Lessons Learned and updated requirements report #1

[June 2021 - M20]

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AUTHORS : UPORTO

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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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Abbreviations and Acronyms

Abbreviation	
BB	Building Block
DoA	Description of Action
DSF	Decision Support Framework
Dx.y	Number of Deliverable
IoT	Internet of Things
KPI	Key Performance Indicator
MTBF	Mean Time Between Failure
MTTF	Mean Time To Failure
OEE	Overall Equipment Effectiveness
OEM	Original Equipment Manufacturer
pdf	Standard file format of Adobe Acrobat
PHM	Prognostics and Health Management
ppt	Standard file format of Microsoft PowerPoint
RUL	Remaining Useful Life
Tx.y	Number of Task
WP	Workpackage
xls	Standard file format of Microsoft Excel

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Summary

The vision of RECLAIM is to demonstrate the physical and virtual technologies, as well as new paradigms in the framework of the Industrial Internet of Things, IIoT, for the real digitalization of the traditional industries based in the refurbishment and re-manufacturing of large industrial equipment in factories, paving the way to a circular economy. The integration of obsoleted or analogical machines into the modern production line is an urgent need for the re-activation of the current economic situation to increase productivity based in efficiency and prevision, where new inversion will not be accessible at the short term. Simultaneously, the retrofitting of machines and production lines at factories to achieve digital performances will position these industries and factories into the market again with competitive and sustainable skills; without the substantial inversion that industrial machinery and tools means.

RECLAIM solutions maintain a health industrial fabric based in the digital change using non-expensive, realistic and accessible services for all industrial sectors and sizes, from micro-SMEs to macro-industries. Those solutions are based in physical and digital retrofitting of the industrial facilities using the minimum invasive approach from the technological point of view. Retrofitting, refurbishment, and re-manufacturing based in smart and heterogeneous IoT sensor, new versatile and functional industrial PC or human interface machine that, combined with the machine learning and data analytic, could support digital twins and decision support tools to demonstrate the robustness of these high innovative technological solutions.

RECLAIM tools aim to support all industrial sectors where the ageing and long-time use is a barrier for their digitalization to transform them into the IIoT age. White goods manufacturer, footwear manufacturer, wood furniture manufacturer, friction welding machines and original equipment manufacturer or home textile manufacturer are the sector where the project will demonstrate the RECLAIM tools benefits. But the extrapolation of RECLAIM results is infinite.

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Disclaimer

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1 Introduction

RECLAIM intends to demonstrate strategies and technologies that enable the re-use of industrial equipment in old, renewed and new factories. The idea behind this solution is to save valuable resources by recycling equipment and using it in a different application instead of discarding it after one way use. In RECLAIM, WP2 (Refurbishment and Re-manufacturing Analysis, Requirements Engineering) defines the project vision, captures the requirements, and use cases that will guide the RECLAIM design. Those requirements are associated with the RECLAIM end-users to improve different indicators in their factories.

1.1 Overall Task Description

After successfully collecting the requirements and the initial developments regarding each pilot scenario, task "T2.4 - Evolutionary Requirement Refinement and Validation of Requirements" has the goal of corroborating if the requirements are according to the pilot needs, consolidating the available information. As a result of the first iteration, the report "Lessons Learned (LL) and updated requirements report #1" describes the pilot scenarios, including their updated requirements and the consolidation of that information in the pilot architecture diagrams (consolidated views).

This retrospective effort will engage the partners directly involved in the prototype implementation and all other partners (especially industrial partners) and stakeholders. The task activities will be presented during a specific workshop, organized in a partners meeting, following a specific methodology based on retrospective templates. LL and the validation of pilots, technology, and market reports will lead to a set of new and updated requirements.

The major outcome will be to discover ambiguous requirements (verification) and fix them and unneeded ones (validation). This way, we can only remain with the most critical requirements. To achieve the proposed outcomes for this iteration, a discussion among all partners will be organized so that all requirements can be revisited and classified. The significant results of this iteration will be:

- Better pilot understanding regarding the pilot scenario, machines, processes.
- Review (e.g., update and validation) of the requirements.
- Classification of the requirements to understand their level of completeness, validity, and reality.
- Aggregation of all information using the pilot architecture diagram (consolidated view).

The remaining document structure includes the four different sections, 1) the Evolutionary Retrospective Process in Section 2, describing the existent steps to validate the requirements, i.e., requirements discussion and validation, classification, among others; 2) the Requirements Iteration #1 in Section 3, including the pilot scenarios description, requirements, and pilot consolidated views; 3) the Lessons Learned in Section 3, which is a summary of the information gained in this task, including a small discussion; and 4) the Conclusion in Section 4.

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2 Evolutionary Retrospective Process

One of the main challenges in projects with a large consortium is to manage the amount, complexity, and priority of requirements defined by project pilots. On the one hand, pilots should guide and indicate how new or existing technologies are relevant. On the other hand, they should demonstrate how the requirements impact their own business and report a competitive advantage towards the initial conditions.

Since there are 5 different pilots in the RECLAIM project, some of the requirements are definitely unique, but some of them might be overlapping or even conflicting. Conflicting requirements might be very difficult to handle since one technology dimension maximizes generalization. If generalization cannot be reached, the effort to develop new technology for each specific requirement is overwhelming. Thus, to understand the overlapping and commonality of requirements and ensure the technology can be developed or used in a broader sense, a constant follow-up of their evolution should exist.

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For the RECLAIM project, an iterative process of requirements review and retrospective is employed, composed of three different iterations. These iterations are suited for the various stages of the project, where a follow-up process is defined. Together with iterations, requirements will be evaluated in many dimensions according to predefined metrics. This allows not only to understand the suitability of requirements but also to assess their evolution over time. It is essential to ensure that the fulfilled requirements are relevant and consistent to pilot business goals and expectations at the end of the project.

Basically, for each of the iteration, a set of main outcomes can be summarized as follows:

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Iteration 1 - Validation by Discussion

- Classification of Requirements through evaluation metrics.
- Set of modification proposals to all requirements.
- Draw the first version of the pilot consolidated view.

Iteration 2 - Validation by Prototyping

- New classification of requirements through evaluation metrics.
- Presentation technology prototypes for business value and expectation alignment.
- Definition of test scenarios for each prototype.

Iteration 3 - Validation by Test Scenarios

- New classification of requirements through evaluation metrics.
- Final report on requirement evolution throughout the project.
- Alignment of requirement with the project demonstrations.

The next three sections describe the steps to iterate over the definition of requirements, including requirements review, requirements classification, and pilot consolidated view definition.

2.1 Requirements Review

The requirements review process uses the requirements matrix excel files collected in the Use Cases task. Those files provide helpful information about the pilots' issues, needs, and problems, facilitating the definition of the RECLAIM technologies to adopt in the pilot scenario. So, we associate a potential solution using RECLAIM technology and components for each issue present in the requirements matrix.

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The components selected to handle the pilot issues provide from different solutions, such as 1) new sensors or other components (e.g., cameras, PLCs) to collect more information about the process, 2) predictive algorithms like fault diagnostics or degradation modelling to infer the machine health, or 3) prescriptive methods like predictive maintenance or process parameter optimization.

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Additionally, each requirement should have a classification to keep track of his evolution through time. The classification of the requirements is also helpful to check the pilot's state and the level of maturity of its solutions. Each requirement is evaluated in each iteration using three different metrics validity, completeness, and realism.

2.2 Requirements Classification

The evaluation metrics are used to 1) make sure that requirements are suitable and aligned with the project goals and 2) their progress can be followed throughout the technology and demonstration implementation. Since only as the project progresses the first results are achieved, the potential and relevance can realistically be estimated at later stages by the pilots. This may cause the requirements to change, e.g., priority. Additionally, since the success of some technologies is also dependent on pilot information and data, it is also important to understand how far and realistically the requirement can be achieved. Since all these dimensions are important , three evaluation metrics were used for the requirements. These metrics fluctuate between 0 and 5, where a higher value corresponds to an increased level of confidence in achieving the metric goal.

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Validity: The functions proposed by pilots should be aligned with the project goals and what needs to be performed. It may be found later that there are additional or different functions/requirements that are required instead. Validity ratings:

- 0: Requirement not valid.
- 1: High probability of being not valid but worth being kept in the requirements list.
- 2: Still unclear if the requirement is valid and further discussion is required.
- 3: Valid requirement with major changes in the future.
- 4: Valid requirement with minor changes in the future.
- 5: Valid requirement with no changes foreseen in the future.

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Completeness: The completeness metric indicates the actual state of the developments regarding a specific requirement. So, in the initial phase of the project, the requirement should be closer to zero and get closer to five during its continuous development (finished). Completeness ratings:

- 0: Requirement is in an initial phase of definition.
- 1: Requirement is already defined and in an initial phase of development.
- 2: Requirement is completely defined, and the developments are in an intermediate version.
- 3: The developments are in a stable version, and the tests are in an initial phase.
- 4: The developments are in a semi-final version, and the tests are in an intermediate phase.

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- 5: The developments are in a final version, and the tests are finished.

Realism: Ensure the requirements can be implemented using the knowledge of existing partners, technology, budget, and schedule. Realism rating:

- 0: Requirement is not feasible and considers its removal.
- 1: High probability of not being feasible but worth being kept in the requirements list.
- 2: Still unclear if the requirement is feasible and further discussion is required.
- 3: Requirement is completely feasible, but major changes / further alignment are required.
- 4: Requirement is completely feasible, but minor changes / further alignment are required.
- 5: Requirement is completely feasible in the context of the project.

Those metrics will evolve during the project according to the state of the pilot scenario developments, particularly the completeness describing the level of progress of that requirement. In each iteration the metrics are updated considering the end-users' feedback during the online workshops and the current state of the developments. The end-users' feedback is provided through the requirements matrixes present in Annex A. Those tables list the requirements for each pilot and associated to each requirement the correspondent solution and metrics classification. That approach is essential to keep track of RECLAIM and pilot developments, because the project is to complex and contains several end-users' scenarios.

2.3 Consolidated View

The requirement analysis, the prioritization of the RECLAIM building block, and the mapping of the stakeholder's needs to the objectives and KPI's provide a profound basis for deriving an initial architecture of the RECLAIM solution. The architecture must fulfil the requirements of the RECLAIM pilots. Additionally, the architecture must be open, allowing the easy adoption of additional needs not known or not in focus.

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The RECLAIM architecture, in Figure 1, basically consists of two levels:

- The Pilot level in which the machines, individual databases, and third-party products and services are located. The RECLAIM solution contributes to the Pilot level by adding technology such as machine wrappers, sensors, or local data analysis services.
- The RECLAIM level which adds various services and frameworks for supporting the lifetime extension of machines and equipment on Pilot level.

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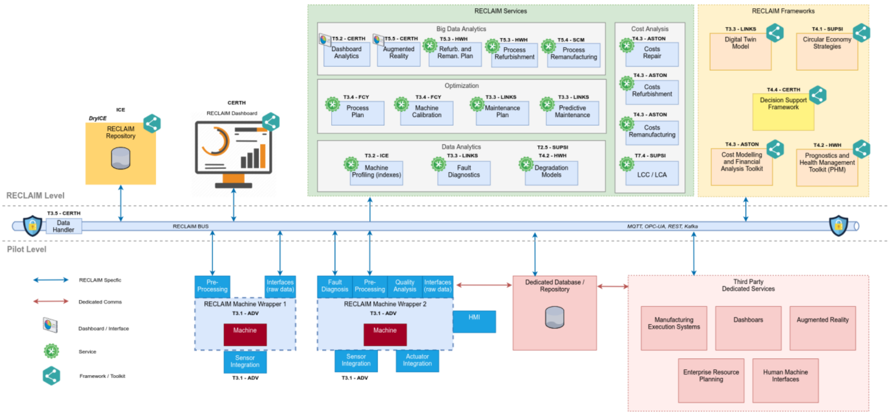

Figure 1 - RECLAIM architecture (RECLAIM consolidated view).

The RECLAIM architecture organizes the RECLAIM building blocks (BB1 – BB9), associating them to the various components in the architecture. The flexible architecture allows the selection for each end-user of the more appropriate and fruitful technologies permitting customizable solutions. The common interfaces between the components allow for a fast and individual customisation of the architecture to specific needs. The next two figures provide examples for individual setups by putting different emphasis on the building blocks.

RECLAIM Building Block (BB)	Short Description
BB1 - Adaptive Smart Sensorial Network and Digital Retrofitting Infrastructure	A distributed and adaptive smart sensor service to collect and process data for industrial environments, including IoT controllers to be attached at existing devices and machines to retrieve data and enabling predictive maintenance tasks.
BB2 - Embedded Cybersecurity for IoT devices	Embed cybersecurity endpoint protection into the design and development processes of Digital Retrofitting Infrastructure but also in the post market phase.
BB3 - Decision Support Framework (DSF) for Optimal Lifetime-Extension Strategies	The DSF component is designed to support and improve the effectiveness of decisions concerning the refurbishment and re-manufacturing of production infrastructure.
BB4 - Cost Modelling and Financial Analysis Toolkit	The cost modelling will carry out cost estimation and analysis by using the combination of parametric costing and activity-based costing methods. The cost model will consider all type of life extension strategies and activities for carrying out refurbishment and re-manufacturing of the industrial equipment, as well as the resources needed for each activity.
BB5 - Prognostic and Health Management Toolkit	The prognostics and health management (PHM) provides a peer-to-peer health evaluation as well as

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	component prediction methods to increase equipment (machine) lifetime, productivity, and service quality
BB6 - Fault Diagnosis and Predictive Maintenance Simulation Engine using Digital Twin	Fault Diagnosis and Predictive Maintenance Engine aim to monitor and predict the performance and status of factory assets, providing information to schedule the maintenance works on the machines, optimizing the production throughput, reducing the production lines stoppages, and avoiding failures.
BB7 - Optimization Toolkit for Refurbishment & Re-manufacturing Planning	This Optimization Toolkit supports the planning optimization through multi-variable monitoring of the machine's operational parameters where the effects of variable changes will determine the best practices/methodologies for model-based plat-site/shop-floor control.
BB8 - In-Situ Repair Data Analytics for Situational Awareness	Used to identify and recognize machine operational and behavioural patterns, make fast and accurate predictions and act with confidence at the points of decision.
BB9 - Novel shop floor AR-enabled Multimodal Interaction Mechanisms	This component aims to provide a novel way to visualize and localize information on equipment refurbishment and re-manufacturing operations directly situated on top of the physical equipment.

The initial architecture provides a profound basis for further specification and development within RECLAIM. It will further be detailed and adapted based on the experiences of integration into the pilots. The pilots' needs are associated with different RECLAIM solutions. Each pilot will have an architecture diagram (pilot consolidated view) allowing the selection and definition of each end user's most relevant components and solutions.

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3 Requirements Iteration #1

The first iteration of the requirements has the goal of review them, discussing, and providing more information about the pilot scenario and the solutions to be developped. Specific scenarios require the selection and prioritization of different requirements according to the pilot needs. This first iteration will review the conditions and information collected by the other RECLAIM tasks, summarize the contents, and validate them in terms of RECLAIM objectives.

The requirements review was done during remote workshops with the pilots' presence and the other RECLAIM partners. The workshops' schedule is composed of 1) an introduction/contextualization of the pilot scenario, including the description of the machines and processes; 2) the discussion of the current requirements and solutions, using for that the requirements matrix of the pilot; and 3) the discussion and validation of the initial consolidated view. The discussion of the requirements allows to select the most relevant ones and reformulate some of them if needed. Additionally, the requirements are classified using the metrics described before.

So, the contents of this chapter describe for each pilot: 1) an initial description of the pilot scenario, including machines, processes, operations, among others; 2) a review of the requirements associated with each pilot, defining the component goal, the application scenario (e.g., machine), the output results, and the requirement classification according to predefined metrics (validity, completeness, and realism); and 3) the consolidation of all information into a graphical diagram, the pilot consolidated view.

3.1 Pilot#1A - Refurbishment & Upgrading of Robot Cells

Robotic cells (RC) are one relevant production line tool at the Gorenje dishwasher (DW) factory manufacturing process. Dishwasher inox tubs, which are the main part of the dishwasher, are manufactured and isolated in robotic cells, where bending, punching, edge profiling, pressing, welding, isolation processes are carried out mainly by automatized robots. RCs for the manufacture and isolation of DW tubs are cells called XL, A, B, C, D, and E.

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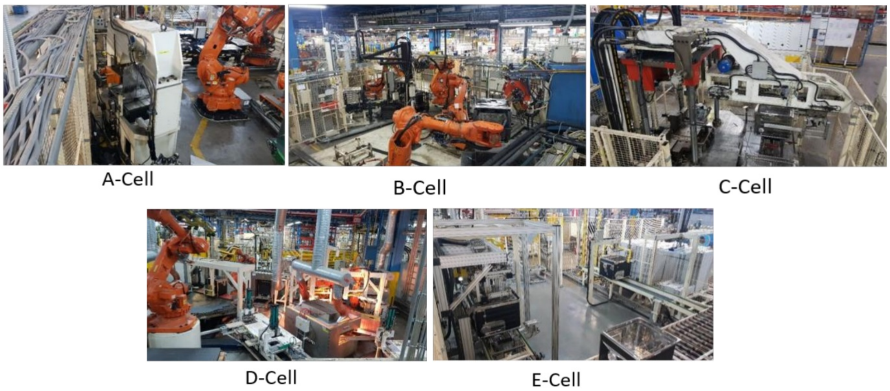

Figure 2 - Pilot#1A robotic cells

The constitution of each robotic cell, in Figure 2, is the following: 1) A-cell: rotating table with 4 places (2 for U and 2 for L), point welding cell, hole cutting machine, 2 presses, 4 robots (1 for welding, 3 for manipulation), hydraulic aggregate; 2) B-cell: spot and seam welding machine, double bending machine, hydraulic aggregate, 6 robots; 3) C-cell: punching machine, double bending machine, hydraulic aggregate; 4) D-cell: 4 furnaces, 2 robots; and 5) E-cell: control/measurement unit.

Requirements List

After summarizing the pilot scenario, including the shop-floor machines, the next stage is the revision of the associated requirements. Those requirements describe systems, components, hardware, and software modules that improve certain indicators, like productivity, quality, waste production, among others. The list below contains the initial requirements, including a classification according to the metrics described in the chapter before, i.e., validity (VLT), completeness (CPT), and realism (REAL).

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- **Vision camera and image processing software for object recognition in Cell A:** This component permits the validation if the small parts are in position for spot welding, e.g., according to the reference project. [classification: VLT:5, CPL:2, REAL:4]
- **Detection sensor for a storage container in Cell A:** This module allows the detection of the stock of small parts, alerting when the stored items reach the minimum value, requiring a new provision. [classification: VLT:4, CPL:1, REAL:4]
- **Prediction of welding electrode worn out/change (Spot welding in Cell A and B):** Component to estimate the replacement of electrodes according to the current values and the total number of welding spots. [classification: VLT:5, CPL:1, REAL:3]
- **Prediction of changing of knifes (Punching machines in Cell A):** Module to estimate the worn out of the punching knifes according to some sensor values or machine vision system. [classification: VLT:5, CPL:1, REAL:3]
- **Predictive maintenance (2 presses in Cell A, double bending and hydraulic aggregates in Cell B and C):** Module to predict the hydraulic oil change, according

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to the different variables, e.g. temperature, viscosity, working hours. [classification: VLT:5, CPL:1, REAL:3]

- **Prediction of worn out of welding reels (Seam welding in Cell B)**: Module to estimate the worn out, sharpening, and changing of the welding reels, requiring the integration with the welding controller to collect different parameters, like the temperature of the reel, welding current, temp. of cooling water, welding reel speed. [classification: VLT:5, CPL:1, REAL:3]
- **Energy consumption profile (All welding machines and ovens)**: Component for monitorization of the electric consumption of the welding machines and ovens, using for that energy meters. [classification: VLT:5, CPL:2, REAL:4]
- **Online welding quality control with camera vision system (Seam welding)**: Module to validate the seam welding quality using for that a machine vision system and image processing techniques. [classification: VLT:5, CPL:2, REAL:3]
- **Robots monitorization (All cells)**: Component to monitor and collect data from each robot control unit, such as stops, failure list, and other data about failures. [classification: VLT:4, CPL:3, REAL:5]
- **Crash protective sensors in Cell B and C**: System to reduce the bad parts (waste) improving the operational effectiveness (stops). [classification: VLT:3, CPL:1, REAL:4]
- **Regulators and control unit of ovens in Cell D**: Component to improve the regulation system for ovens, reducing maintenance costs. [classification: VLT:3, CPL:1, REAL:4]
- **Outer bottom cell upgrades**: Control units upgrade for better efficiency HW and SW upgrading prepared for real-time data and protective sensors against a crash. [classification: VLT:3, CPL:1, REAL:3]
- **Optimization of the cooling water system:** Component to optimize the water consumption using a recycling system and a water flowmeter. [classification: VLT:5, CPL:2, REAL:4]
- **Positioning for robot spot welding in Cell A and B**: System to adjust welding points with robots for each table, providing better efficiency. [classification: VLT:4, CPL:1, REAL:3]

Pilot Consolidated View

The requirements list described before provides an accurate image about the pilot objectives and goals, regarding the components and modules to develop in the next stages. The complete representation of the pilot image is achieved through the pilot consolidated view. The pilot consolidated view includes 1) the pilot scenario composed by the machines, the hardware (infrastructure, sensors, actuators, among others) and local software components; and 2) the RECLAIM technologies including services, frameworks, repository, dashboards, etc. The following diagram shows the pilot consolidated view, considering all the components described before.

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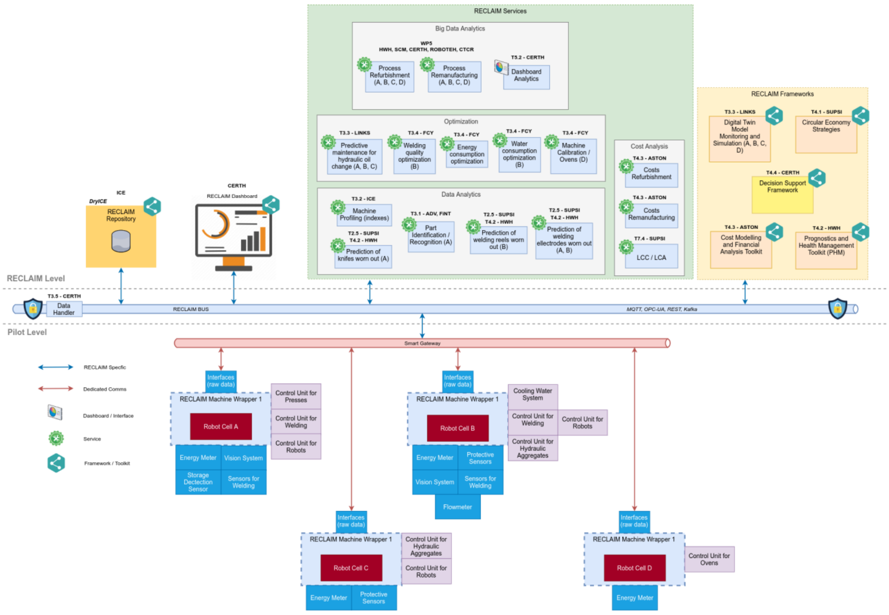

Figure 3 - Gorenje Pilot#1A Consolidated View.

Additionally, the following list presents the core algorithms developed in RECLAIM that can be applied in the Gorenje Pilot#1A machines.

RECLAIM Component	Description
Decision Support Framework	Optimization of different KPIs, e.g., electricity, quality, wasted materials caused by breakdowns/malfunctions.
Reliability analysis tool and degradation models	Analysis of the health and degradation of the equipment weakest components, for example the welding reels worn out or the punching knifes degradation.
Machinery operational profiling	That component computes three different indexes (Health, Performance, and Production) to generate the machine's profile based on the data and parameters provided by the machines of the user partners.
Predictive maintenance and fault diagnostics	Algorithms can predict the component's failure and consequently schedule its maintenance. They can be applied to predict maintenances on the hydraulic oil change.
Digital twin for simulation	The component goal is to evaluate different maintenance scenarios and production strategies using discrete simulation to reduce the impact of maintenance activities on the performances of a production system.

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Cost Modelling and Financial Analysis Toolkit	The component (cost model) will estimate the unit cost of different strategies for equipment or their systems/sub-systems/components, which will support the Decision Support Framework.
Life Cycle Assessment / Life Cycle Cost	The main functionalities of the component are the following: real-time assessment of the sustainability performances, generation of machine use/refurbishment scenarios, comparison of the identified scenarios, and visualization of assessment results.

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3.2 Pilot#1B - Modernisation & Refurbishment of a White Enamelling Line

The white enamelling line is the most important production line for cooktops in cookers manufacturing at Gorenje/MORA. 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; and gas furnace.

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The focus of Pilot#1B is the spraying cabin and the furnace. The spraying cabin applies the powder enamel in the semi-finished products using electrostatic spray guns on one side. Enamel powder is fluidized in the hopper, which is connected to the filter recycling system. Enamelled powder is transported to spray guns, which moves on reciprocator up and down.

The furnace with an air temperature of 830°C performs the reaction from powder into fused porcelain enamel. The conveyor with a U shape brings the parts through the firing zone.

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Figure 4 - Spraying cabin (top image) and furnace (button image).

Requirements List

After summarizing the pilot scenario, including the shop-floor machines, the next stage is the revision of the associated requirements. Those requirements describe systems, components, hardware, and software modules that improve certain indicators, like productivity, quality, waste production, among others. The list below contains the list of the initial requirements, including a requirement classification according to the metrics described in the chapter before, i.e., validity (VLT), completeness (CPT), and realism (REAL).

- **Vision camera and image processing software for parts identification**: Component to identify the raw metal sheet parts at the beginning and end of the line, collecting information about pieces IDs, shapes, among others. [classification: VLT:5, CPL:2, REAL:4]
- **Parameters monitorization (temperature, humidity, conveyor speed)**: System to monitor the environment and process variables affecting the line's performance, such as the temperature and the humidity in the furnace, spraying cabin and surrounding, or the conveyor speed. [classification: VLT:4, CPL:1, REAL:4]
- **Optimization of thickness in enameled parts**: Module to optimize the thickness of the enameled parts, using predictive models to correlate the thickness with other parameters. [classification: VLT:5, CPL:1, REAL:4]

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- **Energy consumption profile**: Component for monitorization of the electric consumption of the machines and consequent optimization of the consumptions. [classification: VLT:5, CPL:2, REAL:4]
- **Optimization of burning emissions**: Module to optimize the burning emissions of the furnace. [classification: VLT:5, CPL:1, REAL:4]

Pilot Consolidated View

The requirements list described before provides an accurate image of the pilot objectives and goals regarding the components and modules to develop in the next stages. The complete representation of the pilot image is achieved through the pilot consolidated view. The pilot consolidated view includes 1) the pilot scenario composed of the machines, the hardware (infrastructure, sensors, actuators, among others), and local software components; and 2) the RECLAIM technologies including services, frameworks, repository, dashboards, etc. The following diagram shows the pilot consolidated view, considering all the components described before.

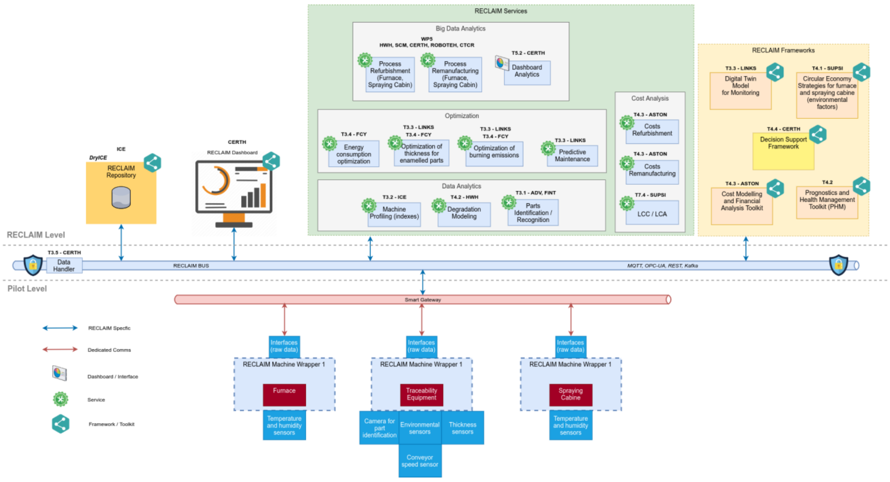

Figure 5 - Gorenje Pilot#1B Consolidated View.

Additionally, the following list presents the core algorithms developed in RECLAIM that can be applied in the Gorenje Pilot#1B machines.

RECLAIM Component	Description
Decision Support Framework	Optimization of different KPIs, e.g., electricity, wasted materials caused by breakdowns/malfunctions.
Reliability analysis tool and degradation models	Analysis of the health and degradation of the equipment weakest components.

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Machinery operational profiling	That component computes three different indexes (Health, Performance, and Production) to generate the machine's profile based on the data and parameters provided by the machines of the user partners.
Predictive maintenance and fault diagnostics	Algorithms can predict the component's failure and consequently schedule its maintenance. They can be applied using as source the environment sensors and other sources of data.
Digital twin for simulation	The component goal is to evaluate different maintenance scenarios and production strategies using discrete simulation to reduce the impact of maintenance activities on the performances of a production system.
Cost Modelling and Financial Analysis Toolkit	The component (cost model) will estimate the unit cost of different strategies for equipment or their systems/sub-systems/components, which will support the Decision Support Framework.
Life Cycle Assessment / Life Cycle Cost	The main functionalities of the component are the following: real-time assessment of the sustainability performances, generation of machine use/refurbishment scenarios, comparison of the identified scenarios, and visualization of assessment results.

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Kommentiert [I4]: Table (see comment above)

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3.3 Pilot#2 - Retrofitting & Upgrades in the Shoemaking Industry

Fluchos covers the complete production process of shoe manufacturing. The whole manufacturing process is divided into five operations: cutting, stock fitting, forming, set up, and finishing. The focus of Pilot#2 is the forming machine for rear parts and the forming machine for front parts.

Figure 6 - Rear parts forming machine (Talonadora) and front parts forming machine (Rotostir).

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Rear part forming machine (Talonadora): Process to shape the shoe's heels; Subsequent application of heat and cold surfaces combined with the precise pressure to reach the desired shape at the leather; The left station is equipped with an electrical resistance device to heat and soften the material; The right station is equipped with capillaries through which a liquid circulates to cool the material; Both parts of the press have rigid lower support and an upper part which consists of a bell with an inflatable leather pad. A pneumatic cylinder lowers the upper support, and the cushion is inflated to press the back of the shoe evenly.

Front part forming machine (Rotostir): The tip forming process consists of going over the sides of the front half of the cut with a small roller; The carousel rotates until the upper part reaches the station, where ahead with a roller at the end rotates around the contour of the shoe; Gear motors for the rotation of the carousel and the head; Electrical or pneumatic cylinders that control the opening of the last, the tension of the upper part, the pressure of the roller against the upper part and the radial movement of the head; Inductive sensors to control the start and end of the movements.

Requirements List

After summarizing the pilot scenario, including the shop-floor machines, the next stage is revising the associated requirements. These requirements describe systems, components, hardware, and software modules that improve specific indicators, like productivity, quality, waste production, among others. The list below contains the initial requirements, including a requirement classification according to the metrics described in the chapter before, i.e., validity (VLT), completeness (CPT), and realism (REAL).

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- **Machine monitorization (Talonadora)**: System to monitor several variables of the Talonadora, such as the temperature for heating and cooling phases, the pneumatic pressure, or the vibration. [classification: VLT:5, CPL:2, REAL:5]
- **Prediction of membrane deformation (Talonadora)**: Component to estimate the membrane deformation after hot pressing and cold pressing. [classification: VLT:5, CPL:3, REAL:5]
- **Anomaly detection and predictive maintenance (Talonadora)**: Module to predict future failures of the machine, using data from sensors, failures, and processes. [classification: VLT:5, CPL:1, REAL:3]
- **Product quality optimization using temperature data (Talonadora)**: Component to analyze the product quality using temperature data collected from sensors or thermal images. [classification: VLT:5, CPL:1, REAL:3]
- **Monitorization of produced parts (Rotostir)**: System to collect the information about the number of produced parts by the machine. [classification: VLT:3, CPL:2, REAL:4]
- **Energy efficiency using current and voltage sensors (Rotostir)**: Component for monitorization of the electric consumption of the machines, and consequent optimization of the consumptions, using for that data from current and voltage sensors. [classification: VLT:5, CPL:2, REAL:5]

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Pilot Consolidated View

The requirements list described before provides an accurate image of the pilot objectives and goals regarding the components and modules to develop in the next stages. The complete representation of the pilot image is achieved through the consolidated pilot view. The pilot consolidated view includes 1) the pilot scenario composed of the machines, the hardware (infrastructure, sensors, actuators, among others), and local software components; and 2) the RECLAIM technologies including services, frameworks, repository, dashboards, etc. The following diagram shows the pilot consolidated view, considering all the components described before.

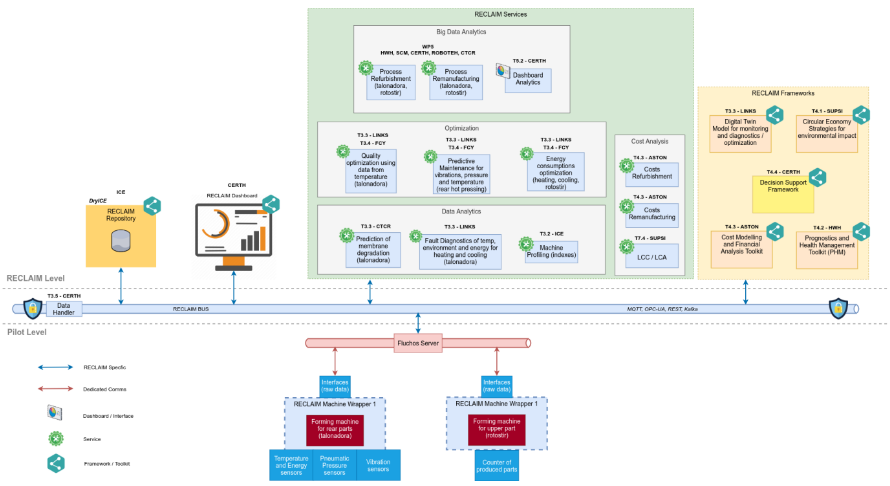

Figure 7 - Fluchos Pilot#2 Consolidated View.

Additionally, the following list presents the core algorithms developed in RECLAIM that can be applied in the Fluchos machines.

RECLAIM Component	Description
Decision Support Framework	Optimization of different KPIs, e.g., electricity, wasted materials caused by breakdowns/malfunctions.
Reliability analysis tool and degradation models	Analysis of the health and degradation of the equipment weakest components, e.g., membrane.
Machinery operational profiling	That component computes three different indexes (Health, Performance, and Production) to generate the machine's profile based on the data and parameters provided by the machines of the user partners.
Predictive maintenance and fault diagnostics	Algorithms can predict the component's failure and consequently schedule its maintenance. They can be applied using as source data from the temperature sensors of the Talonadora.

hat verschoben (Einfügung) [1]

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Digital twin for simulation	The component goal is to evaluate different maintenance scenarios and production strategies using discrete simulation to reduce the impact of maintenance activities on the performances of a production system.
Cost Modelling and Financial Analysis Toolkit	The component (cost model) will estimate the unit cost of different strategies for equipment or their systems/sub-systems/components, which will support the Decision Support Framework.
Life Cycle Assessment / Life Cycle Cost	The main functionalities of the component are the following: real-time assessment of the sustainability performances, generation of machine use/refurbishment scenarios, comparison of the identified scenarios, and visualization of assessment results.

3.4 Pilot#3 - Predictive Maintenance & Refurbishment of a large Woodworking Production Line

The focus of Pilot#3 is the cutting, edge banding, and drilling machines, in Figure 8, which are provided by Podium as a pilot plant within the RECLAIM project scenario. This large manufacturing line deals with the production of high-end wooden kitchens.

Figure 8 - Podium machines (cutting - HOLZMA-HKL, edge bander - IMA and drilling - VEKTOR 15 and MAW ABS 100).

hat nach oben verschoben [1]: Algorithms can consequently schedule its maintenance. They can be applied using as source data from the temperature sensors of the Talonadora.¶

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The panels required for the cabinets are taken using a forklift from the panels' warehouse and charged into the Holzma HKL 380. The machine cut them in the correct dimension required by the desired lot and push them forward in the process. The second step foresees the attachment of bands to the lateral parts of panels requiring them. According to the type of material the bands must be, the process can go into the Homag KL 310 (metallic or special edges) or into the IMA NOVIMAT (plastics edges). Once the panel has been bent, it is necessary to create the holes and housing for the ironware and joints. This operates through two main machines meant to drill and bore the panels according to the CAD files provided. Currently, PODIUM also uses a third machine (HOMAG/MAW ABH 120) that is only used in exceptional cases or to make up for the failure of another machine, the Biesse VEKTOR 15 that can be integrated already into the production process.

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Requirements List

After summarizing the pilot scenario, including the shop-floor machines, the next stage is the revision of the associated requirements. Those requirements describe systems, components, hardware, and software modules that allow the improvement of certain indicators, like the productivity, quality, waste production, among others. The list bellow contains the initial requirements list, including a requirement classification according to the metrics described in the chapter before, i.e., validity (VLT), completeness (CPT), and realism (REAL).

- **Traceability monitoring (Holzma HKL, IMA, VEKTOR 15 and MAW ABH 120)**: System to monitorization of the machine stops, failures, or produced parts, used as source for other algorithms. [classification: VLT:4, CPL:2, REAL:3]
- **Vision camera and image processing software for quality analysis (IMA)**: Component to process and analyse images providing information about the produced parts quality, like cut length imperfection, or visible joints. [classification: VLT:5, CPL:2, REAL:4]
- **Parameters monitorization for glue system using flow/pressure sensor (IMA)**: Module for monitorization of the glue system using for that a flow/pressure sensor, enabling the optimization of the process reducing the errors. [classification: VLT:5, CPL:1, REAL:3]
- **Predictive maintenance (Holzma HKL, IMA, VEKTOR 15 and MAW ABH 120)**: Component to predict the machines failures, using as data source the collected data from other systems. [classification: VLT:5, CPL:2, REAL:4]

Pilot Consolidated View

The requirements list described before provides an accurate image about the pilot objectives and goals, regarding the components and modules to develop in the next stages. The complete representation of the pilot image is achieved through the pilot consolidated view. The pilot consolidated view includes 1) the pilot scenario composed by the machines, the hardware (infrastructure, sensors, actuators, among others) and local software components; and 2) the RECLAIM technologies including services, frameworks, repository,

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dashboards, etc. The following diagram shows the pilot consolidated view, considering all the components described before.

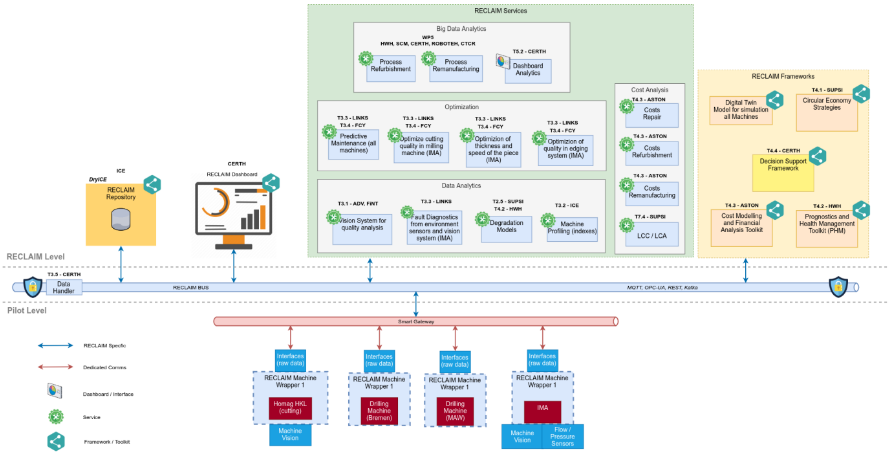

Figure 9 - Podium Pilot#3 Consolidated View.

Additionally, the following list presents the core algorithms developed in RECLAIM applied in the Podium pilot.

RECLAIM Component	Description
Decision Support Framework	Optimization of different KPIs, e.g., electricity, wasted materials, or productivity.
Reliability analysis tool and degradation models	Analysis of the health and degradation of the equipment weakest components.
Machinery operational profiling	That component computes three different indexes (Health, Performance, and Production) to generate the machine's profile based on the data and parameters provided by the machines of the user partners.
Predictive maintenance and fault diagnostics	Algorithms can predict the component's failure and consequently schedule its maintenance.
Digital twin for simulation	The component goal is to evaluate different maintenance scenarios and production strategies utilizing discrete simulation to reduce the impact of maintenance activities on the performances of a production system.
Cost Modelling and Financial Analysis Toolkit	The component (cost model) will estimate the unit cost of different strategies for equipment or their systems/sub-systems/components, which will support the Decision Support Framework.

hat verschoben (Einfügung) [2]

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Life Cycle Assessment / Life Cycle Cost	The main functionalities of the component are the following: real-time assessment of the sustainability performances, generation of machine use/refurbishment scenarios, comparison of the identified scenarios, and visualization of assessment results.

hat nach oben verschoben [2]: Optimization of different KPIs, e.g., electricity, wasted materials, or productivity.¶

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3.5 Pilot#4 - Lifetime Extension of Friction Welding Machines

The focus of the Pilot#4 is the friction welding machine RSM401, in Figure 10, which HWH provides as pilot plant within the RECLAIM project. The friction welding machine was in use at Lufthansa Technik for 10 years and is used to re-manufacture, develop, and test data analysis functions. The pilot scope is the re-manufacturing and upgrading of friction welding machine RSM401, including advanced sensors and data analysis of the gathered data.

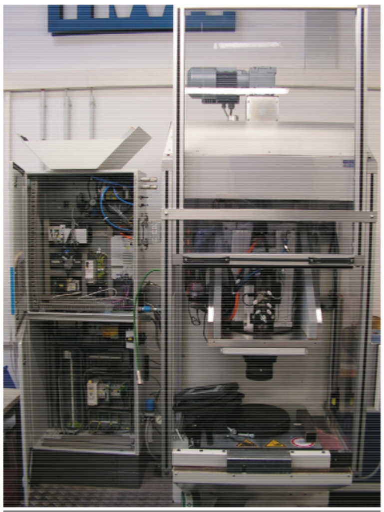

Figure 10 - Friction welding system RSM401

Requirements Update

The RSM401 machine or Lufthansa machine will be refurbished, adding new sensors, components, and software. The installation of new sensors provides valuable information for the software algorithms, which can compute with that data the machine's health, the quality of the welded piece, among others. Besides the new hardware components, the HWH pilot

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includes different software components. Those services and components allow the monitorization of the welding process, predicting failures, or estimating machine health.

- **Machine parameters monitorization**: System to monitor the machine parameters using different sensors, such as force, rotation and angle speed sensors, vibration sensor, gyroscope, humidity/air pressure sensor, or temperature (spindle and motor) sensors. [classification: VLT:5, CPL:2, REAL:5]
- **Servo motor system upgrades**: Replacement of the motor technology by a servo motor, improving the stability and controllability of the system. [classification: VLT:4, CPL:2, REAL:4]
- **PLC system upgrades**: Upgrade of the PLC technology, providing different advantages like a higher acquisition rate or processing capabilities. [classification: VLT:4, CPL:2, REAL:4]
- **Remote Digital twin technology for remote monitoring/maintenance actions (interchangeable HMI)**: Software component to monitor the state of the machine remotely, without requiring the technician's presence in the factory. Additionally, the HMI should be available through different types of devices, facilitating the machine's monitorization. [classification: VLT:4, CPL:2, REAL:4]
- **Reliability analysis tool and degradation models (motor and spindle)**: Analysis of the health and degradation of the equipment's weakest components, e.g., motor and spindle bearings. [classification: VLT:5, CPL:3, REAL:5]
- **Root cause analysis**: Component to identify the actual causes of errors or problems in the process. The basic idea of the root cause analysis component is first to describe the problem as precisely as possible, narrow down the potential problem sources, and systematically follow the error path. [classification: VLT:5, CPL:2, REAL:5]
- **Welding quality analysis**: Module to analyze and optimize the quality of the welded parts; for that, the algorithm could use data collected from the installed sensors and correlate it with the quality. [classification: VLT:4, CPL:1, REAL:4]

Pilot Consolidated View

The requirements list described before provides an accurate image of the pilot objectives and goals regarding the components and modules to develop in the next stages. The complete representation of the pilot image is achieved through the consolidated pilot view. The pilot consolidated view includes 1) the pilot scenario composed of the machines, the hardware (infrastructure, sensors, actuators, among others), and local software components; and 2) the RECLAIM technologies including services, frameworks, repository, dashboards, etc. The following diagram shows the pilot consolidated view, considering all the components described before.

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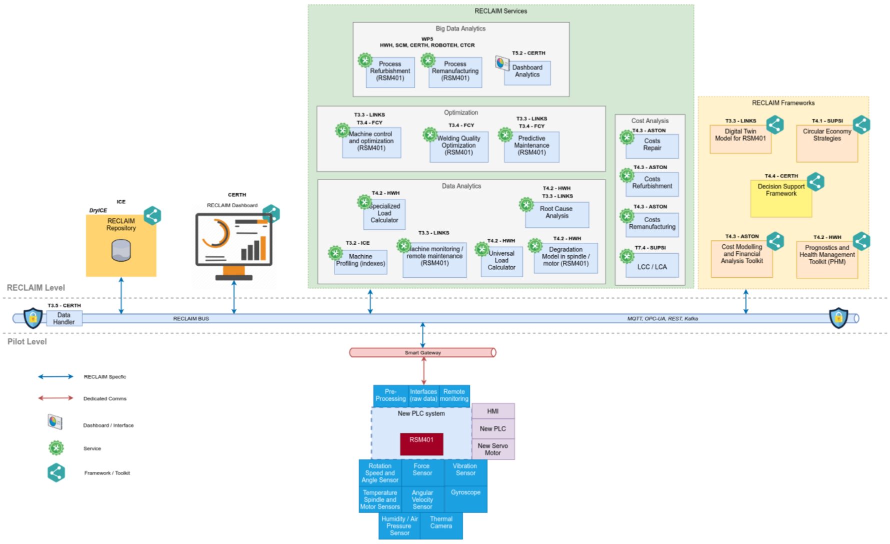

Figure 11 - HWH Pilot#4 Consolidated View.

Additionally, the following list presents the core algorithms developed in RECLAIM that can be applied in the friction welding machine.

RECLAIM Component	Description
Decision Support Framework	Optimization of different KPIs, e.g., electricity, wasted materials caused by breakdowns/malfunctions.
Reliability analysis tool and degradation models	Analysis of the health and degradation of the equipment's weakest components, e.g., motor and spindle bearings.
Machinery operational profiling	That component computes three different indexes (Health, Performance, and Production) to generate the machine's profile based on the data and parameters provided by the machines of the user partners.
Predictive maintenance and fault diagnostics	Algorithms can predict the failure of the component and consequently schedule its maintenance. They can be applied to different welding process components, e.g., motors, spindle.
Digital twin for simulation	The component goal is to evaluate different maintenance scenarios and production strategies using discrete simulation to reduce the impact of maintenance activities on the performances of a production system.
Cost Modelling and Financial Analysis Toolkit	The component (cost model) will estimate the unit cost of different strategies for equipment or their systems/sub-systems/components, which will support the Decision Support Framework.

hat verschoben (Einfügung) [3]

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Life Cycle Assessment / Life Cycle Cost	The main functionalities of the component are the following: real-time assessment of the sustainability performances, generation of machine use/refurbishment scenarios, comparison of the identified scenarios, and visualization of assessment results.

3.6 Pilot#5 - Refurbishment & Upgrading of a Bleaching Machine

Regarding the Zorluteks pilots, the focus in the RECLAIM project is the **bleaching machine**. The bleaching machine, Figure 12, is a long production line with several steps working in a continuous process where the failure of one of its components results in the loss of kilometres of textile and tons of material after their processing.

The magnitude of the bleaching production line is 250 million square meters of manufactured home textile per year. Since the raw cotton fabric comes from different suppliers, the whiteness of raw cotton fabric has a wide range of whiteness degrees; it varies depending on the season, geographic region, climate, and soil diversity. Whiteness degree variation leads to undesired results, especially fabric to be painted and printed. The bleaching is the key point at the factory where the raw cotton fabric achieves the homogeneous whiteness for the processing step of the home textile manufacturing to achieve final products.

Figure 12 -Bleaching machine.

Several parameters (temperature, time, fabric construction, and amount of bleaching chemicals, among others) affect the performance of bleaching and whiteness degree variation at this process. It is quite problematic to arrange these parameters in an optimum level for different characteristics of cotton fabric; this causes a rise in the number of re-processes in bleaching operations. Because of the re-processing operations and the necessary whiteness degree at the end of the bleaching operation, it is important to bring the bleaching machine into the IoT age where humans and sensors work together for the optimal selection of the processing parameters to minimize bleaching defects and process failure due to inspected decisions. Moreover, IoT smart sensor systems will support decision-making protocols creating a bridge between the traditional manufacture and the new smart IIoT factory. In this framework, the new IIoT smart sensor and decision tools have opened the opportunity for retrofitting and integrating innovative technology solutions based on the

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- **hat nach oben verschoben [3]:** Algorithms can and consequently schedule its maintenance. They can be applied to different welding process components, e.g., motors, spindle.¶
- **hat gelöscht:** ¶ ... [6]
- **hat gelöscht:** in
- **hat gelöscht:** kilometers
- **hat gelöscht:** . The color of cotton fabric
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- **hat gelöscht:** there

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smart monitoring and management of the critical parameters at the bleaching process and data analytic for the software-based decision supported tools development.

The bleaching machine groups several components;, these components, Figure 13, are the pre-washers, the bleaching chemical trough, the steamer, the washing baths, and the drying unit. The requirements were reviewed for each machine component; however, the focus will be in the bleaching chemical trough (chemical mixing unit), the steamer, the washing baths, and the drying unit.

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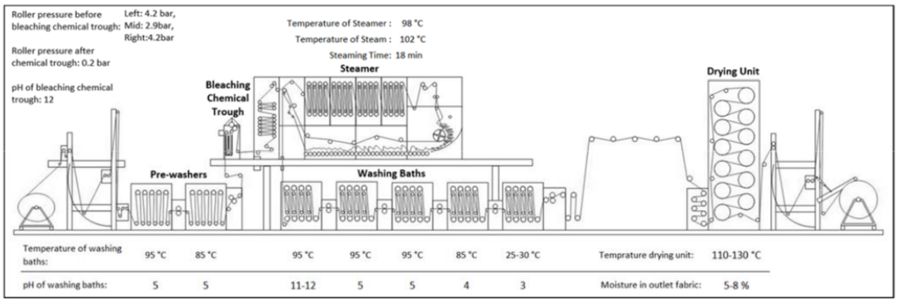

Figure 13 - Phases of the beaching process.

The first step of the bleaching process is pre-washing to wash off the starch and other impurities from desired fabric by using hot water. The bleaching machine contains two pre-washers at the inlet of the machine. Then fabric moves to the **bleaching chemical through** (chemical mixing unit), where bleaching chemicals based on the recipe are applied uniformly. After that, a bleaching reaction takes place in **steamer** at 102°C and in 18 minutes. The next step is to remove bleaching chemicals on the fabric in the **washing baths**. Although the first four washing bats contain hot water, the last one is filled with water at room temperature. Finally, the fabric is dried and ready for the following processes.

Requirements List

After summarizing the pilot scenario, including the shop-floor machines, the next stage is revising the associated requirements. Those requirements describe systems, components, hardware, and software modules that improve specific indicators, like productivity, quality, waste production, among others. The list below contains the list of the initial requirements, including a requirement classification according to the metrics described in the chapter before, i.e., validity (VLT), completeness (CPT), and realism (REAL).

- **Machine parameters monitoring (pH, pressure, temperature, moisture):** System to monitor the parameters from different stages of the bleaching process, including the monitorization of 1) pH in the bleaching chemical through and washing baths; 2) pressure sensor in the bleaching chemical through; 3) temperature in the steamer, washing baths, and drying unit; and 4) moisture in the drying unit. [classification: VLT:5, CPL:2, REAL:5]
- **Dosing pump (bleaching chemical through):** The system is used to inject the required amount of acetic acid into the last washing bath of the bleaching machine. [classification: VLT:4, CPL:2, REAL:4]

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- **Vision camera and image processing software for whiteness prediction**: Prediction of the whiteness level of the final material using computer vision algorithms. [classification: VLT:5, CPL:3, REAL:4]
- **Optimization and analysis of product quality (whiteness)**: Component to associate the bleaching process parameters and variables (temperature, chemicals, process duration) affecting the final material quality (whiteness degree). [classification: VLT:5, CPL:2, REAL:4]

Pilot Consolidated View

The requirements list described before provides an accurate image of the pilot objectives and goals regarding the components and modules to develop in the following stages. The complete representation of the pilot image is achieved through the consolidated pilot view. The pilot consolidated view includes 1) the pilot scenario composed of the machines, the hardware (infrastructure, sensors, actuators, among others), and local software components; and 2) the RECLAIM technologies including services, frameworks, repository, dashboards, etc. The following diagram shows the pilot consolidated view, considering all the components described before.

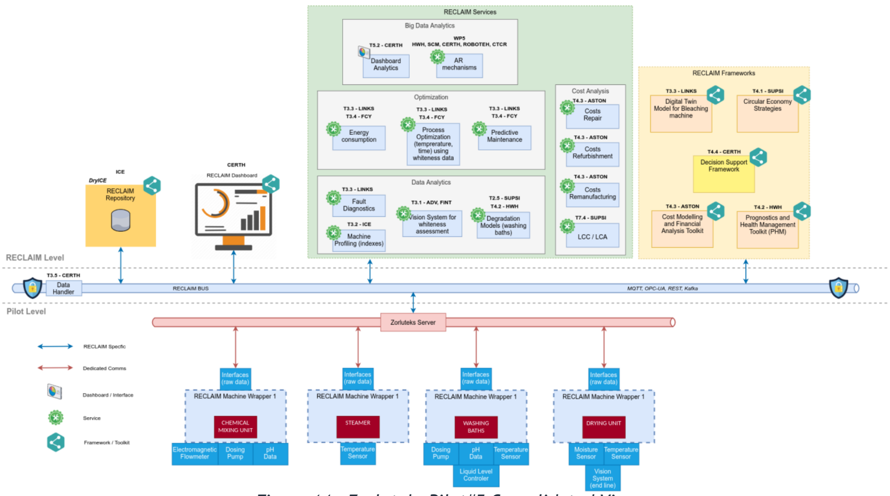

Figure 14 - Zorluteks Pilot#5 Consolidated View.

Additionally, some tools are transversal to all the components present in the bleaching machine. Those tools are the core algorithms developed in RECLAIM.

RECLAIM Component	Description

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Decision Support Framework	Optimization of different KPIs, e.g., water, electricity, chemicals, wasted materials caused by breakdowns/malfunctions.
Reliability analysis tool and degradation models	Analysis of the health and degradation of the equipment weakest components, e.g., bearings, inverters, chemical dosing pump, caps of steam pipe.
Machinery operational profiling	That component computes three different indexes (Health, Performance, and Production) to generate the machine's profile based on the data and parameters provided by the machines of the user partners.
Predictive maintenance and fault diagnostics	Algorithms can predict the component's failure and consequently schedule its maintenance. They can be applied at different bleaching process components, e.g., motors, bearings, or dosing pump.
Digital twin for simulation	The component goal is to evaluate different maintenance scenarios and production strategies using discrete simulation to reduce the impact of maintenance activities on the performances of a production system.
Cost Modelling and Financial Analysis Toolkit	The component (cost model) will estimate the unit cost of different strategies for equipment or their systems/sub-systems/components, which will support the Decision Support Framework.
Life Cycle Assessment / Life Cycle Cost	The main functionalities of the component are the following: real-time assessment of the sustainability performances, generation of machine use/refurbishment scenarios, comparison of the identified scenarios, and visualization of assessment results.
Augmented Reality (AR) mechanisms	Augmented Reality mechanisms to provide to the operator useful information about the machine state.

hat verschoben (Einfügung) [4]

hat verschoben (Einfügung) [5]

hat nach oben verschoben [4]: Analysis of the health equipment weakest components, e.g., bearings, inverters, chemical dosing pump, caps of steam pipe.

hat nach oben verschoben [5]: Algorithms can predict consequently schedule its maintenance. They can be applied at different bleaching process components, e.g., motors, bearings, or dosing pump.

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4 Lessons Learned

The Lessons Learned (LL) is the primary outcome of the task "T2.4 - Evolutionary Requirement Refinement and Validation of Requirements", providing helpful information about the revised requirements to use in the following developments. So, the current section presents the main outcomes and knowledge gained during this iteration, mainly in the workshops with the stakeholders.

The workshops with the end-users and other partners provide helpful information about the pilot scenarios, including issues and potential solutions. The workshop schedule contains an initial description of the pilot scenario, including information about machines, processes, and manufactured products, which serves as the basis for a longer explanation and discussion to improve the pilot's partners' understanding. The next topic addressed in the workshops is the pilot requirements, where the discussion focuses on the requirements validation. Finally, the last topic was the aggregation of that information in the pilot consolidated view.

4.1 Major Outcomes from Iteration #1

As mentioned before, the first iteration focuses on validating requirements through the discussion with the partners. This first discussion includes the classification of requirements through evaluation metrics, the reformulation of the requirements if needed, and the pilot's instantiation of the pilot's consolidated view. After the first iteration, all the collected information was compiled and reviewed. The major outcomes from this first iteration were:

- Collection of extra information and knowledge about the pilot scenario:
  - Definition of the machines and process to use in the RECLAIM.
  - Discussion and explanation of the pilot details, including the components (sensors, PLCs) already installed in the pilot, and the visualization of videos and images about the pilot.
- Requirements review and solutions definition:
  - Definition and revision of new sensors, controllers, or other hardware components to install in the pilot machine.
  - Clarification of the RECLAIM technologies application scenarios, such as components to apply degradation modelling, predictive algorithms objectives for example prediction of failures in motor bearing.
- Consolidation of the requirements information:
  - Classification of the requirements using the defined metrics (validity, completeness, realism), which are useful to check if the requirement is aligned with RECLAIM objectives and to keep track of the developments.
  - Aggregation of all the information in the pilot consolidated view.

The LL results serve as sources of information for other work packages and tasks, such as providing more information to the algorithm developers about the application scenarios of their methods, like the machine components, the most common failures, among others. Additionally, the LL results are helpful for the pilot level definition, providing knowledge about which sensors are beneficial to install or the integration and collection of data.

Finally, this first iteration will act as the initial basis for future iterations. In task "T2.4 - Evolutionary Requirement Refinement and Validation of Requirements", the following two

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iterations validation by prototyping (iteration #2) and validation by test scenarios (iteration #3), will use those contents to verify if the developments are according to the expected contributions and if the test scenarios allow the validation of the RECLAIM solutions.

4.2 Weakest Points and Next Steps

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Overall, the iteration #1 on the collected requirements provided fruitful information about how the RECLAIM solutions will fit the end-users' necessities. However, the restrictions in travelling due to the pandemic situation have difficulted the understanding of the end-users needs and how to handle them using RECLAIM solutions. Those limitations affected most of the RECLAIM application scenarios definition, from the sensors and hardware installation to the algorithms to apply to the collected data. Overall, those dependencies delayed the definition of the solutions. The mitigation actions to address the travelling limitations passed through the organization of online discussions with end-users personal and the RECLAIM partners, promoting the alignment between the RECLAIM technologies and the end-users' scenarios. Besides the requirements validation, those discussion sessions promoted the sharing of information about the end-users' scenario and needs, providing details and videos about the real scenario.

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Those restrictions contribute to some of the weakest points of this iteration, particularly in the level of detail of the requirements and solutions definition. The level of detail could be improved providing more information, such as the data sources for each algorithm, the infrastructure where the solutions will be deployed (e.g. cloud system, edge devices), among others. Those issues will be handled during the next period and considered during the iteration #2. Overall, the next steps will focus on the iteration #2, particularly in the new developments from the algorithms and the installation of the new hardware.

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5 Conclusion

After finishing the first iteration, the overall findings provided an accurate image of the pilot scenarios, requirements, and goals. This knowledge will serve for future developments in the pilots and iterations on the requirements. As mentioned before, one of the most significant outcomes of this iteration was the additional knowledge acquired about the pilot state of play, which is very difficult to obtain because, during the current times, we have several limitations on traveling to visit the factories due to COVID-19. Performing the workshops online instead of face-to-face was challenging due to the difficulties of obtaining the appropriate details of the pilot scenario. The knowledge and information acquisition was through images, videos, and descriptions that the pilot stakeholders collected from the actual machines. Besides those limitations, the online workshops were fruitful, providing helpful information to review the requirements and build up the pilots' consolidated view. Those workshops were performed for each of the five pilots, Gorenje, Fluchos, Podium, HWH, and Zorluteks.

After the pilot workshops, the following steps include the aggregation and consolidation of all information to serve as a basis for the subsequent developments and further iterations. The process of information aggregation produces the list of requirements and the pilot's consolidated view. The knowledge produced include 1) details about the pilot such as machines information, manufactured products, how the process works; and 2) information about the application of RECLAIM solutions to handle the pilot issues, defining application scenarios.

In a nutshell, we can affirm thatthe first iteration successfully contributed to the RECLAIM project, besides the imposed difficulties. With the conclusion of this iteration, the next steps include preparing the second iteration, always keeping track of the developments to validate if they are according to the RECLAIM goals.

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Annex A. Pilot Requirement Matrix

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Table 1 - Gorenje Pilot#1A Requirements Matrix.

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Formatierte Tabelle

USE CASE REQUIREMENTS				Problem	Effect	TECHNICAL SOLUTIONS							CLASSIFICATION		
Pilot	Productive Process	Machine	Parts			Data	Sensors, ...	Provider	Processing / SW	Integration	Refurbishment	Remanufacturing	Validity	Completeness	Realism
Pilot#1 A Gorenje	A Robot cell	Welding cell (table, control unit)	Actual parts recognition with label	Failures, wrong parts...	Bad parts reduction	- are small parts present on right place? (validate if small parts are in the right place)	vision camera	FINT, Roboteh	Image processing software for object recognition / code reader				5	1	4
			Sensors, SW for robot, manual control	Failures, wrong position for welding, wrong parts...	Bad parts reduction	- sensor for 2 storage container for parts (is storage on min.?) (detected there no more pieces)	detection sensor	ADV?	Optimization of the welding process (welding current, temperature of cooling water)				4	1	4
						..wrong current	data from control unit (goes to Roboteh PLC)	Roboteh					4	3	5
						- wrong position for welding	vision system	FINT, Roboteh					5	1	4
						..wear out of electrodes -robot and table	welding counter (Roboteh PLC)	Roboteh	prediction the wear out				5	1	3
		2 punching machines	Punch cylinder, sensors / will not be upgraded	Better efficiency, reduce of complexity	Better efficiency, bad parts reduction	..wear out of punch knives	vision camera: punching counter, Is hole present? or bad punching hole	FINT, Roboteh	Quality prediction and optimization and wear out	Already exisitng data for quality optimization?	Improve the efficiency of the existing process		5	1	4
		2 Presses	Hydraulic valves Control unit Tools	Worn out	Increase of prod. quality, bad parts reduction	- sensors for emulsion level control ..hydraulic oil (T, level, working hours, filter control?) - counter for L an U bending: hydraulic oil level control, temperature, cycles	sensors + SW	Roboteh	Optimize the KPIs	Integration with existing systems to know when a failure occurs	Change of existing parts to reduce wear out of components		4	3	5
		4 robots (1, 2, 3, 10)	Grippers for all robots, robot 2, welding control unit for robot 2	Worn out	Better quality	- control unit: failure list and all data for failures, STOPs	plc upgrade: sensors + alghoritms	Roboteh	Predictive algorithms; Compute KPI (Efficiency, OEE, etc)		Improve the existing systems to reduce wear out of components		3	2	5
	B Robot cell	6 robots (R4, R5, R6, R7, R8, R9)	Grippers and robot hands for R 6,7 , control units for robot 6,7	Worn out (run out)	Better quality	- control unit: failure list and all data for failures, STOPs	sensors + alghoritms	Roboteh	Predictive algorithms; Compute KPI (Efficiency, OEE, etc)		Improve the existing systems to reduce wear out of components		3	2	5

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		Double bending	Protective sensors	Crash	Better efficiency	..crash protective sensors ..cycle counter ..hydraulic agregates (look A)	sensors, PLC	Roboteh	Bad parts, Resource Efficiency, Waste, Maintenace Cost	Integration with existing systems		New capabilities for the machine	3	1	4
		Spot welding	Welding cell (table, control unit)	No repetability, failures, wrong position for welding	Better efficiency, less time loosing of tool changing	..wrong current	data from control unit	Roboteh	Quality prediction and optimization and wear out			New capabilities for changing tools. New gripper?	4	3	5
			Electrodes with click system	No repetability, failures, wrong position for welding		wear out of electrodes - robot and table	welding counter	Roboteh					5	1	3
			New insert of tool	Bad quality	Improving of function										
		Seam welding	Drive unit	Bad welding quality	Better efficiency, better quality										
			Sensors for welding parameters			..speed ..T of cooling water ..wrong current (to eliminate tube)	robot speed adjustment to welding reel speed, data from control unit (data from control unit)	Roboteh	Quality prediction and optimization and wear out; predict when are the lubrication cycles	Integration with existing welding controllers / already existing data to use?			5	1	3
			Welding control unit			wear out of electrodes (welding counter for small and big welding roller and T), to predict lubrication cycles	welding counter	Roboteh					5	1	3
		Cooling water system	Dirty work environment	Bad working condition, bad water quality, dirty, too big water consumption	Lower water consumption	recycling	water flow meter	GAIO	Resource efficiency optimization; Optimize KPI (water consumption)	Already exisitng data?			5	2	4
	C Robot cell	Hydraulic agregate	Hydraulic agregate	Worn out	Better production quality	- sensors for emulsion level control ..hydraulic oil (T, G28level, working hours, filter control?) - counter	sensors + SW	Roboteh	fault diagnosis, KPI optimization		Improve the existing systems to reduce wear out of components		5	1	3
			Control unit	Worn out	Better production quality						Improve the existing systems to reduce wear out of components				
		Tightness control system	Manual	Bad quality	*New system needed*	*counter, statistic*	*sensor*	*potential challenge?*	Control software		Replacement of existing system for a new one				
		Double bending	Protective sensors	Crash	Better efficiency	..crash protective sensors ..cycle counter ..hydraulic agregates (look A)	sensors, PLC	Roboteh	Bad parts, Resource Efficiency, Waste, Maintenace Cost	Integration with existing systems		New capabilities for the machine	3	1	4
	D Robot cell	Ovens (4. pieces)	Control unit and regulators	Electrical unpredictable shutdown the machine	Better efficiency	regulators and control unit	hardware upgrade (regulation system)	?	Monitoring system, Optimize KPIs (big maintenaces costs)		Improve the electrical system of the achine		3	1	4

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		Support for bending bitumen	Jigs for support bitumen	Bad quality	Bad parts reduction						Improve fixture system				
		Cooling system after insulation	Transport system	Too slow	Better efficiency				Monitoring system		Improve speed				
		4 robots (12,13,14,15)	Grippers and robots	Worn out	Better quality	- control unit: failure list and all data for failures, STOPs	sensors + alghoritms	Roboteh	Predictive algorithms; Compute KPI (Efficiency, OEE, etc)		Improve the existing systems to reduce wear out of components	mechanical upgrade in all robots	3	2	5
	E Robot cell	Measurement system	Measurement equipment	No output data	Better quality				Monitoring system	acquire data from existing systems		New capabilites for the system			
	Outer Bottom cell	Robot	Gripper	Worn out	Better quality	- control unit: failure list and all data for failures, STOPs	sensors + alghoritms	Roboteh	Predictive algorithms; Compute KPI (Efficiency, OEE, etc)		Improve the existing systems to reduce wear out of components	mechanical upgrade in all robots	3	2	5
		Welding table	Table	Position of parts	Better efficiency		need to define	GAIO			Improve fixture system				
	All cells	PLC upgrade	Control units	Update	Parameters and parts				Monitoring system		New PLC				
		CE - Declaration of Conformity	CE for all changed and new integrated equipment	Safety reason	Under Low										

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Table 2 - Gorenje Pilot#1B Requirements Matrix.

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Formatierte Tabelle

USE CASE REQUIREMENTS				Problem	Effect	TECHNICAL SOLUTIONS					CLASSIFICATION		
Pilot	Productive Process	Machine	Parts			Sensorization	Processing / SW	Integration	Refurbishment	Remanufacturing	Validity	Completeness	Realism
Pilot#1 B (MORA)	1.Spraying cabine	1.1 Aplication technology of enamelling powder		worn out - new delivery from specific company					Try to link sensorization and other components to refurbishment.				
		1.2 Chain conveyor		worn out									
		1,3 Hangers for parts		worn out									
	2. Furnace	Furnace with new temperature insulation, new gas burners and tubes		worn out - new delivery from specific company									
	3. Traceability	Machine Vision Camera	equippment for identification of parts on the beginning of line	identify different parts at the beginning of line (raw metal sheet parts)	avoid mistakes (men factor) in recording of produced parts	high resolution camera (only one camera)	Image processing software for object recognition / code reader (information about pieces IDs, shape - logistics)				2	1	3
			Equippment for identification of parts on the end of line	identify different parts at the end of line (enamelled parts)	avoid mistakes (men factor) in recording of produced parts	high resolution camera	Image processing software for object recognition / code reader						
		Application (SW) for measuring and recording surrounding parameters	thermometers	we need on line measuring of temperature parameters on several places of line and recording	knowlage of present parameters andhistorical values in spraying cabine, furnace and surounding	Temperature sensors	Monitoring system (see historic)				2	1	3
			measuring of humidity and speed of conveyor	on line measuring and recording of humidity on several places and measuring of speed of both conveyors	to be able to check and control process, possibility to make simulations and have history for better understanding	Humidity and Speed Sensors	Monitoring system (see historic)				2	1	3
		Equipment for measuring of thickness of enamelled parts	Equippment for continuous measuring of thickness of enamell	low and high thickness of enamel means quality problem	we need to check and control optimal thickness of enamell on parts	Thickness (Lazer?) Sensors	Monitoring system (see historic) / Diagnostics (Quality)				3	1	3

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Lessons Learned and updated requirements report #1

Table 3 - Fluchos Pilot#2 Requirements Matrix.

USE CASE REQUIREMENTS				Problem	Effect	TECHNICAL SOLUTIONS					CLASSIFICATION		
Pilot	Productive Process	Machine	Parts			Sensorization	Processing / SW	Integration	Refurbishment	Remanufacturing	Validity	Completeness	Realism
Pilot#2Footwear manufacturing	Forming of rear parts of the shoes, through pressure and thermal treatments	1. Forming machine for rear parts. Talonadora	1.1 Heating (Optim)	1.1.1 Incorrect temperature	The material does not fit the last shape	Reusing Temperature	Quality Optimization	Reusing Temperature	Improve existing capabilities		3	1	2
				1.1.2 Power consumption	Deviations in the average consumption	Current and voltage sensors	Energy Efficiency	Integration with quality monitoring system / user feedback	Improve existing capabilities		3	1	4
			1.2 Hot pressing (ref / rem)	1.2.1 Low pneumatic pressure	Unplanned downtime			New parts?	Improve existing capabilities		4	1	3
				1.2.2 Rubber fatigue	Breakage of membranes	Deformation of membrane	Degradation prediction / Fault Diagnostics	New parts?	Improve existing capabilities		4	1	3
				1.2.3 High membrane pressure	Breakage of membranes	Deformation of membrane		New parts?	Improve existing capabilities		4	1	3
				1.2.4 Vibrations	Unplanned downtime	Not defined (Next Step)	Predictive maintenance / Fault Diagnostics	New parts?	Improve existing capabilities		4	1	3
				1.2.5 Temperature of the material	Material damage	Not defined (Next Step)	Monitoring system	Integration with control system	Improve existing capabilities		3	1	4
			1.3 Cooling (optim)	1.3.1 Incorrect temperature	The material does not keep its shape	Reusing Temperature Sensor from Machine	Quality Optimization	Reusing Temperature Sensor from Machine	Improve existing capabilities		3	1	2
				1.3.2 Power consumption	Deviations in the average consumption	Current and voltage sensors	Energy Efficiency		Improve existing capabilities		4	1	4
				1.3.3 Coolant gas leaks	Unsuitable temperature	Not defined (Next Step)	Fault diagnostics	Integration with control system	Improve existing capabilities		4	1	3
			1.4 Cold pressing (ref / rem)	1.4.1 Low pneumatic pressure	Unplanned downtime		Predictive maintenance / Fault Diagnostics	New parts?	Improve existing capabilities		4	1	3
				1.4.2 Fatigue	Breakage of membranes	Deformation of membrane	Degradation prediction / Fault Diagnostics	New parts?	Improve existing capabilities		4	1	3
				1.4.3 High membrane pressure	Breakage of membranes	Deformation of membrane		New parts?	Improve existing capabilities		4	1	3
				1.4.4 Vibrations	Unplanned downtime	Not defined (Next Step)	Predictive maintenance / Fault Diagnostics	New parts?	Improve existing capabilities		4	1	3
				1.4.5 Temperature of the material	Lack of quality	Reusing Temperature Sensor from Machine	Process Optimization (Quality Optimization)	Reusing Temperature Sensor from Machine	Improve existing capabilities		3	1	2

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	Forming of upper parts of the shoes, through pressure and thermal treatments	**2. Forming machine for front parts. Rotostir**	2.1 Engine	2.1.1 Power Consumption	Deviations in the average consumption	Current and voltage sensors	Energy Efficiency		Improve existing capabilities		3	1	3
				2.1.2 Carbon Footprint	Environmental	Environmental sensors (connected with 2.1.1.)	Energy Efficiency	Integration with control system			3	1	3
			2.2 Hot deforming	2.2.1 Membrane Pressure	Breakage of membranes	Not defined (Next Step)	Degradation prediction	New parts?	Improve existing capabilities		4	1	2
				2.2.2 Temperature of the material	Lack of quality and bad shape of the material	Temperature sensors (not for this iteration)	Process Optimization (Quality Optimization)	Integration with quality monitoring system / user feedback			3	1	2
	Cutting of the leather to obtain the components that will be joined to create the upper part	3. Cutting machine	3.1 Movement (Electric Actuator)	2.2.2 Vibrations	Lack of precision in the process					Mechanical Parts	2	1	2
				2.2.3 Incorrect average speed	Operation time decreasement	Sensors?	Process Optimization	Integration with control system		Mechanical Parts	3	1	3
				2.2.4 Incorrect acceleration	Operation time decreasement	Sensors?	Process Optimization	Integration with control system		Mechanical Parts	3	1	3
				2.2.5 High actuators temperature	Unplanned downtime	Temperature sensors	Predictive maintenance / Fault Diagnostics	Integration with control system	Improve existing capabilities		4	1	4
			3.3 Cutting tool (spin)	2.3.1 Tool wear	Material tearing	Sensors?	Degradation prediction	New parts?	Improve existing capabilities		4	1	2
				2.3.2 Tool temperature	Material damage, tool wear	Temperature sensors	Predictive maintenance / Fault Diagnostics	Integration with control system			4	1	3
			3.4 Leather clamping (suction)	2.4.1 Power consumption	Deviations in the average consumption	Current and voltage sensors	Energy Efficiency		Improve existing capabilities		4	1	3
				2.4.2 Low pneumatic pressure	Lack of quality - precision					Mechanical Parts	2	1	2

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Lessons Learned and updated requirements report #1

Table 4 - Podium Pilot#3 Requirements Matrix.

USE CASE REQUIREMENTS			Problem	Effect	TECHNICAL SOLUTION					CLASSIFICATION		
Productive Process	Machine	Parts			Sensorization	Processing / SW	Integration	Refurbishment	Remanufacturing	Validity	Completeness	Realism
Storage panels	Linde R25F electric lift	Handling	The storage of panels is done by dividing them into clusters by colour and quality. The choice of panels to be processed and the consequent return of the cuttings to be put back in the scans is quite complex.	Waste and scrap management - storage and possibility of reuse	Sensors?	Quality monitoring for more informed decisions						
		Elevation	Different heights stable collision risk	Breakdown and downtime					Mechanical parts			
		Recharge	Battery maintenance and recharge control	if the battery breaks no longer works	Current and Voltage Sensors	Monitor full battery cycles / Fault diagnostics			New capability			
Cutting	Automatic loading	Loading rollers							New capability			
		Robot automation	Loads only the material that is given to it without any system	Automatic storage? With system for the remains ?	Vision system?	Control software / Path planning			New capability			
		Vacuum	Regular maintenance	Does not hold the panel	pressure? sensor	Predictive Maintenance / Fault Diagnostics		improve existing capabilities				
	Holzma HKL Horizontal panel saw X + Y cutting machine	Panel progress	Entry side inlet port is 2100mm, larger panels to be optimized differently						Mechanical parts			
		Cuttig blade	Not precise square cut	Problems for the following processes not relevant for IMA instead Homag problem								
		PC + eletronics	Compatibility with other production management programs	Panel passage control and CNC program management		Monitoting (digital twin) (input data, stops, impact)	Integration with third party systems	Improve / enable existing capabilities		4	2	2
		software	Incompatible / obsolete	Manual programming								
		Print Labels and Scanners? (traceability)	Compatibility with other production management programs	Direct label bonding system?	Monitoring (traceability)		Integration with third party systems	Improve / enable existing capabilities		3	3	4
	Holzma HPP11 "out of series" cuts	Panel progress			new sensors?	Process optimization / GUI		Refurbishment of the whole system	Mechanical / new control systems?			
		Cuttig blade										
		PC + eletronics										
Edgebander	IMA	Scanner	Compatibility with other production management programs	Panel passage control and CNC program management		Monitoting (digital twin)	Integration with third party systems			4	2	2
		Milling machine	Sharpening	Quality of cutting	Quality Sensor (Vision System)	Monitoring (traceabilty of	Integration with control system	Mechanical		4	3	2

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						problem), Quality Analysis						
		Laser	Visible junction, temperature ?	FINAL quality visible joint	Quality Sensor (Vision System)	Monitoring (traceabilty of problem), Quality Analysis	Integration with control system	Mechanical		4	3	2
		Glue PU	Tank pressurization	Avoids the daily cleaning of the element	flow / pressure sesnors	Process optimization	Integration with control system		Electrical / Mechincal system	4	3	2
			Substitution glue - colour	Replacement complicated	sensor	Monitoring (alarm before glue finish)		Improve the replacement process		4	3	2
			Too much glue / too little	Final cleaning and edge hold	flow / pressure sesnors	Process optimization	Integration with control system			4	3	2
		Handling chain	Automatic thickness and speed regulation of the piece			Process optimization / change control system						
			The piece is not held well	Roller cleaning		Process optimization / change control system						
		Edge pressing				Process optimization / change control system						
		Edge storage / Edge	Edge quality (supplier)	Visible joint (see white line)	Quality Sensor (Vision System)	Monitoring (traceabilty of problem), Quality Analysis	Integration with control system			4	3	2
		Edge cutting	Setting	Cut length imperfection	Quality Sensor (Vision System)	Monitoring (traceabilty of problem), Quality Analysis	Integration with control system			4	3	2
		Edge milling	Setting		Quality Sensor (Vision System)	Monitoring (traceabilty of problem), Quality Analysis	Integration with control system			4	3	2
		Edge edging	Regular maintenance			Predictive maintenance / fault diagnostics				4	3	3
		Glue sraper	Regular maintenance			Predictive maintenance / fault diagnostics	Integration with control system			4	3	3
		Scraper	Regular maintenance			Predictive maintenance / fault diagnostics				4	3	3
		Cleaning	Regular maintenance			Predictive maintenance / fault diagnostics				4	3	3
		Electronic control panel	Suffers the summer heat	Additional air conditioner					Mechanical / Electrical			
	Automated return	Robot automation	Turning device	Data loss problems (PC) - due to lowering of maintenance		Monitoring system	Integration with existing system					

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		Rollers	Supported by conveyor belts						Mechanical			
	Homag	Scanner	Compatibility with other production management programs	Panel passage control and CNC program management		Monitoting (digital twin)	Integration with third party systems					
		Milling machine	Sharpening	Quality of cutting		degradation prediction	Integration with control system	Mechanical				
		Glue PU	Pressurization tank						Electrical / Mechincal system			
			Too much glue / too little	Final cleaning and edge hold	flow / pressure sesnors	Process optimization	Integration with control system					
			Substitution glue - colour	Easy to replace				Improve the replacement process				
		Handling chain	Automatic thickness setting			Process optimization / change control system						
		Edge pressing	Regular maintenance			Process optimization / change control system						
		Edge storage	Regular maintenance			Process optimization / change control system						
		Edge cutting	Regular maintenance			Process optimization / change control system						
		Edge milling	Regular maintenance			Process Parameter Optimization						
		Edge edging	Regular maintenance			Process Parameter Optimization						
		Glue sraper	Regular maintenance			Predictive maintenance / fault diagnostics						
		Scraper	Regular maintenance			Predictive maintenance / fault diagnostics						
	Return rollers	Rollers	supported by conveyor belts						Mechanical			
Drilling machine	Drilling machine fronts MAW	Scanner	Is not there at the moment	Compatibility with other production management programs		Monitoting (digital twin)	Integration with third party systems					
		Milling	Yes						Mechanical			
		Drilling	Yes						Mechanical			
		Hardware insertion	Yes						Mechanical			
		Software	Incompatible / obsolete	Manual programming		New control system		Replacement of exisiting system				

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		Scanner	With current labels works, for the programming of the whole production would be to see	Compatibility with other production management programs		Monitoting (digital twin)	Integration with third party systems					
	Drilling machine Bremen	Milling	Yes						Mechanical			
		Drilling	Yes						Mechanical			
		Hardware insertion	Yes						Mechanical			
		Plugs	Yes						Mechanical			
	Homag special CNC	Scanner	Yes	Incompatibility of use for the current system		Monitoting (digital twin)	Integration with third party systems					
		Cutting	Yes						Mechanical			
		Milling	Yes						Mechanical			
		Drilling	Yes						Mechanical			
		Edging	Yes						Mechanical			
Assembly	Weighing caissons	Press	Bottleneck						Mechanical			
		Rollers	Yes						Mechanical			
		Automated assembly		Scan label to read box size?	Vision system / scanner	Classification system						
	Drawer assembly	Grass structure	Assembly of drawers and pull-outs						Mechanical			
		Blum structure	Yes						Mechanical			
		PC for itemized list reading				Monitoring system						
	Final assembly	Rollers	Yes						Mechanical			
		PC reading				Monitoring system						
		Scan labels			Vision system / scanner	Classification						
Packaging	Automatic film coating	Film automation	Yes						Mechanical			
		Scanner -Check to PC ?	Yes	Compatibility with other production management programs		Monitoting (digital twin)	Integration with third party systems					

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	Hardware packaging	Scanner -Check to PC ?	Yes	Compatibility with other production management programs		Monitoting (digital twin)	Integration with third party systems					
			with cardboard boxes									
			with protective film									
	Final storage	Via transpalett							Mechanical			
		Loading platfomr truck	Elevator						Mechanical			
		Outout scanner	Check out goods	What's on a pallet? How many pallets have come out? Has the hardware store been checked and everything's there?	Vision system	Counting and object identification						
		Scanner Hollenstein	Hollenstein load control	What and when did he upload		Monitoting (digital twin)	Integration with third party systems					

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Table 5 - HWH Pilot#4 Requirements Matrix.

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USE CASE REQUIREMENTS				Problem	Effect	Remarks	Technical Development					Classification		
Pilot	Productive Process	Machine	Parts				Sensorization	Processing / SW	Integration	Refurbishment	Remanufacturing	Validity	Completeness	Realism
Pilot#4 Friction Welding Machines	1.Friction welding processes for various applications	1.1 "Lufthansa" machine (RSM401)	1.1.1 Electrical cabinet	Standards on safety not sufficiently implemented	Machine cannot be used	Is made in parallel to the overall Pilot construction; no direct research work				Electrical / Mechanical		1	1	3
			1.1.2 Spindel	No prediction on wear-out	Sudden break-downs	No mechanical adjustment ror modification of the spindle; concentration on performance monitoring of the spindel	New Sensors (rotation speed, force, env temperatures)	Degradation Prediction, Root Cause Analysis, Failure Detection	Integration with existing Controller and sensors			5	2	4
			1.1.3 Motor/converter	No prediction on wear-out; not state of the art (servo technology preferred)	Sudden break-downs	Current drive is to be replaced by an up-to-date servo-based drive; concept analogous to HWH ROTAV system - same basic mechanical structure; manufacturer for servo-based drive company Engel; converter from company Sieb+Meyer (as for ROTAV); interface to Genius already available; PLC card must not be used under any circumstances!	New Sensors	Degradation Prediction	Integration with existing Controller and sensors		New servo motor	5	2	4
			1.1.4 PLC	No standard HWH component, connection to standard HWH technology not possible	Does not fit well in HWH portfolio; double work	To be replaced by a HWH XGenius control		Digital twin technology (for digitalization, monitoring)	Integration with third party systems	New PLC technology		4	2	3
			1.1.5 Panel	Outdated, panel not available anymore	Machine cannot be sold	To be replaced by a new model				New plate		1	2	3
			1.1.6 HMI	Old technology, not state of the art	Machine cannot be sold	Requirements (among others): Web technology, responsive, nice workflow, interactive		Web based technology (flexibility, user frendly) (include degradation)	Integration with PLC / Controller			3	2	4
			1.1.7 Remote maintenance/monitoring	Remote monitoring "just in case" and very restricted	Potential malfunctions cannot be detected in advance	At least remote monitoring in terms of machine data analysis and visualization to be implemented. Internal HWH project name "Odysseus"		Remote Digital twin tehcnology for remote monitoring / maintenance actions (same as HMI, include remote maintenance algorithm)	Integration with PLC / Controller			3	2	4
			1.1.8 Valves	Very slowly; suffer from wear; no maintenance possible	Higher machine downtimes			Control software, Monitoring	Integration with PLC / Controller		New valves technoogy	3	2	3
			1.1.9 Hydraulic collect system	Wear out at sealing	Downtime			Control software	Integration with PLC / Controller		New valves technoogy	3	2	3
		1.2 General friction	1.2.1 Similar to 1.1											

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		welding machine (RSM 410)	1.2.2 Welding stroke	Stroke too slow		At the moment a pneumatic-hydraulic pressure ratio is installed => slow, poorly controllable; the aim is a servo-hydralic pressure ratio; Important: Costs must fit; Therefore we first need to perform a technological feasability study and a cost estimation; Furthermore, a market analysis is required to estimate the demand		Control software	Integration with PLC / Controller		Servo Technology	4	5	4
		1.3 RFSSW (Refill friction stir spot welding) machine (RPS)	1.3.1 RFSSW (Refill friction stir spot welding) machine (RPS)	Very difficult to mount		Limit switches are difficult to install => mechanical revision or saving of the switches; when saving, the control must also be adapted (other referencing must be implemented)					Mechanical part	2	2	3
			1.3.2 Similar to 1.1			At least Genius instead of PLC, new panel, new HMI must be targeted								

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Table 6 - Zorluteks Pilot#5 Requirements Matrix.

Formatiert: Beschriftung, Zentriert, Nicht vom nächsten Absatz trennen

Formatierte Tabelle

USE CASE REQUIREMENTS			Problem	Effect	Sensorization	Processing / SW	Integration	Refurbishment	Remanufacturing	CLASSIFICATION		
Pilot	Productive Process	Machine								Validity	Completeness	Realism
Pilot#5 (Zorluteks)	BLEACHING MACHINE	CHEMICAL MIXING UNIT & BLEACHING CHEMICAL TROUGH	Failure at dosing system	If chemical amount is not enough, reactions cannot take place properly which affects whiteness of fabric		Control Software	Existing controllers			4	1	4
			Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleachingprocess totally								
			Lack of pH sensor	It affects both whiteness and strength of the fabric		Monitoring Manually				3	1	4
			High roller pressure after chemical trough	It causes removing sheer amount of chemical on the fabric surface which affects whiteness		Monitoring Manually				3	1	4
		STEAMER	Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleaching process totally								
			Low steamer timing	Reactions cannot take place properly which affects whiteness of fabric	Temperature Sensor	Monitoring Onlinne	Existing controllers			5	1	5
			High steamer timing	It results diminishing fabric strength								
		WASHING BATHS	Low pH	It is hard to remove de sizing agents which affects whiteness of fabric		Monitoring Manually				3	1	4
			High pH	It lowers to strength of fabric								
			Lack of pH sensor	It affects both whiteness and strength of the fabric								
			Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleaching process totally		Liquid Level Controller						
			Failure at valves for water supply	It prevents recycling of water inside the washers which has a negative effect on both cleaning of fabric and pH of the washers		Control Software	Existing controllers	New system (pump)				
			Failure at bearings	It affects movement of the fabric inside the bleaching machine		Degradation Models (notes about which bearing is failing)				5	1	3
			Low temperature	It is hard to remove caustic on the fabric surface at low temperature which affects whiteness	Temperature Sensor	Monitoring	Existing controllers			5	1	5
		NEUTRALIZING COMPARTMENT	Lack of pH sensor	It affects both whiteness and strength of the fabric.		Monitoring Manually					1	
		DRYING UNIT	Failure at temperature sensor	Temperature level does not be controlled. It affects whiteness	Temperature Sensor	Monitoring	Existing controllers			5	1	5
			High temperature	Colour of fabric turn yellow								
			Failure at moisture sensor	Moisture level, which has a significant importance for the next processes, doesn't be controlled	Moisture Sensor	Monitoring	Existing controllers			5	1	5
			Failure to perform regular cleaning	Condensing steam and dirtiness in the drying unit lead to tenacious stains on the fabric surface								

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				Monitor whitness	Vision System	Monitoring				5	1	5

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