flows Execution & Prediction Flows Execution	• Deployment, execution and monitoring of analytics algorithms outcomes (i.e. calculation flows)	BC2_SR_I_8
	Flows Engineering	• Definition of health status detection algorithms • Configure predictive maintenance algorithms • Train detection and prediction algorithms	BC2_SR_I_9
	Detection & Prediction Flows Execution	• Experiment with different algorithms and compare results	BC2_SR_I_9
UPTIME_DECIDE	Proactive Decision Making	• Define maintenance actions parameters • Receive recommendations for optimal maintenance actions • Receive notifications for autonomous maintenance actions	BC2_SR_I_12, BC2_SR_I_13, BC2_SR_I_14
	Decision Making Feedback	• Provide feedback on maintenance actions performed	BC2_SR_I_16, BC2_SR_I_17
UPTIME_ANALYZE	Operational and Legacy Data Uplifting	• Define APIs for operational, legacy and historical data retrieval	BC2_SR_I_3, BC2_SR_I_5, BC2_SR_I_6
	Operational and Legacy Data Analysis	• Clean and curate operational, legacy and historical data • Apply machine learning algorithms to correlate failure times with machine behavior, maintenance actions history and preventive plans • Extract patterns of machine behavior	BC2_SR_I_10, BC2_SR_I_11
	Rule Generation	• Extract rules for each machine's maintenance	BC2_SR_I_10, BC2_SR_I_11
UPTIME_FMECA	FMECA Analysis	• Calculate risks and identify criticalities in the production line • Predict and assess risks of future failure(s) per machine • Calculate the propagated effects of a machine's failure	BC2_SR_I_18, BC2_SR_I_19
	FMECA Feedback	• Model equipment in the shopfloor	BC2_SR_I_12
UPTIME_VISUALIZE	Visualization	• Monitor machine's health • Calculate and monitor KPIs	BC2_SR_I_20, BC2_SR_I_21
	Reporting	N.A. although evident in the UML Use Case Diagram of the Whirlpool Business Case	BC2_SR_I_20
	Notifications / Alerting	N.A. although evident in the UML Use Case Diagram of the Whirlpool Business Case	BC2_SR_I_13, BC2_SR_I_14, BC2_SR_I_15
	Real-time Monitoring	N.A. although evident in the UML Use Case Diagram of the Whirlpool Business Case	-

	Technical Module in UPTIME Architecture	Functionality identified in D2.1	Relevant BC2 Requirements
	Configuration	N.A. although evident in the UML Use Case Diagram of the Whirlpool Business Case	BC2_SR_I_7, BC2_SR_I_8, BC2_SR_I_12, BC2_SR_I_18

4.3. Existing Business Case Infrastructure

The infrastructure deployed for the needs of the UPTIME project will naturally leverage as much as possible the existing infrastructure at the Whirlpool factory where the piloting activities will take place. The underlying infrastructure consists of a number of control systems, work stations, software systems and databases, connected to Factory LAN, as depicted in the following Figure 4-4.

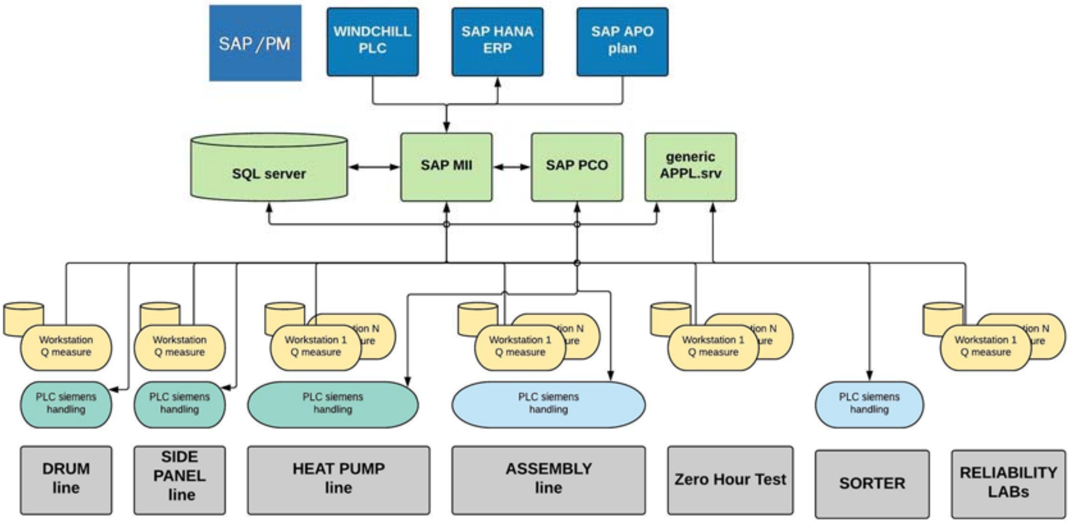


Figure 4-4: Drier factory Infrastructure

In general, each sensor (e.g. in the drum line, the side panel line, etc.) is directly connected to the respective Siemens PLC S7 which is on board of the specific equipment. The internal SCADA system is gathering the data from each PLC and sends them to the SAP-MII layer which in turn stores them into the database (SQL Server).

5. Business Case Evaluation

In this section, the scope of the evaluation of the WHR business case is discussed and put into an appropriate context by defining a solid evaluation methodology and planning its application through concrete evaluation cases and quantitative KPIs. An initial discussion is also provided in respect to the expected benefits and impact of predictive maintenance as addressed in UPTIME, as well as the potential business implications.

5.1. Evaluation Methodology

In general, evaluation is a systematic determination of the merit, added value and significance of a software product / platform / system, using well-defined objective criteria to effectively assess the user experience. It is often associated with the concept of validation and verification (V&V) which, according to ANSI/IEEE Std 1012-2012, aim at addressing: (a) whether the software product / platform / system is built right (verification scope), and (b) if the right software product / platform / system is built (validation aspects). To this direction, for the evaluation purposes of the WHR business case in UPTIME, a mix of techniques effectively combining quantitative and qualitative state-of-the art methods shall be put into use in order to ensure that:

- The UPTIME platform is being built according to the requirements and design specifications as expressed by WHR in section 3.
- The UPTIME platform actually meets the WHR end users' needs, its business case-specific specifications (defined in section 3) were correct in the first place and it fulfils its intended use for predictive maintenance when placed in the WHR demonstration site.

Building on the experience of the FITMAN verification and validation method (Lampathaki et al, 2014) that was successfully applied by the WHR trial in the context of the FITMAN project (2018), the evaluation method to be employed in UPTIME is depicted in Figure 5-1.

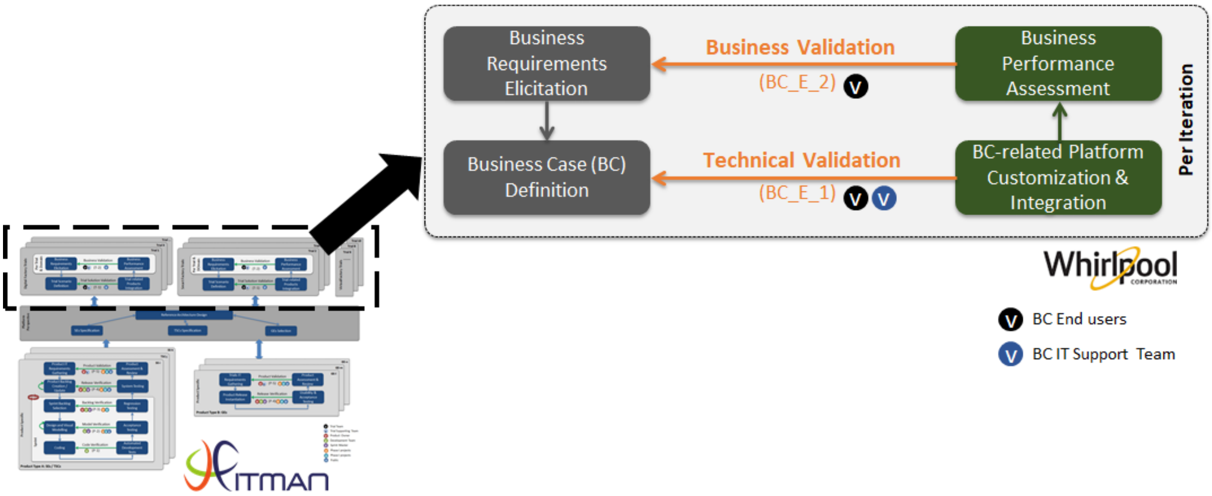


Figure 5-1: WHIRLPOOL Business Case Evaluation Method[4]

[4] Adapted from (FITMAN, 2013a)

In brief (and keeping the terminology of the baseline FITMAN V&V method), the evaluation of the WHR business case to be performed in UPTIME bears two core steps, spanning over both the technical and the business perspectives:

- **Technical Validation (BC_E_1)** to guarantee that the overall UPTIME solution as adapted for the WHR business case satisfies intended use and user needs. Such a technical validation occurs from a technical and functional point of view only.
  Involved Stakeholder group: End users of the Business Case, IT Support Team of the Business Case
  Applicable Methods: (a) User Acceptance Testing by executing specific evaluation cases from a technical and functional point of view (as indicatively mentioned in section 5.2). (b) Guided (semi-structured) interviews and / or online questionnaire based on Unified Theory on the Acceptance and Use of Technology (UTAUT).
  Indicative Evaluation Cases to be implemented:
    - Data monitoring and visualization for predictive maintenance tasks
    - Patterns and rules extraction for each machine's maintenance
    - Prediction and assessment of risk of future failure
    - Notifications and alerts about professional maintenance actions
    - Notifications and alerts about autonomous maintenance actions

  Indicative Technical KPIs to be assessed:
    - Fulfilment of requirements: The degree to which a user believes that the UPTIME platform meets the business case requirements in predictive maintenance.
    - Perceived Usefulness: The degree to which a user believes that the UPTIME platform is beneficial to him/her.
    - Perceived Ease-of-Use: The degree to which a user believes that it is easy to learn the functionalities of the UPTIME platform and use it in his/her everyday work.
    - Reliability: The capability of the UPTIME platform to maintain a seamless, failure-free operation for a specified period of time in a specified environment and to provide accurate results.
    - Efficiency: The capability of the software product to provide high performance, relative to the amount of resources used, under stated conditions.
    - Intention to Use: The degree to which a user intends to use the service.

- **Business Validation (BC_E_2)** to assess whether the overall UPTIME solution as deployed in the WHR demonstration site eventually offers sufficient added value to WHR. Such a business validation intends to demonstrate that the platform developed has clear benefit to WHR, allowing it to operate more efficiently (in terms of cost, time or quality) than before, and supporting it in the transition to predictive maintenance that could not be done before.
  Involved Stakeholder group: End users of the Business Case
  Applicable Methods: Simplified ECOGRAI Methodology, FITMAN (2013b)
  Indicative Business KPIs to be assessed:
    - Improvement of OEE (Overall Equipment Effectiveness) Average (%)
    - Reduction of MTTR (Mean Time To Repair) (%)
    - Increase of MTBF (Mean Time Between Failures) (%)
    - Reduction of Total Cost of Maintenance (%)

In needs to be noted that the technical verification aspects that are inherent to any software platform are not in the scope of the business case evaluation as they will be systematically assessed in WP2, T2.5 "System Validation and Verification".

Finally, the successful implementation of the proposed evaluation framework to be applied in the WHR business case relies on a 6-step procedure (that shall be applied in each iteration):

I. **Preparation** of the Technical Validation (BC_E_1) and Business Validation (BC_E_2) activities by adapting the methods to be employed according to the latest project's and business case's developments, selecting the stakeholders to be involved and creating the necessary material (e.g. evaluation cases, questionnaires, etc.).

II. **Initiation** of the Technical Validation (BC_E_1) activities by running the specific evaluation cases.

III. **Communication** of the preliminary evaluation results to the platform developers to address any critical issues that were encountered in the business case.

IV. **Completion** of the Technical Validation (BC_E_1) activities involving the necessary stakeholders through interviews and online questionnaires (as designed in step I).

V. **Involvement** of key stakeholders in the Business Validation (BC_E_2) activities, by collecting all necessary data to assess the business KPIs.

VI. **Interactive discussions** with the platform developers to discuss and assess the complete evaluation results and plan – to the extent it is feasible – the necessary updates of the UPTIME platform in an efficient manner.

The detailed time plan for the implementation of the different phase of evaluation is defined in section 6.

5.2. Benefits & Impact

The UPTIME data-driven predictive maintenance strategy is expected to directly impact the WHR business case in reducing failure rates, downtime due to repair, and unplanned plant/production system outages as well as in eventually extending the machine's life. The main direct consequences of UPTIME will allow the reduction of the number and the severity of breakdowns: many of preventive maintenance conservative strategies are not affordable from economic point of view, while predictive ones will allow a better planning of resources and spare parts. This in turn will impact positively on overall equipment efficiency (OEE) both due to MTBF and MTTR improvement and because of the direct influence on part quality. In addition, the Total Cost of Maintenance (TCM) will be positively impacted through an improved utilization of spare parts (in principle less than one observed in preventive approach) and resources (through better usage of stop times and planning of intervention).

In this context, the adoption of a reliable preventive maintenance system will help the Drum production line where the UPTIME results will be practically piloted to improve its main business KPIs (as identified in section 5.1). The expectations of how the UPTIME introduction can progressively impact the WHR business case in the 2 iterations are reflected in the following Table 5-1.

Table 5-1: UPTIME Business Case 2: Business KPIs Target Values

Key Performance Indicator	TO-BE Value (M21)	TO-BE Value (M36)
Improvement of OEE (Overall Equipment Effectiveness) Average	+5%	+10%
Reduction of MTTR (Mean Time To Repair)	-5%	-10%
Increase of MTBF (Mean Time Between Failures)	+10%	+30%
Reduction of TCM (Total Cost of Maintenance)	-10%	-25%

In parallel, WHR expected to yield several competitive advantages in the broader perspective, thanks to UPTIME:

- Better industrial cost control giving an improved stability in margin realization;
- Improved quality of the product reflecting both in customer satisfaction and lowering total cost of Quality;
- Leaner production (less work-in-progress, less inventory) improving the reaction to market changes and increasing the ration between Make-to-order vs. Make to Stock.

5.3. Business Implications & Future Trends

At a time when Industry 4.0 is leaping from a hype to reality, predictive maintenance is considered a key manufacturing trend to boost efficiency by cutting down the costs of unplanned downtime and emergency maintenance of a manufacturer's assets.

Adopting a novel predictive maintenance strategy in UPTIME holds the credentials in applying more accurate, secure and trustworthy techniques at machine, production line and factory level. In Whirlpool, the transformation of all the EMEA factories in Professional Maintenance according to World Class Manufacturing is managed centrally by the Operation Excellence department, which shall ensure that all the best practices and technological solutions developed in UPTIME will be in principle applied to all the factories reaching the adequate level of standard (STEP 5 of Professional Maintenance).

In order to leverage the UPTIME benefits to the maximum degree, though, training activities addressed to factory workers and technicians who possess different digital skills are expected to be instrumental in improving their digital literacy and embedding the proposed predictive maintenance mentality in their everyday work.

6. Business Case Implementation Roadmap

Upon elaborating on the business, technical and evaluation aspects of the WHR business case, the time plan for piloting activities is reported in this section. As already highlighted, the overall demonstration activities will be performed in two iterations, following the agile principles adopted in the project. Therefore, in the following paragraphs, the list of detailed tasks & activities to be performed in each iteration is briefly presented. It needs to be noted that the experiences gained from the 1st iteration shall also contribute in identifying any potential fine-tuning it may be needed on the timing and the activities of the 2nd iteration.

6.1. Planning of 1st Iteration

The 1st iteration anticipates the early demonstration of UPTIME framework in the WHR demo site premises and shall be implemented from M9 (May 2018) until M21 (May 2019). The main focus at this stage is on properly setting up the necessary infrastructure, on adapting and deploying the UPTIME platform, on early engaging the alpha adopters (end-users), on providing training and on validating of the platform's functionalities in order to provide concrete and timely feedback to the UPTIME development team for 2nd iteration. During this iteration, both business scenarios (described in section 2.2) will be demonstrated to the degree their related requirements are met by the technical developments in the UPTIME platform.

The detailed time-plan for the implementation of different activities is depicted in the following Table 6-1, along with the detailed description of the different tasks which follows. The milestones for this early deployment coincide with the official WP5 deliverables, namely D5.2 on M15, D5.3a on M18 and D5.4a on M21, as reported in the UPTIME DoA.

Demonstration Activities	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21
I.1 Business case preparation & Review of existing installations in premises													
I.2 Final selection of data attributes for Whirlpool demonstrator													
I.3 Data Collection and Infrastructure Setup													
I.4 Early deployment of the UPTIME platform													
I.5 Testing, Training and Validation													

Table 6-1: Demonstration Activities – 1st Iteration

I.1 Review of existing installations in premises

The main actions that were performed as part of this preparatory activity are briefly reported as follows:

- Visit to the WHR production line under construction and early adjustment of the technical specification as required to the supplier **(M2)**
- Early workshop to engage end users in project activities; support the definition of UPTIME vision and extraction of 1st round of requirements **(M5)**

- Definition of SAP PM and MES tools data sources and integration requirements **(M7) t**o support further the work performed in:
    - Task 1.3 Multi-Source Data Acquisition, Harmonization and Processing Patterns definition
    - Task 3.1 Data Acquisition and Manipulation development task
- End users' engagement activities to gather feedback required for the updates of the UPTIME architecture in Whirlpool case study **(M8)**

The main outcomes of such actions are reported in this document. While we consider this activity as completed at the time of the delivery of this deliverable, minor updates may apply the following months, once we proceed with the integration of the actual infrastructures in the WHR premises.

I.2 Final selection of data attributes for Whirlpool demonstrator

Since M4, an initial FMECA analysis has started in order to study in detail the drum production line. While the core sensor placement for the demonstrator has already been performed, there is the opportunity for including additional sensors (to be ordered on time for the 2nd iteration) in order to effectively integrate the outcomes of the FMECA analysis. The final list of data sources along their attributes is thus expected in **M11.**

I.3 Data Collection and Infrastructure Setup

In close collaboration with the previous activity, the actual task of initiating the data collection process from the factory's shop-floor and the underlying industrial systems (i.e. operational systems and legacy systems). This activity practically deals with setting up the necessary infrastructure (middleware, VPN access) in order to get access to the sensorial data, as well as with investigating the available interfaces (APIs, web services) for retrieving data directly from the systems in operation without disrupting in any way the existing infrastructure defined in section 4.3. Whenever not available, the interoperability interfaces with the relevant Whirlpool legacy systems will be specified. This activity can be practically viewed as putting the data acquisition and manipulation framework in place.

I.4 Early deployment of the UPTIME platform

In this activity, the UPTIME platform will be adapted and deployed for the WHR business case on M18. The necessary variations of the UPTIME predictive maintenance algorithms shall be performed upon intense experimentations to increase the results' accuracy. The initial UPTIME phase to be put into action will be UPTIME_ANALYZE followed by UPTIME_DETECT, UPTIME_PREDICT and UPTIME_ANALYZE. In addition, the user interfaces and dashboards (UPTIME_VISUALIZE) shall be customized according to the needs and requirements of the end users. Detailed documentation and video guidelines on how the different actors may use the UPTIME platform will be prepared to reduce the necessary entry time. The outcomes of this activity are in line with the project milestone about the **Readiness of the UPTIME Demonstrators (1st Piloting Phase)** in **M18**.

I.5 Testing, Training and Validation

In parallel with the deployment of the UPTIME platform, specific training activities and the actual technical and business validation activities as defined in section 5.1 shall be performed. Dedicated workshops will take place and questionnaires will be filled in by the end users to determine the level of conformity with the end users' expectations, requirements and needs. The business KPIs shall be measured while the lessons learnt and the experiences gained shall be appropriately captured. By getting the feedback from end users by **M21**, updates in the development and configuration of the UPTIME platform will take place in collaboration with WP2 and WP3.

6.2. Planning of 2nd Iteration

Following up on the activities performed in the 1st iteration ensuring that the UPTIME platform is up and running in the demo site and that the initial evaluation round has been performed, the 2nd iteration start with the appropriate adjustments, the final deployment and the full demonstration of the UPTIME solution in the pilot premises. During this final iteration, both business scenarios (described in section 2.2) will be fully demonstrated.

The detailed action plan for the 2nd period is to be implemented from M22 (June 2019) until M36 (August 2020) as presented in the following Table 6-2.

Demonstration Activities	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
II.1 Finalization of planning for the 2nd iteration															
II.2 Data Collection Infrastructure Updates															
II.3 Final deployment of the UPTIME platform & integration with WHR systems															
II.4 Final evaluation & Knowledge transfer															

Table 6-2: Demonstration Activities – 2nd Iteration

II.1 Finalization of planning for the 2nd iteration

In order to properly incorporate the considerations and recommendations received during the 1st iteration, the plan for the 2nd iteration shall be revisited to ensure it is in line with the latest advancements and lessons learnt. Whenever necessary, appropriate adjustments shall be made.

II.2 Data Collection Infrastructure Updates

In case the need for additional data sources (especially sensors) has been identified during the 1st iteration (e.g. during the activity I.2), then the necessary updates on the data collection infrastructure shall be made. During this activity, it will be also decided whether there will be a parallel implementation that will be in line with the WHR security and privacy policies to provide direct, real-time access to the sensor data from the shop-floor.

II.3 Final deployment of the UPTIME platform & integration with WHR systems

During this task, the final release of the UPTIME e-maintenance platform will be deployed for the Whirlpool business case. The algorithms that are running shall be improved whenever necessary leveraging the large amount of data that will become available until M22 and taking into account the user experience on their accuracy. The interoperability interfaces with the relevant WHR operational and legacy systems will be also developed and tested to ensure bilateral communication among UPTIME and the WHR deployed IT systems. The end date for the configuration/adaptation of the UPTIME platform in premises is **M30** (in line with the project milestone about the Readiness of the UPTIME Demonstrators - 2nd Piloting Phase); the full functionality will be already available in premises.

II.4 Final evaluation & Knowledge transfer

In this activity, the final evaluation actions at business and technical level shall be implemented while ensure that all feedback from the end users' experience following their day to day interaction with the UPTIME platform is properly gathered. Along with the extensive validation of the platform, the necessary preparatory actions shall be performed to support the effective knowledge transfer within

WHR and the overall exploitation of the UPTIME as an end to end predictive maintenance platform. The deadline for this activity is actually the end of the project, in accordance with the milestone of the work about field trials execution, validation of the technologies developed and performance evaluation of the demonstrators in **M36**.

6.3. Experimentation Boundaries and Constraints

In parallel with the plan of the piloting activities and in order to avoid that the actual experimentation boundaries are tested and endanger in any way the business case implementation, the horizontal task of early identifying the risks and boundaries that may affect the prompt demonstration of UPTIME in the WHR premises has been anticipated. Along with the definition of risks, a mitigation plan is defined to continuously monitor the status of deployment as presented in the following Table 6-3.

Table 6-3: WHR deployment Risk Assessment

Risk ID	Risk Description	Contingency Plan
Development		
T.01	Unexpected delay in delivering the UPTIME platform	Continuous monitoring of the technical developments in WP2 and WP3 / Experimentation with early, "alpha" releases of the components in case the integrated platform is delayed.
T.02	Technological inefficiencies of main components	The rigorous verification of the project results will prevent fails that could impact on its achievement/ Clear understanding of the business case specific objectives
T.03	Difficulties in customization of the UPTIME solution	Along with the deployment of the modules, the technical support partners need to take into account the list of the business case-specific requirements. Through hands on experience on early releases of the platform, the necessary adaptations (e.g. new algorithms or interfaces) shall be performed without difficulty or delays.
T.04	Interfaces incompatibility	Detailed definition of interfaces in WP2 and agreement among partners on early testing the alpha releases of the components (e.g. regression and integration tests) -Compliance with available open standards.
Deployment		
D.01	Unexpected delay at the deployment	The IT support partners of the business case will follow a rapid deployment process to ensure the on-time installation of the UPTIME platform at the demo premises.
D.02	Unavailability of concrete datasets	The business case partner will ensure the prompt access on historical/operational/historical datasets as defined in D5.1.
D.03	Data quality issues	The IT support partners of the business case will ensure that the data collected meet certain quality standards. As the sensor data are not collected real-time but at batch levels, data pre-processing and curation processes will be already performed. In extraordinary cases that there are connection problems that have disrupted the sensor data transmission, effort will be made to fill in the information gaps backwards in time with the help of historical data.
D.04	Lack of accuracy of the algorithms	Initial datasets will be available from the business case to ensure that the algorithms will be tested, customized and trained on time.
D.05	Limited time for analytics tasks	The time period allocated for training/baseline is reasonable according to the data analysts of the IT support partners in order to get accurate results. In case it needs an extension, it will be granted to the extent it does not affect other actions.

Risk ID	Risk Description	Contingency Plan
D.06	Integration problems with the WHR IT infrastructures	Detailed definition of interfaces in WP5 and early discussions of WHR with the relevant IT providers to agree on delivering the related interfaces on their end on time.
Operation		
O.01	Limited acceptance by the end-users	User-centered design already applied for the requirements documented in this report; the agile development and the tight collaboration among WP2-WP3-WP5 will ensure the active engagement of the users at all stages.
O.02	Out of the radar requirements not addressed in the 1st release	Two iterations of the business case to ensure that all system and user requirements are properly addressed.

It needs to be pointed out that such an analysis is applicable to the rest of the demonstrators in the project; however, the focus in this deliverable is about the White appliances demonstrator and the specificities of UPTIME deployment in the WHR business case.

7. Conclusions and Next Steps

The scope of this document was threefold: (a) To examine the current situation in the pilot site and further define the vision for the Whirlpool Business Case; (b) To extract the list of pilot demonstrator specific requirements that will further enable the definition of specifications for the UPTIME framework instantiation in the specific business case; and (c) To provide the early version of the evaluation methodology along with the definition of the time-plan for the implementation of demonstration activities in the Whirlpool business case in the White Goods / Home Appliances industry.

Overall, this document introduces the Whirlpool business case and provides the initial positioning and visibility on how the UPTIME predictive maintenance framework shall be incorporated in the current maintenance processes in the manufacturing plant and provide added value for WHR and broadly for the business stakeholders in the industry.

Following an early review of the existing physical installations and processes for handling the maintenance activities in the WHR premises, the business case context is identified through: a) the business vision and the to-the-point business scenarios for predictive maintenance in the automatic drum line, b) the detailed requirements analysis at stakeholders, system and technical levels, according to the D2.1 requirements methodology (note: the stakeholder requirements are reported in D2.1), c) the mapping of the as-is processes, the profiling of the available data and the demonstration of the relevant IT systems. The business stakeholders were actively enrolled in the task in order to properly communicate their actual needs and requirements.

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 WHR 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 WHR business case was elaborated on the basis of the UPTIME needs and leveraging the past V&V (Verification and Validation) experiences in the FITMAN project. 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 release of the business case.

The linkage of this work with the rest of the tasks in WP5, namely Task 5.3 about Data Collection and Infrastructure Setup, Task 5.4 for the deployment of UPTIME and integration with Whirlpool IT Infrastructure and task 5.5 about System Evaluation, Learning and Improvement is obviously tight.

D5.1 is overall considered as a living document acting as the specifications manual for the implementation of the demonstration activities in the WHR business case for the remaining project period.

References

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