RECLAIM Use Cases Definition & Operational Requirements #2

[September 2021 – M24]

AUTHORS: Dra. Nieves Murillo, Alejandro Gazulla

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Technical References

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

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Contributors list

No.	Organization name	Name	Country
1	HARMS & WENDE GMBH & CO KG	Dr. Michael Peschl Niels Mitzschke	Germany
2	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS	Dimmos Ioannidis	Greece
3	ASOCIACIÓN PARA LA PROMOCIÓN, INVESTIGACIÓN, DESARROLLO E INNOVACIÓN TECNOLÓGICA DE LA INDUSTRIA DEL CALZADO Y CONEXAS DE LA RIOJA	Alfonso Pascual Saul Iñiguez	Spain
4	SCUOLA UNIVERSITARIA PROFESSIONALE DELLA SVIZZERA ITALIANA	Andrea Barni	Italy
5	UNIVERSIDADE DO PORTO	Eliseu Pereira	Portugal
6	FUNDACIÓN TECNALIA RESEARCH & INNOVATION	Dra. Nieves Murillo Alejandro Gazulla Daniel Gil Irene Pérez	Spain
7	STEINBEIS INNOVATION GGMBH	Maeva Pratlong	Germany
8	ADVANTIC SISTEMAS Y SERVICIOS SL	Jose Javier de las Heras	Spain
9	FUTURE INTELLIGENCE EREVNA TILEPIKINONIAKON KE PLIROFORIAKON SYSTIMATON EPE	George Bogdos	Greece
10	SCM GROUP SPA	Giorgia Zanelli	Italy
11	ROBOTEH D.O.O.	Katja Oberzan	Slovenia
12	TTS TECHNOLOGY TRANSFER	Antonio Avai	Italy
13	INFORMATION CATALYST FOR ENTERPRISE LTD	Oscar García	United Kingdom
14	GORENJE GOSPODINJSKI APARATI D.D.	Majda Meza Jiří Balhar	Slovenia
15	FLUCHOS S.L.	Antonio Saenz Martínez	Spain
16	PODIUM SWISS SA	Asia Savino	Switzerland
17	ZORLUTEKS TEKSTIL TICARET VE SANAYI A.S.	Murat Yildirim Meltem Turgut	Turkey

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Reviewers list

N°	Name	Surname	Beneficiary
1	Silvia	Menato	SUPSI
2	Lucrecia	Quarato	SCM

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Abbreviations & Acronyms

Abbreviations & Acronyms	
3D	3-Dimensional
AR	Augmented Reality
ASN	Adaptive Sensorial Network
CEN	European Committee for Standardisation
CPPS	Cyber-Physical Production System
DOA	Document of Agreement
DSF	Decision Support Framework
DW	Dishwasher
FPGA	Field-Programmable Gate Array
HMD	Head-Mounted Display
HMI	Human Machine Interface
ID	Identifier
IEC	International Electrotechnical Commission
IIoT	Industrial Internet of Things
IMU	Inertial Measurement Unit
IoT	Internet of Things
ISO	International Standard Organisation
KoM	Kick-Off Meeting
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
M2M	Machine-to-Machine
MTBF	Mean Time Between Failures
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair
PLC	Programmable Logic Controller
PMS	Performance Measurement Systems
RC	Robotic Cell
SCADA	Supervisory Control And Data Acquisition
TPmer	Gorenje's Internal Application
UML	Unified Modeling Language

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Summary

The RECLAIM project is focused on the development of smart physical and virtual solution for their demonstration into six heterogenous Pilot covering form good manufacture to industrial equipment to achieve a new digitalization approach on large industrial manufacturing lines near their obsolescence or the analogical to digital refurbishment in older but essential machines. The new demands of the Industrial Internet of Things, IIoT, are opening new opportunities that required new strategies for the real integration of digital solution into the traditional industries based in the refurbishment and re-manufacturing of large industrial equipment in factories, paving the way to a circular economy.

The main objective of the re-manufacturing approach from the RECLAIM concept is to guarantee the coexistence of new high digitalized machines with analogical ones at the same production line. The way to achieve such challenge is the implementation of a set of digitalization tools, physical and virtual, connected with the Internet of Things to obtain the necessary information for the advanced management of the complete production process. This goal is not just an economical matter is a mechanism for the productivity increase centered on the prevision and the efficiency increased. The refurbishment and the re-manufacture of active machines going into the digital obsolescence is a green deal goal link with the sustainability to reduce the waste produced in the cases where the machines are dismissed and to reduce product carbon footprint by the optimal maintenance and energetic performance. Furthermore, the digitalization is a tool for the market position of industries, and it could make the difference between competitors or market success.

In this sense, RECLAIM solutions integrated into one unique architecture a complete pool of technologies from the physical layer, smart and heterogeneous IoT sensor, new versatile and functional industrial PC or human interface machine, etc., with the advanced software based in machine learning and data analytic for the decision support tool and digital twins virtues demonstration. Where the preparation and anticipation of the factories to be digitalized will guarantee the competitiveness of the European Industrial sector. RECLAIM solutions will allow to the democratization of Digital tools, physical and virtual, independently of the industries size with a minimal inversion based on non-invasive approach where the focus is the technologies instead of the renovation of the machines and equipment. Although, the RECLAIM tools are focused from the technical point of view to support all industrial sectors, six used cases have been identified for the demonstration of the technological benefit of the RECLAIM tool set on the physical and/or virtual digitalization of ageing and long-term exploited machines. The sectors where RECLAIM solution will demonstrate the technological tool kits are going from goods manufacturer, footwear manufacturer, wood furniture manufacturer, friction welding machines and original equipment manufacturer to home textile manufacturer with the aim to transform them into the IIoT age. These technological demonstration activities will address the future transference of the RECLAIM technologies to the complete industrial spectrum of Europe because of the modular approximation that guarantee the scale-up of the RECLAIM solutions.

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The D2.6 deliverable, RECLAIM Use Cases Definition & Operational Requirements #2, in its second deliverable of T2.2. The deliverables of T2.2 are proposed as a subsequent evaluation of the Use Cases Definition & Operational Requirements along the project evolution on the technical and demonstration activities. The Use Case Scenario link with Pilot demonstration activities are explained for the technical approach understanding and Unified Modeling Language diagram, UML, are proposed as a graphical media to represent the nexus and flows between components and data exchange. The diagrams and schematic representation of the Use Case Scenarios integrated the RECLAIM solutions involved into the different Pilot Demonstration. As preparatory action for WP6, Integration and Industrial Demonstrations, where Pilot activities will need of metrical indicators to measure their efficiency and success. The analysis of the Grant Agreement Key Performance Indicators (KPIs) and their confluence into the most important ones to guarantee the Pilot demonstration activities evaluation was been performed at the present deliverable D2.6.

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Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°869884

List of Figures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°869884

List of Tables

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1 Introduction

The D2.6, RECLAIM Use Cases Definition & Operational Requirements #2, deliverable of RECLAIM project collects the mains results and conclusion from the activities developed at the T2.2, Industrial Use Cases and Scenarios Design, in its second iteration. This deliverable links with deliverables D2.2, submitted on July 2020, and D2.7, where subsequent version of this deliverable will be conducted in its #3 version for the complete analysis and revision of the RECLAIM Use Cases.

The transformation of the high-level description of the industrial use-cases into realistic requirements and reachable demonstration scenarios is a long-term activity that evolve along the project execution based in the constant approach between technical capabilities and end-user requirements. To visualizes the technical potential of the RECLAIM tools on the digitalization into practical Use Cases six practical Pilots has been define. The activities have been structured into three main steps. The first one reported in D2.2 was focused to the requirements establishment and their understanding into practical specifications, general or specific depending on the technology and the pilot industrial actor and sectorial needs. The second one, based on the previously mentioned is to materialize this specification into practical operational diagram where the specific technical solutions will be used and implemented during pilot's demonstration. And the third one, is the KPI metric definition and valorisation into RECLAIM project results. At this deliverable, UML diagrams and KPIs proposition are described and compiled.

The activities developed and the methodology use are shown at Figure 1, with the following main steps:

- To identify the potential machines and production line in each industrial use cases for the implementation of RECLAIM high-tech solution following obsolescence, ageing and retrofitting potential criterium.
- To define the requirements matrix, categorizations, and criteria.
- To identify the potential technological solutions and its maturity level for the technology matrix proposition.
- To analyse the requirements matrix and technological matrix for the use case understanding.
- To transform the requirements of the use cases into practical scenario based in the RECLAIM technological solutions.
- To propose the first approach for RECLAIM Pilot Scenarios for the project concept and technologies demonstration and validation.

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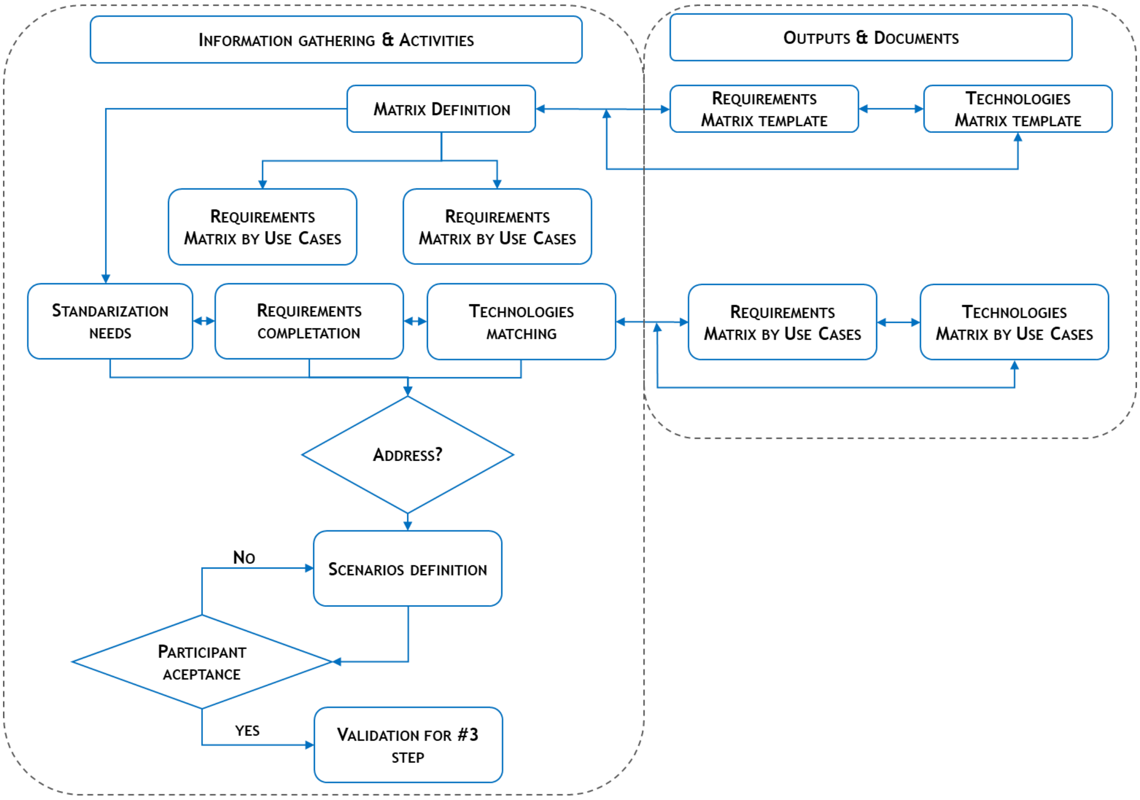

Figure 1.- Task 2.2 methodology diagram

The document is structured in five sections to conduct the reader onto the advances on each of the scenarios of the RECLAIM pilots, the UML proposed for each Pilot and the analysis of the KPI, Key Performance Indicators technologies.

The first chapter is this introduction to the document contents. The second chapter is focused in showing the updates on the use case scenarios base on the validation of the requirements and the first test developed on each scenario, so there are some components that have been started to be refurbished and remanufactured and connect to some of the RECLAIM tools. A third chapter will introduce the reader to the description of all the Key Performance Indicators of RECLAIM that will be used to evaluate the results of RECLAIM in each of the pilots and showing the current values, if the pilot is measuring them, of each indicator. Chapter four shows the UML Use Case Diagram for each pilot and a short explanation in order to knowing better each scenario. This section is the starting point for some activities on task 2.3 among others. Chapter five is a sum up of the document and includes a brief conclusion of the activities perform to gather the information for this deliverable and how the activities will continue on task 2.2 with more work on the scenarios' diagrams and the Key Performance Indicators.

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2 Use Case Scenario evolution for pilot demonstration

This chapter focuses on the evolution of the scenarios starting from the results that were obtained on D2.2 'RECLAIM Use Cases Definition & Operational Requirements #1' on the chapters 5 and 7. On these chapters, the pilot scope and the use case scenario were shown, defined by Gorenje (Pilot#1A and #1B), Fluchos (Pilot#2), Podium (Pilot#3), Harms & Wende (Pilot#4), Zorluteks (Pilot#5) and the collaboration from the technological provider partners constituted by ADV, CERTH, CTCR, FCY, FEUP, FINT, ICE, ROBOTEH, SCM, SUPSI, TEC and TTS.

The main elements for each pilot are summarised below:

- **Pilot#1A.** Refurbishment and renovate Robot cells for making dishwasher tubs. Some important equipment adjustments have been made to keep up with the development of new types of dishwashers.
- **Pilot#1B.** Modernization and refurbishment of White Enamelling line. It is interesting to re-use very old industrial equipment for stable improved production processes with less machine failure, increase the effectiveness and optimize production processes, reduce maintenance and production costs, reduce environmental impact.
- **Pilot#2.** Shoemaking industry has a complicated production process that requires more than 200 operations, a great deal of industrial machinery, such as cutting machines, industrial sewing machines, skiving machines, moulding machines, grinding machines etc., and is a labour intensive procedure, requiring manual intervention in many operations, such as shoe lasting.
- **Pilot#3.** Podium manufacturing line deals with the production of high-end wooden kitchens. The line covers 1800 m^2. It processes 500 pieces per day. The system is composed by machines from several vendors interconnected. These machines work over one shift of 8.4 hours.
- **Pilot#4.** The pilot case is built around a friction welding machine. Such machines are used for the reliable joining of welded metal parts and for a huge variety of materials like steel, aluminium, ceramics, brass, copper etc. Friction welding can also be used with nearly no conductance of the materials and independently from surface quality e.g. zinc, lacquer, or enamel.
- **Pilot#5.** Zorluteks Textile Company has a large variety of products including home textiles (curtains, roller blinds, bed sheets, bed linens, bed covers, table clothes, coverlets, etc.). In this Pilot use case, the Bleaching Machine will be tested, which is used for bleaching the raw cotton fabrics. The function of bleaching is to remove blue-absorbing yellow contaminants.

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RECLAIM Pilots

01 Gorenje Group
White Goods Manufacturer, End Consumer Products, **Industrial Mass Production**

02 Fluchos
Footwear Manufacturer, End Consumer Products, predominantly **Artisanal Production**

03 Podium
Woodworking Manufacturer, End Consumer Products, **Medium Size Industrial Production**

04 Harms+Wende
Friction Welding Machines, Machine Builder, **Medium Size Industrial Production**

05 Zorluteks
Textile Manufacturer, Semi-finished Goods, **Industrial Mass Production**

Figure 2.- Pilot's overview diagram.

A further definition of the use cases has been carried out in this iteration, for a major understanding of the technical aspects of the use cases, a definition of solution for pilot demonstration and the interrelation among the different components (hardware, software, algorithms, etc) and the system flows. As it could be seen in the following subsections.

2.1 Pilot #1 - Home Appliance Manufacture

2.1.1 Pilot #1A

Robotic Cells, RC, are one relevant production line tool at the manufacturing process in Gorenje dishwasher, DW, factory. Dishwasher inox tubs, which are the main part of dishwasher are manufactured and isolated in robotic cells, where bending, punching, edge profiling, pressing, welding, isolation processes are carried out mainly by automatized robots. Most of the semi-finished products come from the pre-manufacturing of the raw material section (sheet metal presses); the basis of the DW tub are the L sheet (bottom / back) and the U sheet (sides and top). Insulation parts are a product of external suppliers. RCs for the manufacture and isolation of DW tubs are a set of cells called XL, A, B, C, D and E. The process is supervised by operator.

At the beginning of cell A, the order is displayed as a PLC code, and according to this code, a label is printed and fixed by the worker to the U panel.

This code is used for statistics, mainly for counting semi-finished products. The PLC code serves as information in certain crucial places (e.g. making holes, etc.). The system is deficient, insufficient, and unreliable. Full automotive and effective manufacturing is necessary to avoid many problems.

In cell A the following will be implemented:

- vision camera and image processing software for object recognition (anomaly recognition),

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- sensors for 2 storage containers to detect if storage is on minimum level,
- predictive of welding electrode and punching knifes worn out; PLC data will be used,
- predictive of hydraulic oil change; different sensors (temperature, oil level…) will be installed. PLC data will be used,
- monitoring of robot and other equipment operations for predictive maintenance and compute KPIs.

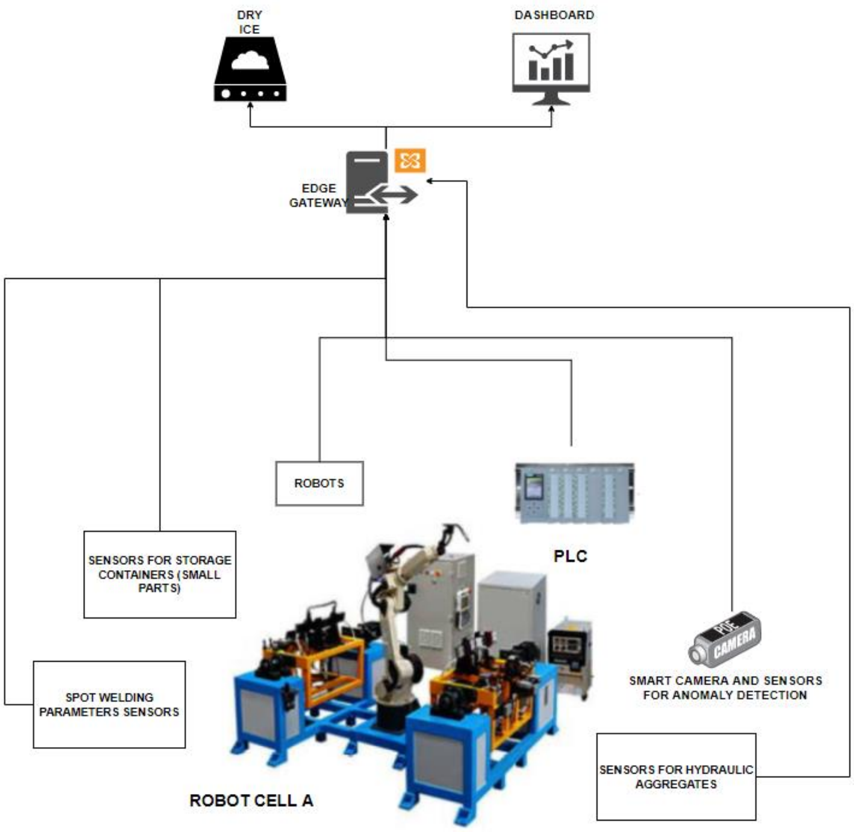

Figure 3.- Gorenje 1A Field-Related diagram Cell A.

In cell B and C, the following will be implemented:

- predictive of welding reels worn out, predict changing of reels. PLC data will be used.
- vision camera for online welding quality control,
- monitoring of robot operation and other equipment for predictive maintenance and compute KPIs; PLC data will be used,
- predictive of hydraulic oil change; different sensors (temperature, oil level …) will be installed. PLC data will be used,
- water flowmeter for water consumption monitoring.

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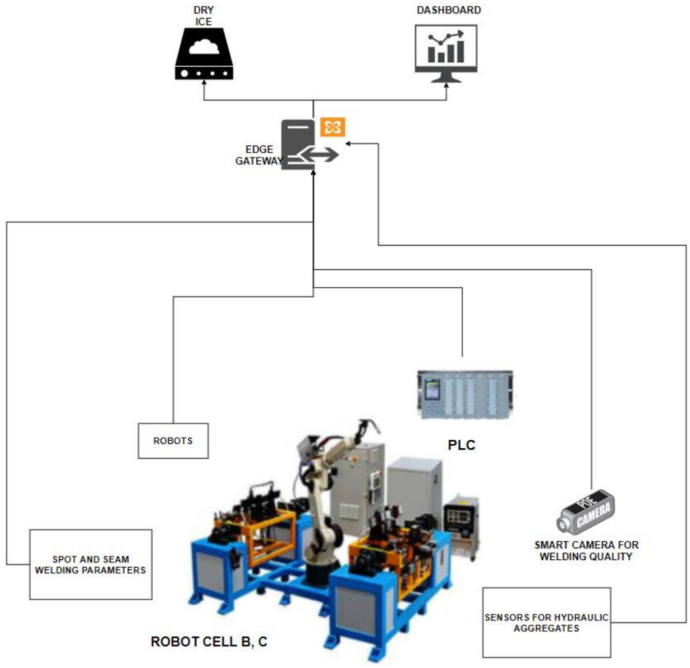

Figure 4.- Gorenje 1A Field-Related diagram Cell B and C.

In cell D, OBC will be implemented:

- monitoring of robot's operation and other equipment for predictive maintenance and compute KPIs; PLC data will be used,
- predictive of welding electrode worn out, PLC data will be used.

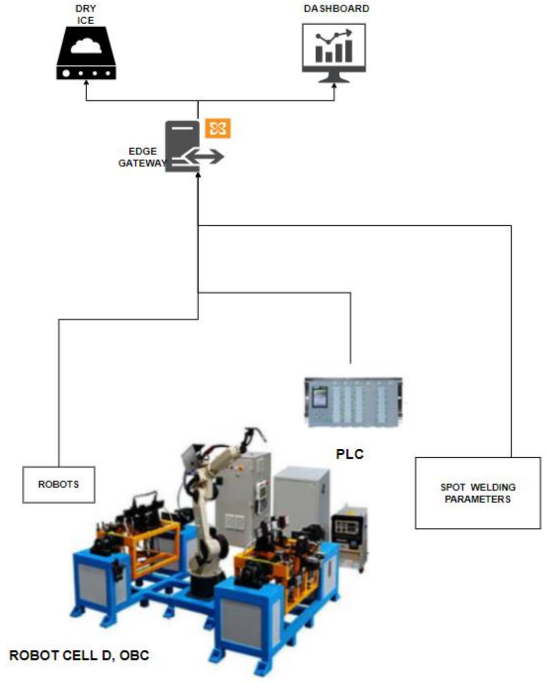

Figure 5.- Gorenje 1A Field-Related diagram Cell D and OBC.

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2.1.2 Pilot #1B

White enamelling line is the most important production line for cooktops in cookers manufacturing at Gorenje/MORA company. The enamelling process consists of several stages:

- degreasing line (dirty raw cooktops coming from presses are decreased from oils).
- automatic spray booth for enamel powder application with recycling filter unit.
- infra-red dryer.
- manual re-hanging from one powder conveyor to furnace conveyor.
- gas furnace.

Current technology is based in one side spraying of powder enamel, one piece (cooktop) is hung on the hook, with the upgrading of actual line to two pieces (cooktops) per hook, big increase of efficiency of the enamelling line is expected.

There will be implemented two cameras for recognition of different variants of cooktops at the enter of the white enamelling line. On the 8 places near the line will be placed wireless sensors for measuring temperature and humidity. One position will be outside of hall to register outside conditions. At the end of the line enamelled cooktops are checked and wrong parts sorted and registered on touch screen according to type of fail and type of cooktop.

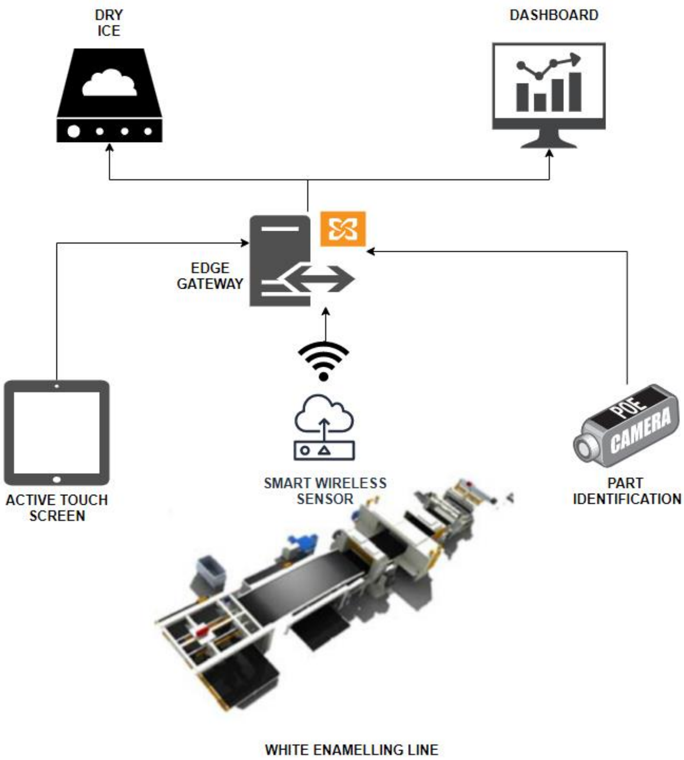

Figure 6.- Mora Field-Related diagram.

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2.2 Pilot #2 – Shoemaking Industry

The scope of this pilot is to improve the productivity of this machinery, since most of the equipment is over 10 years old and it does not have a modern monitoring or electronic control to manage the manufacturing operation and the operating parameters in an accurately manner. Two machines are being digitized, the rear part forming machine and the front part forming machine.

The rear part forming machine, Talonadora, is used for joining a pad in the lower part of the shoe, for making the heel more comfortable. This process consists of two similar steps. In both ones, the operator puts the shoe in the last, then, by pressing two buttons, the fixative mould goes down until it touches the shoe, which is between the mould and the last.

The front par forming machine, Rotostir, consists of a rotative base where the operator puts the shoes. Then, with a roller, the front of the shoe is given its final form, fixing it with the down part. Left and right shoes are alternate, so the operator must put each one in the correct mould. Then, by pressing two buttons, the machine tours. The left part of the machine fixes the left shoes, and the right part does the same with the other pair.

Talonadora

To have a better knowledge about the boundary conditions of this process, there has been installed on the machine different sensors and equipment within the activities performed on the WP3.

The cold bulb temperature must be around -9,9 ºC. If the temperature is over that value, the fixation between the shoe and the pad could be wrong, resulting in a defective product. If the temperature is lower, the last could get frozen, leaving it useless for a long time.

The hot bulb temperature must be around 122 ºC. If the temperature is over that value, the shoe could get burned, having a bad aspect and, for last, be wasted. If the temperature is lower, the fixation will not be correct.

Controlling these parameters will lead to any of the deviations that could appear would be registered with the objective of predicting possible failures.

In addition, the deformation on the bulb will be monitored by a flexible sensor.

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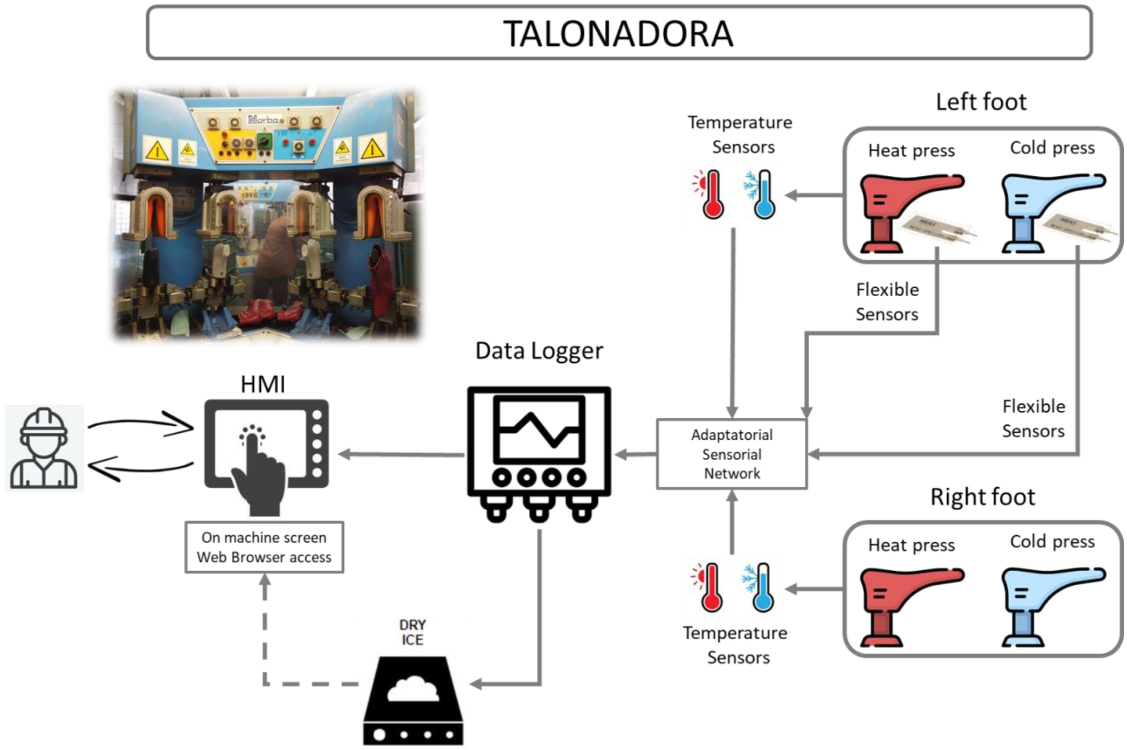

Figure 7.- Fluchos Talonadora Field-Related diagram.

The information gathered with the sensors to control the temperature and the deformation of the bulb, will be send by MQTT to the DryICE platform and will be analysed and check for possible deviations.

Rotostir

To have a better knowledge about the boundary conditions of this process about the PLC states and the power consumption of the machine, there has been installed on the machine different sensors and equipment within the activities performed on the WP3.

The equipment that have been installed in this machine, is for reading parameters about power consumption. In each power line from Rotostir there are:

1) V Lx: voltage of each line, that must be divided by 10 to have the magnitude in Volts.

2) I Lx: intensity of each line, that must be divided by 1000 to have the magnitude in Amperes.

3) P Act Lx: active power of each line, that must be divided by 1000 to have the magnitude in kilowatts.

4) P React Lx: reactive power of each line, that must be divided by 1000 to have the magnitude in volt-ampere reactive.

These parameters should be very similar in the three lines, which would reveal that the installation is well balanced. If not, it must be fixed, because any imbalance can change into an overload, causing the machine breakdown.

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In addition, the control parameters from the machine PLC will be extracted and merge with consumption parameters and all the parameters that brings the rotation motor, in order to know better the different stages of the process and analyse the implications of each stage of the process with the consumption.

All the data gathered from the Rotostir will be merge in a JSON message and send by MQTT in order to have in DryICE platform to be analysed.

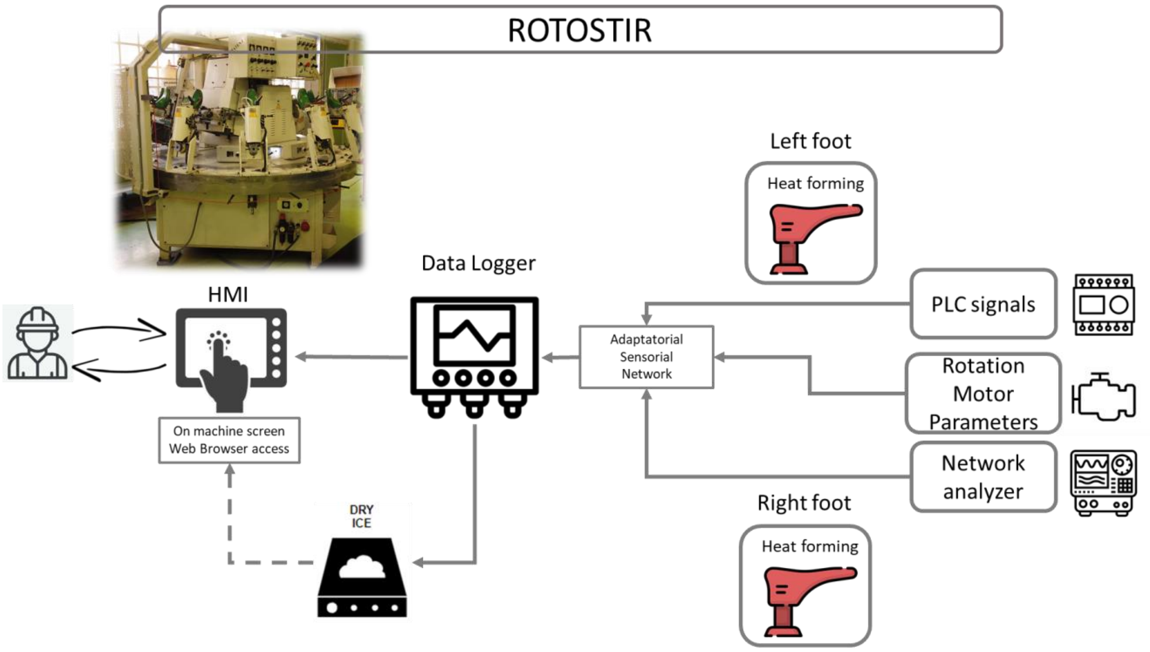

Figure 8.- Fluchos Rotostir Field-Related diagram.

2.3 Pilot #3 – Woodworking Production

Furniture manufacturing (i.e. to produce box-shaped cabinets) can be broadly summarized into 6 main steps carried out by different specialized machinery types.

1. **Storage:** Wood-based panels in standard sizes are moved into the factory and to the main working stations.
2. **Cutting:** Wood-based panels are cut into desired shapes and sizes.
3. **Edge Banding:** The exposed sizes of the panels are covered by customized materials strips.
4. **Drilling:** Holes are drilled in different panel points in order to prepare for assembly and insert metallic components.
5. **Finishing:** The panels are given different surface textures according to the requested aesthetic features.
6. **Assembly and packaging:** The cabinets are assembled or packaged in order to be assembled by the buyer.

With the digital retrofitting of the drilling machine and the digitalization of the edging machine, Podium can make a reliability analysis of these production processes.

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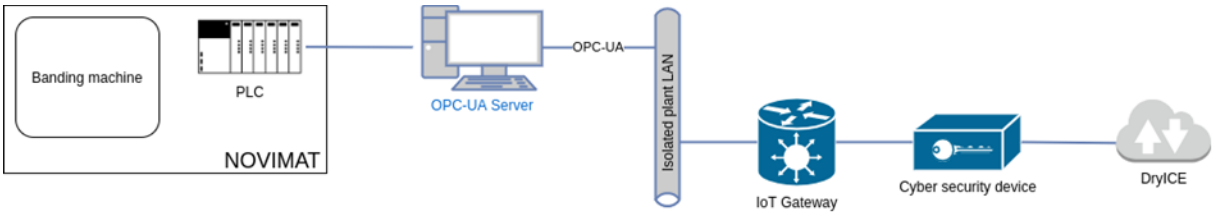

Figure 9.- Podium Field-Related diagram

The results of the analysis could be integrated in the digital twin shop floor simulation that allows Podium to analyse different scenarios about for example changes on production or maintenance plan, and so on. Digital Twin can also understand the machines behaviours through simulated different scenarios, in fact it is directly connected to the predictive maintenance approach and anomaly detection, in order to optimize the time management of the production. Other important information that Digital Twin receives are the LCA tool data that allows the simulator to consider the production behaviour from other side.

The entire solution allows Podium to optimise the production scheduling and to facilitate the make decision process.

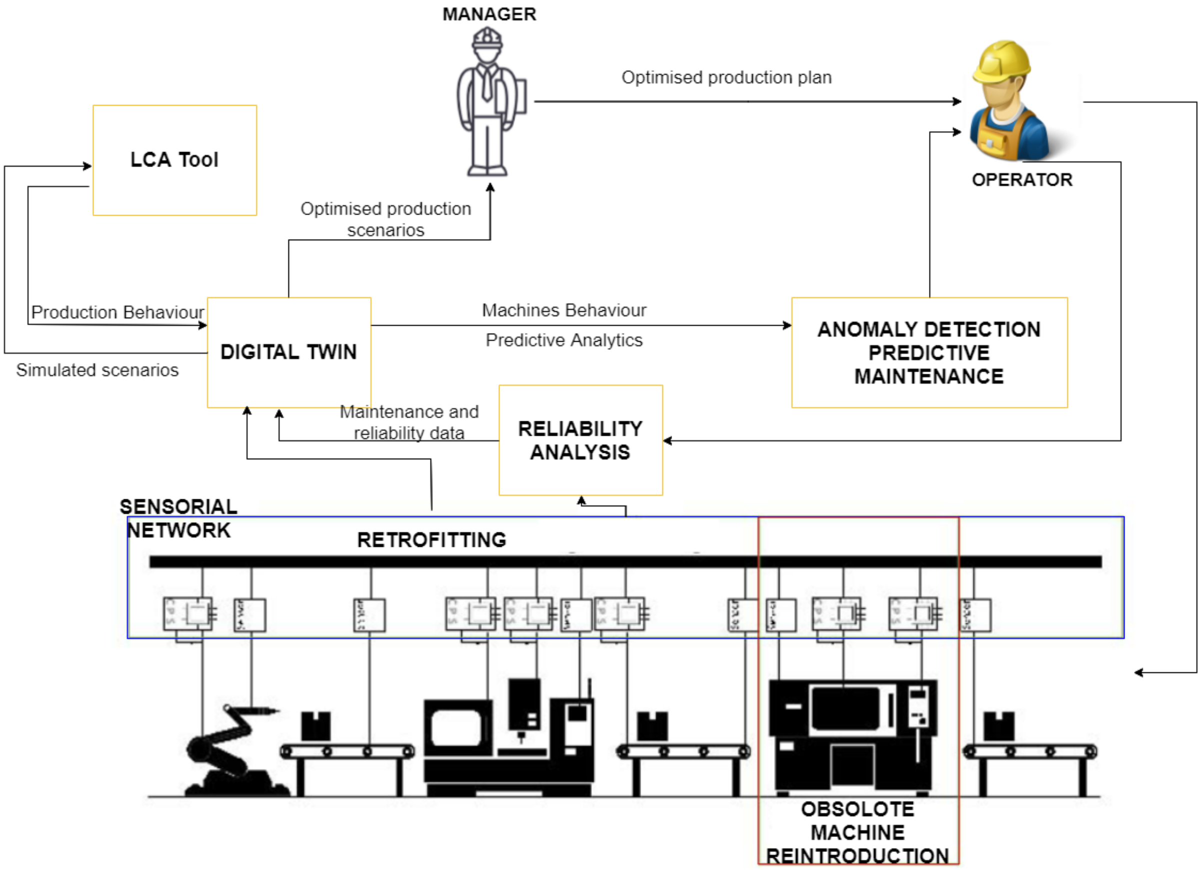

Figure 10.- Podium integration of the set of solutions diagram.

The picture above represents the integration of the set of solutions envisaged in the project. In addition to the three solutions already explained, there are also:

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Anomaly detection methodology & Information modelling tool

The pilot-agnostic methodology for anomaly detection and predictive maintenance will be applied to the drilling machine MAW ABS 110 and to the edging machine IMA NOVIMAT.

By exploiting both historic and digital twin acquired data, the information modelling tool will be exploited to provide updated information related to the state of the machines in terms of reliability and lifetime expectancy. The tool will be firstly adopted to monitor and evaluate the situation of the edging machine, analysing the specific equipment composing them, wherever possible.

The tool will be therefore taken as a starting point to structure a more thorough analysis of production system reliability related issues and keep a continuous monitoring of system across time.

Life Cycle Assessment Tool

The tool will be here deployed to support the analysis of the current status of the machines from a sustainability perspective and identify the sustainability-oriented optimization strategies able to extend the lifetime of the machines and/or the production scenarios able to best match environmental and economic indicators.

By connecting with the digital twin of the production system, the tool will be able to manage the real time data (in particular related to the MAW ABS 110 and IMA NOVIMAT) of the machines and exploit them to generate as is analytics based on historic machines behaviour or forecast the production system sustainability-oriented performances by means of simulating different possible use scenarios.

2.4 Pilot #4 - Friction Welding Technologies

Harms & Wende intends to update and to significantly enhance their traditional welding devices by predictive maintenance features. The pilot scope is the re-manufacturing and upgrading of friction welding machine RSM401, including the use of *advanced sensors* and on *data analysis* of the gathered data.

Within the re-manufacturing and upgrading processes the focus is on the following aspects:

- sustainable system design to produce future-proof welding systems.
- use of identical parts to reduce production costs and improve service as well as maintenance of the welding systems.
- proactive and tailored service through predictive maintenance.
- ensuring holistic resource efficiency.
- fast, user-friendly, energy-efficient system design.
- smart management and operation.

HWH friction welding machines are currently controlled by a standard PLC. According to the internal strategy of increasing the depth of the added value, the PLC shall be

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replaced by the HWH product Genius. This conversion is a basic requirement for the implementation of RECLAIM technology. The connection between the Genius to the HWH software XPegasus provides data storage and data analysis functionality. Furthermore, XPegasus is also connected to the RECLAIM sensor gateway, which communicates process data to the RECLAIM data repository DryICE. A use case defined by Harms&Wende is to develop an interchangeable Human Machine Interface (HMI) with which friction welding systems can be operated both via a connected control panel and via mobile devices. One of the important requirements is remote monitoring of the equipment either from withing local Network or/and Internet. Monitoring implies observation of sensor and process data, equipment status, degradation state, etc. To meet the requirements, we implemented widely used standard interfaces for data communication and exchange. After defining the gap between current sensors and data needed for further monitoring applications e.g. quality, process as well as machine monitoring for predictive maintenance the types of sensors were selected, and their installation location were discussed. The introduction of a standardized modular system will make it possible to replace components with equivalent ones or to upgrade or downgrade them.

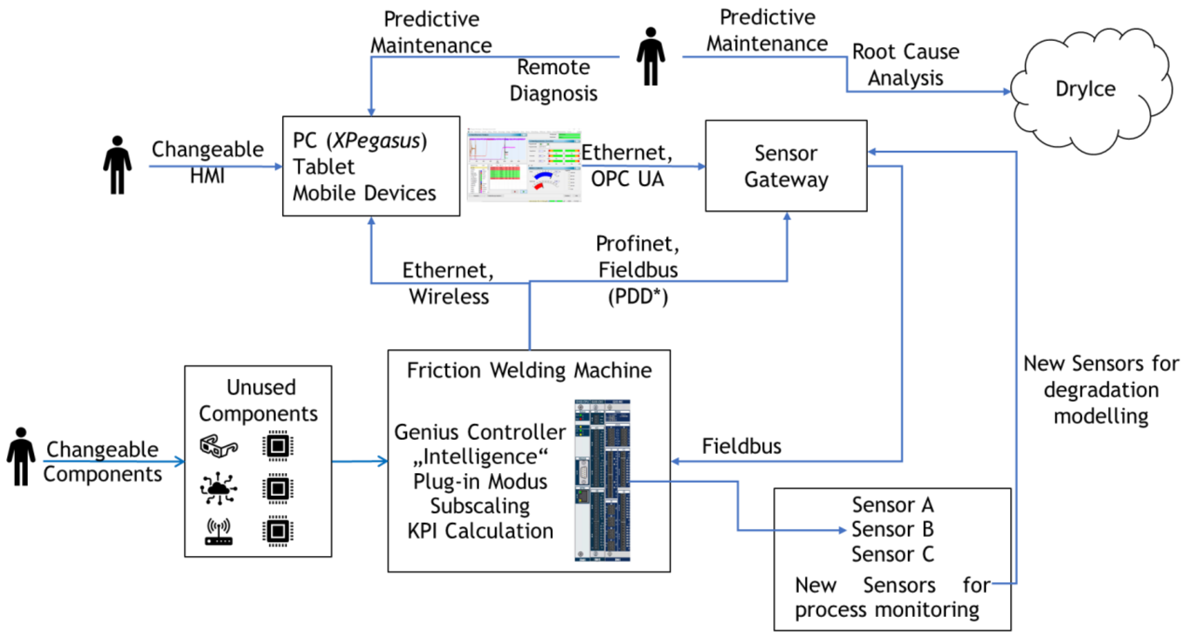

Figure 11.- HWH Field-Related diagram.

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2.5 Pilot #5 - Textile Manufacturing

Raw cotton, like all-natural fibres, has some natural colouring matter, which confers a yellowish-brown colour to the fibre. The purpose of bleaching is to remove this colouring material and to confer a white appearance to the fibre.

The objectives of bleaching are described below:

- The main objectives of bleaching are to get a sufficiently high and uniform degree of whiteness in the textile materials.
- To get a high and uniform absorptivity in the textile materials.
- Bleaching agent occur some damage to the textile materials. So, bleaching must be accompanied with minimum fibre damage.
- To preserve a good user and technological properties of the textile materials.
- The process must be ecologically and financially sensible.
- To accelerate the next dyeing process.

The bleaching process is carried out in order to obtain a constant whiteness value in cotton fabrics. Bleaching, which is one of the most important steps in textile pretreatment processes, is carried out in bleaching machines. The most important purpose of the bleaching process is to obtain white fabrics by removing the ecru color originating from the natural structure of cotton.

Zorluteks has three continuous bleaching machines. The difference between the three bleaching machines is their working width. The maximum working speed of the machines is 100 m/min. Bleaching chemicals are given in the Table 1.

Table 1.- Chemical Recipe.

Chemical Substance
Hydrogen Peroxide
Caustic
Stabilizer
Wetting Agent
Sequestering Agent

In Bleaching Machine there are a total of 7 washing chambers, 2 before the steaming chamber and 5 after. Wetting is given to the fabric in order to increase its hydrophilicity at the entrance of the washing baths. Afterwards, the fabric goes

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through two washing baths with water at 95˚C and 85˚C, and it is purified from the desizing chemicals left over from the previous process.

Then, bleaching chemicals are given to the fabric in the foulard (flexnip) located at the top of the machine and the fabric passes into the steaming cabinet right next to the Flexnip. In the steaming cabinet, the fabric is kept at a temperature of around 102˚C for 18 minutes, and bleaching reactions occur. Then the fabric passes through the washing baths located at the bottom of the machine. In the washing baths section, rinsing is carried out in baths 3-6 at 95˚C and neutralization is carried out in the last bath. In the first part of the last washing bath, which is double chambered, there is water containing acetic acid for fabric neutralization. The tank pH is adjusted between 4-5. In the second part, after the fabric is rinsed and the excess water is removed, it passes through the sensors (named mahlo) to prevent the fabric from entering unevenly in the weft direction. Finally, the fabric passing through the dryer is wrapped on the batching trolley at the exit.

The equipment that will be installed in this machine, is for reading necessary parameters about the bleaching level and its correlation with the different states of the machine:

- *Whiteness Degree of the Fabric*. - The parameters that are the most effective on the whiteness of the fabric were investigated and found by laboratory tests. Then, a search was made for an online whiteness sensor, it was decided that the most suitable technology was in the Shade Bar whiteness measuring sensor, and a demo sensor was installed on the bleaching machine.
- *Multiparameter Chemical Sensor*. - Measure the main chemical parameters of the process. In only one device will be merged different sensor to gather all the important information from the recipe.
- *Industrial Camera*. - For the whiteness prediction with deep learning process in scope of T5.2, Zorluteks purchased an industrial camera which specifics were determined with CERTH. Its installation was made at the end of September. This camera can be seen in the Figure 12. The camera system ensures that a certain area of the fabric is photographed periodically and stored in the desired folder by naming it.
- *PLC/SCADA*. - Extraction of the data that is being monitored by the SCADA system and it is needed to be merged with the rest of information from the different sensors.

The data gathered from the shade bar cameras and the industrial camera will go through a PC installed at Zorluteks, analysed on that PC and the results will be send to the DryICE platform.

The data gathered from the chemical sensor and from the PLC will be merge in a JSON message and send by MQTT in order to have in the DryICE platform to be analysed.

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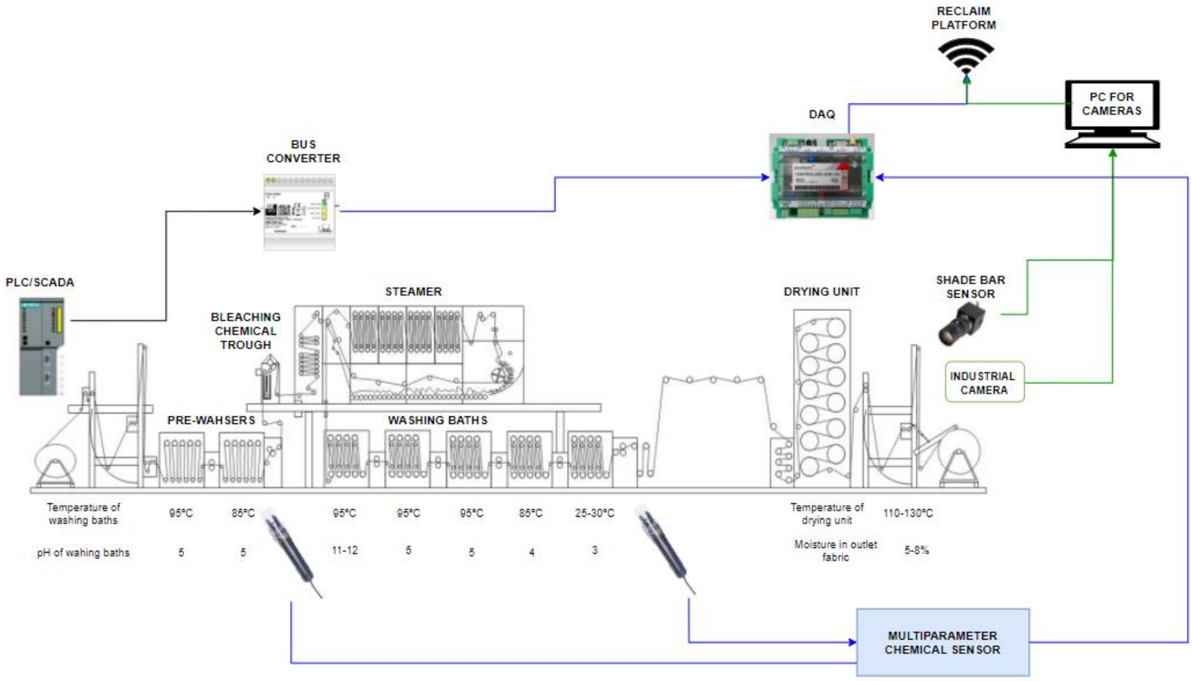

Figure 12.- Zorluteks Field-Related diagram.

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3 Identification of metrics: from requirements to Key Performance Indicators

The measurement of the impact is a fundamental for all companies and institutions; because, the results impact directly to the production, the success, the quality and a long etcetera of measurable results. The impact measurement is a fundamental stage for the evaluation of the objective consecution. The Performance Measurement Systems (PMS) is introduced by Lucianetti, L et all[1] as a tool for the visualization and analysis of the performance of the different processes. However, it is essential to define the Key Performance Indicators (KPIs)[2,3]. The KPIs are the essential measurable unit that could be used as the control tool for any process evaluation under any type of organization. Aspect such as efficiency, quality, resources management, repair activities, production, customer satisfaction are some of the activities that could be measured through KPIs units. Nevertheless, KPIs must reflect institution or the set of activity to be monitored through KPIs metrics. KPIs have also to be meaningful, coherent, objective driven, and a standard for objectively comparing different organizations[4,5,6]. It is important to highlight that the process of selecting KPIs is difficult because of the wide range of alternatives. And the correct identification of adequate KPIs allow to obtain a greatest benefit; but, an adequate number must be chosen to have beneficial result, otherwise the measured result will not show the real impact of the KIPs in the organization or the element where they are applied.

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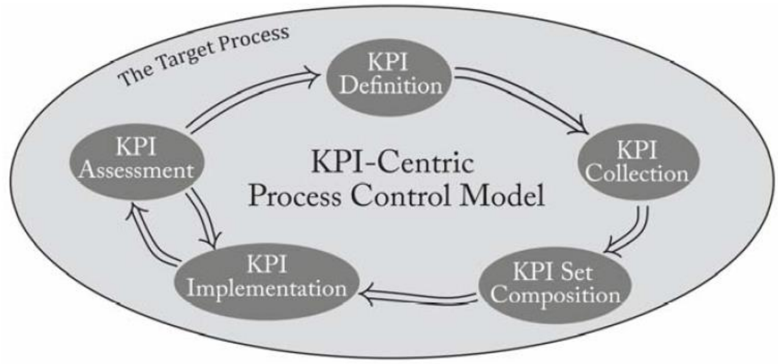

Figure 13.- KPIs cycle[7].

The KPIs cycle schematic representation, Figure 13,where the cycle starts with the KPIs identification and definition, to continue with their collection, their composition and implementation to follow with their assessment. Nevertheless, the most critical point of the KIPs measurement process is the identification of the criteria. The most used criteria in the manufacturing KPIs selection process area[8]:

- Costs → reduce;
- Productivity → increase;
- Quality → increase;
- Employee satisfaction → increase;
- Safety → increase;
- Learning and growth → increase;
- Customer satisfaction → increase

Using this approach and based on the KPIs proposed at the DOA by the RECLAIM project the KIPs analysis has been performed. All the KPIs included at the DOA are listed at the Annex I. Due to the fact that the KPIs are linked with the RECLAIM project objectives, Annex II include a table where the objectives are listed. The KPIs analysis result in their structuration into the following categories:

- General Project KPIs with the following subcategories:
  - ✓ General Results KPIs
  - ✓ Pilots
  - ✓ Transversality / Transference
- Industrial KPIs that could be applied to any manufacturing company of production plant with the following subcategories:
  - ✓ Safety
  - ✓ Quality
  - ✓ Employees satisfaction
  - ✓ Productivity
  - ✓ Productivity Management & Programming and
  - ✓ Planification

[7] Hester, Ezell, Collins, Horst, and Lawsure: A Method for Key Performance Indicator Assessment in Manufacturing Organizations IJOR Vol. 14, No. 4, 157–167 (2017)
[8] Liu, P.; Tsai, C. Using Analytic Network Process to Establish Performance Evaluation Indicators for the R&D Management Department in Taiwan's High-tech Industry. Asian J. Qual. 2007, 8, 156-172.

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The last category is well aligned with the criteria proposed by Liu, P. et al. and are the most significant for the impact measurement of transferable and replicable results of RECLAIM project.

The first criteria to measure RECLAIM impact is centered in the measurable output of the project, potential standards, exploitable results and successfully refurbished or re-manufactured machines during the project development, all of the well stabilised and measurables along the project and after their end it could be possible to follow these KPIs evolution.

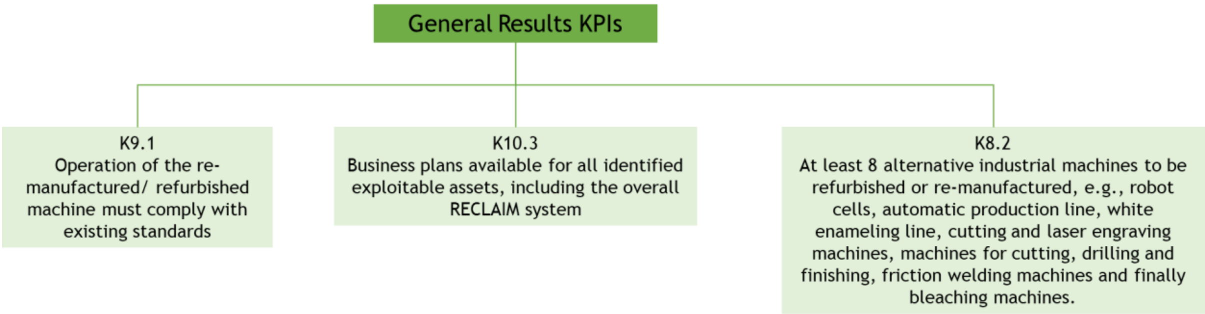

Figure 14.- General Results KPIs of the RECLAIM project.

Three general project KPIs link with the WP3 to WP5 result to be demonstrated at the WP6 at the different pilots was proposed at the DOA, Figure 15.

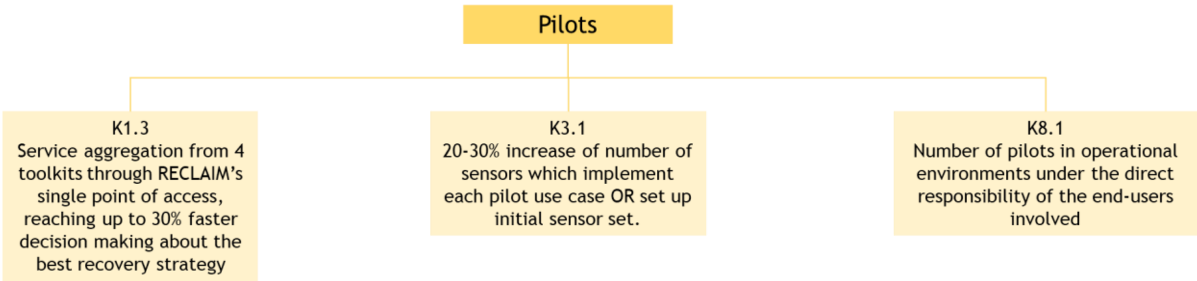

Figure 15.- General Pilots KPIs of the RECLAIM project

The transference and transversality of the RECLAIM result was proposed to measure over the KPIs shown at Figure 16. It is important to highlight that some of these KPIs represent the measurable replicability of the RECLAIM result over other industries.

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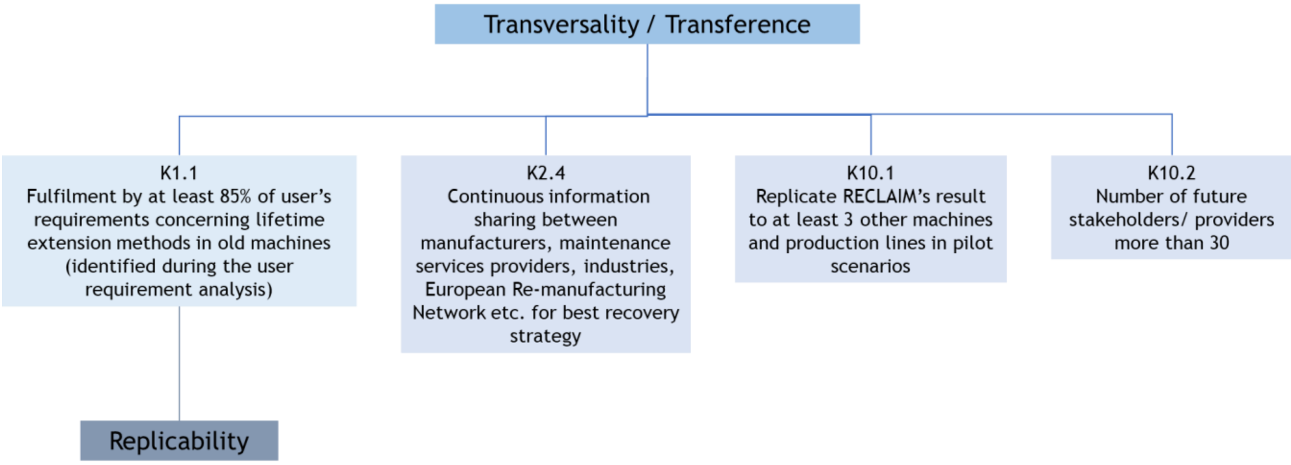

Figure 16.- General KPIs of the RECLAIM project link with the transversality or the transference of the project results.

The next compendium of KPIs proposed at the DOA are not specifically of the project results or project output measurement; those KPIS are linked with the Industrial and operational performance of the manufacturing plant o process. And as proposed by Lu et al. These KPIs are measurables units of the productivity, the customer or employee satisfaction or the quality improvement by the refurbishment or re-manufacturing tools and action carried out in their facilities. To being the description of the KPIs link with the measurement of the Industrial activity, that translated to RECLAIM project could be resembled by the Pilot demonstration activities, one of the most important KPIs is the K9.2 link with the Safety impact measurement, Figure 17. One of the scopes of the RECLAIM tool kit solutions is to reduce the number of accidents related with the malfunctioning. This KPIs is difficult to be estimated during the Pilot demonstration activities but it is extremely important on the industrial sector to measure the impact of the implemented refurbishment and re-manufacturing solutions at the manufacturing plant. Maybe some estimation might be calculated from other KPIs like the implantation or integration of technical solution to avoid the failures and the malfunctioning based in the statistics of the different industrial actors owners of the Pilot demonstration activities at the project, whenever the data will be available.

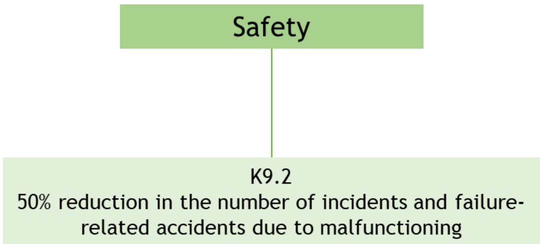

Figure 17.- Industrial KPI link with the Safety impact measurement.

The next set of KPIs were clustered under the Quality objective, one of the most important measurement unit very valuable for the increase of the productivity and decrease of cost link with malfunctions and machines failures during the manufacturing cycle. Three KPIs has been proposed in this sense, K2.2, K3.3 and K3.4, *Figure 18*. The K3.3 could be estimated at RECLAIM Pilot based on the data

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coming from each Pilot to DryICE system. Nevertheless, even if K2.2 are very important measurement units, it could be very difficult to estimate some realistic values for the accuracy of the implemented solution, mainly due to the fact that non historic data are available in the majority of the industrial case. The calculation of the machinery Health Index could be considered for their calculation in some of the Pilot when all the necessary data will be available.

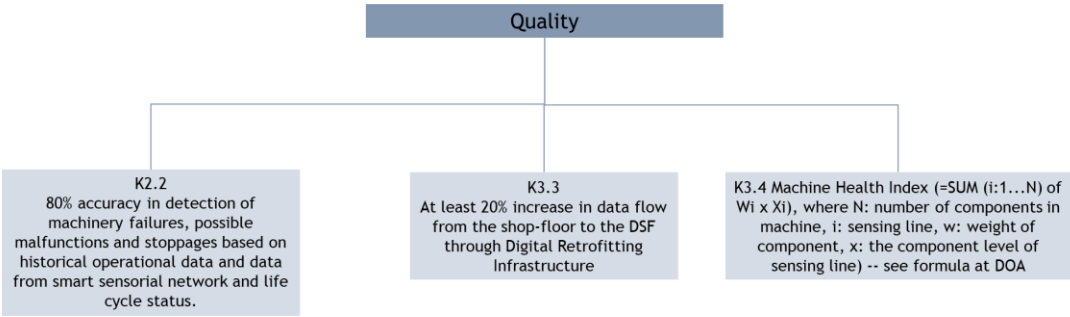

Figure 18.- Quality impact KPIs.

A very important metric unit when new tolls or solutions are implemented on a production plant is the Employees satisfaction, moreover technical solution that could affect their day to day operational functioning. The adoption and compression of the technologies by employees is very relevant for the successful implementation of technical solutions. The measurement of this KPIs at the different Pilots could be very difficult because more of the involved personnel of the different industrial actors of the project have a high technological background.

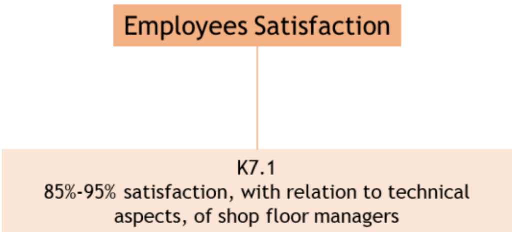

Figure 19.- Employees Satisfaction KPIs.

The biggest clustering group of KPIs of the Industrial activity are related with the Productivity and the future impact of the refurbishment and the re-manufacturing solutions of the production pant or the individual machinery. Those clustering of KPIs have been split into three categories: those that will impact in the general productivity, Figure 20, those related with the management and the programming of the reparation, substitution of component or maintenance operations, Figure 21, and the KPIs lined with planification, Figure 22. These KPIs have been individually adapted to the different Pilot demonstration of the RECLAIM project to measurement the impact of the technical solution for the refurbishment and the re-manufacturing of the different selected machine, and the approach done to these KPIs is described at the following sections for each Pilots.

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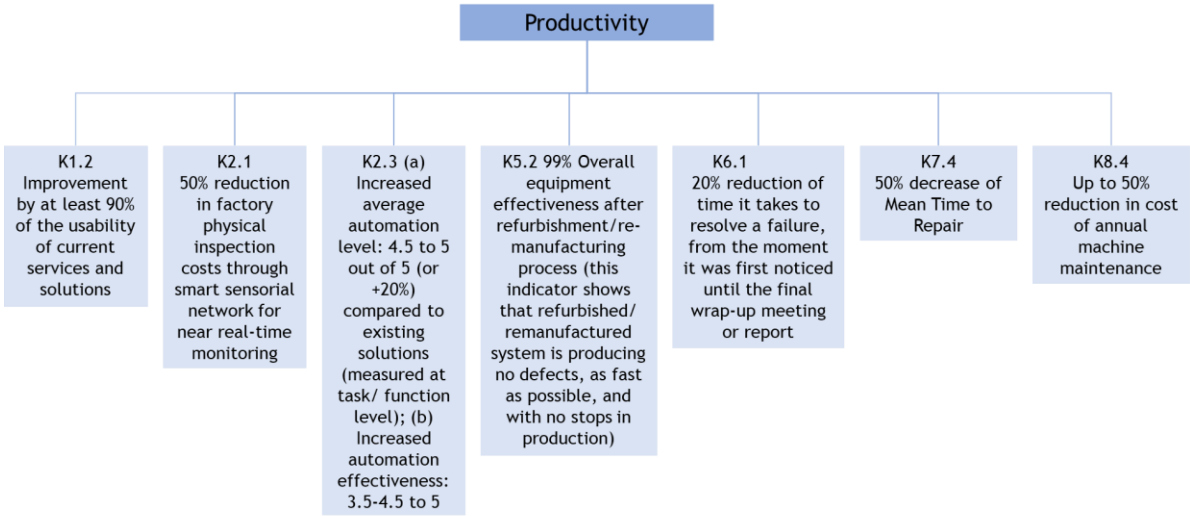

Figure 20.- Industrial Productivity KPIs.

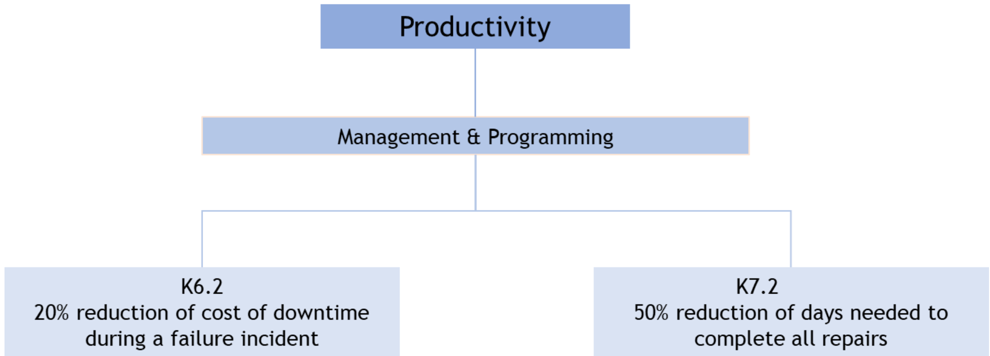

Figure 21.- Industrial Productivity focus on Management and Programming KPIs.

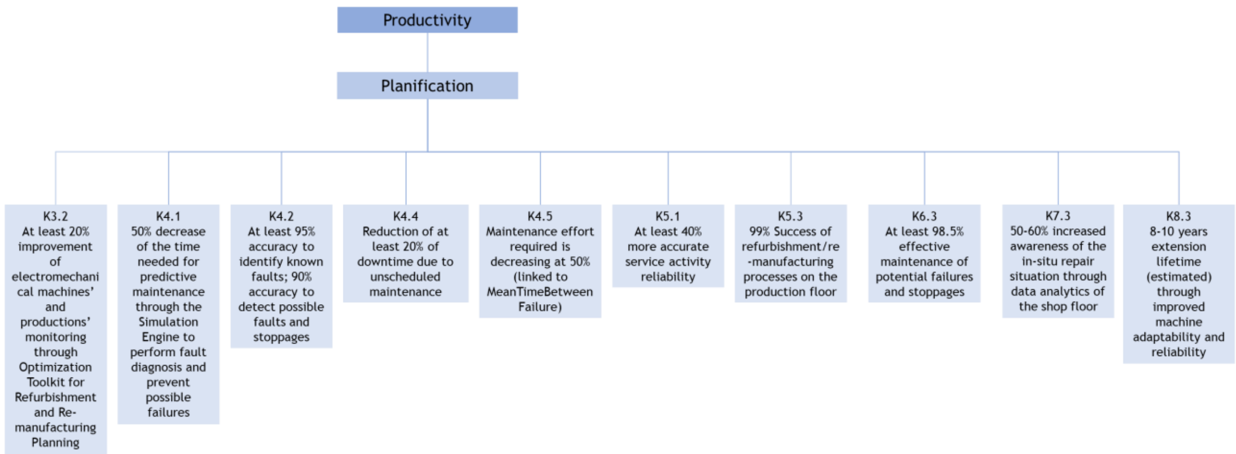

Figure 22.- Industrial Productivity focus on Planification KPIs.

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3.1 Pilot individual industrial KPIs approach

This section, and based in the previous categorization of the KPIs, present the approach and the understanding of the general KPIs proposed at the DOA to any of the RECLAIM Use Case and Pilot activity for the technological demonstration of the refurbishment and re-manufacturing tool kits.

To the KPIs identified at the DOA and listed in Annex I, there are few specific or evolved KPIs for each Pilot, this specific KPIs were numbered as KP# and the number of the pilot followed by the number of the indicator.

At this section the KPIs description and approach has been divided into 5 section due to the number of industrial actors involved in the project that have Pilots demonstration activities. Nevertheless, the total number of Pilots is six because GORENJE has two Pilots demonstration numbered 1.A and 1.B. The Pilots KPIs have been organized following the previous categorization.

The evolution of the KPIs and their measured values is an ongoing task related to the activity of the task T2.2 of WP2 and the indicators of the WP6 activity. The confluence of both activities under the measurements of the KPIs is under discussion and it will be a result of the next deliverables.

3.1.1 Pilot #1A - Refurbishment and renovate 2 Robot cells in B-Cell for making tubs DW40 Home Appliance Manufacture.

The Pilot #1A is focus on the home appliance manufacture sector and specifically on the refurbishment and the renovation of the robotic cells of the manufacturing plant. Their main specific KPIs are detailed below, together with their declination in the specific pilot case.

Table 2.- General Results KPIs Pilot#1A.

KP#1A.1	Improvement of the safety conditions for the Robotic Cells, RC, at the dishwasher production line.
This KPI has two well stablished objectives: 1. The aim of Robotec to align the refurbishment activities of the RC with the RECLAIM standardization activities to accomplish with EU future regulation and normative to achieve the European Conformity declaration of refurbished product at the robotic framework. This objetive is into the General Results KPIs. 2. The improvement of the safety condition of employees at the RC production line. This objective is categorized into the safety criteria. Nevertheless, it has been decided to keep this KPI as is and do not split it into two.	

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K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
Gorenje 1A is working on the robotic cells for manufacturing tubs. And this robotic unit will contribute to the KPI project indicator to achieve the proposed number of machinery where the RECLAIM technological solution will be implemented and demonstrated.	

Table 3.- Quality KPIs of Pilot#1A.

KP#1A.2	Hydraulic tightness to 90% focus on Environment
Hydraulic tightness will be improved for 100 %, because after refurbishment the oil leakage will be 0. It's visible, and the hydraulic aggregates will be monitored by sensors (oil changing, T, oil level…) The inclusion of measurable sustainable KPIs is very important to fulfil with the future regulations and indicator of green products and sustainable manufacturing that the EC is discussion for the nearest future. The estimation of this KPI will based on the annual consumption of the oil at the Robotic Cell of the Gorenje manufacturing plant.	

Table 4.- Safety KPIs of Pilot#1A.

K9.2	Operation of the re-manufactured/ refurbished machine must comply with existing standards
CE - Declaration of Conformity is planned to be done by Roboteh at the end of the project. There are internal working manuals. So, it will comply with the standards. Link to KP#1A.1, the measurement of this KPI for the Pilot #1.A will be done based of project standardization actions where UNI has an essential role on the successful achievement of this objective and the accomplishment of the relevant figure at this KPI.	

Table 5.- Productivity KPIs of Pilot#1A.

K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring
Currently, there are not so much physical inspections on the line. Nevertheless, the new components and the new sensors, that will be implemented on the robotic cells, will support to achieve this reduction and to have good figures at the present KPI. As	

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initial approach, Gorenje believe that it could be in the range of 50% of cost reduction.	
K5.2	99% Overall equipment effectiveness after refurbishment/re-manufacturing process (this indicator shows that refurbished/ remanufactured system is producing no defects, as fast as possible, and with no stops in production)
The aim for Gorenje on this pilot and KPI is to produce parts without defects and without stops, but the percentage at Gorenje's point of view is too high and difficult to be achieve or measure.	
K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report
This value currently is not measured by Gorenje due to this kind of problems they solve as soon as possible but without urgent because the production process could continue running.	
K7.4	50% decrease of Mean Time to Repair
In Gorenje's opinion is very difficult to reduce MTTR about 50% because of the time values used actually. ▪ Current values for MTTR are: ○ Cell A: 105 minutes. ○ Cell B and C: 67 minutes.	
KP#1A.5	Operational Effectiveness. Increase 70% after upgrading (today is about 63%).
The stops and the failures will decrease because of the refurbishment and re-manufacturing actions. That it could be translate into more operational effectiveness and the increase of productivity. 1) the current operation effectiveness is about 63% measured by TPmer (Gorenjes' internal application) 2) With the refurbishment and all improvements perform on the robotic cells will bring to less stops due to failures. The objective of the 70% is calculated based on economic data: effective time divided by available time. The 4M, men, machine, material, method, were analysed.	
KP#1A.6	Equipment Effectiveness. Increase 80% after upgrading (today is about 70%).
It will be calculated based on the following formula: **effective time** (of equipment) divided by **available time** (just stops of equipment and machinery is considered).	

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KP#1A.7	Expected useful lifetime = 15 years lifetime extension
This KPI is linked to K8.3 and it will comply with that KPI of 8-10 years extension. Upgrade and refurbishment of robot cell equipment is necessary to improve machinery condition and to reduce unplanned machine failure, to reduce production and maintenance costs and to extend the machinery lifetime for further 15 years. Due to the project duration is difficult to measure this KPI.	
KP#1A.9	**Return of Investment**
It is proposed that the return of investment for the rfurbishement and the re-manufacturing done at this pilot will take up to 5 years. And, Gorenje follows Hisense instruction for ROI calculation. Their internal rules indicate that business case calculation is obliged to be done for every investment.	
KP#1A.3	**Reduce cooling water by 10% focus on Environment**
The outsider cooling water system was re-manufactured. As consequence the recycled water achieve the level of freshwater for their re-use and their internal consumption will be estimated. Having positive and sustainable result of this action.	

Table 6.- Productivity/Management & Programming KPIs of Pilot#1A.

KP#1A.4	Maintenance Cost Effectiveness
The desirable achievement figures at this KPIs is to decrease cost for at list one 50%. Where, the present economic costs are detailed by components: ▪ XL press: 758,40€ ▪ B,C-cell: 61.703,99€ ▪ A-cell: 31.696,21€ ▪ E-cell: 39.165,23€ ▪ RC base of dishwasher (reposition due to failure): 13.770,24€ ▪ RC insulation inner door (reposition due to failure): 21.305,09 Some of the data necessary for this KPI calculation is the production of this manufacturing plant during a reasonable period to be agree with Gorenje based int their historical data recorded in their internal management system, SAP. Based in this information an estimation of this KIP will be done.	
KP#1A.8	**Material and Resource efficiency = Improvement of 10%**

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The waste figures are monitored manually on the interna Gorenje management system, SAP, together with other data of the manufacturing plant. And they could be used on KPIs calculation.

Table 7.- Productivity/Planification KPIs of Pilot#1A.

K3.2	**At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning**
Gorenje is considering using this Toolkit for this pilot. Nevertheless, it will be evaluated more in detail during the next months based on the applicability to this pilot of the technical solutions and algorithms.	
K4.2	**At least 95% accuracy to identify known faults; 90% accuracy to detect possible faults and stoppages**
The measurable values to be achieved in the accuracy to identify and to detect possible failures are based on the technological activities that are ongoing in the WP3 to WP5. At the present time, it is difficult to know if this value could be achieved or if this value will be lower than proposed initially during the project preparation.	
K4.4	**Reduction of at least 20% of downtime due to unscheduled maintenance**
The downtime is monitored at Gorenje by their TPmer system and it will be available for KIP calculation.	
K4.5	**Maintenance effort required is decreasing at 50% (linked to Mean Time Between Failure)**
The Mean Time Between Failure, MTBF, is actually over 8-10 days. It will be difficult to estimate the MTBF even if there are the support of the prediction tools for maintenance activities planification. Gorenje consider that 50 % is high value to be achieved.	
K8.3	**8-10 years extension lifetime (estimated) through improved machine adaptability and reliability (based on results from pilot scenarios)**
This KPI is related to KP#1A.7.	

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3.1.2 Pilot #1B, Modernization and refurbishment of White Enamelling line

Table 8.- General Results KPIs of Pilot#1B.

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines
Gorenje 1B is working on the white enamelling line.	

Table 9.- Quality KPIs of Pilot#1B.

K9.2	Operation of the re-manufactured/ refurbished machine must comply with existing standards
CE - Declaration of Conformity is planned to be done by Roboteh at the end of the project. There are internal working manuals. So, it will comply with the standards.	

Table 10.- Safety KPIs of Pilot#1B.

KP#1B.5	Equipment Effectiveness. Selection of good parts after first spray will increase by 2%
During rehanging of cooktops at the output of furnace also quality check is provided and number of wrong cooktops is registered.	

Table 11.- Employees Satisfaction KPIs of Pilot#1B.

KP#1B.2	Lower Working temperature outside of oven - surrounding temperature lower by 5°C
In summer 2019 the temperature was measured next to furnace, the measured value was 46,5°C. In summer 2021 was measured, with the same conditions with a measured value of 39,8°C.	

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Table 12.- Environmental KPIs of Pilot#1B.

KP#1B.1	10% lower emission (new burners with low emission of NOx and COx)
In 2019 the measured values were the followings: ▪ NOx - 96 mg/m^3 and ▪ CO 49mg/m^3. After the start of the refurbishment, the measures were made again 2021, getting the following values: ▪ NOx – 19 mg/m3 and ▪ CO 2mg/m3	

Table 13.- Productivity KPIs of Pilot#1B.

K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring
Currently, there are not so much physical inspections on the line but the parts identification and the new sensors to be applied on the robotic cells will help to this reduction but Gorenje thinks that could not be as much as 50% of cost reduction.	
K5.2	99% Overall equipment effectiveness after refurbishment/re-manufacturing process (this indicator shows that refurbished/ remanufactured system is producing no defects, as fast as possible, and with no stops in production)
The aim for Gorenje on this pilot and KPI is to produce parts without defects and without stops, but the percentage at Gorenje's point of view is too high and difficult to be achieve or measure.	
K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report
On the spraying cabine the fail are usually some blended spraying nozzles or hoses, which must be cleaned it take about 15 minutes, much less mistakes are due to high voltage fail, this kind of mistakes take more time.	
K7.4	50% decrease of Mean Time to Repair
From Mora thinks that reduce MTTR by 50% is so unrealistic, so this indicator should be worked during the next iteration for adjust the value to achieve. Currently, these are the MTTR:	

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▪ Spraying cabine: 20,7 minutes. ▪ Furnace: 59 minutes.	
KP#1B.3	**30% decrease the expenses for maintenance and spare parts after modernization**
Expenses for maintenance in 2019 was thousands of €. We can compare it with maintenance expenses in year 2021.	
KP#1B.4	**Operational Effectiveness. Increased for 18%, cycle time will be reduced**
Before refurbishment into spraying cabin went only one cooktop on one hinge and enamel was applied from one side, after reconstruction two cooktops will be placed on one hinge and enamel will be applied from two sides. In the same time speed of conveyor will be decreased. All together – productivity will increase at least 18%.	
KP#1B.6	**Equipment Effectiveness. Scrap will decrease by 1%**
During rehanging wrong cooktops are sorted into two groups: 1) Cooktops which can be repaired (they go through enamelling line for second time) 2) Cooktops which cannot be repaired – scrap. Scrap is moving from 0,3% to 0,5%.	
KP#1B.7	**Expected Useful Lifetime. 15 years lifetime extension after modernization**
This KPI is linked to K8.3 and it will comply with that KPI of 8-10 years extension. Upgrade and refurbishment of each equipment is necessary to improve its condition and to reduce unplanned failures, to reduce production and maintenance costs and to extend the machinery lifetime for further 15 years.	
KP#1B.8	**Material and Resource Efficiency. Scrap at the output of the line will decrease 1%**
Scrap is measured as monthly percentage of scrap value divided by value of all produced cookers. Scrap is moving from 0,3% to 0,5%.	
KP#1B.9	**Material and Resource Efficiency. Decreasing of consumption of gas for burning oven by 18%**
Refurbishment and update of old furnace (new isolation and new more efficient burners brings saving of consumed gas – decrease of consumption of gas by 18%.	
KP#1B.10	**Return of Investment = up to 7 years**

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Up to 7 years, Gorenje follows Hisense instruction for ROI calculation; Business case is obliged to be done for every investment.

Table 14.- Productivity/Planification KPIs of Pilot#1B.

K3.2	At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning
By this moment, Gorenje for this pilot is considering using this Toolkit but it will be evaluated the possibilities of the tool during the next iteration	
K4.2	At least 95% accuracy to identify known faults; 90% accuracy to detect possible faults and stoppages
This KPI is on an ongoing activity due to there are some doubts about the percentages of both parameters, it will be worked on the next iteration of the activity and with the rest of technical partners of the project.	
K4.4	Reduction of at least 20% of downtime due to unscheduled maintenance
The parameter will be monitored from TPmer the internal application from Gorenje.	
K4.5	Maintenance effort required is decreasing at 50% (linked to Mean Time Between Failure)
The current maintenance efforts, MTBF is 2,5 days. Gorenje 1B can only obtain data from manual records of fails and maintenance efforts. With the refurbishment these records could be update automatically.	
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability (based on results from pilot scenarios)
This KPI is related to KP#1B.7, so it will be evaluated directly on the pilot indicator.	

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3.2 Pilot #2 - Shoemaking Industry

Table 15.- General Results KPIs of Pilot#2.

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
Fluchos is working on two machines: Talonadora and Rotostir so it will be accomplished.	
K1.1	Operation of the re-manufactured/ refurbished machine must comply with existing standards
Currently there are not standards that apply to the Fluchos production, but they have found that there are standards that indicate if a final product is defective or not. So, on the RECLAIM framework the aim is to reduce the number of defects with the implementation of a preventive and proactive maintenance plan that comply with the standards.	

Table 16.- Safety KPIs of Pilot#2.

KP#2.1	10% reduction in the number of incidents and accidents due to malfunctioning
If the temperature in the Talonadora is very high, the worker could be injured in case of not detecting the error. In Rotostir case, if the electrical parameters are not well balanced, the worker could be injured as well.	

Table 17.- Productivity KPIs of Pilot#2.

K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring
Currently, there are not physical inspections, when some component fails it is repaired or in case, so the costs don't exist, but it will be an improvement on the components control and supervision.	
K5.2	99% Overall equipment effectiveness after refurbishment/re-manufacturing process (this indicator shows that refurbished/ remanufactured system is producing

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	no defects, as fast as possible, and with no stops in production)
The aim for Fluchos is to produce parts without defects and without stops, but the percentage could be a little bit excessive due to Fluchos is going from no maintenance control to deploy a new one. This KPI is mainly focused on Talonadora production.	
K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report
The current times for solve the failures are as follow: ▪ **Talonadora:** 1) Cooling: once every three months. Breakage of a capillary in the cold bulb, because of handling the aluminium lasts. 2) Last fixing: wear of the bronze ring and breakage of the fixing screw. It is necessary to dill and tap for a correct reparation. 3) Pneumatic system: once every three months everything must be checked, pressure switches, valves, etc. 4) Shutdowns are used for maintenance, cleaning condensers, revisions, greasing, etc. ▪ **Rotostir:** 1) Lasts: every day, resistors are melted. This is a problem for the temperature control which is currently controlled in open loop. However, when the machine is stopped, for loading or organization, the temperature increases under significant figures. 2) Rotary table: every four months, the clutch needs to be calibrated to guarantee the stop of each mould in the correct position. Every two years, reducers that allow the turning must be adjusted. 3) The fastening screw of the last is repaired in dead times between production in just half an hour.	
K7.4	50% decrease of Mean Time to Repair
The membrane change is produced every week and it takes 2 minutes to change it. There are two new membranes always in stock. For Rotostir there is not calculated this parameter.	
KP#2.2	Maintenance Cost Effectiveness. 10% of reduction in the costs or reparations (per machine).
By developing a predictive maintenance plan, it is expected to reduce the number of stops in both machines: Talonadora and Rotostir.	
KP#2.3	Operational Effectiveness. Increase 10% of reduction in time wasted by productions stop due to breakdowns/malfunctions (today is about 50%)

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OEE = Performance x Quality x Availability (where Availability = Actual Production Time / Operating Time). Some of the processes are not correct, so the product they make is a waste because it can have any defect, although the machine is apparently working well, but the temperature is out of range. The result is that the final product is not well processed.	
KP#2.4	**Equipment Effectiveness. 10 % of increase of effectiveness**
Trying to improve the machine lifetime, predicting when it is going to fail or when it needs to be turned off in advance. All can be done by monitoring the current consumption.	
KP#2.5	**Expected Useful Lifetime**
The expected useful lifetime will be increase in a 20% of current lifetime with the membrane breakage prediction will increase the component lifetime and also the machine's one.	
KP#2.6	**Material and Resource Efficiency. 10% of reduction in wasted materials caused by breakdowns/malfunctions**
By improving the use of the materials and resources is expected to reduce the incorrect forming processes, which means an important waste, especially in Talonadora.	
KP#2.7	**Return of Investment**
2 years	

Table 18.- Productivity & Planification KPIs of Pilot#2.

K3.2	**At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning**
By this moment, Fluchos is not considering using this Toolkit but it will be evaluated the possibilities of the tool on this pilot during the next iteration.	
K4.2	**At least 95% accuracy to identify known faults; 90% accuracy to detect possible faults and stoppages**
This KPI is on an ongoing activity due to there are some doubts about the percentages of both parameters, it will be worked on the next iteration of the activity and with the rest of technical partners of the project.	

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K4.4	Reduction of at least 20% of downtime due to unscheduled maintenance
As there is no maintenance plan in Fluchos every action is an unscheduled maintenance, so the implementation of the new maintenance plan will achieve this percentage	
K4.5	Maintenance effort required is decreasing at 50% (linked to Mean Time Between Failure)
Currently this parameter is not being measured, with RECLAIM it will be deployed a maintenance plan, but it could not be compared because the was not one before.	
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability
This KPI is related to KP#2.5, so it will be evaluated directly on the pilot indicator.	

3.3 Pilot #3 - Woodworking Production

Table 19.- General Results KPIs of Pilot#3.

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
Podium is working on its 2 machines (edging and drilling ones), so they accomplish with this KPI.	
KP#3.4	Equipment Effectiveness. 30% of increase in the refurbished machines
Podium and its technical partners are working on 2 of 6 machines on its line (edging and drilling), so they are going to achieve the increase of 30%.	

Table 20.- Safety KPIs of Pilot#3.

K9.2	Operation of the re-manufactured/ refurbished machine must comply with existing standards
Currently, the machines don’t comply with standards, but the new deployment will comply with them.	

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Table 21.- Productivity KPIs of Pilot#3.

K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring
Currently, there is not any kind of monitoring or inspection activities. Quality control is only good's visual inspection by the operator of each process	
K5.2	99% Overall equipment effectiveness after refurbishment/re-manufacturing process (this indicator shows that refurbished/ remanufactured system is producing no defects, as fast as possible, and with no stops in production)
This KPI is focused on MAW ABS 110.	
K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report
Maybe, the time to resolve a failure could be decreasing by preventing the tool's change.	
K7.4	50% decrease of Mean Time to Repair
Current Mean Time to Repair of Vektor15 (drilling/milling machine): 00:03:20 Podium is working to obtain data for other machineries. The following activities help to accomplish this KPI: anomaly detection though algorithms and simulation model update the mechanical components of drilling machine	
KP#3.2	Maintenance Cost Effectiveness. 50% of reduction in the costs or reparations (per machine).
This KPI will calculate as follows: Maintenance cost per machine = Components/materials replaced costs + service contract + maintenance cost (both internal that external). Currently there is no data, but it is an ongoing activity for Podium to obtain them.	
KP#3.3	Operational Effectiveness. Increase 30% the operational effectiveness minimizing productions stoppages due to breakdowns/malfunctions.
Currently for drilling/milling machine there are 31 failures/month	

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OEE = Performance x Quality x Availability (where Availability = Actual Production Time / Operating Time)	
KP#3.5	**Expected Useful Lifetime = 6/8 years**
The useful life of an asset is the estimated duration to which you can reasonably expect an asset will remain functional and generate income or provide other benefits. It refers to the average amount of time in years that an item, in this case the drilling machine MAW ABS 110, has. The drilling machine was bought in 2005 and with this project Podium has the goal to extend its useful life of 6/8 years thanks to a revamping process.	
KP#3.6	**Material and Resource Efficiency. 30% of reduction in wasted materials caused by breakdowns/malfunctions.**
Waste can be generated in the organization's own activities, for example, during the production of its products and delivery of services. Waste can have significant negative impacts on the environment and human health when inadequately managed. Similarly, the type and amount of materials the organization uses can indicate its dependence on natural resources, and the impacts it has on their availability. ▪ Total material input intensity = Total material input (kg) / normalization factor ▪ Waste intensity = Total waste generated (kg) / normalization factor.	
KP#3.7	**Return of Investment**
Podium has the goal to retake the cost of the investment that RECLAIM solutions needed until 3 years.	

Table 22.- Productivity & Planification KPIs of Pilot#3.

K3.2	**At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning**
Podium has not considered yet the use of this tool. It is expected that in the next months it would be a presentation for the pilots of the optimization toolkit into details. But for this moment it is very difficult to Podium to identify a possible target value to achieve	
K4.2	**At least 95% accuracy to identify known faults; 90% accuracy to detect possible faults and stoppages**
This KPI is on an ongoing activity due to there are some doubts about the percentages of both parameters, it will be worked on the next iteration of the activity and with the rest of technical partners of the project.	

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Podium define that these machineries: VEKTOR and IMA will be the ones considered for the evaluation of this KPI.	
K4.4	Reduction of at least 20% of downtime due to unscheduled maintenance
We could consider the time to repair as the time to unscheduled maintenance, because Podium doesn't do maintenance planned except weekly cleaning and some operations.	
K4.5	Maintenance effort required is decreasing at 50% (linked to MeanTimeBetweenFailure)
Currently Podium has not any kind of maintenance management, so all efforts are used to repair/solve the failures of the machineries. On RECLAIM, PODIUM would like to implement the predictive maintenance (and so on), so the effort will increase for sure... Actually, the stops will decrease but not the efforts, so it would be better if this KPI is linked to the "downtime", and not to "mean time between failure".	
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability
This KPI is directly related to one of the pilots, so it will be evaluated on that indicator, as Podium indicator is looking for an extension of 6/8 years, this KPI will be granted.	

3.4 Pilot #4 - Friction Welding Technologies

Table 23.- General Results KPIs of Pilot#4.

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
One Friction welding Machine	
K9.2	Operation of the re-manufactured/ refurbished machine must comply with existing standards
Currently, valid standards had to be and were complied with in all of HWH equipment. The new equipment will comply with valid standards.	

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Table 24.- Safety KPIs of Pilot#4.

KP#4.1	**50% reduction in the number of incidents and accidents due to malfunctioning**
There was only one known accident (person injured) in 15 years because a customer fault.	

Table 25.- Productivity KPIs of Pilot#4.

K2.1	**50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring**
Currently, in a series production, the inspection effort is about 2 minutes per part for a simple workshop inspection and a volume of 10 parts.	
K5.2	**99% Overall equipment effectiveness after refurbishment/re-manufacturing process (this indicator shows that refurbished/ remanufactured system is producing no defects, as fast as possible, and with no stops in production)**
The aim for HWH is to produce the machines and without stops, but the percentage could be a little bit excessive due to Zorluteks maintenance plan for now is a review of the machine once a year and it will be improved by RECLAIM.	
K6.1	**20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report**
One Friction welding Machine	
K7.4	**50% decrease of Mean Time to Repair**
As HWH has introduce on the KPI 4.4 they estimate 4 hours of total reparation but decreasing this time a 50% will be connected more with the capabilities of the staff and the stocks of spare parts more than in the application of RECLAIM tools.	
KP#4.2	**Maintenance Cost Effectiveness. 50% of reduction in the costs or reparations (per machine).**
Currently these are the costs of maintenance, this cost depends on the kind of reparation: ▪ With no defects: approximate 500€.	

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	▪ Part who fail due to degradation: Motor: 500€-2500€, Spindle: 2000€-7000€.
KP#4.3	Increase 60% the operational effectiveness minimizing productions stoppages due to breakdowns/malfunctions.
There aren't any data available at the moment about the stops produced by breakdowns malfunctions. Currently the operational effectiveness is 95-98% according to the specifications.	
KP#4.4	Expected Useful Lifetime. 8 years extension lifetime
By a better adaptability of the machine and by knowing the reliability of the machine	
KP#4.5	Return of Investment
Up to 3 years.	

Table 26.- Productivity & Planification KPIs of Pilot#4.

K3.2	At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning
To be calculated after the Pilot demonstration activity based in the Pilot conclusions and results obtained.	
K4.2	At least 95% accuracy to identify known faults; 90% accuracy to detect possible faults and stoppages
This KPI is on an ongoing activity due to there are some doubts about the percentages of both parameters, it will be worked on the next iteration of the activity and with the rest of technical partners of the project.	
K4.4	Reduction of at least 20% of downtime due to unscheduled maintenance
The current downtime is approximatively estimated in 4 hours if spare parts and trained staff are available. So maybe this reduction will be difficult to achieve on this pilot.	
K4.5	Maintenance effort required is decreasing at 50% (linked to MeanTimeBetweenFailure)
Currently these are the maintenance efforts: ▪ Daily: 5 Minutes	

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▪ Weekly: 30 Minutes ▪ Monthly: 40 Minutes Every 6 Month: 45 Minutes	
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability (based on results from pilot scenarios)
Our RMS401 machine served for about 10 years. After refurbishment, it will serve for another 10 years.	

3.5 Pilot #5 - Textile Manufacturing

Table 27.- General Results KPIs of Pilot#5.

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
Zorluteks is working on the bleaching machine	

Table 28.- Safety KPIs of Pilot#5.

K9.2	Operation of the re-manufactured/ refurbished machine must comply with existing standards
Currently, the machines don't comply with standards, but the new deployment will comply with them. In order to solve the standardization problem in whiteness, a search was made for a sensor for Zorluteks Textile's needs. Interviews were held with companies, detailed examinations were made, and as a result of these detailed examinations, it was decided that the Shade Bar was the most suitable device for the company's goal of upgrading its whiteness problem.	

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Table 29.- Productivity KPIs of Pilot#5.

K2.1	**50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring**
Currently, there is not any kind of monitoring or inspection activities. There are some data on the SCADA system, but it is not use for inspection.	
K5.2	**99% Overall equipment effectiveness after refurbishment/re-manufacturing process (this indicator shows that refurbished/ remanufactured system is producing no defects, as fast as possible, and with no stops in production)**
The aim for Zorluteks is to produce the fabric with a right level of whiteness and without stops, but the percentage could be a little bit excessive due to Zorluteks maintenance plan for now is a review of the machine once a year and it will be improved by RECLAIM.	
K6.1	**20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report**
This value currently is not being measure by Zorluteks because the maintenance team solves the problem as soon as possible without controlling the time that takes do it.	
K7.4	**50% decrease of Mean Time to Repair**
In the year 2020 Zorluteks MTTR is 39,65 min and in the year 2021, it is 37,41 min. So, there is 5.6% decrease. To reduce this value, first Zorluteks have reviewed the periodic maintenance performed once a year. Zorluteks evaluates the periodic maintenance periods on a machine-based basis and try to determine separate maintenance periods and dates for each machine in line with the needs of the machine. And then it is being increase the training given to the maintenance team and determined action plans to be implemented in case of malfunction.	
KP#5.1	**10% of reduction in the costs or reparations (per machine).**
This KPI will calculate as follows: Maintenance cost per machine = Components/materials replaced costs + service contract + maintenance cost (both internal that external).	
KP#5.2	**Operational Effectiveness. Increase 10% the operational effectiveness minimizing productions stoppages due to breakdowns/malfunctions.**

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Diminish in number of reprocesses can be done by predictive maintenance resulting in a 10% increase in operational efficiency OEE = Performance x Quality x Availability (where Availability = Actual Production Time / Operating Time)	
KP#5.3	**Equipment Effectiveness. 30% of increase in the refurbished machines**
Component lifetime will be extended with preventive maintenance practices, thus increasing the number of unrepaired machine components, and increasing equipment efficiency by 10%.	
KP#5.4	**Expected Useful Lifetime**
It is aimed to decrease the number of reprocesses by increasing the operational time of the bleaching machine and to reduce the number of unrepaired components of machine by increasing the component lifetime. It is expected that these targets will be achieved with preventive maintenance and decision support system and a 20% increase in expected useful lifetime will be achieved.	
KP#5.5	**Return of Investment**
Zorluteks is expected to achieve return on investment in 2 years with predictive maintenance activities and decision support system.	

Table 30.- Productivity / Management & Programming KPIs of Pilot#5.

KP#5.6	**10% of reduction in wasted materials caused by breakdowns/malfunctions.**
A reduction of water, chemical, energy and fabric will be achieved by diminishing the number of reprocesses with the decision support system which will be developed for the bleaching machine. Thus 10% increase in material and resource efficiency will be provided.	

Table 31.- Productivity & Planification KPIs of Pilot#5.

K3.2	**At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning**
Zorluteks is considering the use of this tool. It is expected that in the next months it would be a presentation for the pilots of the optimization toolkit into details. But for this moment it is very difficult to Zorluteks to identify a possible target value to achieve	

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K4.2	**At least 95% accuracy to identify known faults; 90% accuracy to detect possible faults and stoppages**
This KPI is on an ongoing activity due to there are some doubts about the percentages of both parameters, it will be worked on the next iteration of the activity and with the rest of technical partners of the project.	
K4.4	**Reduction of at least 20% of downtime due to unscheduled maintenance**
It could be considered the time to repair as the time to unscheduled maintenance, because Zorluteks do once a year a total maintenance and weekly cleaning operations.	
K4.5	**Maintenance effort required is decreasing at 50% (linked to MeanTimeBetweenFailure)**
Currently, the maintenance procedure in the factory is made following the instructions of periodic maintenance (1 times/year) given by the machinery manufacturers and the active maintenance are implemented when the failure occurs. There is no predictive maintenance strategy implemented, so the maintenance is carried out without a strict and planned control.	
K8.3	**8-10 years extension lifetime (estimated) through improved machine adaptability and reliability**
This KPI is directly related to KP#5.5 from the pilot, so it will be evaluated on the pilot indicator.	

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4 Diagrams based on scenarios as input for pilot deployment

The main activity of the second iteration of task 2.2 was to analyze the use case scenarios with each of the pilots and the technical providers for each one and to prepare the UML Use Case Diagrams.

In this section the diagrams are presented with an explanation of what it is expected in each of the cases. In addition, in each use case there are indicated the different roles of the people who will have the access to the data generate on the pilot or in the different tools that apply to the pilot in order to make adjustments on the production or knowing how the pilot is going.

4.1 Pilot #1 - Home Appliance Manufacture

4.1.1 Pilot #1A

Robotic cells for the making and isolating of dishwashers tubs are a series of 'cells' called A, B, C, D, E and XL cells. Many technological operations are performed as punching (hole cutting), bending, spot and seam welding, double bending, IR-heated isolation processes, etc. 15 automated robots are primarily responsible for welding and manipulation.

The whole procedure is supervised by an operator. With implementing of adaptive sensorial network and digital retrofitting many important process parameters, data about machine failures, maintenance data, part identification, energy consumption etc. will be monitored and be able to provide updated information related to the state of machinery (data collecting). With algorithms, simulation and degradation models defined and developed by RECLAIM partners, the new data and numerous inputs will be available to technical director, maintenance, and technology staff, to manage production. They will get a sufficient amount of useful data to make important decisions about the production process and to predict maintenance and prevent failures, manage further actions, decisions etc.

At the operational level, the operator will use specific data for more efficient process management to reduce machine failures. The maintenance will be planned before some machine parts will broke, as well as the defective parts of the machine will be replaced before they can cause damages to the machinery.

The UML diagram defined at Figure 23, could be explained as follow. The operational parameters of the machine proposed by the operator together with the sensor input will be the input data for the algorithms. The algorithm output will be combined with the general management system input for the model simulation. The output of the model simulation will be the decision-making process of the production manager.

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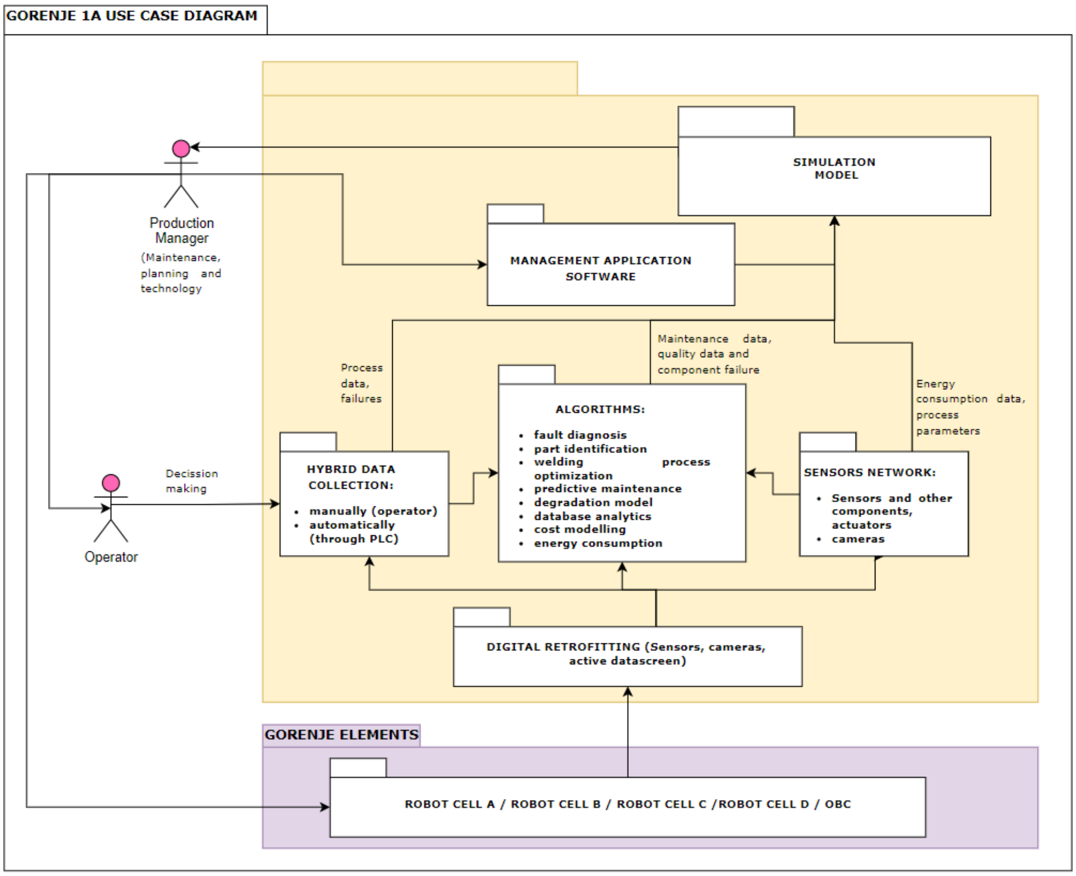

Figure 23.- Gorenje#1A Use Case UML Diagram.

Access rights

Production Manager - needs to have access to simulation model to be able to set the maintenance planning and have write access to the management application software to schedule and adapt the maintenance plan. They also need online information about defects in the process to be able to make corrections.

Operator- enters quality data with help of touch screen.

4.1.2Pilot #1B

From the different places of whole white enameling line are collected data from sensors, 8 sensors for temperature and 8 sensors for humidity, that are the responsible of the diagnostic process data.

On the beginning of white enamelling line will be placed two cameras to recognize different types of cooktops and calculate number of pieces for each type during the shift. At the end of the shift there will be a list with code of cooktop and its quantity, named logistic data.

At the end of the white enamelling line there is quality control, the cooktops. These cooktops are taken from conveyor, checked for defect, and sorted into palettes. There will be placed active touch screen on which person mark bad parts. There will be pre-defined possible defect of enamel and worker for each code of cooktop

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choose relevant defect. At the end of shift there will be overview of fails (cooktop code 1010 has following fails in mentioned quantities), named quality data.

When we compare fails with data at the beginning of the line we need to receive:

- number of parts produced at first attempt.
- number of failed parts
    - number of repairable parts
    - number of scrap (not repairable parts)

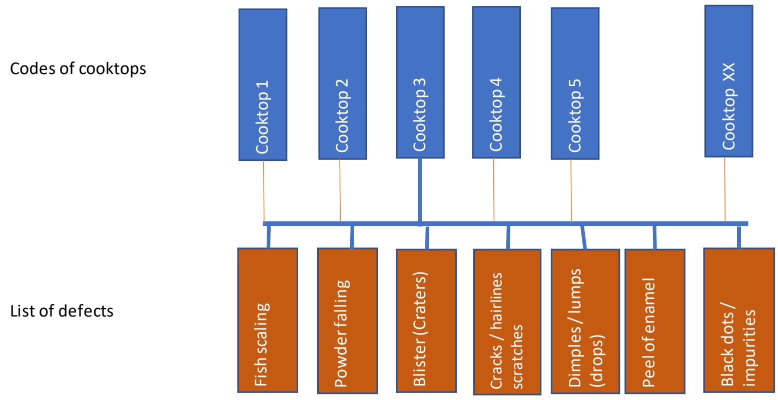

Figure 24.- Gorenje#1B defect classification.

The UML diagram based in the previous operational process description will present the classification process of the component quality classification based in camera sensor and operator actions for the defect classification.

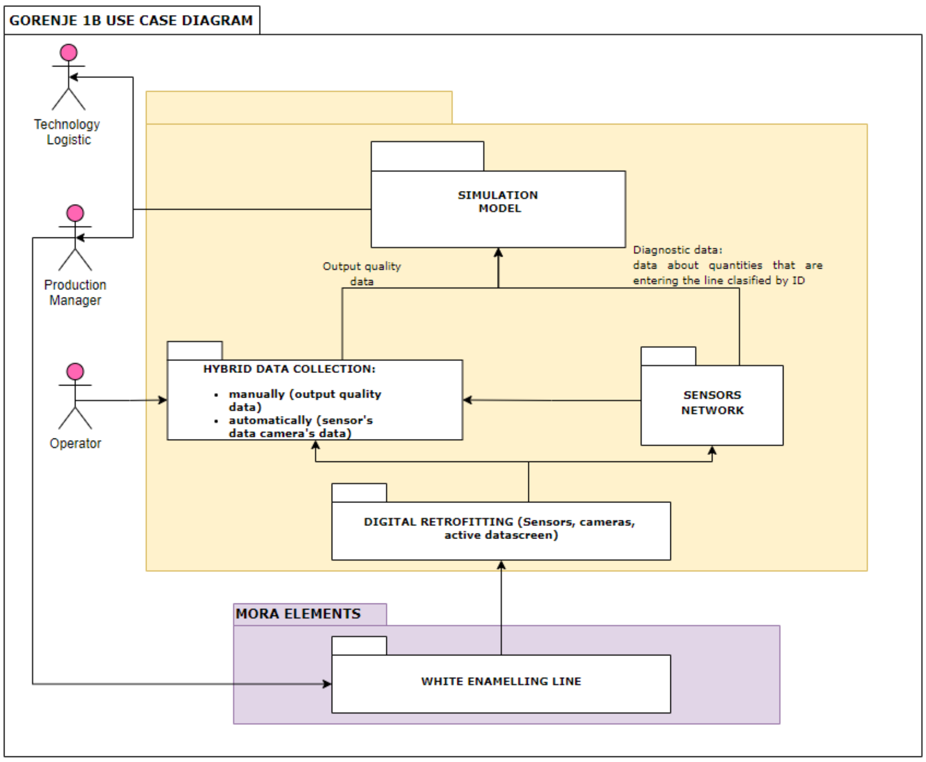

Figure 25.- Gorenje#1B Use Case UML Diagram.

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Access rights

Technology - need to have access to diagnostic data to be able to set optimal technology process, also should have availability to check historical data about temperature and humidity and number of fails at that time to be able to compare with present situation. They also need online information about defects in the process to be able to make corrections.

Logistic – needs to have information about quantity of good produced parts, about number of parts which will be repaired, as well as about quantity of scrap.

Quality – need information about kind and number of defects

Operator - enter quality data with help of touch screen

4.2 Pilot #2 - Shoemaking Industry

Footwear production at Fluchos factory, as well as in most manufacturing companies of the sector, has a high component of artisan operations involving manual labour or one-operation machines. Although, these simplified operations are combined with includes large and automated production lines where operations, that require a greater mechanical component including force application, pressure or temperature, are carried out.

The production lines, where the largest and highly productive machines are involved, is the forming area. Moreover, the cutting production line includes complex machinery for some manufacturing operations.

Two mahis was selected for their refurbishment and their re-manufacturing art RECLAIM project due their valuable production in this traditional sector. The same data acquisition structure was proposed for both machines even if their sensoring network implement by RECLAIM partners are different in each machines.

Two layers of data acquisition are defined in the machine depending on their origin. First of all, the connection to the machine's automation will be enabled in order to extract basic behavioural information and to avoid duplication in the instrumentation necessary for production supervision. It is done through a communication bus integrated in the machine's own PLC for Rotostir and by Modbus for Talonadora. This machine has not got a PLC; its operation is ruled by wired logic. It will be considered that the insertion of this additional electronics should not influence the normal behaviour of the machine, non-invasive devices.

In addition to the existing variables, complementary sensors are being integrated which will provide additional information as the ContactLess Monitoring Supervision for monitoring the operation of the main motor of Rotostir and the measuring of the electrical consumption for obtaining production costs per part, as well as the extraction of indicators of the ecological impact of production. On the other hand the flexible sensors will be used for controlling the deformation and possible breakage of the membrane on the Talonadora and monitoring the process of forming the part through force, time, temperature, etc, which allows obtaining information

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regarding the actual quantity of units processed and the quality of the production of these.

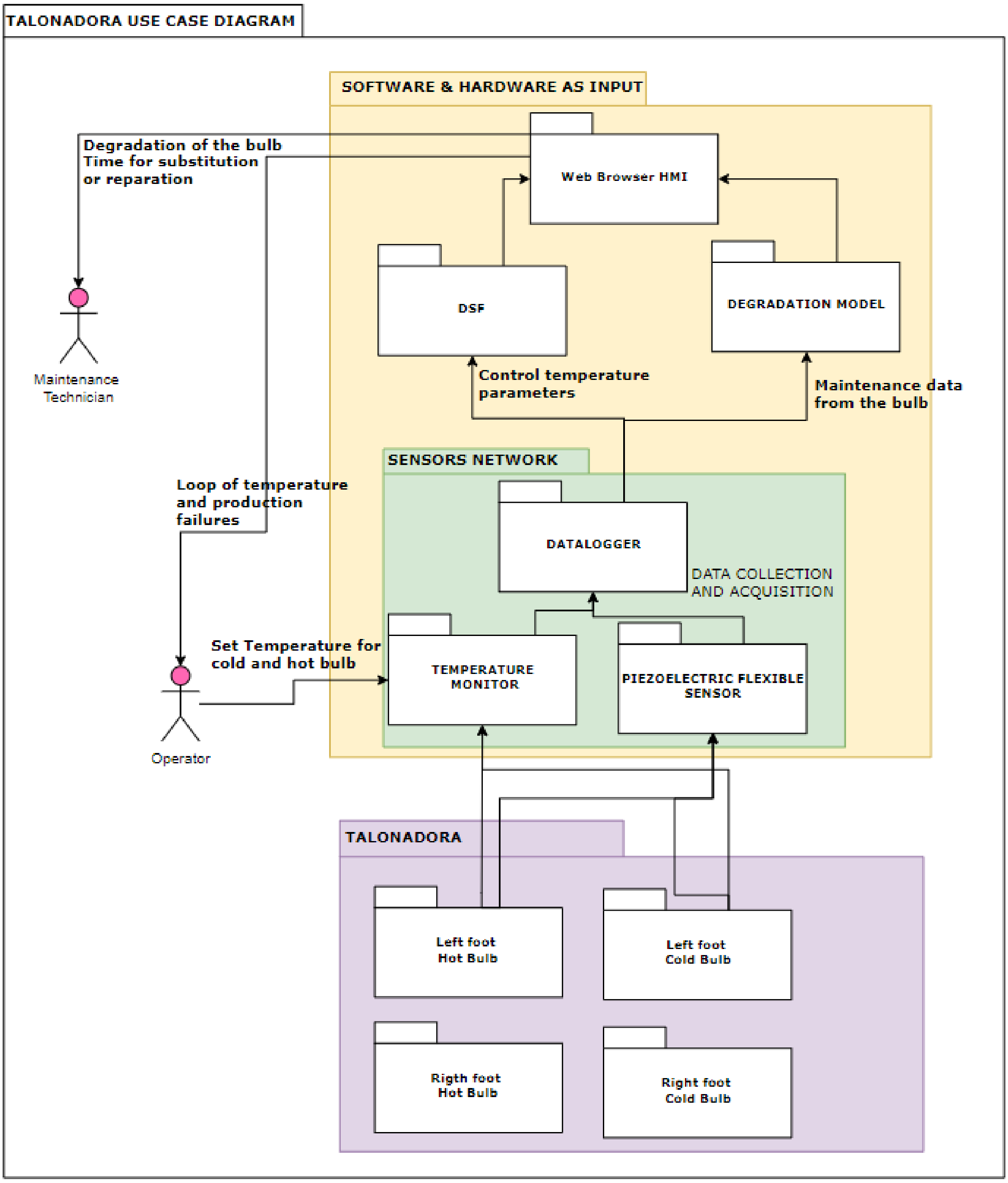

Figure 26.- Fluchos Rotostir Use Case UML Diagram.

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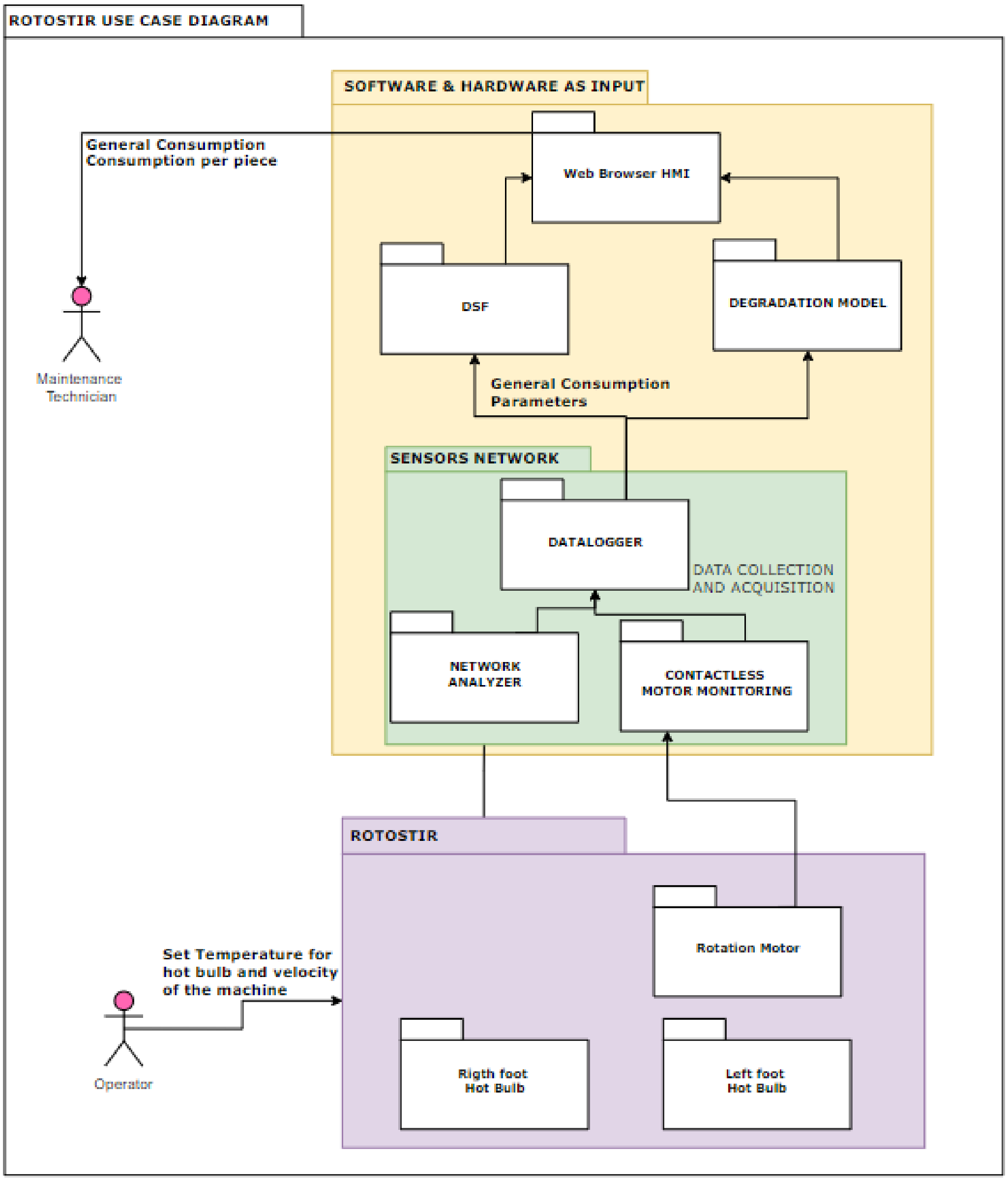

Figure 27.- Fluchos Rotostir Use Case UML Diagram.

Access rights

In both machines the access rights are similar.

Maintenance Technician - as the person in charge of the maintenance plan of both machines is necessary to the web browser HMI in order to know the vlues of the different parameters to establish the correction actions or changing the schedule of maintenance actions. He also needs online information about defects in the process to be able to make corrections.

Operator – enter parameters for pressure and temperature for the different bulbs.

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4.3 Pilot #3 - Woodworking Production

The Podium-scenario planned into RECLAIM project will bring a very important change in different activities of the company.

Particularly, the activity of acquisition of data and monitoring will be implemented, and they allow company to introduce some strategies such as predictive maintenance.

At the end, the revamping/refurbishment activity will allow to increase the production and to decrease the downtimes.

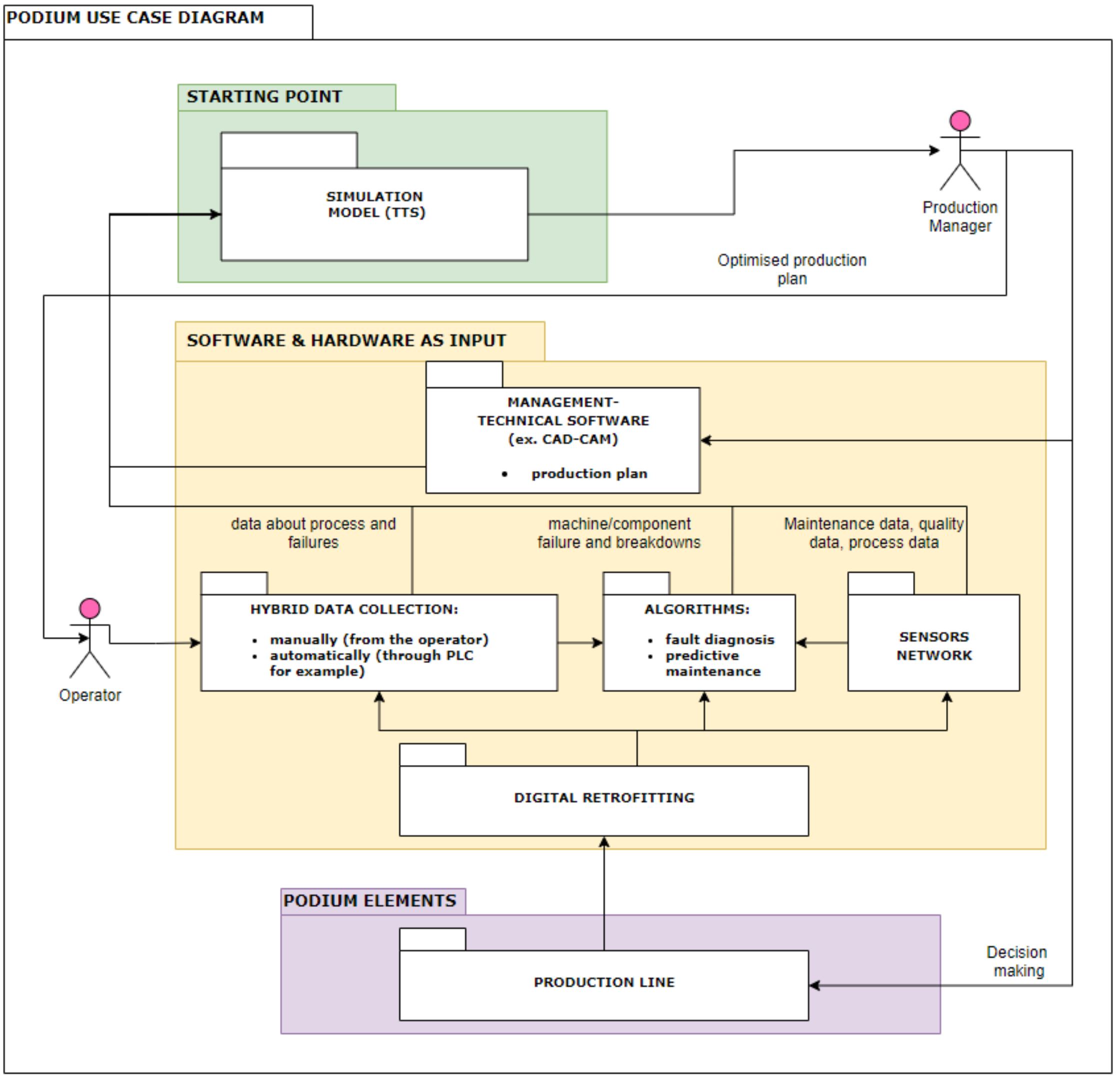

Figure 28.- Podium Use Case UML Diagram.

Access rights

Production Manager - will use the simulation model to plan and to manage the production by considering all predictive maintenance actions and all downtime planned. The improvement office could improve the productivity and the availability of the machineries through the modellation of them.

Operator – enter parameters for controlling the process with the information provide trough the production manager from the simulation model.

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4.4 Pilot #4 - Friction Welding Technologies

4.4.1 Interchangeable System Components

A highly flexible system architecture is required to meet future customer requirements and to react flexibly to infrastructure requirements and heterogeneous boundary conditions. The Genius platform from Harms&Wende forms the basis of the desired architecture. In addition to that, HWH also needs to reach a more agile product configuration. A modular design system could enable easy adaption of the machine to different welding jobs assuring a product life extension together with sophisticated methods for lifetime diagnosis and predictive maintenance tasks. Such a design of products also increases agility when it comes to the reconfigurability of production lines or the replacement of individual components. The synergy effects resulting from this approach will reduce both development costs and production times.

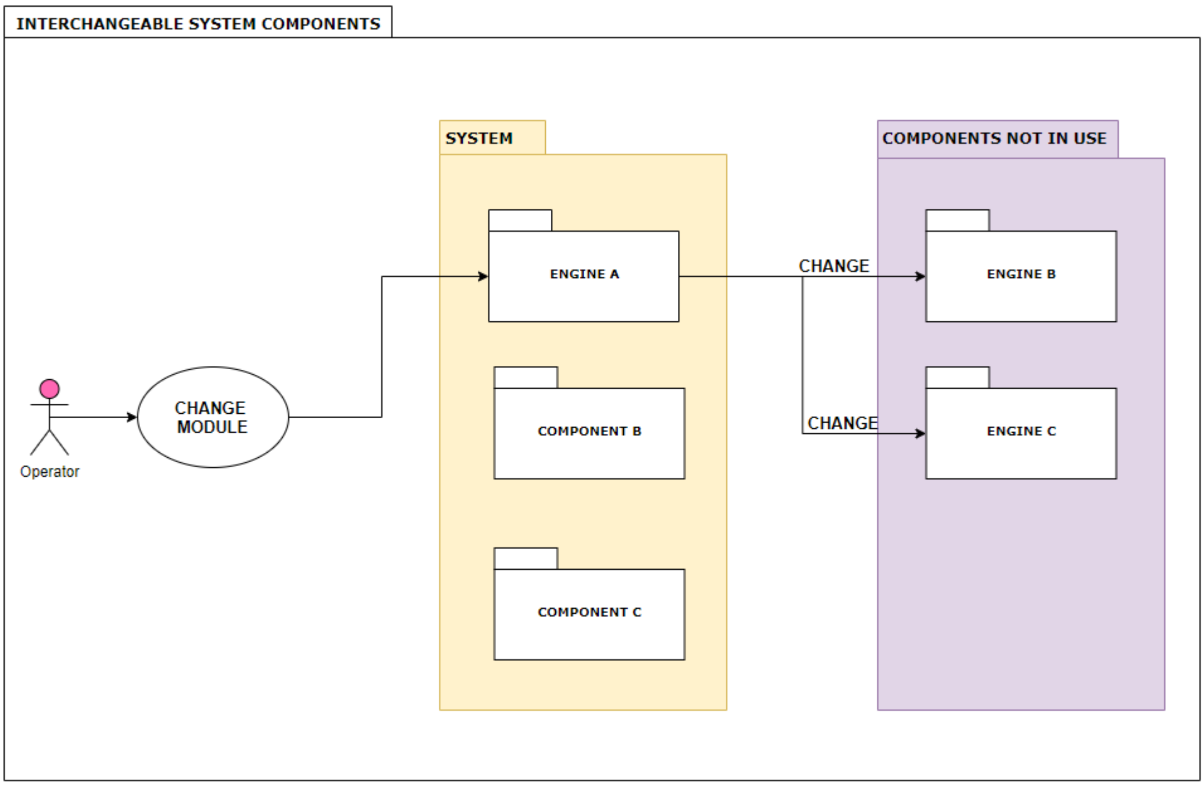

Figure 29.- HWH Use Case UML Diagram Interchangeable System Components.

4.4.2 Remote Diagnosis

Remote diagnosis describes the remote access to systems, whether in the LAN or via the Internet. Access is provided by a team of experts in the service department, but also by parts of the development department according to customer requirements. Troubleshooting through remote diagnosis promises considerable savings in resources, as well as an improvement in the ecological footprint through reduced travel activities.

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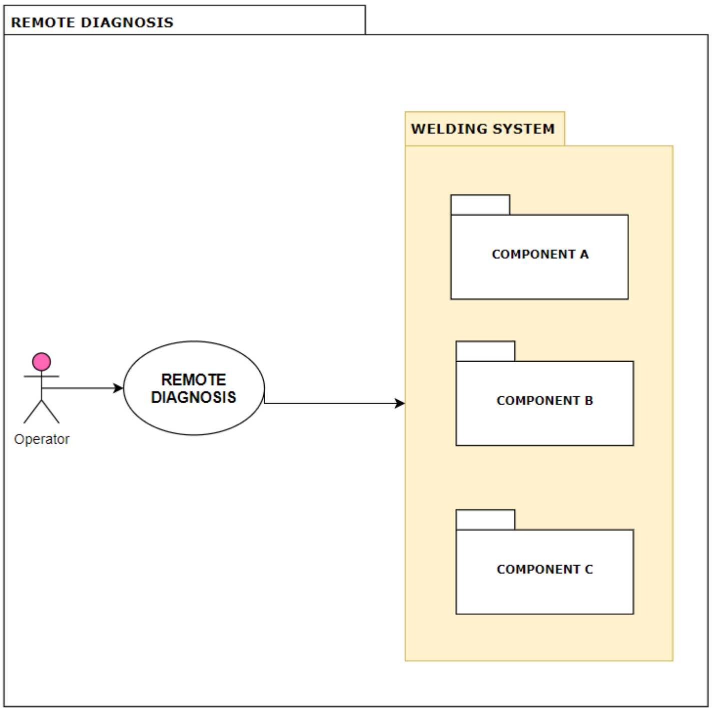

Figure 30.- HWH Use Case UML Diagram Remote Diagnosis.

4.4.3 Interchangeable Human-Machine-Interface (HMI)

The human-machine interface is particularly influenced by digitalization. The focus is shifting away from static machine operation to a user-defined operating philosophy that enables systems to be operated with many devices. Thereby smartphones and tablets are an integral part of the future operating concept.

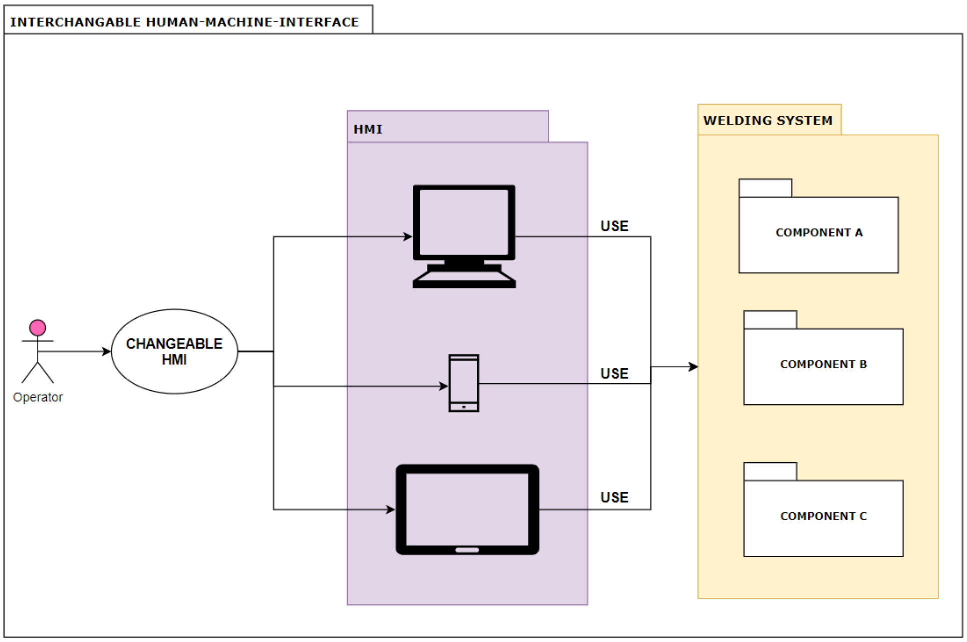

Figure 31.- HWH Use Case UML Diagram Interchangeable Human-Machine-Interface.

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4.4.4 Predictive Maintenance

Predictive maintenance is defined as a maintenance process based on the evaluation of process and machine data. Real-time processing of the underlying data enables predictions to be made which form the basis for needs-based maintenance and consequently for the reduction of downtimes. This requires not only the interpretation of sensor data but also further real-time analysis techniques.

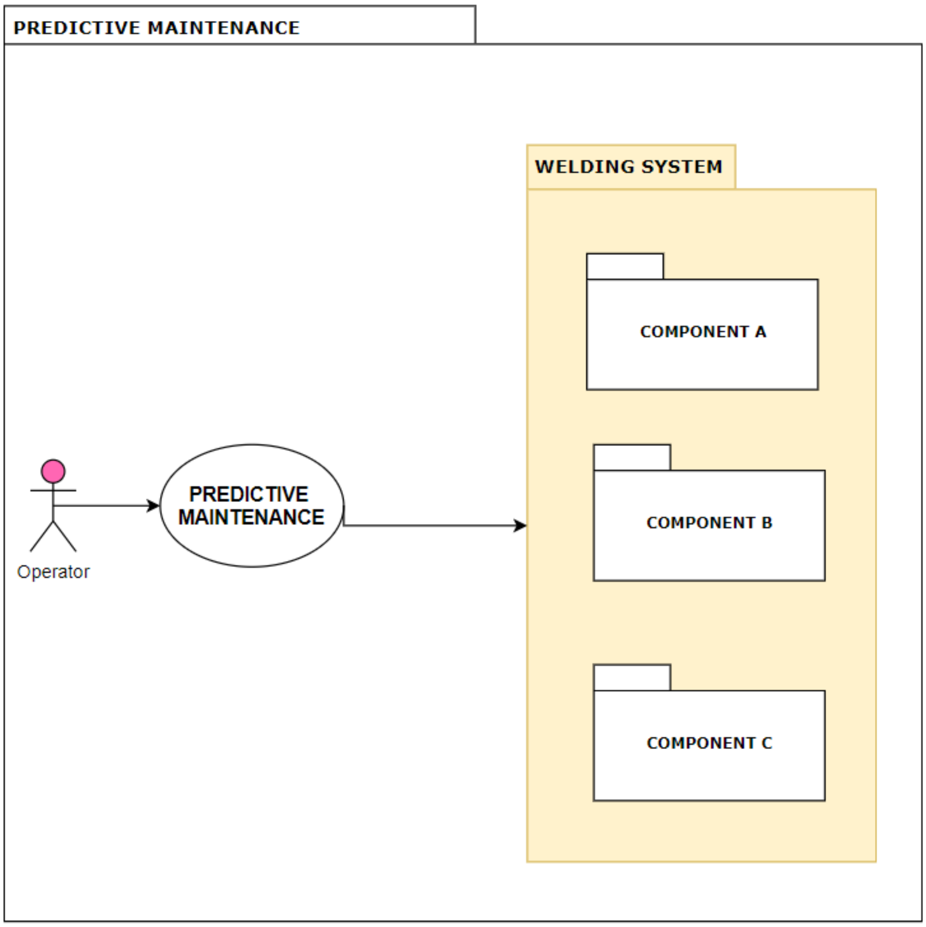

Figure 32.- HWH Use Case UML Diagram Predictive Maintenance.

4.4.5 Root-Cause Analysis

The Root Cause Analytics (RCA) helps to identify the actual causes of errors or problems in the process. The idea is not to treat symptoms, but to identify and eliminate sources of problems. The basic idea of a Root Cause Analysis is first to describe the problem as precisely as possible, to narrow down the potential problem sources and then to systematically follow the error path. With the help of sensors and a self-awareness of the machine, the time to find the root cause can be reduced considerably.

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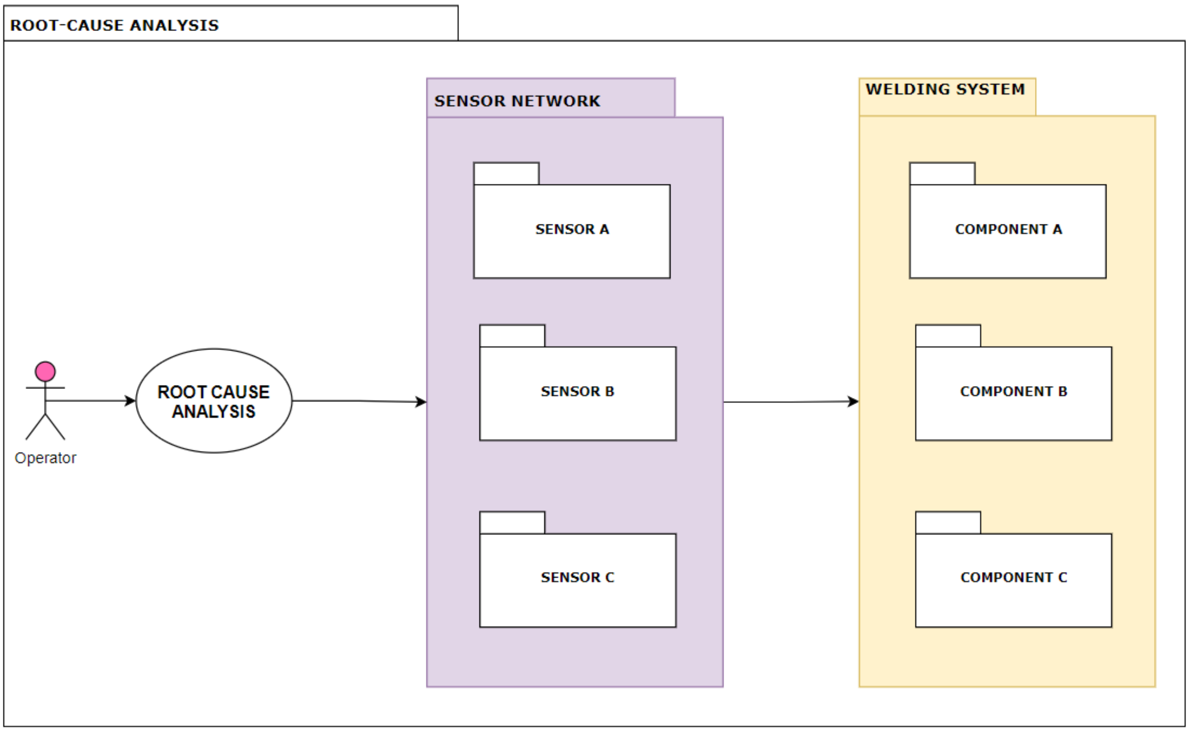

Figure 33.- HWH Use Case UML Diagram Root Cause Analysis.

Access rights

In the use cases from H&W by the moment the operator is the only person with access rights.

4.5 Pilot #5 - Textile Manufacturing

In order to reach the remanufacturing, refurbishment and upgrading of bleaching machine goals, Zorluteks carries out studies to adapt the technologies to be developed within the scope of RECLAIM, for its own needs.

In this direction, the necessary elements for value creation, real time optimization and digital transformation were installed on the bleaching machine and some improvements are still being made with some of those elements. The following UML diagram shows the deployment view of the whiteness sensor integrated into the bleaching machine and the decision support system created to obtain the desired whiteness degree can be seen.

A decision support system (DSS) gathers and analyses data, synthesizing it to produce comprehensive information reports. Data collection is one of the important steps for constructing DSS. So that, firstly, several experiments were performed to gather clean data to ensure DSS. The effect of parameters (chemical concentration, roller pressure, and machine velocity) on whiteness was investigated by laboratory experiments. Results of those experiments will be used for the DSS for machine learning. DSS will be capable of calculating process parameters to get desired

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whiteness degree. After that, it monitors and changes the important machine parameters for whiteness automatically.

Then, at the end of the bleaching process, the whiteness of the fabric will be measured by whiteness sensors. If the whiteness degree is out of expected values, DSS works to produce the fabric that will have desired whiteness degree by changing the parameters of the machine which are chemical concentration, roller pressure and machine velocity.

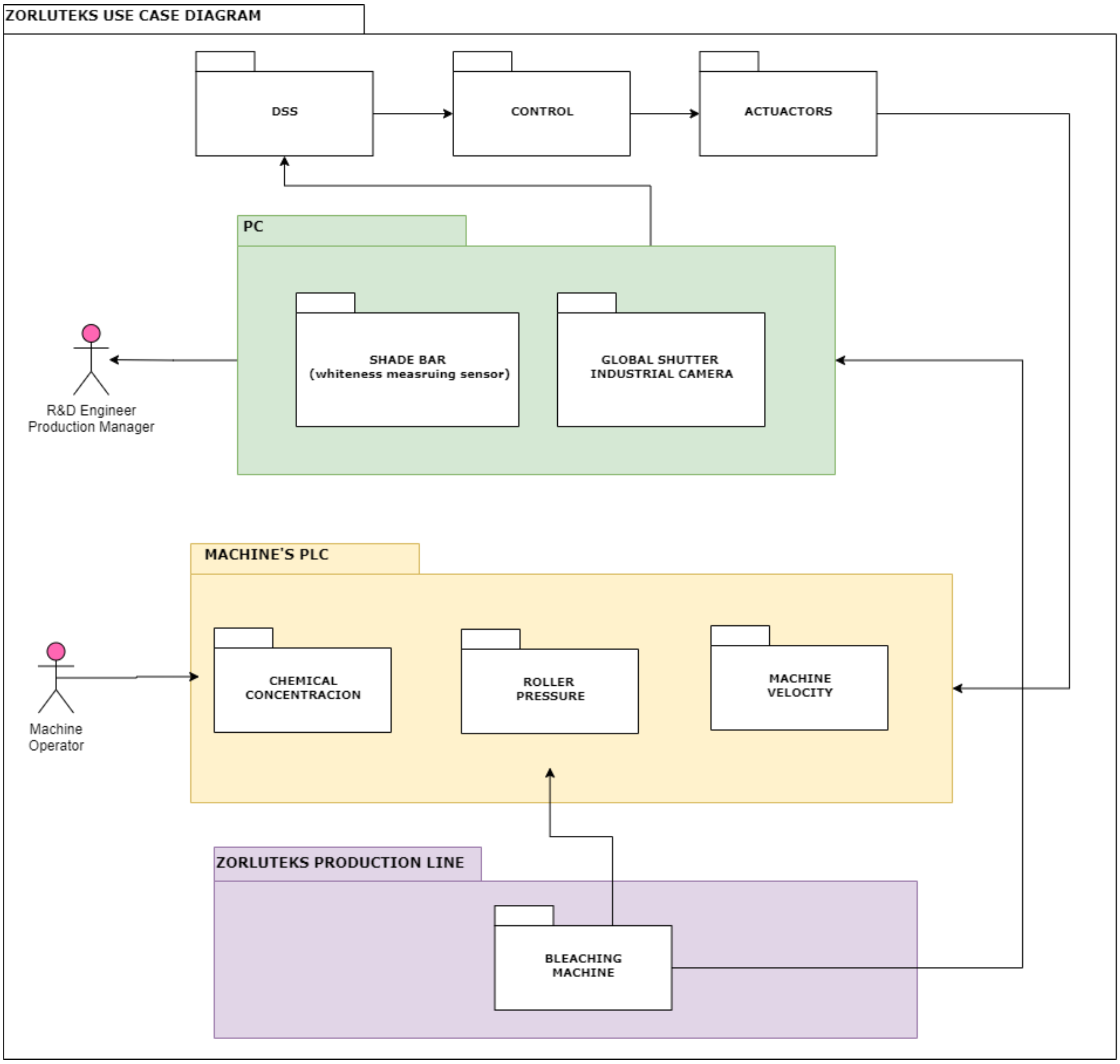

Figure 34.- Zorluteks Use Case UML Diagram.

Access rights

Production Manager / R&D Engineer. - both will have access to the data generated by the camera and the shade bar to control the whiteness degree.

Operator. – enter parameters for controlling the process, changing the recipe for chemical concentration, adjust the roller pressure and the machine velocity.

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5 Conclusion

The D2.6, RECLAIM Use Cases Definition & Operational Requirements #2 is the second iteration for the approach of the consortium to understand the production lines from five different manufacturing company's really different but with a similar problem, Their focus on the obsolescence and ageing of machinery relevant for the production continuity and the need to incorporate them into the Industrial Internet of Things and the Digitalization.

RECLAIM scenarios for the demonstration and validation of the Physical and Digital tools are a good representation of the overall manufacturing sector at Europe. The consortium has on board companies manufacturing small and major household and domestic appliances with automatic and robotised production lines, representing the good manufacturing sectors. The manufacturing of artisan product with a minimum integration of automatized lines and very specific old and customized machines, with high quality standards and at the top of products portfolio in its category, is also represented at RECLAIM.

This deliverable has introduced the indicators (KPIs) to evaluate at the end of the project how was the influence on each pilot of RECLAIM solution. In the different tables it has been presented all the indicators and the current levels of this parameter, if the pilot is measuring it, and how will be the influence of the indicator on the development of the pilot. Furthermore, the use case diagram and UML schemes have been depicted.

The scenarios defined in this deliverable are in their second iteration but they are still evolving to be able to incorporate the advances that the technological partners in close collaboration with the industrial ones will perform in the following months going in depth into more detailed and precise scenarios and its elements. Moreover, the KPIs that have been shown on chapter 3 will be the main activity for the next iteration of task 2.2 in connection with others because they will show at the end the impact on each pilot of RECLAIM solutions.

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Annex A.- KPIs Listed on DOA

DOA_KPI ID	Title	Objective	WPs
K1.1	Fulfilment by at least 85% of user's requirements concerning lifetime extension methods in old machines (identified during the user requirement analysis)	O1	WP2 to WP7
K1.2	Improvement by at least 90% of the usability of current services and solutions	O1	WP2 to WP7
K1.3	Service aggregation from 4 toolkits through RECLAIM's single point of access, reaching up to 30% faster decision making about the best recovery strategy	O1	WP2 to WP7
K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring	O2	WP3
K2.2	80% accuracy in detection of machinery failures, possible malfunctions and stoppages based on historical operational data and data from smart sensorial network and life cycle status.	O2	WP3
K2.3	(a) Increased average automation level: 4.5 to 5 out of 5 (or +20%) compared to existing solutions (measured at task/ function level); (b) Increased automation effectiveness: 3.5-4.5 to 5	O2	WP3
K2.4	Continuous information sharing between manufacturers, maintenance services providers, industries, European Re-manufacturing Network etc. for best recovery strategy	O2	WP3
K3.1	20-30% increase of number of sensors which implement each pilot use case OR set up initial sensor set.	O3	WP3
K3.2	At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning	O3	WP3
K3.3	At least 20% increase in data flow from the shop-floor to the DSF through Digital Retrofitting Infrastructure	O3	WP3
K3.4	Machine Health Index (=SUM (i:1...N) of Wi x Xi), where N: number of components in machine, i: sensing line, w: weight of component, x: the component level of sensing line) -- see formula at DOA	O3	WP3

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K4.1	50% decrease of the time needed for predictive maintenance through the Simulation Engine to perform fault diagnosis and prevent possible failures	O4	WP4
K4.2	At least 95% accuracy to identify known faults; 90% accuracy to detect possible faults and stoppages	O4	WP4
K4.3	Support effective maintenance process development	O4	WP4
K4.4	Reduction of at least 20% of downtime due to unscheduled maintenance	O4	WP4
K4.5	Maintenance effort required is decreasing at 50% (linked to MeanTimeBetweenFailure)	O4	WP4
K5.1	At least 40% more accurate service activity reliability	O5	WP4
K5.2	99% Overall equipment effectiveness after refurbishment/re-manufacturing process (this indicator shows that refurbished/ remanufactured system is producing no defects, as fast as possible, and with no stops in production)	O5	WP4
K5.3	99% Success of refurbishment/re-manufacturing processes on the production floor	O5	WP4
K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report	O6	WP5
K6.2	20% reduction of cost of downtime during a failure incident	O6	WP5
K6.3	At least 98.5% effective maintenance of potential failures and stoppages	O6	WP5
K7.1	85%-95% satisfaction, with relation to technical aspects, of shop floor managers	O7	WP5
K7.2	50% reduction of days needed to complete all repairs	O7	WP5
K7.3	50-60% increased awareness of the in-situ repair situation through data analytics of the shop floor	O7	WP5
K7.4	50% decrease of Mean Time to Repair	O7	WP5
K8.1	Number of pilots in operational environments under the direct responsibility of the end-users involved	O8	WP6
K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic	O8	WP6

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	production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling and finishing, friction welding machines and finally bleaching machines.		
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability	O8	WP6
K8.4	Up to 50% reduction in cost of annual machine maintenance	O8	WP6
K9.1	Operation of the re-manufactured/ refurbished machine must comply with existing standards	O9	WP7
K9.2	50% reduction in the number of incidents and failure-related accidents due to malfunctioning	O9	WP7
K10.1	Replicate RECLAIM's result to at least 3 other machines and production lines in pilot scenarios	O10	WP3 to WP8
K10.2	Number of future stakeholders/ providers more than 30	O10	WP3 to WP8
K10.3	Business plans available for all identified exploitable assets, including the overall RECLAIM system	O10	WP3 to WP8

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Annex A.- Objectives Listed on DOA

OBJ ID	Title	Addressed
O1	To devise and deploy circular economy strategies addressing the end-of-life issue of large industrial equipment, aiming to extend the lifetime of machines, improve performance and increase resource efficiency of heavy machinery.	WP2 to WP7
O2	To develop the appropriate tools and decision support methodologies for a) the inspection and assessment of malfunctions; b) the planning and preparation of the necessary refurbishment or re-manufacturing of large industrial equipment.	WP3
O3	To deploy an adaptive sensorial network and fog computing framework for near real-time monitoring of the machinery health status and the production line.	WP3
O4	To adapt and implement a simulation engine to perform fault diagnosis and predictive maintenance to contribute to effective damage repair.	WP4
O5	To optimise the planning of refurbishment and re-manufacturing activities & processes.	WP4
O6	To deploy novel HMIs for refurbishing/re-manufacturing large-scale electrical and mechanical machinery.	WP5
O7	To raise situational awareness through the in-situ repair process.	WP5
O8	To validate and demonstrate the proposed solutions through a set of real-life pilot sites.	WP6
O9	To ensure the safe and secure operation of the refurbished/ remanufactured equipment.	WP7
O10	To scale-up to other industrial environments through a virtual replication design.	WP3 to WP8

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