Refurbishment and re-manufacturing of large industrial equipment

RECLAIM Use Cases Definition & Operational Requirements #1

[July 2020 – M10]

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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 & Acronyms

Abbreviations & Acronyms	
3D	3-Dimensional
AR	Augmented Reality
ASN	Adaptive Sensorial Network
CPPS	Cyber-Physical Production System
DSF	Decision Support Framework
FPGA	Field-Programmable Gate Array
HMD	Head-Mounted Display
IMU	Inertial Measurement Unit
IoT	Internet of Things
IIoT	Industrial Internet of Things
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
M2M	Machine-to-Machine
MTBF	Mean Time Between Failures
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair
SCADA	Supervisory Control And Data Acquisition
CEN	European Committee for Standardisation
ISO	International Standard Organisation
IEC	International Elechtrotecnical Commission
UNI	Ente Nazionale Italiano di Unificazione
NAMUR	User Association of Automation Technology in Process Industries
KoM	Kick-Off Meeting
RC	Robotic Cell
PLC	Programmable Logic Controller
DW	Dishwasher

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Summary

The vision of RECLAIM is to demonstrate the physical and virtual technologies, as well as, a 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 this industries and factories into the market again with competitive and sustainable skills; without the substantial inversion that industrial machinery and tools means.

RECLAIM solutions will support Europe to maintain a health industrial fabric based in preparedness to the digital change in a really non expensive and realistic way accessible for all industrial sectors and sizes, from micro-SMEs to macro-industries based in the physical and digital retrofitting of its facilities without 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 that could support digital twins and decision support tool to demonstrate the robustness of these high innovative technological solutions.

RECLAIM tools aims 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.

The D2.2 deliverable, RECLAIM Use Cases Definition & Operational Requirements #1, in its first version will approach from the industrial requirements to the technological solution to consolidate the real activities within the project objectives. To perform this activity several workshop, physical and virtual, has been carried out for the completion of a depth analysis from the use cases and the solution to satisfy their digitalization needs.

Disclaimer

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1 Introduction

The D2.2, RECLAIM Use Cases Definition & Operational Requirements #1, deliverable of RECLAIM project collects the mains results and conclusion form the activities developed at the T2.2, Industrial Use Cases and Scenarios Design, in its first approach. This deliverable links with deliverables D2.6 and D2.7, where subsequent version of this deliverable will be conducted in their #2 and #3 version for the complete analysis and revision of the RECLAIM Use Cases.

Based in the initial high-level description provided by the industrial Use Cases leaders at the KoM, all consortium members involved directly or indirectly in this task has perform a structured analysis of the RECLAIM use cases to understand the problems involved in any of the use cases for its retrofitting based in the RECLAIM physical and digital tools. This exercise aims to propose as its first approach an initial vision of the Pilots where the scientific and technological solutions will be demonstrated and validated. The RECLAIM Use Cases Definition & Operational Requirements #2 will include detailed description of the Pilots and the technical components for the demonstrations, diagrams, schemes, etc, and the #3 document will cover the refinement of requirements, technical specifications and scenarios based in the natural evolution of the Pilots understanding due to the developments of the project activities. The Key Performance Indicators, KPIs, to measure the effectiveness of the Pilots demonstration will be proposed at the second version and reviewed at the D2.7.

A short summary of the **methodological main phases** for operational requirements and scenario definition of RECLAIM use cases is as follow:

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

The document is structured in nine section to conduct the reader to a full understanding of the RECLAIM pilots, technologies and scenarios, in its first version from the based on the retrofitting of ageing and obsoleted machines and production lines at the white goods, footwear, wood furniture, welding and home textile sectors. These sectors will have potential homogeneous conclusions, even if the sector diversity is substantial, the methodology proposed try to structure the analysis

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in two pillars, use cases requirements matrices and technologies matrices, both of them supported for the standardisations existing or future requirements. The first chapter is this introduction to the document contents. The second chapter is focused to the description of the methodology use for the requirements and technologies collection, structuration and analysis based on the specifically developed matrix, including the matrices categorization and prioritization. Followed by the presentation of the methodology proposed for the data gathering. A third section will introduce the reader to analysis of the main results obtained from the chapter 2 and their analysis in the framework of the project. The chapter 4 described the industrial use cases in detail, followed by the section 5 where the physical and virtual RECLAIM solutions are described briefly. The chapter no. 6 compiles the scenarios and the technologies that fit within these scenarios for their practical demonstration into WP6 and to be develop along WP3 and WP4. The alignment with current and future standardization requirements is conducted at chapter 7, followed by eighth and ninth section where the initial conclusion of the T2.2 are detailed and the reference, respectively. Several annexes, from 1 to 4 are included to complement these sections' content.

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2 Methodology description.

The identification of operational requirements for the detailed definition of use cases could be addressed top-down when the final application in one end-user centred. At RECLAIM project, six use cases from a broad spectrum of manufacturing sectors are proposed and the used of the traditional approach top-down, where a detailed list of requirements are defined or collected from the main representative industrial actors at the sector for their categorization, is not possible because of the process rigidity. Due to this fact, bottom-up methodological approach has been developed for the detailed approach to the operational requirements definition and their matching with the technological solution to reach a precise proposition of the RECLAIM scenarios for the demonstration of the Pilots. This methodology was proposed by Tecnalia at the CARONTE project (G.A.: 606967) where a multi-sectorial and multi-actor (authorities, stakeholder, industrials, etc) approach were required for the transport sector.

The methodology architecture is detailed at Figure 1, where the main objectives are the compilation of the following information:

- Requirement identification by use cases.
- To prioritize requirements.
- Technical specification definition.
- To align requirements and technical specifications for its demonstration.
- To include standardization need (current and futures).
- To define the Pilot scenario for the RECLAIM solution validation.

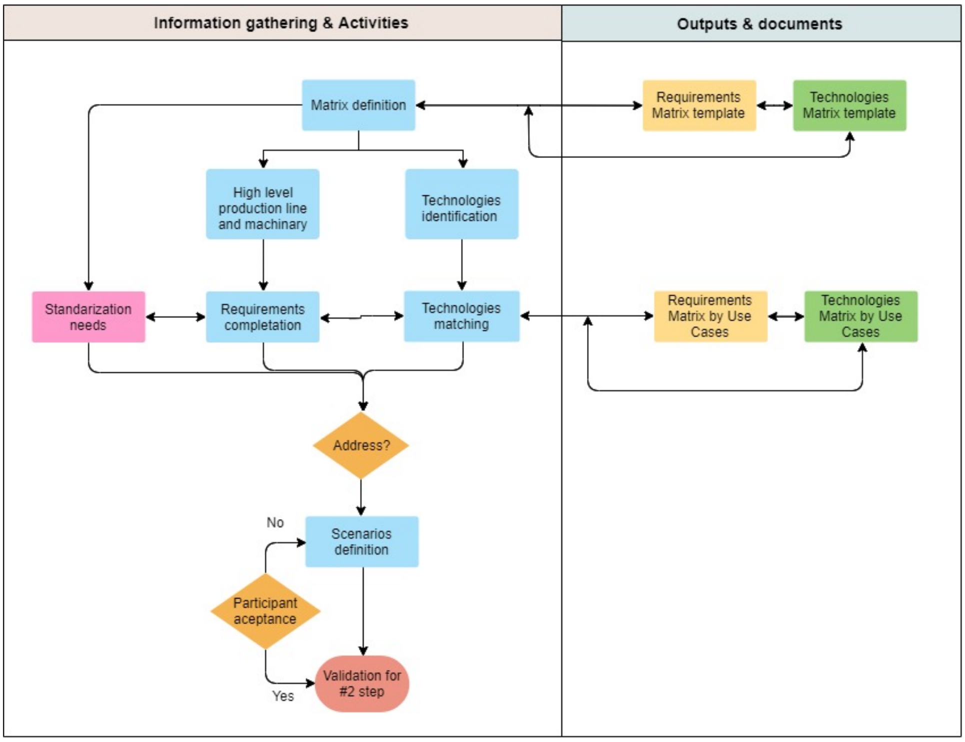

Figure 1 Methodology structuration of the activities and documents.

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The exercises were carried out between all the partners involved in the T2.2 and all consortium members than voluntarily took place of the activities, workshop and analysis for the understanding of the requirements and the technologies for its successful demonstration. The activities have involved the preparation, adaptation or documentation to develop the necessary documents where the industrial and technological partners implement its information, matrix templates, virtual panels, virtual and physical meetings and templates documents to gather all the information described at the present deliverable. The exercise had been performed for the six RECLAIM pilot individually, except the general meeting for the methodology presentation.

The tools, that had been developed, were available for RECLAIM project members during the process and they are detailed in next sections. The first approach has been performed using two matrixes, section 2.1; the first one, for each pilot requirements identification and, the second one, for the technological specification identification. To go deeper in those requirements and technologies, with the industrial and technological actors involved in the pilots and the volunteer partners, face-to-face and virtual meetings and interviews have been carried out. The methodology of these interviews is presented in section 2.2.

2.1 Matrix formulation.

2.1.1 Matrix of Requirements.

The collection with a structured and uniform method required of the development of tools for the consortium members where all the requirements could be represented in a unified and comprehensible manner. The first step toward achieving a homogeneous view of all industrial use cases is the division of the RECLAIM pilot into the different productive process of the factories. After the productive process identification, the compendium of machinery susceptible of retrofitting, remanufacturing or refurbishment due to obsolescence or ageing was the second step of the matrix. Due to the fact that the refurbishment need could not affect to the full machine, a new category was introduced for the detailed understanding of the requirement to be fulfil by RECLAIM technological solutions. The matrix structure is shown in Figure 2.

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USE CASE REQUIREMENTS			
Pilot	Productive Process	Machine	Parts
Pilot#2Footwear manufacturing	1.Forming machine for rear parts	1.1 Heating	1.1.1 Temperature control
			1.1.2 Power Consumption
		1.2 Pressing	1.2.1 Efforts
			1.2.2 Vibration
			1.2.3 Temperature material

Figure 2 Requirements Matrix: columns for the identification of the pilot and the specific component of the machine to be considered for requirements identification.

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For the practical use, the first columns at Figure 2 was assigned to the pilot numbering and identification, the second one was the productive process involved in the use case, the third described the different machines followed of the component of element of the machine where the obsolescence problem and issues had been observed.

The first area of the matrix is focus on the classification and identification of the manufacturing process, and its followed by the problem categorization area, Figure 3, where the problem to be address is described including their consequences, their classification and the severity definition. Followed by a fifth column dedicated to the priority assignation to each problem addressed at the use cases. This two last columns, severity and priority will be the basic for the identification of the main problems were the technological effort should be addressed, as long as the RECLAIM technological solution could solve the problem when its magnitude has the necessary relevance to be considered an important requirement for the industrial sector that the pilot owner represent or similar to additional sectors not represented at the project properly.

Problem	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
		Classification	If Other is selected write a little explanation		
Low temperature for the proccess	Deformation of the shoe (Bad piece)	Mechanical		4	5

Figure 3 Requirements Matrix: identification of the problem to be addressed.

The problems' typology has been described in a short, precisely and succinct for each machinery elements or components. A general classification of the problem typology has been defined into main categories, electrical, mechanical, chemical and software, a fifth category were included for other aspects that could not be included in the previous ones. The severity of each problem should be expressed in the matrix by the industrial use cases leaders to support the prioritization between requirements and technologies. The detailed information of any concept was included in the requirements matrix and the concept are shown in Figure 4.

Priority	Definition
1	Very low. The solution could not imply a significant added value.
2	Low. The added value or the cost/effeteness does not justify the technical or economical effort.
3	Medium. The solution is a partial advance to solve the existing problem.
4	High. The solution fit with the existing problem.
5	Necessary. The solution is necessary to will reduce obsolescence.
6	Indispensable. The solution is essential for the machine/process refurbishment.

Clasification
Electronical
Software
Electrical
Mechanical
Other

Severity
1
2
3
4
5

No.	Title	Leader	Location
Pilot#1 (A)	Refurbishment and renovate 2 Robot cells in B-Cell for making tubs DW40	Gorenje - White Goods	Slovenia
Pilot#1 (A)	Modernization and refurbishment of White Enamelling	Gorenje - White Goods	Czech Republic
Pilot#2	Maintenance and Upgrade of Cutting Machines in shoemaking industry	Fluchos S.L.	Spain
Pilot#3	Predictive Maintenance and refurbishment of the woodworking large production line	Podium	Switzerland
Pilot#4	Friction Welding	Harms & Wende	Germany
Pilot#5	Textile Manufacturer	Zorluteks	Turkey

Figure 4 Requirements Matrix: categories and concept definition.

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The categories section of the requirements matrix describes the meaning of the different grades that could be gave to each of the problems described, where priority goes from 1 to 6, being 1 a very low priority and 6 an indispensable problem to be solved. Moreover, the severity level goes from 1 to 5, being 1 a low severity and 5 the maximum severity that reflect a problem that cause a big issue on the machine and affect the production line operation.

The full requirements matrix as result of the requirements identification exercise are included on the Annex 1, as received from the partners involved in its preparation. The six Pilot were named and numbered from #1 to #5 where the Pilot#1 was divided into A and B, because there are two manufacturing plants belonging to the same industrial company. The pilots name and numbering are:

- Pilot #1.A: Refurbishment and Renovation of Robot Cells for Making Tubs lead by Gorenje in Slovenia.
- Pilot #1.B: Modernisation and Refurbishment of a White Enamelling Line lead by Gorenje in Check Republic.
- Pilot #2: Retrofitting and Upgrades in the Shoemaking Industry lead by Fluchos in Spain.
- Pilot #3: Predictive Maintenance and Refurbishment of a large Woodworking Production Line lead by Podium in Switzerland.
- Pilot #4: Lifetime Extension of Friction Welding Machines lead by Harms & Wende in Germany.
- Pilot # 5: Refurbishment and Upgrading of a Bleaching Machine lead by Zorluteks in Turkey.

2.1.2 Matrix of Technologies.

The methodology used for the technologies compilation and its structuration to be aligned with pilot requirements was similar to the described previously at section 2.1.1. All the technological partners involved in T2.2 and some volunteers FEUP, CERTH and UNI worked together to gather all the technical and standardization information for the technical specification definition based in the requirements identify by the pilots’ leaders. The technical specifications defined in this deliverable will be the basis for the Pilot demonstration activities and the starting point for the technological development and implementation to be conducted at WP3 and WP4.

RECLAIM technological tools could support the pilots’ requirements by the implementation of IoT smart heterogeneous sensors, intrusive and non-intrusive solutions, new industrial PC and human interface machine dashboard more flexible and friendly to use, soft sensors, data analytics, predictive models and algorithms based in machine learning and IA or digital twins. Any of these tools by their owns could made a significant advance in the move towards the retrofitting and digitalization, creating new business opportunities and services like the remote diagnosis or the sustainability of the companies’ products. Giving the opportunity for the conversion of analogic factory to the digital industry.

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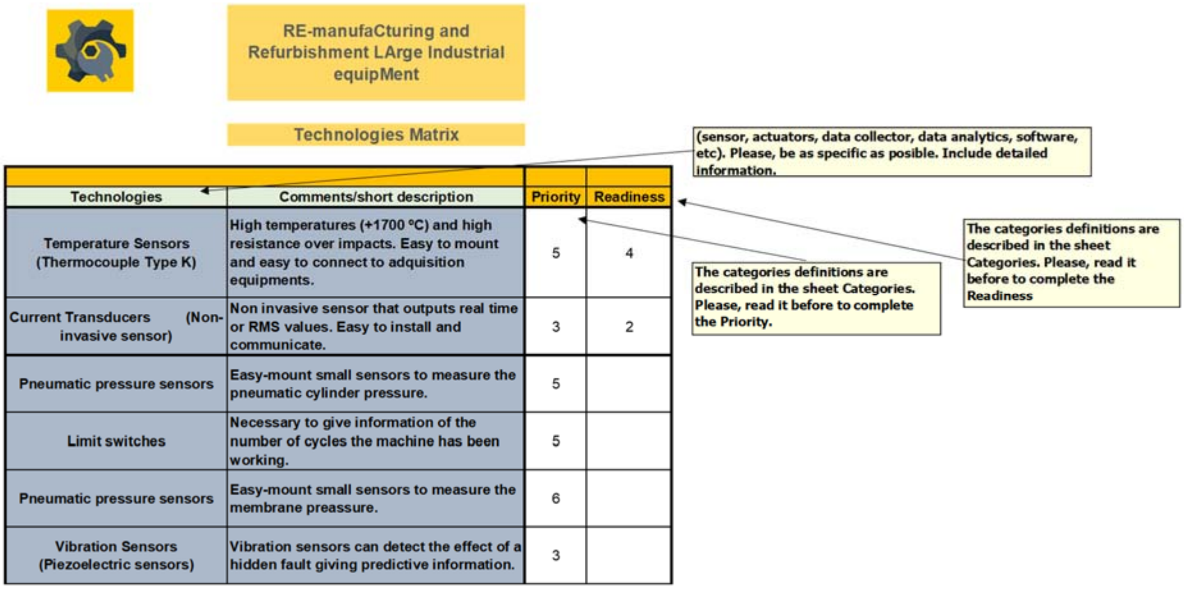
The matrix was structured into two main columns for the technology identification and its short description, respectively, at the left size of the table, see Figure 5. The categorization exercise has been done based in two main categories, priorities and readiness or technological maturity of the proposed solutions for their implementation into the pilot demonstrations. These categories are detailed in Table 1 and Table 2. It is important to highlight that the readiness concept was based in the Technology readiness levels (TRL) defined by the European Commission with the necessary adequation to the project scope and timeline. The readiness categories were numbered from 1 to 6 and its definition would like to reflect the technology status and availability its demonstration at the pilot together with the necessary effort and its combability with other system of the RECLAIM tools.



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Technologies Matrix

Technologies	Comments/short description	Priority	Readiness
Temperature Sensors (Thermocouple Type K)	High temperatures (+1700 ºC) and high resistance over impacts. Easy to mount and easy to connect to adquisition equipments.	5	4
Current Transducers (Non-invasive sensor)	Non invasive sensor that outputs real time or RMS values. Easy to install and communicate.	3	2
Pneumatic pressure sensors	Easy-mount small sensors to measure the pneumatic cylinder pressure.	5	
Limit switches	Necessary to give information of the number of cycles the machine has been working.	5	
Pneumatic pressure sensors	Easy-mount small sensors to measure the membrane preassure.	6	
Vibration Sensors (Piezoelectric sensors)	Vibration sensors can detect the effect of a hidden fault giving predictive information.	3	

Figure 5 Matrix of Technologies: Enumeration and categorization.

Table 1 Matrix of Technologies: Priority definition

Priority	Definition
1	Very low. The solution could not imply a significant added value.
2	Low. The added value or the cost/effeteness does not justify the technical or economical effort.
3	Medium. The solution is a partial advance to solve the existing problem.
4	High. The solution fit with the existing problem.
5	Necessary. The solution is necessary to will reduce obsolescence and ageing.
6	Indispensable. The solution is essential for the machine/process refurbishment.

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Table 2 Matrix of Technologies: Readiness

Readiness	Definition
1	Very Low. The solution required development that escape the project time framework.
2	Low. The solution integration into Pilot implies the redesign/reconfiguration of other solutions/systems involving or its compability (software/physical) is null.
3	Medium. The solution requires than other system/solutions will be modified or adjusted prior it integration and demonstration.
4	High. Good readiness is expected after some development and adjustment for its demonstration.
5	Very High. The readiness is optimal for its demonstration at the Pilot with small modifications.
6	Optimal. The solution will be ready for its demonstration in the Pilot.

The different Pilots categories (pilots name, machine and process) were available by pull-down option for their link to the proposed technology, based in the different meeting and conversations that technological and standardization partners had have with the industrial pilot leaders. The pilot selection columns, see Figure 6, were located between technologies and the categories one, shown in Figure 5.

Pilot #1 (A) Gorenje			Pilot#1 (B) Gorenje			Pilot#2 Fluchos			Pilot#3 Podium			Pilot#4 Harms & Wende			Pilot#5 Zorluteks		
Pilot	Machine	Process	Pilot	Machine	Process	Pilot	Machine	Process	Pilot	Machine	Process	Pilot	Machine	Process	Pilot	Machine	Process
Not			Not			Not			Yes	Laser-Base Edgebanding	Wooden Kitchen Manufacturing	Yes	Welding Head	Friction Welding	Yes	Bleaching	Cotton home textiles

Figure 6 Matrix of Technologies: nexus between with the pilots.

This Matrix of Technologies is a live working document where the technological and industrial partners will continue working for the 2nd and 3rd evolution and refinement of the present deliverable. The full Matrix of Technologies is included at Annex 2.

2.2 Data gathering.

The data gathering process is one of the most important steps for the understanding and alignment between industrial requirements and technical specifications, between problems at the machine components and technological solutions to solve them, between industrial actor in the project and technological providers. The dialogue, the meetings and the constant contact are the most useful tools to success at the data gathering task.

In an ideal situation, face to face meetings and interview are the most useful way to gather the necessary information at each pilot. Nevertheless, the health situation at Europe and at the world restrain the planned face to face meeting between the different actors involved at the pilot. Nevertheless, and based in human creativity and need of communications, several online tools for the idea sharing and virtual workshop supporting tools, the information was share with the shared efforts of all

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partners. Mention that two pilot, Pilot #2: Retrofitting and Upgrades in the Shoemaking Industry lead by Fluchos and Pilot # 5: Refurbishment and Upgrading of a Bleaching Machine lead by Zorluteks, were the only one that they could be processed with face-to-face meetings.

2.2.1 Face-to-face interviews.

The physical interviews were carried out to get a complete overview and the collection of the full catalogue for the requirements and the scenario design by the develop face-to-face meeting among industrial and technological partners.

The meetings with Fluchos and Zorluteks have been performed in the end users' facilities or in person, analysing in depth the pilot and its scenario during these workshops. During these meetings it has been commented, in detail, the machines and components problematics and going in depth into each requirement from these pilots for which these interviews have been performed.

2.2.2 Virtual Workshops.

The pilots, where physical meetings could not be accomplished and the visit to user facilities were not possible, were performed virtually. At the virtual workshop the same in depth analyse of machines and components were achieved that in the face-to face meetings. The virtual meetings dynamization was based in the use of dashboards using the Ideaboardz[1] online tool, where the participant might deploy ideas by virtual post-tick like in the physical meetings.

The detailed information collected during the virtual meeting is presented in Annex 3, and, as in the face-to-face meeting was the background formation to produce the present deliverable.

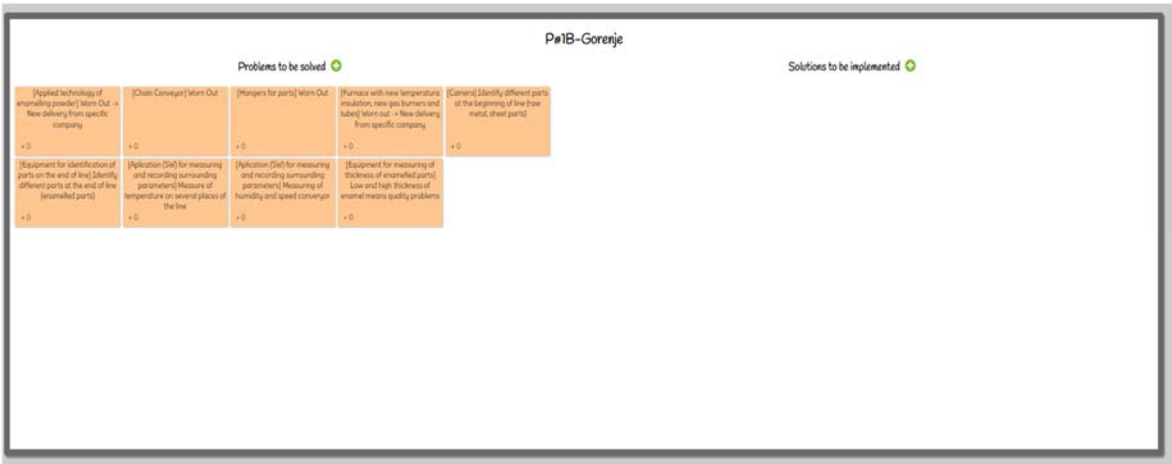

Figure 7 Example of IdeaBoardz panels.

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3 Use Case description.

3.1 Pilot #1 - Home Appliance Manufacture.

Gorenje is one of the leading European home appliance manufacturers (8th largest manufacturer in Europe) with a history spanning more than 60 years. Gorenje produces and sells major household appliances and small domestic appliances. Its global presence is built on two brands: Gorenje, which includes the entire range of home products of the upper-mid price range; and ASKO, which is positioned as a global premium brand. Gorenje sells over 5M home appliances under the global brands Gorenje and ASKO and under six regional brands (Atag, Pelgrim, Upo, Mora, Etna and Körting). Gorenje brings users across 90 countries worldwide technologically advanced, innovative, energy-efficient and beautifully designed household appliances that provide a simple, intuitive user experience and make their lives easier.

Gorenje Group brings together some 10,000 employees of 42 different nationalities and generates 95 percent of its revenues in the global market. The company has production facilities across Europe, in Slovenia, Serbia and in the Czech Republic, as well as development and competence centres in Sweden, in the Netherlands, in the Czech Republic and in Slovenia. In 2019, our revenue amounted to EUR 1,23 billion. We generated most of the revenue in Russia, the Netherlands, Germany, Scandinavia, Central and Southeast Europe, USA and Australia. Among our other businesses are also ecology-related services, toolmaking, engineering, catering and trade. Since 2018 Gorenje Group has been part of the Hisense corporation, one of the world's leading electronic and white goods manufacturers with 75.000 employees and revenues of close to EUR 13 billion.

The vision of Gorenje is to become a world leader in design-based innovations that bring added value to the consumers and simplifies their lives. Gorenje is also one of the most environmentally aware companies in Slovenia as it implemented an ISO-14001 compliant environmental management system in 2000 and was the first Slovenian company to join the EU Eco-Management and Audit Scheme (EMAS) in 2004.

Gorenje main role in the project RECLAIM is to bring different possible pilots as a base for different tools development for the lifetime extension of existing old large industrial equipment used in production of white goods. Gorenje will have important role in development stage of the project and will lead demonstration of during the RECLAIM project developed functional components in white goods production. Within the project an old equipment will be refurbished, renovated, modernized, upgraded and remanufactured.

Gorenje as a main production company inside Gorenje Group participates in this project RECLAIM as lead partner for Pilot #1 - White Goods Manufacture. Gorenje leads activities on Use Case Pilot #1.A - Refurbishment and renovate Robot cells for making dishwasher tubs. Most of the equipment dates from 1994. Some important equipment adjustments have been made to keep up with the development of new types of dishwashers. Same time Gorenje will closely cooperate with Mora Moravia

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on Use Case Pilot #1.B - Modernization and refurbishment of White Enamelling line. Gorenje interest is to re-use very old industrial equipment for stable improved production processes with less machine failure, increase the effectiveness and optimize production processes, reduce maintenance and production costs, reduce environmental impact. As a result of all those activities the lifetime of those equipment will be extended and at the same time the efficiency will increase.

3.2 Pilot#2 - Retrofitting and Upgrades in the Shoemaking Industry.

Fluchos is a family business created in the 1960s that manufactures shoes for men and women located in Arnedo (La Rioja), one of the most important footwear producing regions in Spain. Since then, it has distinguished itself by incorporating the latest technical advances into its production systems while maintaining its artisan character. It grew with a multitude of innovations decade after decade and now it has boosted its external projection and exports representing about 50% of the 2 million pairs produced by the company.

Fluchos currently has five production plants in Arnedo with some of the latest machinery to produce cutting-edge shoes. On these plants, Fluchos covers the complete production process of shoes manufacturing. The whole manufacturing process is divided in five operations:

- Cutting
- Stock Fitting
- Forming
- Set Up
- Finishing

Each section has several stages, and, in each stage, there is specific machinery. The Table 3 shown all the manufacturing processes carried out in the production process for the shoe manufacture.

Table 3 Fluchos manufacturing process categorized by the operations.

Section	Stage
ZONE A	
Cutting	Cutting
	Splitting
	Skiving
	Leather Printing

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ZONE B	
Stock fitting	Lining gluing
	Trademark laser engraving
	Sewing
	Eyelets attaching
ZONE C	
Forming	Toe cap forming
	Vamps forming
	Backs forming
	Toe cap moulding
	Sole preparation (halogenated)
	Insole preparation
ZONE D	
Set up	Toe centring and thermo-adhesive application
	Forming and wrinkles elimination in furnace
	Seating out and steaking machine
	Application of glue by hand with a brush
	Sole cementing with pneumatic gun
	Upper brushing
	Roughing
	Upper glue application by hand with brush
	Drying furnace through hot air blown system and reactivation
	Pneumatic pressure
	Cooling tunnel

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ZONE E	
Forming	Last slinging
	Sole stitch
	Helmet-type sole stitch
	Heel attaching
	Cold and hot conformed with inflatable membrane
	Painting
	Drying
	Brushing/Polishing

3.3 Pilot #3: Predictive Maintenance and Refurbishment of a large Woodworking Production Line.

PODIUM Industries SA, based in Cadenazzo (Ticino), it’s a company with 40 years of tradition and leader in the production of wooden furniture, with specialization for kitchens, wardrobes, bathroom furniture and furnishing accessories. The firm has 40 employees, with a revenue of about 7 million CHF and is managed by the Bernasconi family.

Figure 8 Company Headquarters in Cadenazzo

Short history

PODIUM Industries SA bases its origins as a manufacturer of kitchens in Cadenazzo in 1980, the year of the foundation of Mercolli Legno SA thanks to the acquisition of the company Thema AG. In 1989 the PODIUM brand was born out of the desire and the need to give an imprint and identity to the product. In 1994 the company underwent an extension of 1400 m², thanks to which warehouses, offices and exhibition spaces were added. In 2004 PODIUM SWISS SA is founded, thanks to the acquisition by the Bernasconi family of the entire shareholding, bringing a new vision

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for the future, the company is reorganized and improved in terms of workflows. In 2011 a new expansion was carried out, including a warehouse of 5300 m^2 and an exhibition area of 1000m2. In 2017 the company's operations were taken over by PODIUM INDUSTRIES SA, leaving PODIUMSWISS SA as the owner of land and buildings.

Company main characteristics

Thanks to the experience gained over the years in the sector, PODIUM has been appointed as a representative brand of "Swiss made" and has direct access to the Ticino market through Vibor SA. The company has a high level of customer loyalty and provides teams of qualified professionals with valuable know-how. The company's mission of continuous improvement has also led to an excellent level of production automation.

Investments

PODIUM in the last 15 years, has always had a vision of growth and innovation. This is demonstrated by the more than CHF 10 million invested in production machinery and space expansion. Some examples are in 2010 with the purchase of a laser edge banding machine from IMA, and in 2015 with the purchase of a Homag BMG 311 CNC centre to produce wardrobes. Special attention has also been paid to the environment in recent years, with the total renovation of the energy plant, allowing the company to make full use of wood waste for heating all the buildings.

A further strength of the company is the working environment, designed and cared for to foster a positive dynamic among employees. Furthermore, PODIUM promotes the individual improvement of its employees, recommending and bearing the costs of training course.

Table 4 Highlights from PODIUM

Exclusive Interior Design offer for bathrooms and kitchens	Swiss Leader	Customers Network
PODIUM is Switzerland's leading supplier of exclusive, tailor-made solutions for kitchens and entire home furniture. The Group offers a unique combination of design, supply, installation, maintenance, testing, commissioning, training, spare parts, and all related services.	The Group originated in 1980 and has maintained an authoritative reputation in the market ever since. Thanks to its high-quality work, PODIUM has acquired important customers PODIUM proudly represents the "Swiss Made" culture within the sector.	PODIUM is always ready to invest in relationships with the people and customers around it, remaining available to take care of products with enthusiasm and professional. Excellent Swiss network of loyal distributors and business partners.

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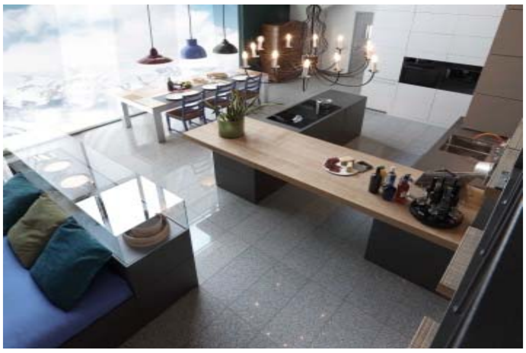
Qualified and professional Employees	Stable financial situation	Modern structure and strategically located
With a total of 40 employees, the Group has highly qualified and professional employees The working environment in PODIUM creates a positive dynamic and this is confirmed by the exceptionally low staff turnover.	PODIUM has constantly increased its revenue and profitability, investing regularly in technology, automation, and innovation Business outlook is positive and in line with growth in recent years.	With its plant in Cadenazzo, in the heart of Ticino and close to the main transport hubs, PODIUM has an excellent geographical position. The plant is equipped with the latest generation of machinery and has additional space for development.

Products and Market:

PODIUM has a specialization in the creation of design kitchens, with attention to the uniqueness of the product and the quality of natural raw materials. The company, in line with the latest market trends, is specializing in offering solutions aimed at the philosophy of "essential living", then furniture for small apartments, up to larger sizes. Furthermore, the company provide all need service such as: installation, test, maintenance and production of spare parts.

The market has a volume of about 500 pieces of furniture equivalent to about 45 kitchens per week, to which must be added the rest of the furniture range consisting of wardrobes, bathroom furniture and complete furnishings. The market is divided by 50% for furniture for the German-speaking part of Switzerland, 35% for furniture for the French-speaking part of Switzerland and the remaining 15% for furniture for the Italian-speaking part of Switzerland.

Looking to the future, PODIUM has increased its revenues investing regularly in technology, automation and innovation, and the business outlook is positive in line with the growth of recent years. In the following table some examples of PODIUM products are presented.



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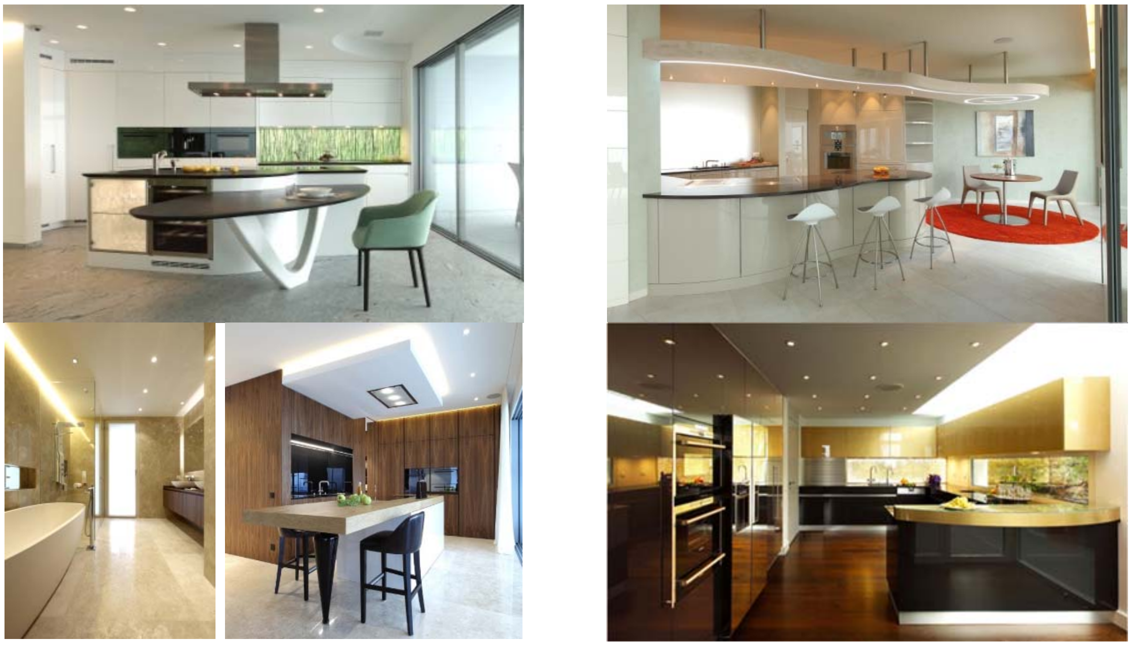

Figure 9 Production goods from PODIUM.

3.4 Pilot #4: Lifetime Extension of Friction Welding Machines.

Harms & Wende, is a medium-sized producer of control systems in the welding sector, since 1946. Its focus is on pressure resistance welding. The company occupies the first place as supplier for automotive manufacturers and the second regarding the tier industry in Germany (e.g. Mercedes Benz, Benteler and BMW). Harms & Wende is provider also at the EU level (e.g. Volvo, Faurecia and CITROEN) as well as in other foreign countries. Harms & Wende, however, supplies customers directly via a network of suppliers e.g. in the areas of household appliances and constructional steel. The customers are often manufacturers of welding machines who employ Harms & Wende welding control systems. Harms & Wende supplies resistance welding equipment in form of control devices, quality assurance systems and complete packages to well-known machine construction companies. With the control system of Harms & Wende it is possible to master all forms of resistance welding technology such as spot, projection and seam welding. The welding controls can be networked enabling them to be incorporated into large scale production plants with a central control room. The welding controls of Harms & Wende are in-dispensable when considering product liability and ISO 9000 standards.

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3.5 Pilot #4: Refurbishment and Upgrading of a Bleaching Machine.

Europe's biggest home textile exporter, and among the top three in the global home textiles market, Zorluteks, is the largest integrated producer of cotton home textiles in Europe with a total of 250,000 square meters of enclosed space and 4000 employees. Zorluteks, which consists of four plants comprising of home textile, curtain weaving-knitting, finishing and garment factories, produces 250 million square meters of home textile products per year. Including curtains, roller blinds, bed sheets, bed linens, bed covers, table clothes, coverlets, etc., Zorluteks has a large variety of products based on home textile.

Exporting 65% of Turkey's home textile production and 34% of curtain production, Zorluteks delivers 18% of its exports and 24% of bed linen exports alone. The market leader in a market of 700 million, exports 62 percent of its production to different markets, primarily to the US, Europe, Japan and Russia; while the rest is sold domestically by TAÇ, Linens and Valeron brands.

Zorluteks Textile has spent years on innovation in textiles and has made its mark in the forefront. R&D department of Zorluteks Textile is accredited as "R&D Centre" by the Turkish Ministry of Science, Industry and Technology. Many smart products that have been developed by R&D team such as self-cleaning blinds and cloth curtains, cool keeping pique, LED light curtains and QR-coded bed linen that produce content are produced to make consumers' lives easier by using the technology of the future. In addition to home textiles production, R&D department had placed emphasis on technical textile like tarpaulins, sailing cloths, outdoor fabrics, and marine fabrics.

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4 Requirements analysis.

The requirements, identified during the information gathering phase, have been analysed for their understanding and the elaboration of the detailed explanation of the use cases and the machine involve in the refurbishment, remanufacturing and retrofitting during RECLAIM project.

As mention in section 3, the industrial partners, Gorenje, Fluchos, Podium, Harms & Wende and Zorlutek, have completed the matrix of requirements for the identification of the potential problems to be the challenge at RECLAIM project. These matrices were complemented with the need and gap in the standardization filed,which is an important aspect to be considered for the technical solution in the future. The standardization analysis performed by all partners involved at this task were conducted by UNI.

4.1 Pilot#1 Home Appliance Manufacture.

Pilot#1 lead by Gorenje is divided into two pilots located in different countries and covering different technological challenges. The tow pilot were numbered as #1.A and #1.B for its distinction.

The pilot main scope are:

- Pilot #1.A: Refurbishment and Renovation of Robot Cells for Making Tubs in Slovenia.
- Pilot #1.B: Modernisation and Refurbishment of a White Enamelling Line in Check Republic.

4.1.1 Pilot#1.A.- Robot Cells for Making Tubs

The analysis of requirement covers the technical requirements from the machines and components point of view and the standardization understanding, that occasionally are responsible of the need for refurbishment or retrofitting to accomplish with the new standards and regulations.

Standard

The standardisation analysis reveals in the case of the robotic cells standardisation and regulatory does not represent an explicit obstacle to develop project requirements. Main implemented standards are connected to Management system, safety of machinery, as of DIRECTIVE 2006/42/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006 on machinery, and amending Directive 95/16/EC, and people, environmental management.

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Main standardisation gap to be considered during the RECLAIM project are:

- Monitoring sensors: alignment verification, quality and density of water pipeline, energy consumption of the furnace, real time monitoring.
- Predictive maintenance: definition of standards to predict shutdown.
- Human error: need of standardized procedure to record spare parts.

The summary of the identified standards is presented at Table 5.

Table 5 Standards identified for Pilot#1.A: the Robotic Cells for Making Tubs

Standard No.	IMPORTANT IMPLEMENTED STANDARDS
	ROBOT CELLS
EN ISO 9001:2015	Quality management systems[2]
EN ISO 1400:2015	Environmental management[3]
EN ISO 45001:2018	Occupational health and safety management[4]
EMAS	Gorenje, d.o.o. enrolled in EMAS acc. To Regulation (EC) No 1221/2009 on the voluntary participation by organisation in a Community eco-management and audit schema (EMAS) H15 I9 and amendments.
EN ISO 12100:2010	Safety of machinery - General principles for design - Risk assessment and risk reduction[5]
EN 60204-1:2006 (IEC 60204)	Safety of machinery - Electrical equipment of machines - Part 1: General requirements[6]
EN ISO 10218-1:2011	Robots and robotic devices - Safety requirements for industrial robots - Part 1: Robots[7]
EN ISO 10218-2:2011	Robots and robotic devices — Safety requirements for industrial robots — Part 2: Robot systems and integration[8]
ISO/TS 15066:2016	Robots and robotic devices — Collaborative robots[9]
ISO 9283:1998	Manipulating industrial robots — Performance criteria and related test methods[10]
EN ISO 13849-1:2015	Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design[11]
ISO 13857:2019	Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs[12]

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Requirements

The following activities are required for upgrading robots and other machinery with peripheral hardware. The ID#no.at the end of the requirements refer to the ideaboardz working panel, available at Annex 3 (A.3.1).

In Cell A:

- SCADA system and part recognition (part number - ID) internal for RC process and connection with raw department and assembly line. ID[1]: n#17., ID: n#1.
- Part dimensions/shape recognition. ID: n#1.
- Positioning for robot spot welding. ID: n#1.
- Upgrade of punching machine for more effective production process. ID: n#2.
- Spot welding parameters control system (welding current, temperature of cooling water). ID: n#4.
- Real time data with fault diagnosis and predictive maintenance solution for bending machines (temperature, pressure, defects alarm, filter control etc.) by upgrade of 2 hydraulic aggregates. ID: n#12, ID: n#3.

In cell B:

- Positioning for robot spot welding with upgrading of rotation table. ID: n#7.
- Upgrading of fast change welding electrodes on rotation table. ID: n#8.
- Spot welding parameters control system CS (welding current, temperature of cooling water).ID: n#9, ID: n#10.
- Seam welding parameters control system (welding current, pressure, temperature of cooling water, speed of welding roles in connection with robot speed; robot and welding role electro drive synchronisation). ID: n#10.
- Seam welding parameter – temperature of seam rolls. ID: n#10.
- Protective sensors against crash for double bending (breakage sensors). ID: n#6.
- Rearrangement of outside cooling water system (collection, reuse…). ID: n#11.
- Door lock – relocation from Cell A to Cell B; new welding jig (3 tables) and other adaptions of machinery. ID: n#14.

In Cell C:

- Upgrade of hydraulic aggregates for real time data with fault diagnosis. ID: n#12 ID: n#3.
- Protective sensors against crash for double bending (breakage sensors). ID: n#6.
- Transport rollers.
- Developing new control system of tightness of the tub. ID: n#13.

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In Cell D:

- Replacement of furnace regulators. ID: n#15.

In Cell E:

- Upgrading of actual automatic measuring system with real time data management (integration of key dimensions). ID: n#19.

In Outer Bottom (OB) Cell:

- HW and SW upgrading (new process unit) prepared for real time data with fault diagnosis and predictive maintenance solutions, protective sensors against crash. ID: n#16.
- Spot welding parameters control system CS - welding current, temperature of cooling water. ID: n#16.

In All Cells:

- Mechanical upgrade of robot and robot griper prepared for real time data with fault diagnosis and predictive maintenance solutions. ID: n#4.
- PLC upgrade. ID: n#22.
- Conformité Européenne, CE - Declaration of Conformity. ID: n#23.

4.1.2 Pilot#1.B.- Modernisation and Refurbishment of a White Enamelling Line.

All the analysis of machines and operations of Pilot #1.B and the standardization approach are detailed in the following paragraphs.

Standards

The Pilot#1.B is already involved in standardisation activities at national, at Slovenian and at European level. The department involved in the standardizations is a different one from the R&D department.

Table 6 Standards identified for Pilot#1.B Modernisation and Refurbishment of a White Enamelling Line.

Standard No.	IMPORTANT IMPLEMENTED STANDARDS
	SPRAYING BOOTH & CONVEYOR SYSTEM
N 11.36 (INTERNAL)	Procedure for automatic spraying of combi enamel on EIC line

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FURNACE & TRACEABILITY	
EN ISO 9001:2015	Quality management systems[13]
EN ISO 14001:2015	Environmental management systems[14]
EN ISO 45001: 2018	Occupational health and safety management systems[15]
EMAS: Gorenje, d.o.o enrolled in EMAS acc.	To Regulation (EC) No 1221/2009 on the voluntary participation by organisation in a Community eco-management and audit scheme (EMAS) H15 I9and amendments
EN ISO 12100:2010	Safety of machinery — General principles for design — Risk assessment and risk reduction[16]
EN 60204-1:2006 (IEC 60204)	Safety of machinery - Electrical equipment of machines - Part 1: General requirements[17]
EN ISO 13849-1:2015	Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design[18]
ISO 13857:2019	Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs[19]
N12.13 (INTERNAL)	Předpis na vypalování v tunelové vypalovací peci VGT/U 18,6

Requirements

The following activities are required for upgrading enamelling line with peripheral hardware:

Upgrade of automatic spraying booth for enamel powder application, following parts must be renewed:

- working stack of powder with magnetic separator.
- automatic and hand spraying guns with installation material (hoses, electric cables, gun holders...).
- pumps for transfer of powder to guns.
- control system for guns and update of actual stainless-steel cabinet due to communication between new and old parts of equipment.
- two reciprocators for moving with automatic guns.
- coding system for automatic setting of spraying parameters according to moving parts.

Upgrade of burning furnace, following parts must be renewed:

- cooling zone after exit of the furnace.
- temperature insulation of walls, roof and bottom of furnace.
- casing of furnace.
- ventilation parts of air barriers.
- radiant tubes.
- low emission FLOX burners.
- exhaust tubes and chimneys.

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- electro box – new control of furnace + better regulation.
- electric connection cables, distribution of gas and air, adding of safety valves of gas pipes for burners.
- isolation of furnace conveyor including of sheets and hooks of conveyor.
- "bricks" (functional cartridge) for fluoridated absorber.

Upgrade of transport system with hinges for spraying cabin:

- renewing of chain of spraying conveyor with drive unit.
- renewing of hooks for hanging of parts.
- renewing of turn stations on conveyor.

Upgrade of transport system with hinges for furnace:

- renewing of chain of furnace conveyor.
- renewing of hanging arms from heat resistant material INCONEL601.

Build better traceability of production semi-parts through the enamelling process line (recognition function, counting function, statistic function, identifying different enamelling parts at start and end of the line). For better evidence and elimination of human mistakes automatic recognition system is needed. ID: n#5.

Build automatic system for recording/measuring and statistics of surroundings parameters (temperature, humidity, ...) /ID: n#7.

Equipment for measuring powder enamel thickness (before burning out in furnace). ID: n#9.

4.1.3 Pilot#2.- Retrofitting and Upgrades in the Shoemaking Industry.

The results obtained from the identification of the machines and components problematic to be considered at the project and the associated standards are detailed at this section.

Standards

FLUCHOS has low knowledge and implementation of standards, considering both the ones connected to regulatory (e.g. Directive 2006/42/EC of 17/05/2006) and voluntary ones. Internal knowledge is managed informally, internal know how is not standardised. No standards are implemented related to requirements and technology analysed.

Cultural barrier focus on short term results and products are main features, standardisation represents then a key asset to boost innovation and sustainability to define a Remanufacturing strategy. Main requirement needs identified are:

- Environmental management, ISO 14000 series[20]

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- Maintenance: definition of indicators, type of damages, internal management
- Safety of machinery, Directive 2006/42/EC of the European parliament and of the council of 17th May 2006 on machinery and amending directive 95/16/EC (recast).

A first state of art analysis on existing standards at EU and ISO level was provided, see Annex 4.- Requirements and standards state of the art.

Requirements

The main problems link to the refurbishment and retrofitting at Fluchos production lines are described in the following tables. These problems should be addressed in order to minimising the risks, to reduce the environmental footprint and to extend the life of the machines that are indispensable and difficult to substitute.

Table 7 Forming machine for rear parts requirements.

Production line steps & functions	Operational malfunction / initial problem / risks for the machine functioning
Forming machine for rear parts (Model 88CF NORBA)	
Heating	Wrong temperature
	Power consumption
Hot pressing	Low pneumatic pressure
	Rubber fatigue
	High membrane pressure
	Vibrations
	Temperature of the material
Cooling	Wrong temperature
	Power consumption
	Coolant gas leaks
Cold pressing	Low pneumatic pressure
	Fatigue
	High membrane pressure
	Vibrations
	Temperature of the material

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Table 8 Requirements of the forming machine for front parts.

Production line steps & functions	Operational malfunction / initial problem / risks for the machine functioning
Forming machine for front parts (Model 11000.6 SABAL)	
Rotating platform	Power consumption
	Coil temperature
Forming last	Low pneumatic system pressure
	Wrong temperature of the last
Forming arm	Power consumption
	Coil temperature
	Low cylinder pneumatic pressure
	Incorrect wheel contact pressure

Table 9 Leather cutting machine requirements.

Production line steps & functions	Operational malfunction / initial problem / risks for the machine functioning
Leather cutting machine	
Cutting tool (spin)	Power consumption
	Low pneumatic pressure
Leather clamping (suction)	Power consumption
	Low pneumatic pressure
Movement 1 (electric actuators)	Power consumption
	Vibrations
	Incorrect average speed
	Incorrect acceleration
	High actuators temperature

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4.1.4 Pilot#3.- Predictive Maintenance and Refurbishment of a large Woodworking Production Line.

The analysis of requirements and standardization need for the pilot#3 is described in the following paragraphs.

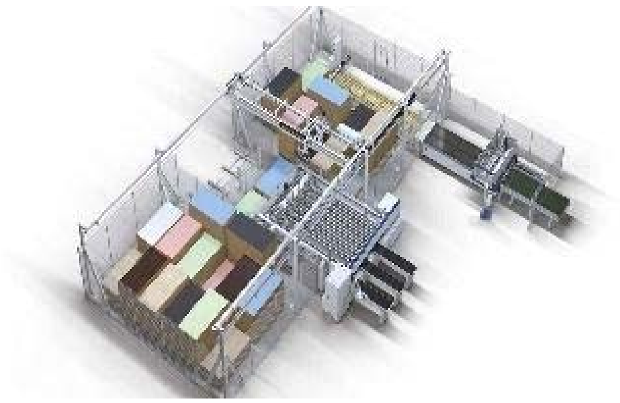
Standards

PODIUM is implementing main standards and normative requirements connected to EU safety legislation requirements (Directive 2006/42/EC of 17/05/2006).

Requirements

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

Table 10 Wood furniture manufacturing steps

Operational malfunction / initial problem / risks for the machine functioning	Machines for wood furniture manufacturing
STORAGE	
Wood-based panels in standard sizes are moved into the factory and to the main working stations	Warehouses + forklift 
CUTTING	

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Wood-based panels are cut into the desired shapes and sizes	Beam saws 
EDGE BANDING	
The exposed sizes of panels are covered by customized material strips	Edge banders 
DRILLING	
Holes are drilled in different panel points in order to prepare for assembly and insert metallic components	Drilling machines 
FINISHING	
The panels are given different surface textures according to the requested aesthetic features	Sanding machines

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ASSEMBLY AND PACKAGING	
The cabinets are assembled or packaged in order to be assembled by the buyer	Assembly machines 

4.1.5 Pilot#4.- Lifetime Extension of Friction Welding Machines.

The compilation of the requirement for the use case of HWH and the standards need for their implementation in the project concept development are detailed in this section.

Standards

HWH has a good knowledge and awareness of standards that are properly implemented in the pilot as shown in the Table 11.

Table 11 Standards identified for the friction welding machines.

WELDING MACHINE (RSM401) PART (from aeronautic sector: LUFTHANSA)	
Standard No.	**IMPORTANT IMPLEMENTED STANDARDS**
ELECTRICAL CABINET	

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EN ISO 9001:2015	Quality management systems[21]
DIN EN 61439-1 (VDE 0660-600-1:2012-06)	Low-voltage switchgear and control gear assemblies Part 1: General rules[22]
SPINDEL, REMOTE MAINTENANCE/MONITORING	
2006/42/EG°1[23]	On machinery, and amending Directive
MOTOR/CONVERTER	
DIN EN 60034-5 ((VDE 0530-5) - Part 5	Degrees of protection provided by integral design of rotating electrical machines (IP code) - Classification[24]
DIN EN 60034-1 (VDE 0530-1)	Rotating electrical machines Part 1: Rating and performance[25]
PLC, PANEL & HMI	
DIN EN 61439-1 (VDE 0660-600-1:2012-06)	Low-voltage switchgear and control gear assemblies Part 1: General rules[26]
VALVES	
ISO 8573-1:2010	Compressed air[27]

Main gaps connected to standardization requirements and welding machine are:

- Interoperability: Definition of cross sectoral and interoperable definition maintenance and KPI (Type of machinery and market application, stability of component, time to Repair (MTTR), type of damage, type of repairs.
- Safety of machine: Safety standards[28] are known, but not implemented properly. The welding machine is too obsolete to comply with standards requirements.
- Ownership of data in remote control need to be defined, in order to communicate data properly.
- Human machine interaction: A codified skills framework related to maintenance is needed to develop professional figures related to remanufacturing.

Requirements

The mains requirements identified for the friction welding machines to be studied at the project for the solution by the demonstration of the RECLAIM tools potential are detailed in the following paragraphs.

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Table 12 Problematic to be studied at the friction welding machine sector.

Part/Machine Components or elements	Problem	Consequences & impact in the production line
ELECTRICAL CABINET		
Hydraulic collet system	Quality management systems	Downtime
GENERAL FRICTION		
Like electrical cabinet	Standards on safety not sufficiently implemented	Machine cannot be used
WELDING MACHINE (RSM 410)		
Welding stroke	Stroke too slow	No process regulation possible
RFSSW (REFILL FRICTION STIR SPOT WELDING) MACHINE (RPS)		
Sensor and actuators attached	Very difficult to mount	High repair times, high downtimes
Like electrical cabinet	Standards on safety not sufficiently implemented	Machine cannot be used

4.1.6 Pilot#5.- Refurbishment and Upgrading of a Bleaching Machine.

The called bleaching machine is a long production line with several steps working in a continuous process where the failure of one of its components result in the loss of kilometres of textile and tons of material after their processing. The analysis about the main requirements for the retrofitting of the machine and the standardization need and gaps are described in the following paragraphs.

Standards

Zorluteks has strong knowledge of standardization: several standards are implemented linked to requirements for bleaching machine, as shown in the Table 13. Standards implemented include also recommendation developed by private consortia.

Table 13 Standards links to the textile manufacturing sector.

BLEACHING MACHINE PART	
Standard No.	IMPORTANT IMPLEMENTED STANDARDS

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PREPARATION OF BLEACHING RECIPE	
EN 60529	Degrees of protection provided by enclosures (IP Code)[29]
EN 61010	Safety requirements for electrical equipment for measurement, control, and laboratory use[30]
IEC/EN 61326[31]	Electrical equipment for measurement, control and laboratory use - EMC requirements
NAMUR NE 21	Recommendation for uniform practical procedures for determining whether the devices used in laboratory and process control are immune to interference
NAMUR NE 43	Standardisation of the Signal Level for the Failure Information of Digital Transmitters[32]
ANSI/ISA-S82.01	Electric and Electronic Test, Measuring, Controlling, And Related Equipment: General Requirement[33]
CAN/CSA-C22.2 No. 1010.1-92	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use[34]
PREWASHER (De size Wash) & STEAMER	
IEC/EN 60751:2008	Industrial platinum resistance thermocouple and platinum temperature sensors[35]
NEUTRALIZING COMPARTMENT	
TS EN 61000	Electromagnetic compatibility (EMC) Part 6-1: Generic standards - Immunity for residential, commercial and light-industrial environments[36]
TS EN 61000-6-2	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments[37]
IEC 60335-2-41	Household and similar electrical appliances - Safety - Part 2-41: Particular requirements for pumps[38]
IEC 60335-1	Household and similar electrical appliances - Safety - Part 1: General requirements[39]
EN 60332	Tests on electric and optical fibre cables under fire conditions

Requirements

The requirements identified are related with physical and virtual sensors need for the optimization of the bleaching process in a very complex production line.

Table 14 Requirements identified at the bleaching machine.

BLEACHING MACHINE PART

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Problem	Consequences & impact in the production line
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
Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleaching process totally
Lack of pH sensor	It affects both whiteness and strength of the fabric
High roller pressure after chemical trough	It causes removing sheer amount of chemical on the fabric surface which affects whiteness
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
High steamer timing	It results diminishing fabric strength
PREWASHER	
Low pH	It is hard to remove de sizing agents which affects whiteness of fabric
High pH	It lowers to strength of fabric
Lack of pH sensor	It affects both whiteness and strength of the fabric
Failure at bearings	It affects movement of the fabric inside the bleaching machine
Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleaching process totally
Low roller pressure before bleaching chemical trough	Excess water on the fabric lead to decrease concentration of chemical mixing unit
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
WASHING BATHS	
Low pH	It is hard to remove de sizing agents which affects whiteness of fabric
High pH	It lowers to strength of fabric
Lack of pH sensor	It affects both whiteness and strength of the fabric

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Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleaching process totally
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
Failure at bearings	It affects movement of the fabric inside the bleaching machine
Low temperature	It is hard to remove caustic on the fabric surface at low temperature which affects whiteness
NEUTRALIZING COMPARTMENT	
Lack of pH sensor	It affects both whiteness and strength of the fabric.
DRYING UNIT	
Failure at temperature sensor	Temperature level does not be controlled. It affects whiteness
Failure at moisture sensor	Moisture level, which has a significant importance for the next processes, doesn't be controlled
Failure to perform regular cleaning	Condensing steam and dirtiness in the drying unit lead to tenacious stains on the fabric surface
High temperature	Colour of fabric turn yellow

The magnitude of the bleaching production line is 250 million square meters of manufactured home textile per year. Due to the fact that the raw cotton fabric comes from different suppliers, the whiteness of raw cotton fabric has a wide range of whiteness degree. The colour of cotton fabric 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.

There are several parameters (temperature, time, fabric construction and amount of bleaching chemicals, among others) that affects performance of bleaching and whiteness degree variation at this process. It is quite problematic to arrange these parameters in an optimum level for different characteristic of cotton fabric. This causes rise in number of re-processes in bleaching operation. Because of the re-processing operations and the necessary whiteness degree at the end of the bleaching operation, there 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 in the 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

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has opened the opportunity for the retrofitting and the integration of innovative technological solutions based on the smart monitoring and management of the critical parameters at the bleaching process and data analytic for the software-based decision supported tools development.

The efficiency and productive reasons should be jointed with the need for the lifetime extension of bleaching machine. The bleaching machine at Zorluteks is a 1996-year Küsters model. The bleaching machine life cycle is around 20 years and, considering that the usual failure time has an average of 0.5 failures at day, their economic impact in the full productivity of the factory is relevant. The categorization of the most important failures typologies could be assigned to mechanical, electronics and electrical problems combined with the variations coming from the raw cotton fabric that must be solved by the adapting of the production line. The bleaching machine lacks sensors dedicated to measure the conditions of the machine and collect data for the process optimization to avoid failures, to increase its lifecycle and guaranty the productivity. The physical and decision support tools developed at RECLAIM will provide the understanding for its refurbishment and retrofitting to achieve lifecycle extension and the improvement of their operation mode reducing the current rates.

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5 Pilot Scope.

This section is focus on the understanding of the pilots proposed at RECLAIM project based in the use cased defined by Gorenje, Fluchos, Podium, Harms & Wende and Zorlutek and the technical requirements defined in collaboration with TEC, CTCR, SUPSI, ADV, FCY, SCM, ROBOTEH, TTS, ICE, FEUP and CERTH. This is a consolidated view about the general problematic that RECLAIM could address to increase European manufacturing community competitiveness by the implementation of smart heterogeneous IoT sensors and soft-based decision support tools, including the exploration of the digital twins.

5.1 Pilot #1 - Home Appliance Manufacture.

The Pilot#1 consists in two use cased and scenarios with a different problematic to be address by RECLAIM tools located in two European countries, where both of them are lodged by Gorenje. The first approach to Pilot #1 scope is described at the following sections.

5.1.1Pilot #1.A.- Refurbishment and Renovation of Robot Cells.

Robotic cells, RC, are one relevant production line tool at the manufacturing process in Gorenje dishwasher, DW, factory. Dishwasher inox tubs, which are the main part of dishwasher are manufactured and isolated in robotic cells, where bending, punching, edge profiling, pressing, welding, isolation processes are carried out mainly by automatized robots. Most of the semi-finished products come from the pre-manufacturing of the raw material section (sheet metal presses); the basis of the DW tub are the L sheet (bottom / back) and the U sheet (sides and top) represented at Figure 10. Insulation parts are a product of external suppliers. RCs for the manufacture and isolation of DW tubs are a set of cells called XL, A, B, C, D and E, see Figure 11. The process is supervised by operator.

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

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

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Figure 10 Manufacturing scheme, Dishwasher tubs, L and U sheet products manufactured by Gorenje.

Upgrade and refurbishment of robot cell equipment is necessary to improve machinery condition and to reduce unplanned machine failure, to reduce production and maintenance costs and to extend the machinery lifetime for further 15 years.

The robotic cells operating at the DW tube manufacturing process are:

- XL press: robot cell with 1 robot, 1 press with transfer.
- 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.
- B-cell: spot and seam welding machine, double bending machine, hydraulic aggregate, 6 robots.
- C-cell: punching machine, double bending machine, hydraulic aggregate.
- D-cell: 4 furnaces, 2 robots.
- E-cell: control/measurement unit.
- Outer bottom cell: spot welding unit, 1 robot, 1 press, hydraulic aggregate.
- RC insulation inner door: 1 robot.

A detailed scheme of the RC production line at Gorenje facilities is presented at Figure 11.

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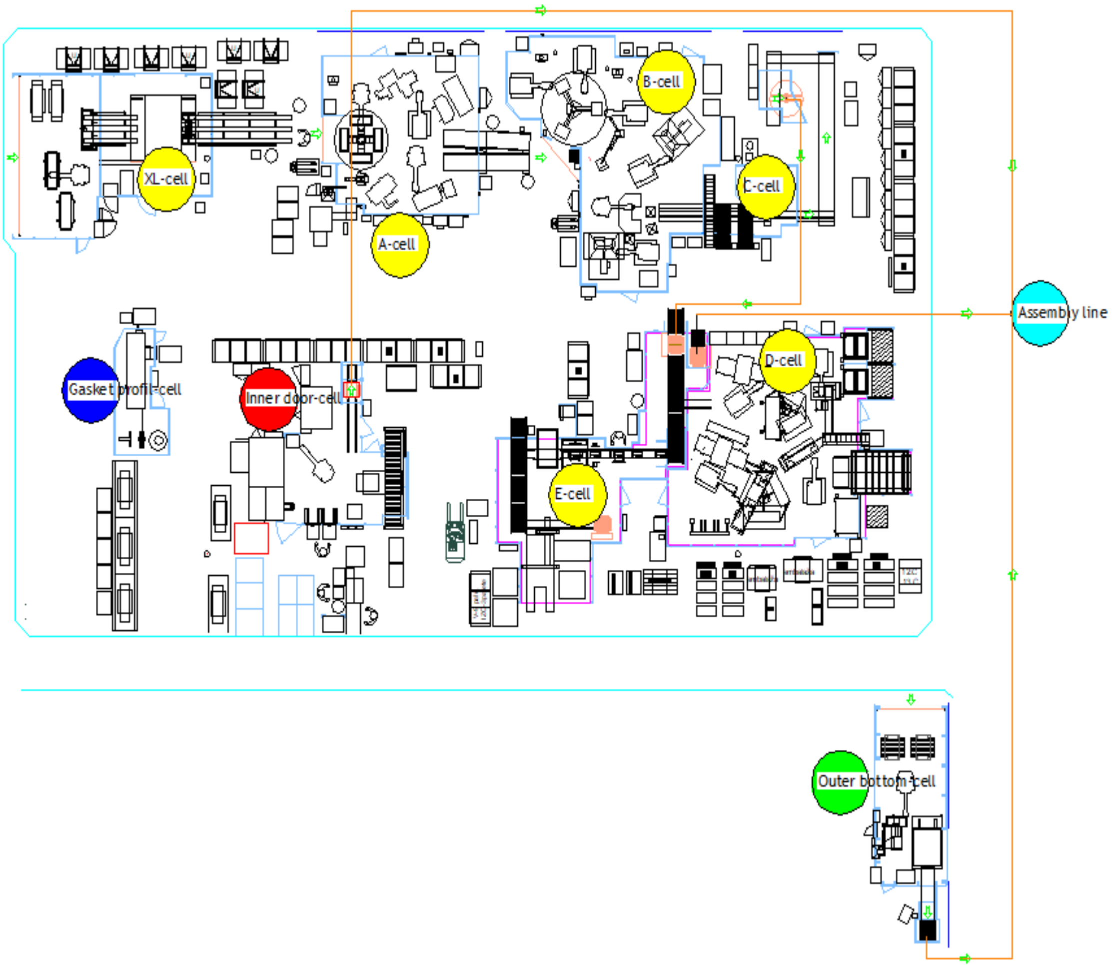

Figure 11 GORENJE's production line map.

A-cell:

The basic element for making the dishwasher is a flat sheet of stainless steel, called L and U sheet, on which various small parts are installed, further welded to the necessary semi-finished products, then the necessary holes are cut and the U and L plate are blended into the corresponding U and L shape.

Equipment: rotating table with four places (2 for U and 2 for L), point welding cell, hole cutting machine, 2 presses, 4 robots (1 for welding, 3 for manipulation).

B-cell:

In the B-C robotic cells L and U dishwashers' plates are joined.

The basic element to produce dishwasher tubs are the flat stainless-steel sheets/plates of two dimensions (L and U), which previously came out of the A-cell and are manually loaded by the worker onto a 3-station turning table.

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Joining is done by bending, spot and seam welding. Additional punching is carried out if necessary.

U-pieces are equipped with a bar code, the code is read by the worker before the piece is picked up from the conveyor and thus it is known which piece is in the B-cell at which place. The table on which the pieces are assembled is 3-position, which means that in one place the piece is assembled and in the other two places it is welded. B cell is a group of multiple robots that receive basic data from a PLC8 controller that controls also a rotary table.

Existing welding machines do not provide process data such as welding current and other important process parameters. HW and SW upgrading is necessary to reduce bad quality of products and increase efficiency and capability of the manufacturing process.

Equipment: spot and seam welding machine, double bending machine, 6 robots

C-cell:

The C-cell has the function of punching one hole, which depends on the PLC code. Because of this, a barcode laser scanner is installed in front of this cell to decide whether to cut. Additionally, at the back edge double bending is performed.

Equipment: punching machine, double bending machine

Refurbishment of actual machine with real time data system is needed to increase product quality and process efficiency.

D cell:

Products are automatically fed to the D-cell via the transport system. The heated bitumen sheets are pressed and melted on the outer part of tub. Containers are transported by robots throughout the cell and data on the type of container is also transmitted through the transfer. It’s important to use type of insulation for a type.

Equipment: 4 furnace, 2 robots, rotating table, manipulator.

Furnace regulators are worn out, replacement is needed.

E-cell:

Additional manual small operations and dimension control are carried out.

Equipment: transport system, control/measurement unit

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Upgrading of actual automatic measuring system with real time data management (integration of key dimensions) is necessary to improve the quality and increase the efficiency of the process.

Outer bottom (OB) cell:

OB cell is a cell for reshaping the flat pre-formed sheet of the dishwasher base. We insert flat semi-finished products on a pallet into the cell with a forklift, followed by the automatic operation of the process. The robot takes over the base and moves it to the welding point of the reinforcement, which is automatically dosed. After welding, the robot transfers the base to the press where we roll the threads and bend the base to the desired shape. Transport to the assembly line follows. The removal of flat footings acts on the need for removal in mounting. Equipment: welding unit, robot. HW and SW upgrading (new process unit) prepared for real time data with fault diagnosis and predictive maintenance solutions, protective sensors against crash and spot-welding parameters control system CS (welding current, temperature of cooling water) is needed for better quality and better accuracy.

5.1.2 Pilot #1.B.- Modernisation and Refurbishment of a White Enamelling Line.

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

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

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

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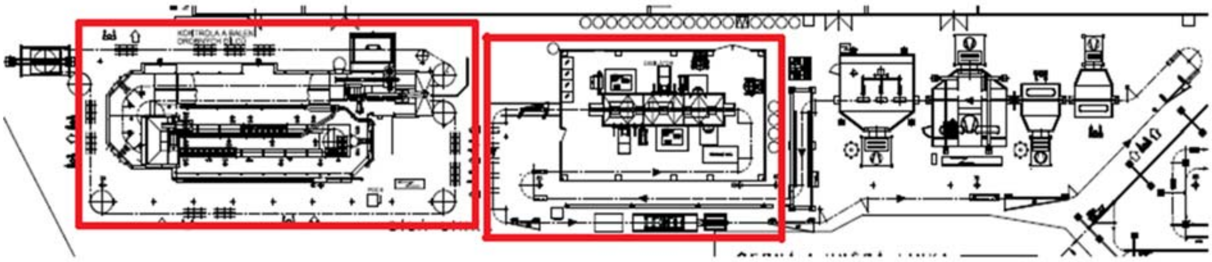

Figure 12 The specific process selected for its refurbishment are the spraying cabin and the furnace highlighted in red.

Automatic spraying booth for enamel powder application:

Semi-finished products hung on hooks travel through the cabin, where powder enamel is applied with 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.

Figure 13 Automatic spraying booth cabin.

Burning furnace:

It is highly insulated furnace with air temperature of 830°C; conveyor in U shape bear the parts through the firing zone. Burning process makes reaction from powder into fused porcelain enamel.

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Figure 14 Burning furnace images.

Diagnostic and logistic data:

There are three width of cooktops (500, 600, 700mm) and each width have several variants (3-7) according to openings for burners or heating zones.

5.2 Pilot #2: Retrofitting and Upgrades in the Shoemaking Industry.

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

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

Table 15 Machines and tools for the main production lines involved in the RECLAIM scenario.

Production Line	Machines & Operations
ZONE A	
Cutting	Cutting
	Splitting
	Skiving
	Leather Printing

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ZONE C	
Forming	Toe cap forming
	Vamps forming
	Backs forming
	Toe cap moulding
	Sole preparation (halogenated)
	Insole preparation

The scope of this pilot is to improve the productivity of this machinery, since most of the equipment is over 10 years old and it does not have a modern monitoring or electronic control to manager the manufacturing operation and the operating parameters in an accurately manner. To achieve this challenge, it is necessary to undertake a refurbishment and updating of some machines or, at least, theirs most relevant components, based in the implementation of IoT heterogeneous sensors to provide an accurate measurement of the operating parameters at the machinery.

Rear part forming machine:

This process consists in the shaping of the shoe’s heels made in leather by the subsequent application of heat and cold surfaces combined with the precise pressure to reach the desired shape at the leather.

The left station of forming machine is equipped with an electrical resistance device to heat and soften the material. In the other hand, the right station is equipped with capillaries through which a liquid circulates to cool the material. Both parts of the press have a rigid lower support in the shape of a last and the upper part consists of a bell with an inflatable leather pad. The upper support is lowered by a pneumatic cylinder and the cushion is inflated to evenly press the back of the shoe.

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Figure 15 Rear-part forming machine (Model 88CF NORBA).

Front part forming machine:

The tip forming process consists of going over the sides of the front half of the cut with a small roller. For this purpose, an automated robotic carousel is used. Adjustable heated lasts located on the perimeter of the carousel keep the cut stretched and the skin-tight. The carousel rotates until the upper part reaches the station where a head with a roller at the end rotates around the contour of the shoe.

This is a complex machine that incorporates gear motors for the rotation of the carousel and the head and 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. It incorporates different inductive sensors to control the start and end of the movements, as well as a PLC that coordinates all the elements.

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Figure 16 Front-Part forming machine (MODEL 11000.6 SABAL)

Cutting machine:

The automatic cutting machine is used for cutting new shoe designs due to its versatility. The designs of the pieces to be cut are sent by computer to this equipment and an automated header oversees cutting and punching these designs without the need of additional tools.

The operation of this equipment is electric and pneumatic and consists of two suspended telescopic arms that mount a head at each end. The equipment mounts various servomotors that control the movements of the heads around the work area. The cut is made by an oscillating blade with a vibrating motor and the punching tools are driven by compressed air. The tools are height-adjustable, and the blade has an additional turning movement to orient the cutting edge. Finally, the leather is held on the conveyor belt by lower suction through micro-perforations in the belt.

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Figure 17 Cutting machine (MODEL Comelz CZ/M).

In addition to this, the updating of the equipment is intended to achieve better human-machine interaction to improve employee productivity and facilitate the control and use of accurate and correct process parameters.

5.3 Pilot #3: Predictive Maintenance and Refurbishment of a large Woodworking Production Line

The basic structure of the production flow is described below:

1. Once the project of the kitchen has been approved by the customer, Podium can start the production. Wood panels (dimensions usually 2800mmx2050mm and thick 16mm to 25mm) are first cut in the desired dimension by a numeric control machine.
2. The border of the panel is applied by a numeric control machine located after the cutting/saw machine.
3. The panel is then drilled with a numeric control machine and the hinges are placed.
4. The panels are assembled, and the cabinet is moved to the shipping area where it is prepared for shipping.

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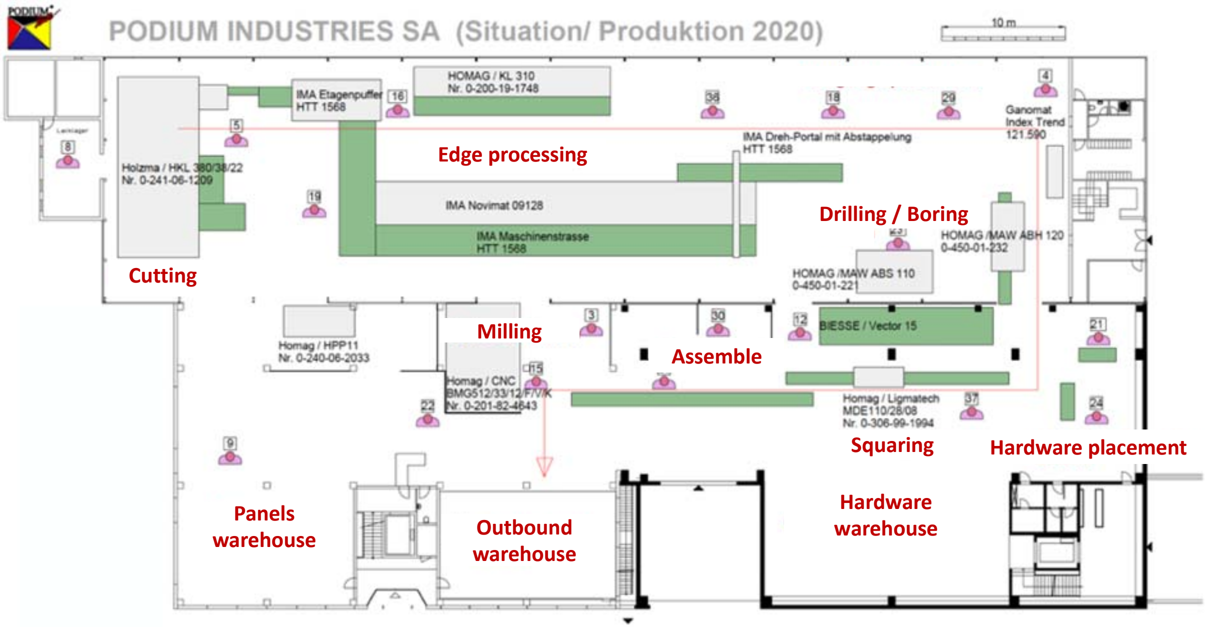

Figure 18 PODIUM's production process map.

Panels Cutting:

The panels required to manufacture the cabinets are taken by means of 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.

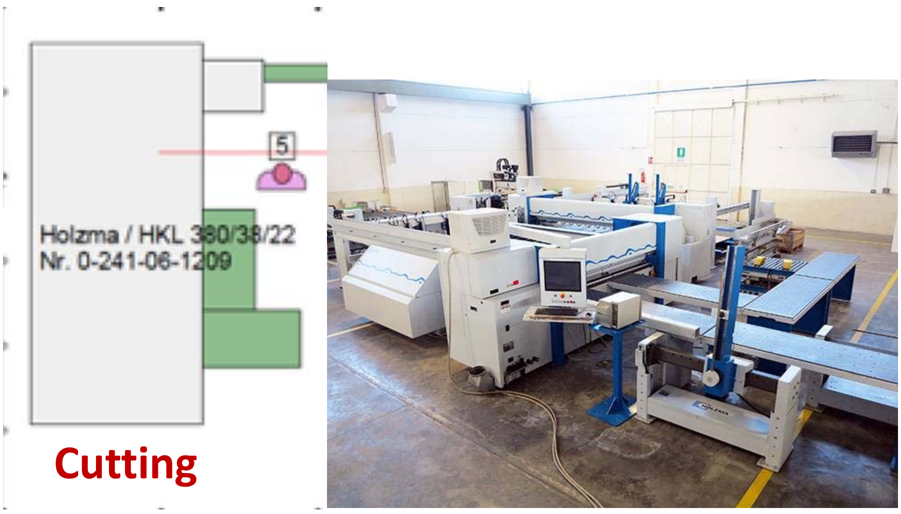

Figure 19 Cutting block and machine involved (HOLZMA-HKL 380/38/22).

HOLZMA-HKL 380/38/22: Numeric controlled angular beam panel saw with automatic loading. This type of system allows full automated processing thanks to a trimming unit integrated in the rip saw. The recuts can be dealt with in one cycle without a trimming unit. The process works simply and reliably: the rip saw no longer deals just with rip cuts, but also, as needed, with recuts – using one and the same saw

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blade This is achieved in the following way. Where recuts are required, the panel is not cut along the entire length, but only to up to a defined point. The downstream cross-cut saw completes the cross cuts in the usual way, making two cross cuts where the recut was before effected. As far as possible, the software positions waste parts exactly in these positions in the cutting pattern. This additionally saves time and money.

General specifications:

- Manufacturer: Holzma
- Model: Hkl 380/38/22
- Dimension (l x w x h): 13560 x 5550 x 2150 mm
- Weight approx. 9000 Kg
- Useful working cutting width 3800 mm
- Useful working cutting length 2200 mm
- Max. main blade projection 95 mm
- Automatic lateral aligner with pneumatic cylinder.

Panels edge banding:

The second process 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).

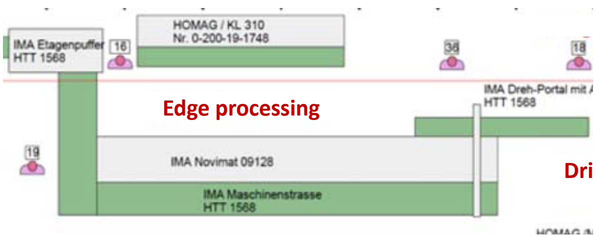

Figure 20 Panels edge banding block.

IMA Etagenpuffer HTT 1568 – Novimat compact R3: The Novimat Compact R3 edge banding machine makes highly professional edge processing possible on an industrial scale. This IMA edge bander handles all aspects of edge processing. Coiled materials can be applied with glue such as EVA or PUR. It also includes additional units for grooving or smoothing operations. By automating essential functions, the Novimat Compact R3 can perfectly process all pending tasks and edging tapes. With sleeplessly variable feed speeds up to 25 m/min. and quick glue change via the IMA quick-lock system, the Novimat Compact R3 lets the industry perform cost-effective, high-quality edge banding without restrictions.

General specifications:

- Manufacturer: IMA

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- Machine length: 9130 mm
- Total weight: 7200 Kg
- Compressed air connection: 7 bars
- Connected load: 21 KW
- Panel width min 65 mm
- Panel length min 150 mm
- Panel thickness min 8mm / max 60 mm

Figure 21 Machine involved (IMA Etagenpuffeer HTT 1568 Novimat compact R3).

Edge Bander HOMAG KAL 310: Series of single-sided, universal edgebanders from Homag. The edge banding is carried out with a wafer-thin glue joint, no reworking is necessary. For the frictional locking of the connection and a rapid operational readiness of the machines is provided by the Quickmelt system, which at the same time makes the operation more energy efficient. Optionally, the PU 34 gluing system, for resistant, water- and water- resistant heat resistant gluings on Polyurethane base. The machine works energy-saving and environmentally friendly. It is equipped with a PC control without limit switch. With the drive solution low noise and maintenance-free frequency converter technology is used. The machine is provided of an automatic safety system, to stop the engine when it is necessary.

General specifications:

- Manufacturer: Homag.
- Model: Kal 310.
- Single edger and automatic edge banding machine on straight profiles.
- Max. workable panel height with straight edge 60 mm.
- Edges applicable in coils: thin and PVC up to 3 mm.
- Edges applicable in wood strips: solid wood up to 20 mm.

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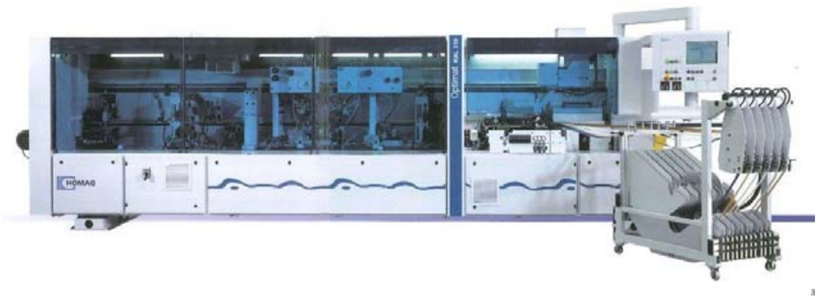

Figure 22 Machine involved (Edge Bander HOMAG KAL 310).

Drilling and boring:

Once the panel have been bended, it is necessary to create the holes and housing for the ironware and joints. This is currently done by means of two main machines that are meant to drill and bore the panels according with the CAD files provided.

In this phase currently in PODIUM is also present a third machine (HOMAG/MAW ABH 120) that, although in working order, has been shut down and is only used in exceptional cases or to make up for the failure of another machine. This because the machine is not up to date in terms of software anymore, therefore replaced by the Biesse that is able to be integrated already in the production process.

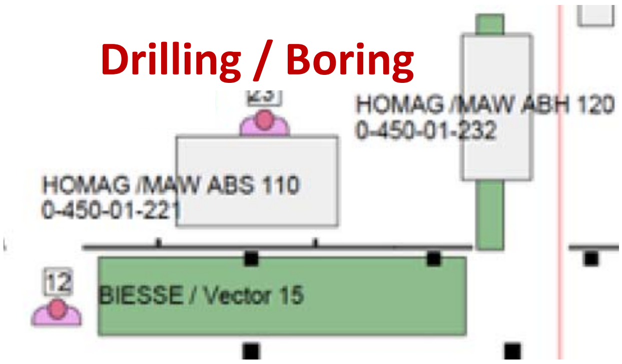

Figure 23 Drilling and boring block.

Biesse BREMA VEKTOR 15 CNC Drilling Machine: Vektor 15 is a NC vertical through-feed boring machine able to sequentially drill, mill, route and insert panels with different dimensions without manual set up. The top of the range Vektor 15 has a new "patented" panel handling system, which allows the processing on the four edges at the same time up to the panel squaring area. It can be equipped with self-selecting drilling units or with a 10 position-revolving unit and hardware inserting units. Ideal for JIT production for any kind of processing.

General specification:

- Model: Brema Vektor
- Machine dimensions: 1950 x 1950 x 3100 mm

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- Weight: 4000 Kg
- Min panel length: 260 mm
- Max panel lengt: unlimited
- Maximum speed: 85mt/min
- Working heigt: 900mm
- Compressed air pressure: 6 bars

Figure 24 Machine involved (Biesse BREMA VEKTOR 15 CNC Drilling Machine).

HOMAG/MAW ABS 110: Drilling and inserting machine for BLUM hinges, GRASS drawer hooks and pull-outs, insertion of rubber bumpers.

Same typology as ABH120 but prepared for the processing of doors and fronts for kitchens and cupboards. The data input and machining process are the same as with the ABH 120. Consequently, possible operator errors and problems are similar. The machine is currently in full working order, waiting to be upgraded through RECLAIM or shut down in favour of a more up-to-date machine.

Figure 25 Machine involved (HOMAG/MAW ABS 110).

Cabinets assembly and squaring:

The last process phase conceives the introduction of the ironware and the joints within panels and then proceed with the assembly of the cabinets to be then shipped and assembled in site. This phase basically conceives a manual or machine-driven

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introduction of ironware on the panels, the assembly of the panel in cabinets the squaring of the cabinets in a dedicated machine to make them perfectly aligned.

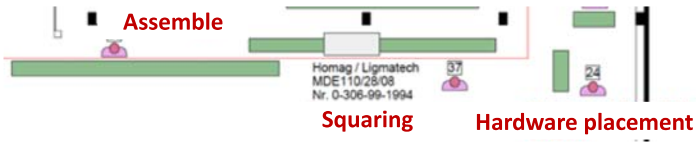

Figure 26 Cabinet assembly and squaring block.

Homag / Ligmatech MDE110/28/08: Complete line for transport, assembly and pressing of furniture bodies. With stretch film packaging system (optional). In this case, the present module is LIGMATECH" clamping system Mod. MDE 110/28/08, with motorized through conveyor belt.

General specification:

- Line capable of processing furniture of size:
- Width (Min/Max): mm 280 / 1250
- Depth (Min/Max): mm 120 /800
- Height (Min/Max): mm 300 /2800

Figure 27 Machine involved (HOMAG/Ligmatech MDE 110/28/08).

5.4 Pilot #4: Lifetime Extension of Friction Welding Machines.

Friction Welding Process:

The structure of the process is illustrated in Figure 28 and highlights the basic process parameters. These are the axial feed s_f, the axial force F, the rotary speed n and the torque M. Typically, the process is force controlled either by a hydraulic or a servo-electric feed system. The rotary speed is either driven by a continuous drive motor or an energy storage, e.g. a fly wheel. The first variant is referred to as direct drive

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friction welding (DDFW), whereas the latter is known as inertia friction welding (IFW). The basic difference between both is that DDFW allows the rotary speed to be controlled arbitrarily, while at the rotary speed run in the scope of IFW is a function of the initial energy and the physics, e.g. the torque history, of the weld.

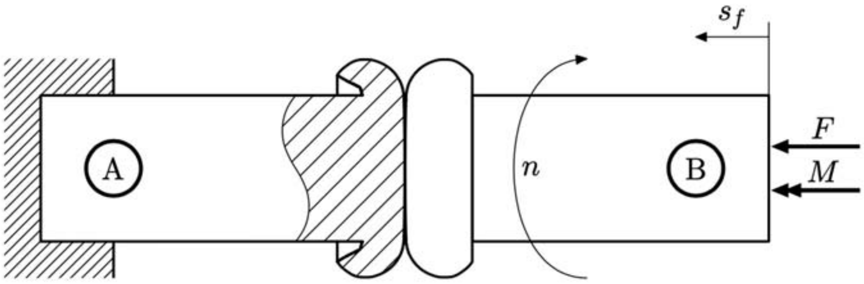

Figure 28 Schematic representation of the friction welding process with its process parameters.

One of the advantages of both process kinds is their robustness, meaning that suitable friction welds can be achieved even under rough conditions. Friction welding is comparatively insensitive to unclean surfaces of the parent parts. The weld interfaces obtain a self-cleaning effect due to the formation of the collar, commonly known as flash of the weld. In comparison to conventional fuse welding processes, the range of working process parameters is very wide; process properties are stable and, moreover, reproducible. The welding procedure is symmetric, so distortions of the welded parts attributed to the thermal load are usually low. Given a rigid machine, precise process control, true-to-size parent parts and high-quality clamping chucks, the welded parts can reach a very high degree of position accuracy. Advanced feedback control systems implemented in directly driven friction welding machines can achieve both, highly accurate axial as well as angular positions. The process is suitable for automation, which implies economic benefits in the scope of mass production. Cycle times are usually rather dominated by loading and unloading, the process itself is rather fast. A unique feature of RFW is that a wide variety of similar and dissimilar materials can be welded to each other. Many case studies show successful welds for most industrially applied metals, such as various types of steels, cast iron, magnesium, nickel-based alloys or aluminium, for instance. In many cases, e.g. when the flash is removed, the strength of the base material can be reached or even exceeded. The heat affected zone (HAZ) is smaller than it is in fuse welding processes. This is the reason because of the heat generation is located directly at the interface, while the highest temperatures are limited by the solidus temperature of the softer material and process times are rather short. Thus, also in terms of energy efficiency, RFW is advantageous.

In contrast to all these virtues, the application of RFW mostly requires special purpose machines. Moreover, the mechanical loads on the weld parts are high, which requires complex clamping techniques. The weld flash is often an indispensable feature of friction welding and must be machined off in regard with the specifications of the component part.

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Figure 29 shows the friction welding machine RSM401 which is provided by HWH as pilot plant within the RECLAIM project. The friction welding machine was in use at Lufthansa Technik for 10 years and is used in the project for re-manufacturing, development and testing of data analysis functions.

Figure 29 Friction welding system RSM401 as pilot @ HWH.

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

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

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

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5.5 Pilot # 5: Refurbishment and Upgrading of a Bleaching Machine

Zorluteks has carried operations in 250,000 square meters of enclosed space. The production mill has several large-scale equipment including weaving, knitting (flat and circular), pre-finishing, dyeing, printing (flat, rotational, digital), finishing, coating, embroidery machines. Within the scope of RECLAIM, the bleaching production line was the most suitable machinery for the implementation of the project solutions to extend machine lifetime and to increase its productivity by the incorporation of physical and virtual sensors for the evaluation of decision support tools.

Figure 30 Bleaching production line.

Bleaching operation:

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

Following are the objectives of bleaching:

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

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In Zorluteks production plant, hydrogen peroxide is used as a bleaching agent. The bleaching bath composed of hydrogen peroxide as a bleaching agent, an alkali activator (caustic soda), stabilizer, sequestering agent and wetting agent.

Though hydrogen peroxide is stable in acidic medium, but bleaching occurs by the addition of alkali or by increased temperature. Hydrogen peroxide liberates per hydroxyl ion (HO_2^-) in aqueous medium and chemically behaves like a weak dibasic acid. The per-hydroxyl is highly unstable and in the presence of oxidizable substance (coloured impurities in cotton), it is decomposed and thus bleaching action takes place as in the following chemical reaction:

$$H_2O_2 + OH^- \leftrightarrow H_2O + HO_2^-$$

The bleaching of textile fabric with hydrogen peroxide is dependent on many aspects such as pH, temperature, time, stabilizer type etc.

Effect of stabilizer: Stabilizers ensure proper degradation of peroxide during bleaching. In this way maximum efficiency of hydrogen peroxide is achieved.

Effect of pH: The separation of hydrogen peroxide depends on the amount of alkali in the bath. Hydrogen peroxide is a weak acid. The activation of peroxide occurs at pH 10-12, so hydrogen peroxide is not an active bleaching agent for cellulose fibres in acidic and neutral environments.

Effect of temperature: Hydrogen peroxide solution at low temperature is very stable and reacts very slowly; as the temperature rises, the stability of hydrogen peroxide decreases. So that the bleaching process usually takes place at 90-100°C.

Effect of time: The time required for bleaching with hydrogen peroxide depends on the temperature, the type of fibre and the equipment used. In general, the duration of bleaching is inversely proportional to the temperature of steamer.

Bleaching Machine components:

Following figure and table demonstrates continuous bleaching machine (Küsters-1996) and recipe that is used during the bleaching operation in Zorluteks' production plant.

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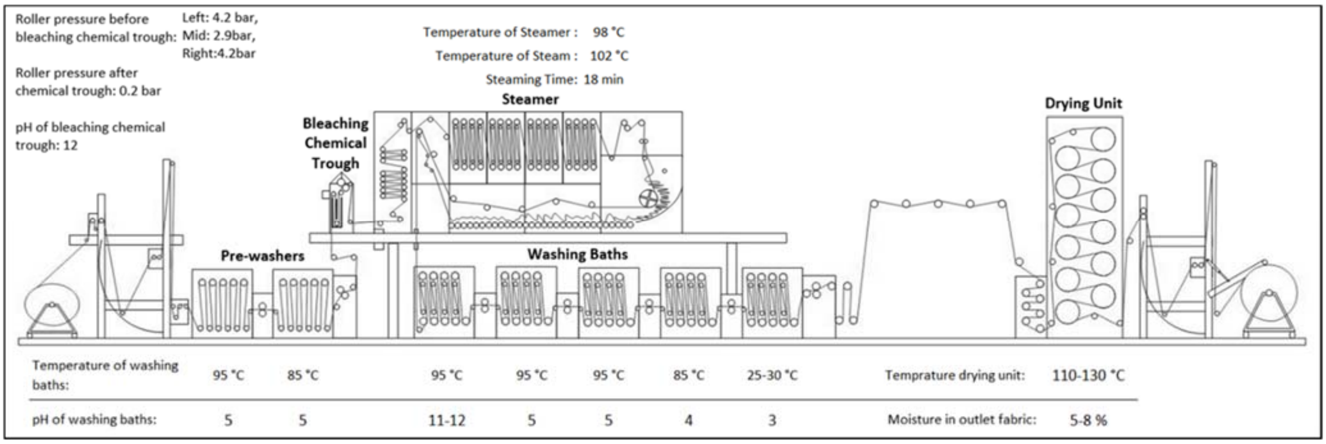

Figure 31 Bleaching Machine and main operational parameters.

After finishing desizing process fabric comes to the bleaching machine. (Sizing weaving production serves to protect the yarn during to withstand high mechanical stress during weaving. Starch is used for sizing agent. Before bleaching operation, desizing operation must be done to get rid of sizing agent by using enzyme). First step is pre-washing to wash off the starch and other impurities from desized fabric by using hot water. There are 2 pre-washers at the inlet of the machine.

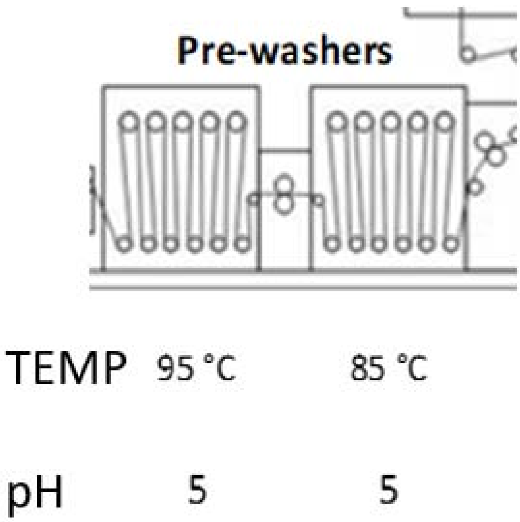

Figure 32 Pre-washers stage and its main parameters.

Then fabric moves to bleaching chemical through which is the place that bleaching chemicals based on the recipe are applied uniformly on the fabric.

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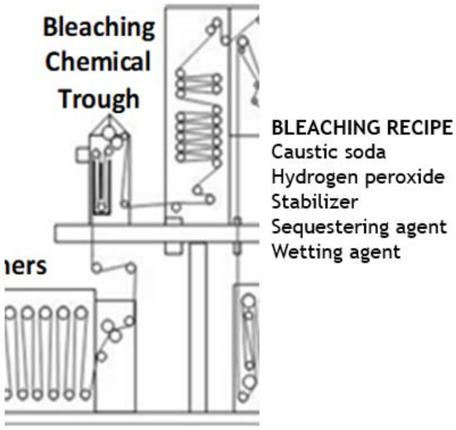

Figure 33 Bleaching Chemical Trough and its recipe.

After that, bleaching reaction takes place in steamer at 102°C and in 18 minutes.

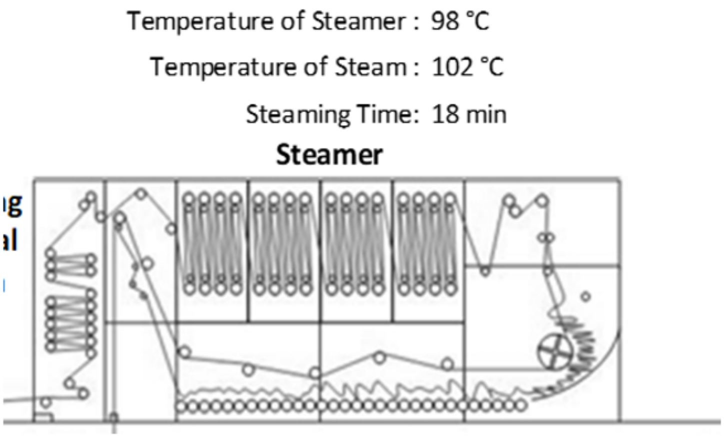

Figure 34 Steamer stage and its main parameters.

The next step is to remove bleaching chemicals on the fabric in washing baths. Although the first four washing bats contain hot water, the last one is filled with water at room temperature. The reason behind is that neutralization is occurred with acetic acid.

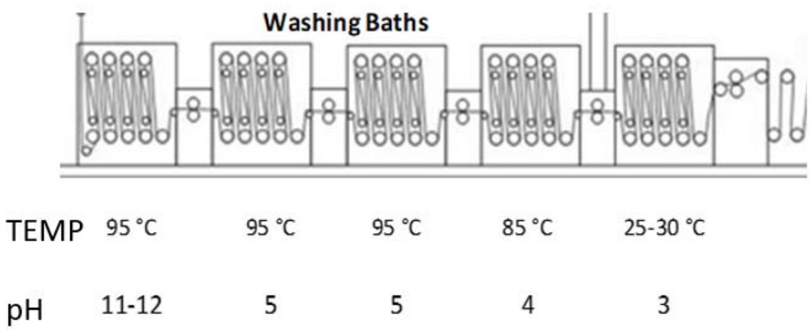

Figure 35 Washing Baths stage and its main parameters.

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Finally, fabric is dried and ready for the following processes.

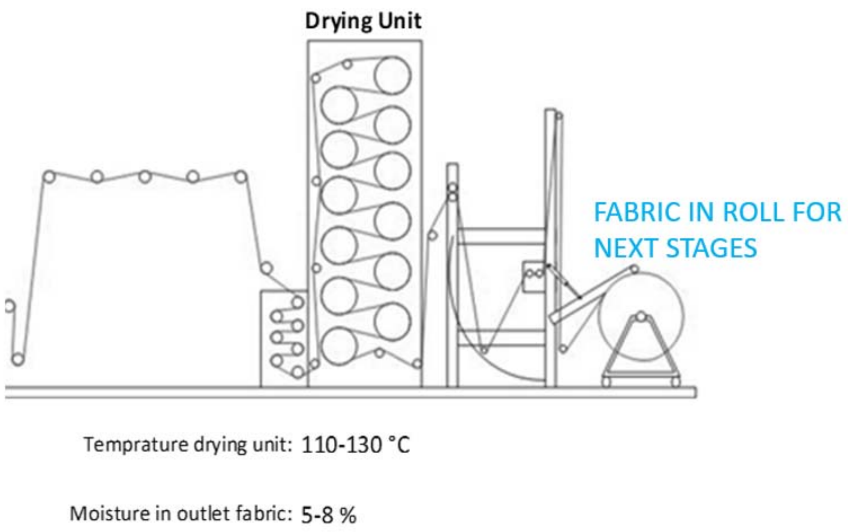

Figure 36 Drying unit stage its main parameters and fabric roll.

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6 RECLAIM Technical tools

Currently, the following architectural components with the described functionalities have been defined within the context of the ongoing T2.3 and will be described in more detail along with the few missing components in all three versions of D2.3, due for M10, M20 and M30:

Adaptive Sensorial Network with IoT Cybersecurity:

Edge Device with Digital Twin integration and data processing algorithms: Digital Twin technology based in Python that is used to interface with physical components, process their data and send them to information systems. Additionally, it is possible to design and deploy a machine to machine (M2M) communication to build a cyber physical production system. This cyber physical production system design is based on IEC61499 industrial standard where blocks are used to graphically program the dynamics of CPPS. As the digital twin is built using Python, the state-of-the-art artificial intelligence methods can be used.

IoT Gateway software stack: The software stack will be comprised of the communication and protocol adaptation services for the IoT device communication and will provide the necessary tools, libraries and middleware for using the TensorFlow framework on IoT gateways based on the NVIDIA Jetson platform.

FPGA-accelerated cyber security module: This module will enable the use of an FPGA-accelerated software appliance as a configurable, intelligent, high-throughput edge security for use in the pilot premises.

RECLAIM Repository:

Distributed data storage and analytics (DRy): This tool is part of the RECLAIM repository. It consists of a distributed storage and a set of data aggregators tailored according to requirements.

Data handler with cybersecurity: This component transforms the format of data exchanged between the RECLAIM Repository and other components. A holistic data model (information model) will be used for storing data in the database of the RECLAIM Repository. The data handler will also include cybersecurity mechanisms that will ensure the secure data communication with the Distributed data storage and analytics component. It needs to be clarified among partners during which of the following transfers the data handler will need to be transforming the format:

- Input from machinery data collectors and end users to RECLAIM Repository.
- Input from RECLAIM Repository database to the algorithmic components (DSF, In-Situ Repair Data Analytics, AR mechanisms).
- Output from algorithmic components to RECLAIM Repository database.
- Output from RECLAIM Repository database to users' interfaces.

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Decision Support Framework:

<u>RECLAIM Information Modelling tool:</u> This tool implements statistical analysis to calculate machines reliability, average residual useful life and other relevant indicators. Starting from different sets of historical data (e.g. MTTR, MTTF, MTBF, others), reliability analysis tool is able to build failures probability functions (e.g. Weibull 2 param, Weibull 3 param). This tool will be used to develop simple analysis in order to have a first overview about machines' reliability.

<u>Machinery Operational Profiling:</u> This algorithm is part of the Machinery Operational Profiling. It consists of an algorithm that calculates the three indexes (Health, Performance, Production) from the data and parameters provided by the RECLAIM user partners.

<u>Fault Diagnosis and Predictive Maintenance Simulation Engine using Digital Twin:</u> The main goal of this component is to create a Digital Twin of the factory environment and to use it to monitor and predict the performance and status of factory assets. This will allow providing to the user all the features needed to schedule the maintenance works on the machines to avoid failures being predicted by the Prognostic and Health algorithms; to perform proper maintenance planning, optimizing the production throughput and reducing the production lines stoppages. This component is going to include at least the following sub-components:

- *Digital Twin for simulation:* This component imports the status of the factory assets from the RECLAIM repository, the machinery profiles and a predictive maintenance and/or a faults model if available. The goal is to evaluate different maintenance scenarios and production strategies by means of discrete simulation to reduce the impact of maintenance activities on the performances of a production system.
- *Anomaly Detection:* Techniques to find abnormal behaviours that deviate from normal process conditions to raise warnings and find root causes for the problem.
- *Predictive Maintenance:* The predictive maintenance approach is composed of
  a) a component failure prediction in the future (e.g. 48h),
  b) an optimization module for scheduling future maintenance actions based on the existing scheduling.

<u>Optimization Toolkit for Refurbishment and Remanufacturing Planning:</u> This component is part of the Optimization Toolkit for Refurbishment and Remanufacturing Planning. It aims to support the planning optimization through multi-variable monitoring of the machines' operational parameters where the effects of variable changes will be possible to determine and combine learning methodologies for model-based plat-site/shop-floor control. Based on the multimodal data provided by the IoT infrastructure, new approaches of real-time production planning optimization algorithms will be developed to apply proven optimization methodologies to deliver measurable performance improvements. Also, this monitoring takes into consideration the data collected from the sensors network, the machine profiles, production processes, and previous predictive maintenance

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simulations. This component is going to include at least the following sub-component:

- *Algorithms for quality prediction and process parameter optimization:* Algorithms to predict the final product quality in a specific machine based on the parameters used for the process. These methods are based on data, where both parameters and final quality should exist in order to train machine learning models, both regression and classification. Ultimately, based on the quality predictive model it is possible to estimate future machine parameters if a new product needs to be yielded.

Degradation models: Machine-learning-based models to model the degradation patterns of certain components, and based on this, calculate the KPIs to classify machine's health. They will be a part of the Prognostic and Health Management Toolkit.

Cost Modelling and Financial Analysis Toolkit: Based on the requirements (T2.1, T2.2 and directly from Pilot case study partners), it is going to provide cost estimation to support financial analysis, cost optimization and decision making.

Integrated Decision Support Framework (DSF) for Refurbishment & Remanufacturing Optimization - core component: Based on evaluation metrics to be defined, raw data from the Adaptive Sensorial Network, the output of data analysis components about the Machinery Operational Profiling, Fault Diagnosis and Predictive Maintenance Simulation Engine using Digital Twin, Optimization Toolkit for Refurbishment and Re-manufacturing Planning, Prognostic and Health Management Toolkit, as well as the Cost modelling and financial analysis toolkit, along with lifetime extension strategies, the DSF will infer

- the most suitable remanufacturing/refurbishment strategy.
- the preferable timeframe for the implementation of the strategy.
- the right components to be remanufactured/refurbished.
- the optimal design alternative.

In contrast with the Optimization Toolkit for Refurbishment and Re-manufacturing Planning defined above, which performs only operational optimization in single machines, this component performs operational optimization globally, i.e. in whole production lines or set of machines of each pilot use case, considering also business aspects (financial etc.).

In-Situ Repair Data Analytics:

The exact role of this component will depend on the pilot needs. In any case, it will consist of algorithms and visual analytics. One possible option is that a camera or laser sensor that will be taking 3D data from the product is installed, and an image processing algorithm (supervised or unsupervised, depending on the presence or absence of ground truth data respectively) will be comparing it with the ideal form of the product and based on that will be inferring (in the supervised case) what

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action should be taken on the equipment producing it. If 3D data cannot be acquired, process data from machinery data collectors may be used as input instead.

- AR mechanisms: This component will have the following functionalities:
  1. Develop novel Localization Mechanism:
     a) Research Inside-out 3D registration [based on Inertial Measurement Unit (IMU) and Vision hybrid methods]
     b) Research Outside-in 3D registration (based on Bluetooth/WiFi/Zigbee etc. triangulation)
     c) Implement hybrid indoor localization using above methodologies
  2. Develop novel AR Visualization Mechanism:
     a) Implement head-mounted display (HMD) and Mobile device-based AR Visualization pipeline
     b) Integrate Indoors localization to AR 3D visualization
     c) Implement real-time Localized 3D Annotation module
     d) Research multimodal (gesture voice) interaction techniques
  3. Integrate with Adaptive Sensorial Network: Use the ASN to provide context-aware instructions and notifications
  4. Integrate with DSF: Integrate DSF proposed solutions in instructions and notifications
- Life Cycle Assessment: This component will have the following functionalities:
  1. real-time assessment of the sustainability performances
  2. generation of machine use/refurbishment scenarios
  3. comparison of the identified scenarios

Users Interfaces for RECLAIM Platform: This component consists of the visualization panels of the RECLAIM platform and the hardware on which this visualization will take place. The visualizations will correspond to output of the Decision Support Framework, the In-situ Repair Data Analytics Toolkit, the AR Mechanisms and the LCA tool.

IoT smart heterogenous sensors, industrial PC and communication tools.

The physical layer for the data gathering and the refurbishment of pilot machines and components at RECLAIM project will be based in the following smart IoT systems solutions, amount other that are under definition:

- Self-powered electronics based in energy Harvesting to gather data from smart sensors
- Piezoelectric Sensors to monitor stress, strains and vibrational diagnosis
- Power analyser
- Miniaturized low cost piezoresistive sensors
- Multi-platform wireless HMI
- Thermographic camera
- Magnetic sensors to monitor electrical power loss
- Real time energy consumption and load profile monitoring of machinery
- Smart Sensors to gather process parameters

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- Smart wireless sensors to gather process parameters such as current, cooling water temperature, squeeze pressure
- Machine Vision Camera
- Working conditions monitoring network to avoid unhealthy/unsafe events for workers and machinery
- IoT Heterogenous Sensor Network
- Edge Industrial gateway: flexible gateway that can connect different machines, sensors, cameras, etc... and hosts different type of algorithms using a ARM+FPGA or ARM+GPU approach. AI algorithms can be optimized to work on FPGA/GPU to be faster and consume less power
- IoT controller to control device remotely by creating a bridge between the industrial devices and the Cloud
- Chemical Sensor
- pH online sensors
- Flexible sensor for semi-rigid
- Low power electronics
- IoT industrial communication units for sensors
- Temperature and humidity sensors

As summary, RECLAIM technical tools will combine physical and virtual tools for their demonstration into the Pilots descried at the present deliverable as exhibit in

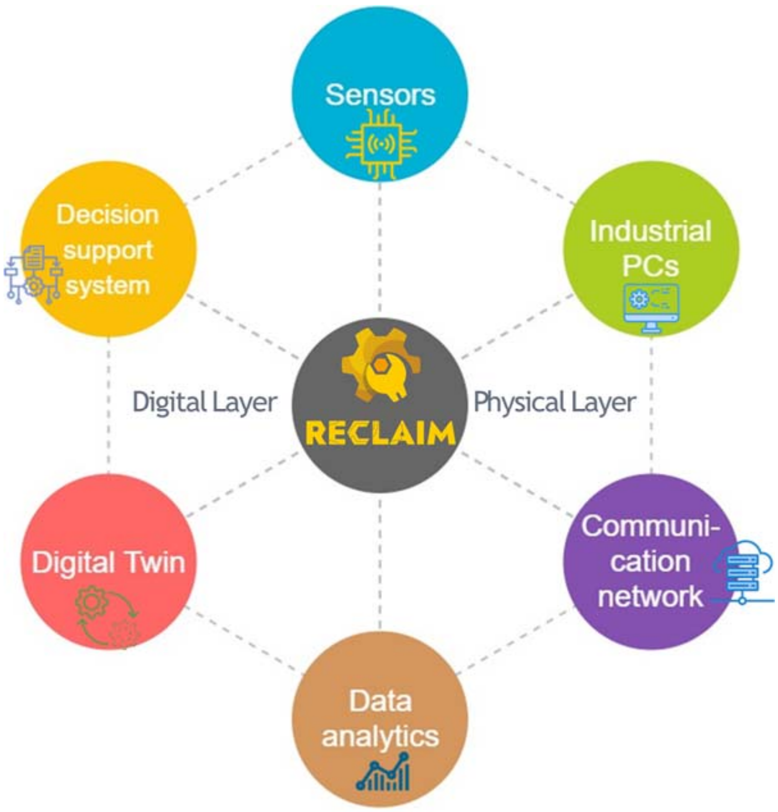

Figure 37 RECLAIM Physical and Virtual tools.

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7 RECLAIM Pilots: Scenarios & Technologies.

7.1 Pilot #1 - Home Appliance Manufacture.

As previously described, Gorenje scenarios include a wide variety of problems to be solved through the addition of sensorial networks in first place. These include the following:

- Real time energy consumption and load profile monitoring of machinery focused on the implementation of an early warning identification of furnace shutdown.
- Smart wireless sensors to gather process parameters such as current, cooling water temperature, squeeze pressure to feed predictive maintenance process.
- Working conditions monitoring network to avoid unhealthy/unsafe events for workers and machinery. This include measurement of temperature, humidity, gases and conveyor belt speed.

At Gorenje pilots, several technologies are going to be implemented including machine vision and addition of new physical sensors.

Regarding machine vision, the main purpose is to use cameras for part identification and alignment verification which will provide solution to problems related to welding of small parts, identifying if the right parts are present according to material list. Moreover, the same technology is going to be used for solving issues related to identification of different parts at the beginning of production line (e.g. raw metal, sheet parts etc). By applying computer vison, the part identification, part counting and statistics about used parts will become possible, allowing Gorenje to improve its traceability accuracy.

Regarding addition of new sensors, the main purpose is to feed the predictive maintenance module with the appropriate data improving the current processes. Problems related to the worn out of specialised tools and hydraulic valves can be monitored through appropriate sensors providing information related to their status and through the predictive maintenance module to prevent possible failures.

Moreover, in order to support the above functionalities, accordingly, configured gateways will be provided and installed to manage the above described sensors and cameras. Such HW will provide accelerated ML and DL capabilities at the edge, operate as a border router for WSNs and provide configurable dataflow and event-driven services for achieving business intelligence at the edge.

The Distributed data storage and analytics component is needed for the upgrading of actual automatic measuring system with real-time data management. The Information Modelling Tool will be used for measuring various parameters for better prediction of machine service (e.g. oil changing, filter changing) and for measuring

indicators (frequency of faults, statistics etc.). The Digital Twin for Simulation will be used at robot cell B with the purposes of cycle time reduction and efficiency improvement. The anomaly detection and predictive maintenance algorithms will receive as input at least the temperature of seam rolls. A real-time fault diagnosis and predictive maintenance solution will be applied also for bending machines. In addition, algorithms for quality prediction and process parameter optimization will be applied using variables from the spot-welding parameters control system (welding current, temperature of cooling water) and the seam welding parameters control system (welding current, pressure, temperature of cooling water, speed of welding rolls in connection with robot speed). Furthermore, the In-Situ Repair Data Analytics toolkit will be used for the SCADA system and part recognition, as well as part dimension/shape recognition.

Scenario (Modernization and refurbishment of White Enamelling line), the Distributed data storage and analytics component will be used in the automatic continuous measuring system for enamel thickness. Similarly, to the previous use case, the Information Modelling Tool will be used for measuring various parameters for better prediction of machine service and for measuring indicators (frequency of faults, statistics etc.). An anomaly detection algorithm will be needed for the spray booth, the conveyor and the furnace, but the related parameters have not been defined yet. Also, a predictive maintenance algorithm will be needed for the enamel powder application. Additionally, the In-Situ Repair Data Analytics toolkit will be used for automatic part recognition.

More details about the adoption of the Cost Modelling and Financial Analysis Toolkit, the optimization tools, the user interfaces or also other components in each of the two scenarios still need to be defined.

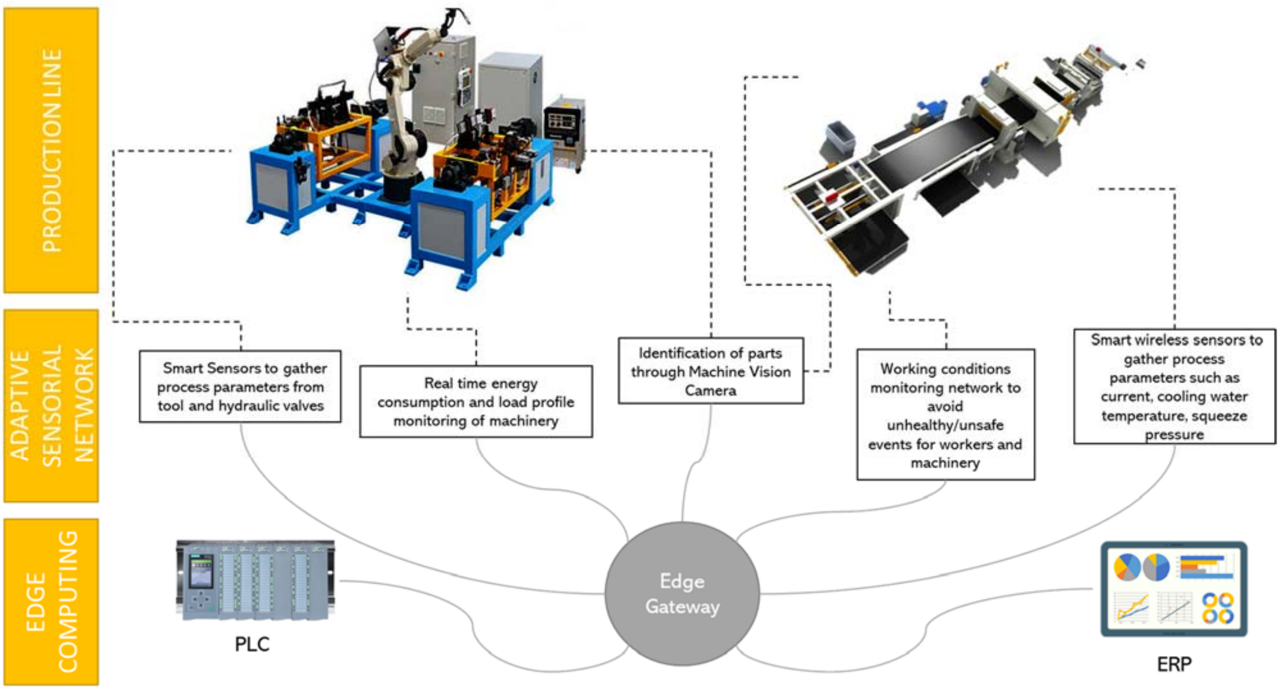

Figure 38 Diagram block of the Pilot#1.

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7.2 Pilot #2: Retrofitting and Upgrades in the Shoemaking Industry.

After analysing the different types of large equipment existing in Fluchos facilities, mainly in the cutting and forming sections, the pilot has focused on three different and repeated types of machinery in several production lines.

These machines will be updated through the application of non-intrusive smart sensors and electronics that will improve their operation and the control and analysis of parameters so that this information can be managed by a server and facilitate human-machine interaction.

Developments will include self-powered devices to gather processes parameters and local SCADA to be run in multiple HMIs such as mobile, rugged tablet or laptop.

The main objective of monitoring the machines, defined in previous section, is to digitalize the state of the asset in the operating cycle in order to supervise production. This digitalization process involves acquiring data from the machine, transporting and storing the information. Analysing the behaviour of the machine and extracting the necessary KPIs for monitoring the production cycle.

The data collection will include all the necessary hardware for the acquisition of the variables of the machine's behaviour, while the transport and storage of the information will include both the hardware and the software necessary to have a database capable of being analysed and consulted remotely. Data mining and extraction of production KPIs will be performed on the system's data server, requiring a learning period through which the algorithms necessary to supervise that the production cycle of the machine is optimized.

Monitoring:

Two layers of data acquisition are defined in the machine depending on their origin. First able, the connection to the machine's automation will be enabled in order to extract basic behavioural information and to avoid duplication in the instrumentation necessary for production supervision. If the extraction of information is feasible, it must be done through a communication bus integrated in the machine's own PLC, however, if the impossibility of integrating of this type of interface is detected, the signals will be acquired through modules I/O associated to the inputs and outputs of the PLC. It will be considered that the insertion of this additional electronics should not influence the normal behaviour of the machine, (Non-invasive devices).

In addition to the existing variables, complementary sensors should be integrated which will provide additional information, that currently is not available. It measures the electrical consumption for obtaining production costs per part, as well as the extraction of indicators of the ecological impact of production. On the other hand,

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the integration of instrumentation for monitoring the process of forming the part through force, time, temperature, etc, which allows obtaining information regarding the actual quantity of units processed and the quality of the production of these.

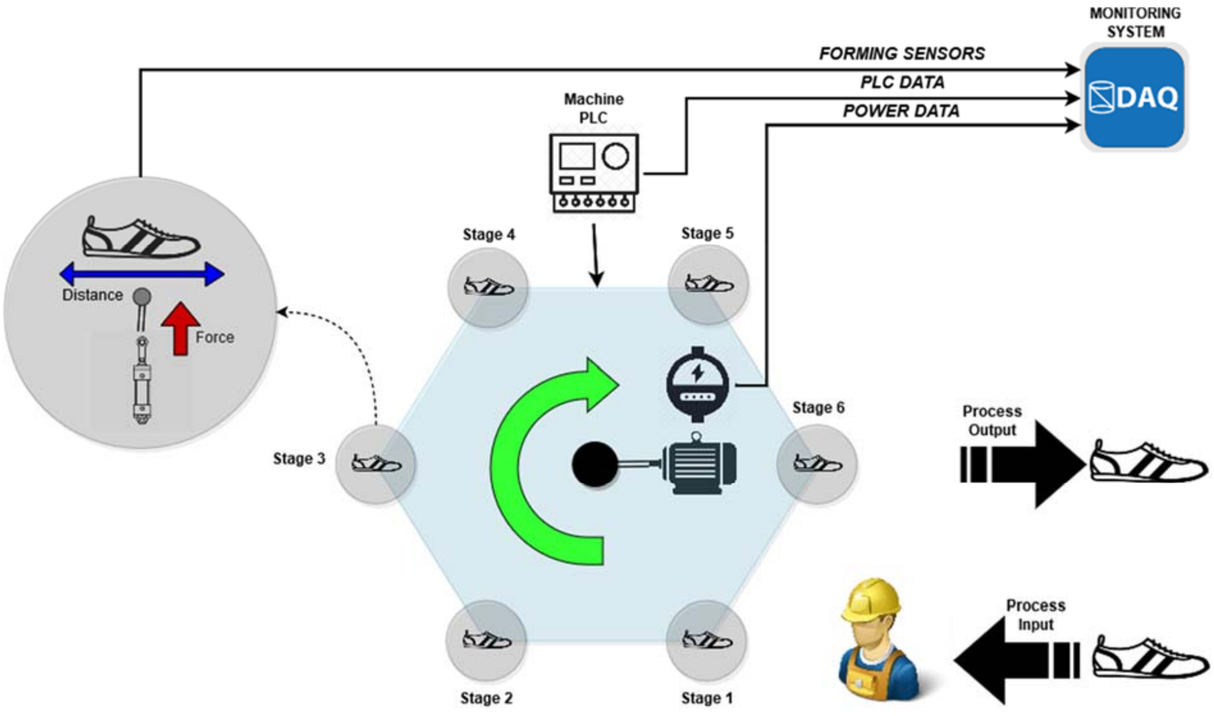

Figure 39 Diagram block at machine level.

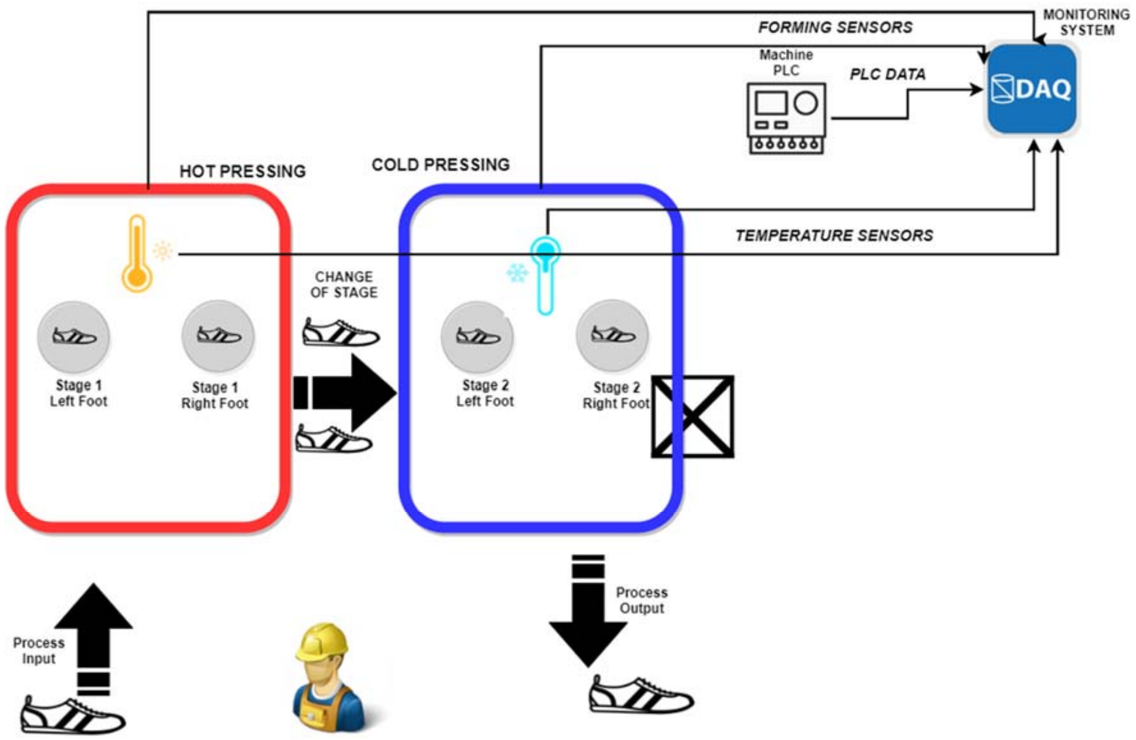

Figure 40 Diagram block at machine level ("TALONADORA").

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7.3 Pilot #3: Predictive Maintenance and Refurbishment of a large Woodworking Production Line.

With respect to the aforementioned production cycle, two machines can't be currently fully integrated in the design and production process because of their aging. In particular, the HOMAG/MAW ABS 110 & HOMAG/MAW ABH 120 (currently dismissed) are two machines that, although mechanically operative, can't be directly embedded within the production cycle due to a totally missing connection with the software layer. Therefore, for these machines is not possible to have a direct linkage from the technical office, with direct impacts both on productivity, due to relented production cycle deriving from the intervention of the operator to reprogram them each time a different product has to be manufactured; and on production quality, as reprogramming of the machine allows for one more degree of uncertainty with respect to a direct connection with the post-processing software.

Moreover, being 15 years old, the machines are entering in a phase where the production quality and their reliability should be monitored in detail, in order to avoid the risk of spending more time and money on their maintenance, instead of their operation.

In order to comply with the aforementioned issues, the following actions are expected to be accomplished in this pilot:

- Digital retrofitting of the machines in order to make them integrated within the production flow;
- Development of a digital twin allowing to capture real time operation of the machines and simulate the production behaviour, instrumental to parallelize the production on the dismissed machine;
- Integration of algorithms to support the forecasting of machines' performances and breakdowns;
- Integration of the information modelling tool to analyse reliability of the machines based on the current data;
- Integration of the LCA analysis tool as an enabler of a sustainability-oriented optimisation of the production process.

With the integration of the aforementioned technologies, the PODIUM pilot is expected to achieve the following advancements with respect to the current state of the production process:

- Re-introduction and more efficient utilisation of two machines currently in a dismissing state.

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- Integration of a more extensive machines' reliability culture in the production operators and at management level.
- Availability of updated and easily manageable indicators to support the monitoring and optimisation of maintenance policies.

Optimisation of the overall production process with respect to production system performances in terms of availability of the production machines (particular focus on the HOMAG/MAW ABS 110 & HOMAG/MAW ABH 120), environmental performances of the overall system; productivity of the system, thanks to the parallelisation of certain production tasks.

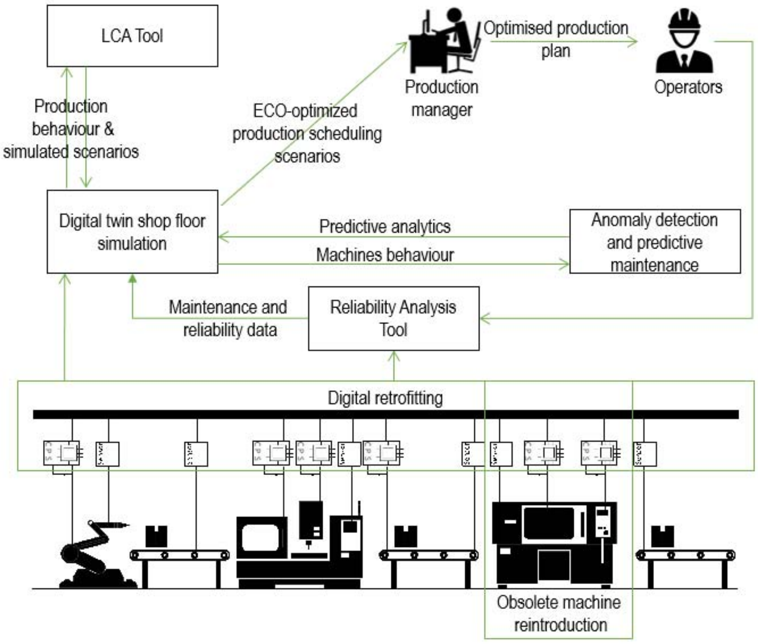

Figure 41 Diagram of Podium Use Case.

According to the problem statement defined above, hereinafter the main technologies adopted within the Podium Pilot are described.

- Digital retrofitting of the machines in order to make them integrated within the production flow;
- Development of a digital twin allowing to capture real time operation of the machines and simulate the production behaviour, instrumental to parallelize the production on the dismissed machine;
- Integration of algorithms to support the forecasting of machines' performances and breakdowns;
- Integration of the information modelling tool to analyse reliability of the machines based on the current data;
- Integration of the LCA analysis tool as an enabler of a sustainability-oriented optimisation of the production process.

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Digital retrofitting:

The aim of this activity is related to making the machine compliant with the framework of connected production. In other words, whereas the concerned machines are working properly as far as mechanical processing is concerned, their full potential cannot be integrated into PODIUM's production cycle, due to the fact that, in contrast with the other company machinery they cannot be remotely programmed, and their conditions cannot be monitored. Therefore, a dedicated analysis and implementation work will need to be performed, with the following sub-tasks:

- Identification of the most suitable gateway solution to connect the machine.
- Identification of the main desirable/achievable measurements to perform condition monitoring.
- Electronic components (sensor, gateway) sourcing/design/customization
- Components integration within machinery.
- Machinery integration within the PODIUM digital process management platform.

Digital twin shop floor simulation:

The digital twin for shop floor simulation is meant to evaluate the impacts of planned and predictive maintenance activities on the performances of Podium shop floor. The evaluated performances can be resources utilization, throughput, WIP, etc., and they are assessed over a production period that can be defined by the end user.

This digital twin must represent:

- All the production resources of Podium system, in terms of machines, equipment. Each resource can be characterized by some properties like production capacity, cycle time needed to work each product, availability, MTTR and MTTF, etc.
- The material handling devices to move materials from the loading area of the system to the delivery area. These devices can be characterized by some properties like capacity, speed, availability, MTTR, MTBF, etc.
- The control logic for handling the movement of material through the system such as: the routing rules, the rules to manage different queues, etc.
- The control logic of each production resource to work each product in a correct way.

The main benefit for Podium comes out from the possibilities to analyse different scenarios to find out best trade-off between carrying on all the planned maintenance activities and respecting all the delivery dates as stated in the production/scheduling plan. To achieve these goals, the digital twin allows to analyze different scenarios in a short time, with changes on production or maintenance plan, routing rules, some input parameters, for instance putting in production the dismissed machines. Each

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scenario can be simulated, and the results can be analyzed in detail. Simulation result can be also used as input for other apps developed in RECLAIM. At the end, the results of the selected scenario can be transferred to the Podium shop floor.

The digital twin for Podium shop floor simulation will help in:

- increasing machine utilizations and operational effectiveness because of the reduction of breakdowns malfunctions due to a lack of predictive maintenance,
- increasing material and resource efficiency because of maintenance will be planned before some machine parts will broke,
- reducing maintenance cost effectiveness because defective machine parts will be replaced before they can cause high damages to the machine tool.

Anomaly detection methodology:

The pilot-agnostic methodology for anomaly detection and predictive maintenance will be applied to the drilling machines HOMAG/MAW ABS 110 and HOMAG/MAW ABH 120.

Information modelling tool:

By exploiting both historic and digital twin acquired data, the information modelling tool will be exploited to provide updated information related to the state of the machines in terms of reliability and lifetime expectancy. The tool will be firstly adopted to monitor and evaluate the situation of the two oldest machines within the production process (HOMAG/MAW ABS 110 and HOMAG/MAW ABH 120), analyzing the specific equipment composing them, wherever possible. The tool will be therefore taken as a starting point to structure a more thorough analysis of production system reliability related issues and keep a continuous monitoring of system across time.

Life Cycle Assessment Tool:

The tool will be here deployed to support the analysis of the current status of the machines from a sustainability perspective and identify the sustainability-oriented optimization strategies able to extend the lifetime of the machines and/or the production scenarios able to best match environmental and economic indicators. By connecting with the digital twin of the production system, the tool will be able to manage the real time data (in particular related to the HOMAG/MAW ABS 110 and HOMAG/MAW ABH 120) of the machines and exploit them to generate as is analytics based on historic machines behavior, or forecast the production system sustainability-oriented performances by means of simulating different possible use scenarios.

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7.4 Pilot #4: Lifetime Extension of Friction Welding Machines.

Interchangeable system components:

A highly flexible system architecture is required in order to meet future customer requirements and to react flexibly to infrastructure requirements and heterogeneous boundary conditions. The (X)Genius platform forms the basis of the desired architecture. The synergy effects resulting from this approach will reduce both development costs and production times.

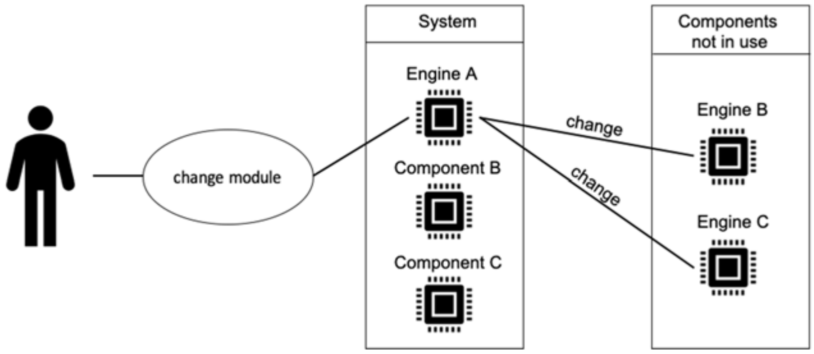

Figure 42 Interchangeable system components.

Remote Diagnosis:

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

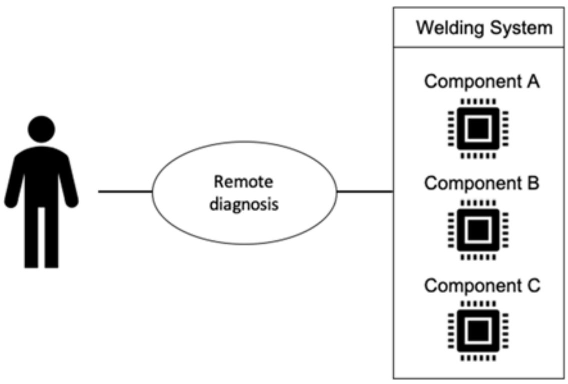

Figure 43 Remote Diagnosis.

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Interchangeable HMI:

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

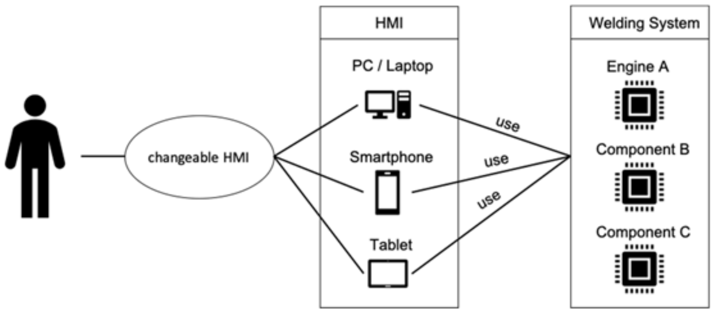

Figure 44 Interchangeable Human-Machine-Interface.

Predictive Maintenance:

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

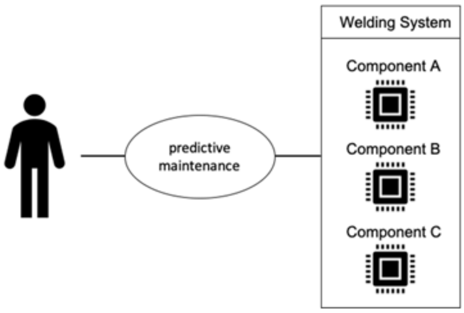

Figure 45 Predictive Maintenance.

Root Cause Analysis:

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

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and a self-awareness of the machine, the time to find the root cause can be reduced considerably.

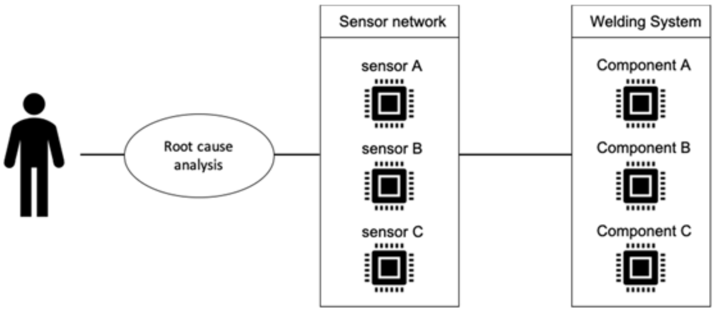

Figure 46 Root cause analysis.

At least two different technologies will the implemented, namely 1) an algorithm for Fault Diagnosis and 2) a Predictive Maintenance algorithm.

As for the Fault Diagnosis, the main idea is to detect anomalies in equipment based on quality baselines of correct behaviour. The goal is to signal some anomalies to the users and trigger maintenance / quality correction actions. In order to execute this algorithm, the following inputs need to be available:

- Time-series sensor and process data of normal (or abnormal) behaviour from components and / or equipment;
- Possible failures that might have occurred (for supervised algorithms)

As for the main outputs of the algorithm, based on the identified patterns, the goal is to classify online data into abnormal or normal data to therefore trigger the execution of some other decision-making tool for, e.g. optimization. The interfaces of the algorithm will be mostly with the RECLAIM repository and a possible machine-2-machine communication with HWH equipment. Specifically, for the outputs, it might be also considered the integration with some HMI for user interaction with the system.

The developed system can be divided into 3 main parts:

- Data Preparation so it can be suitable for feature engineering before any training procedure or feed it to a classifier (Figure 47 and Figure 48);
- Feature engineering where a set of steps is applied so one can take as much as possible of the provided data (Figure 49 and Figure 50);
- Execution procedure where a prediction is made and only when a sequence of anomalies is detected, an alarm can be raised and the users informed (Figure 51).

In Figure 47 it can be seen the data preparation in a time window used to extract features from the data throughout time. This is a data preparation step so it can be in the right format for feature engineering. This image refers to the data preparation in the online execution of the anomaly detection algorithm.

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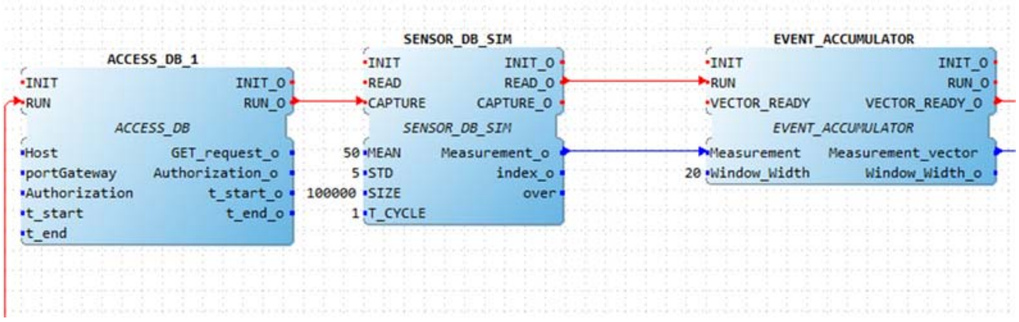

Figure 47 Data preparation in the online execution of the algorithm.

In Figure 48 the same approach is taken but instead a reference dataset is used to prepare the train process of the anomaly detection algorithm.

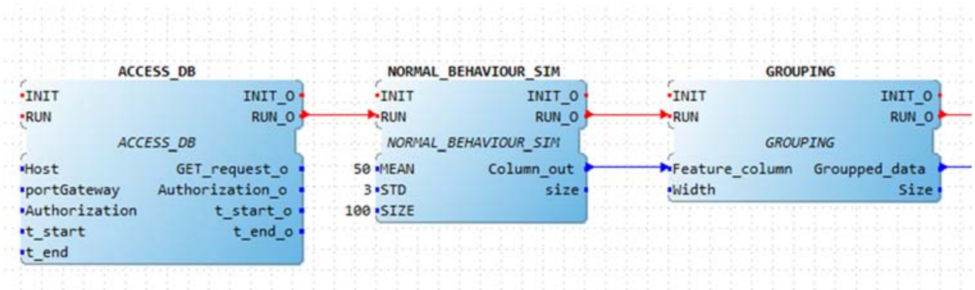

Figure 48 Data preparation in the offline training of the algorithm.

As can be seen in Figure 49, one of the most important stages for any machine learning approach to be successful is the feature extraction phase. In this case, three different stages are used, being the first an approach based on a "*global*" analysis of the data (macro and micro behaviours are analysed), then a normalization step is done to put all features into the same degree of magnitude, and then a PCA transformation for dimensionality reduction is performed. Additionally, since the figure refers to the train stage, a set of pickles are stored to be used afterwards in the online execution of the algorithm.

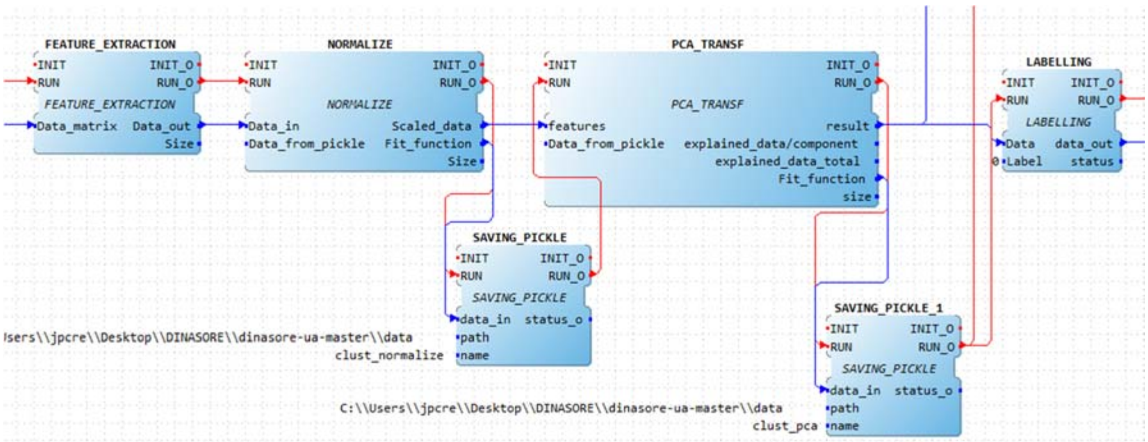

Figure 49 Feature Engineering based on the input dataset provided as a baseline (either abnormal or normal behaviour).

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In Figure 50 the same approach is taken, but the normalization and PCA transformation trained methods are loaded so they can be used in new arrived data to be classified.

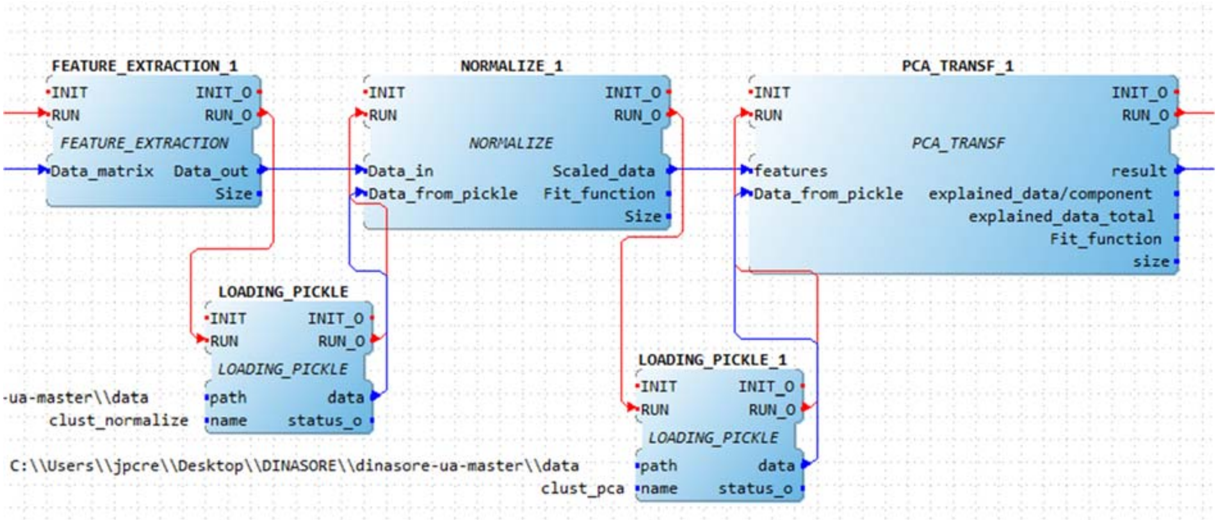

Figure 50 Feature Engineering based on the already trained methods based on the input dataset provided as a baseline (either abnormal or normal behaviour).

Finally, in Figure 51 the algorithm K-means is used to perform a prediction, then the results are stored in a CSV file for further consultation and visualization, and finally, the amount of sequential classifications as anomaly is observed so one can trigger an alarm only when a pattern is observed, and not whenever an outlier is detected.

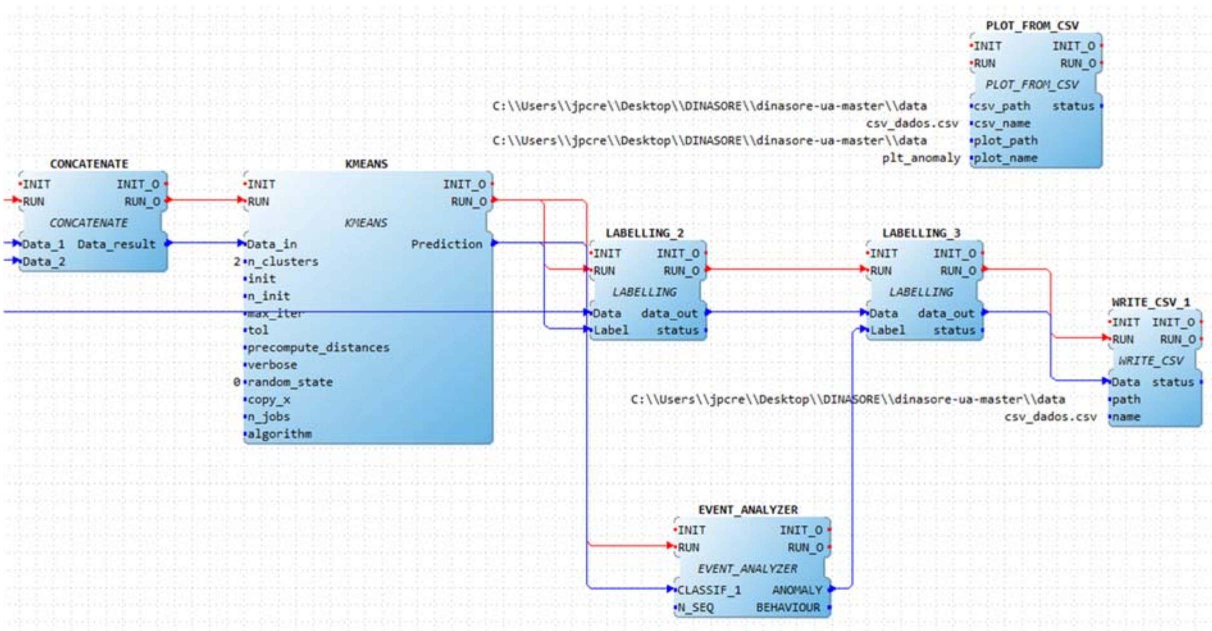

Figure 51 Execution of the K-means algorithm and the accumulation of events detect regularity in anomalies.

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As for the Predictive Maintenance algorithm, the main idea is to first detect which component is failing and when it will fail in the future (e.g. possible MTTF), secondly recommend when to perform maintenance actions based on current scheduling of shop-floor operations, and thirdly how to reconfigure machines (increasing / decreasing throughput) so there's a minimization of impact for production. The Predictive Maintenance algorithm is intended to be developed in Python as well. In order to execute the algorithm, the following inputs are required to be available:

- Time-series sensor and process data from components and / or equipment.
- Maintenance actions (name, duration and components involved).
- Machine Errors.
- Possible failures that might have occurred (for supervised algorithms).
- Production schedule.

As for the outputs, the following are expected:

- Which component will fail.
- When the component will fail.
- Recommendation of maintenance actions.
- When to perform it (Component; Duration; Maintenance Action).
- Machines reconfiguration (increasing / decreasing throughput) so there's a minimization of impact for production.

The interfaces of the algorithm will be mostly with the RECLAIM repository and a possible machine-2-machine communication with HWH equipment. Specifically, for the outputs, it might be also considered the integration with some HMI for user interaction with the system. Figure 52 presents the main building blocks of the algorithm to be implemented for the HWH regarding predictive maintenance activities.

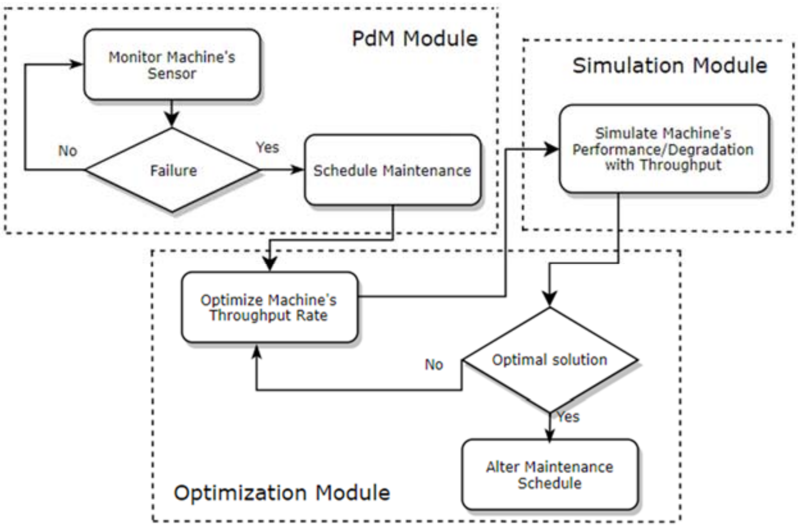

Figure 52 Overall architecture of the Predictive Maintenance algorithm.

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7.5 Pilot # 5: Refurbishment and Upgrading of a Bleaching Machine.

The aim is to develop a dynamic decision support framework for continuous bleaching machine in order to produce cotton fabrics with the targeted whiteness indices. Several parameters are involved in the bleaching process that affect the whiteness index, such as chemical parameters, mechanical parameters and physical parameters. Firstly, data collection process will be conducted for all relevant parameters and resulting whiteness degrees. With the help of artificial intelligence, smart decisions support system will be developed under dynamic conditions by means of collected data. Required refurbishment techniques will be applied on the large electrical machinery to enable integration of smart decisions support system.

At the inlet and exit of the continuous bleaching machine online colour monitoring cameras will be integrated. According to inlet whiteness degree of fabric, parameters (recipe, temperature, steaming time etc.) will be adjusted by designed artificial intelligence system to get desired whiteness degree of fabric. Cameras at the exit will control whether desired whiteness degree is achieved or not. This system enables to work human less and decides working parameter by itself. Moreover, IoT controller will be used to control device remotely by creating a bridge between the industrial devices and the Cloud.

The dynamic decision support tool will ensure the optimization of parameters and the refurbishment of the machine subprocess at the bleaching operation, with the consequent impact in quality of the product, the reduction in raw materials loss and the maintenance cost. That’s why, it provides to reduce the number of failure and maintenance activity of the bleaching machine. It brings about lifetime extension of bleaching machine. Also, it is expected that efficiency of production and quality of the product will be enhanced.

Below it will be described some of the sensors that will be included in the final scenario.

Temperature sensor:

It is used to measure temperature in washing baths and steamer. This sensor measures temperature by using a resistance change to denote the temperature value. Resistance change for each degree Celsius change is 0.385Ω. Measurement range is varied from -200 to 650 °C.

Pressure Transmitter:

It is extremely economical compared to other technologies. If a level is to be made in an open vessel a pressure transmitter (PT) is placed at the bottom and the head pressure caused by the weight of the liquid can be used to calculate the height of

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the liquid. In our bleaching machine, pressure transmitter is used in chemical bleaching trough to calculate level of the liquid.

Liquid Level Controller:

It is used to detect level (charge or discharge) of liquid in the liquid tank. In our process, it is used for whether washing baths contains any liquid or not.

Residual moisture sensor:

It is used for detecting level of moisture values on the fabric surface at the end of the dryer.

Dosing Pump:

It is used for injecting required amount of acetic acid into last washing bath of bleaching machine.

Electromagnetic Flowmeter:

It works with electromagnetic measuring principle. DC magnetic field is created through a switched direct current of alternating polarity. In our process, it is used for dosing wetting agent, peroxide and caustic into chemical mixing part.

Chemical sensors (pH Sensor):

The pH probe measures hydrogen ion activity by generating a small amount of voltage at the sensor. The voltage meter converts this measure to a pH value, and it could be displayed on its digital display or be sent by a wireless protocol.

SCADA system and PLC:

SCADA stands for supervisory control and data acquisition. It is a type of software application program for process control. As software, it helps control the hardware and makes a record of the data collected from all remote locations. SCADA is connected to computers, graphical user interfaces, sensors and networked data communications in order to provide a broad picture of the process.

PLC (programmable logic controller) stands for data collection, receiving critical information about the flow and input within the system. It is also able to perform

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basic interventions, triggering outputs when the parameters programmed into the system are met.

In Zorluteks, both PLCs and SCADA software are used within processing plants. These technologies are essentially partnering for safe and efficient plant operation. PLCs are a part of the system that SCADA oversees. The PLCs need SCADA to control their function, but SCADA relies on data from the PLCs to complete its overview.

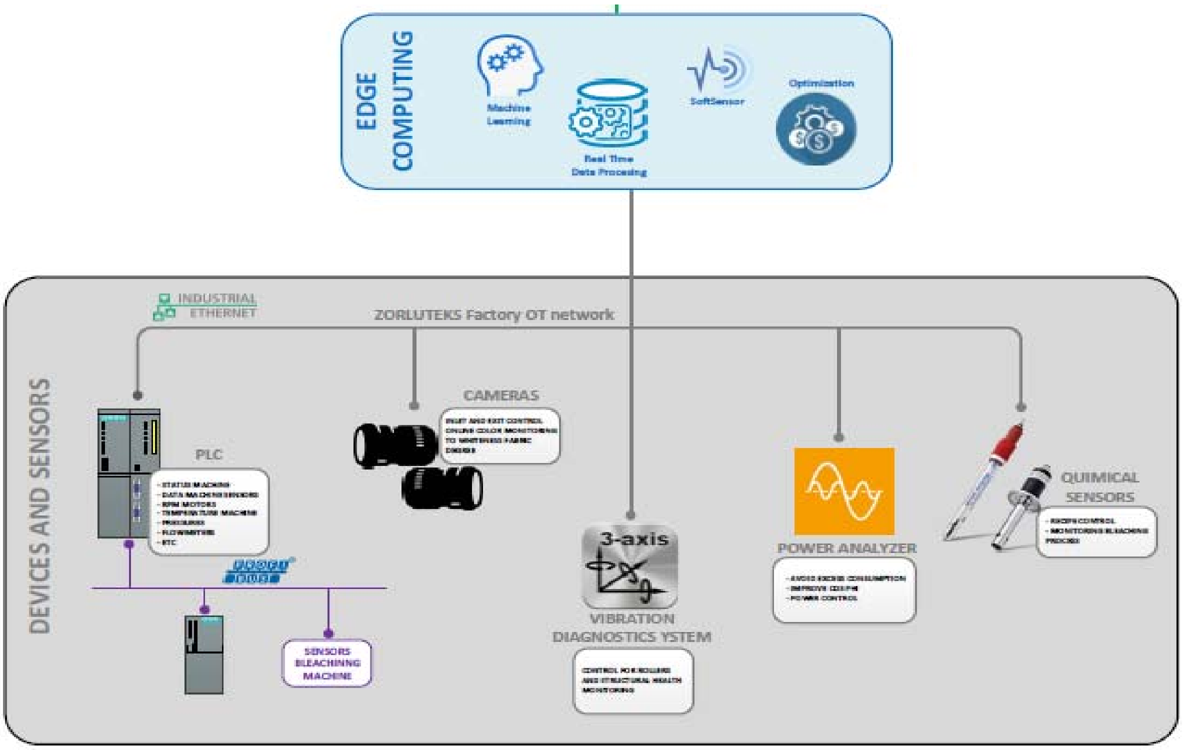

Figure 53 *Diagram block at bleaching machine level.*

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8 Standardization

A standard is a *"document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context"* [40]. A standard is a document that sets out requirements, metrics, methodology, process or technologies for a specific item, material, component, system or service.

Standards facilitate international trade and competitivity ensuring compatibility and interoperability of components, products and services. They bring benefits to businesses, research and consumers in terms of reducing costs, enhancing performance and improving safety and quality.

Official standardisation bodies are:

- **ISO - International standards organization** (https://www.iso.org/), is an independent, non-governmental international organization with a membership of 164 national standards bodies.
- **CEN - European Committee for Standardization** (https://www.cen.eu/) officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level. It an association that brings together the National Standardization Bodies of 34 European countries.
- **National standardisation bodies**, acknowledged by EU Reg. 1025/2012, developing standards at national level. UNI is the Italian Standardisation Body, officially representing Italy at EU (CEN) and global level (ISO).

Table 16 Standards impact on several features of industrial value chain.

TYPE OF STANDARD	DESCRIPTION OF THE TYPE OF STANDARD
Terminology and classification methods.	Define common language, terminology, metrics (e.g. ISO 9000:2010[41], ISO 8373:2012[42]...)
Metrology, measurement and test methods	Define common KPIs, metrics and related testing and measurement methods (ISO/TR 20218 part 1 and part 2 :2018[43]…)
Quality, innovation and environmental management system	Defining quality and environmentally sustainable methodologies to applied to organization system (e.g. ISO 56002:2019[44]; ISO 14000 series[45]; ISO 9001 …)
Process standards	Defining characteristics and features of process and procedure (ISO 11161:2007[46]…)

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Product and performance	Defining product characteristics, performance, design (e.g. ISO 13990:2006[47] series...)
Health and safety	Defining health and safety features connected to products, process and people (e.g. ISO 12100:2010[48]…). It often deals with existing regulation and legislation (e.g. Machinery Directive 2006/42/EC)
Skills and competence	Defining standardized skills and competence framework (e.g. ISO 18436:2012 series[49])
Approaches, values, human rights	Defining innovative approaches with impact on society, citizens and social business model (e.g. ISO 26000 …[50])

Standardisation is acknowledged as a fundamental tool to **boost innovation and technology transfer** (https://www.standardsplusinnovation.eu/). It creates a foundational framework from which innovators can design specific solutions and a set of parameters to work within so that they can focus their energies on creating tailored and impactful solutions.

Standards bridge the gap from research to market codifying innovative terminology, products, process, methodologies and organization model enhancing marketability of innovative R&I solution.

Accordingly, to a recent market search within the EU project BRIDGIT2[51], standardisation has substantially contributed to exploitation and sustainability of FP7 and H2020 project in the following ways:

1. **Using existing standards for the R&I activities**: projects screening, reviewing or implementing existing standards to build their activities on common and state-of-the-art knowledge and methods.
2. **Developing, revising and proposing new standards**: projects aiming to initiate or go through the process of producing standards or revising existing ones.
3. **Drafting requirements or specifications for future standards**, for possible future standards, although not directly contributing to the development of standards.

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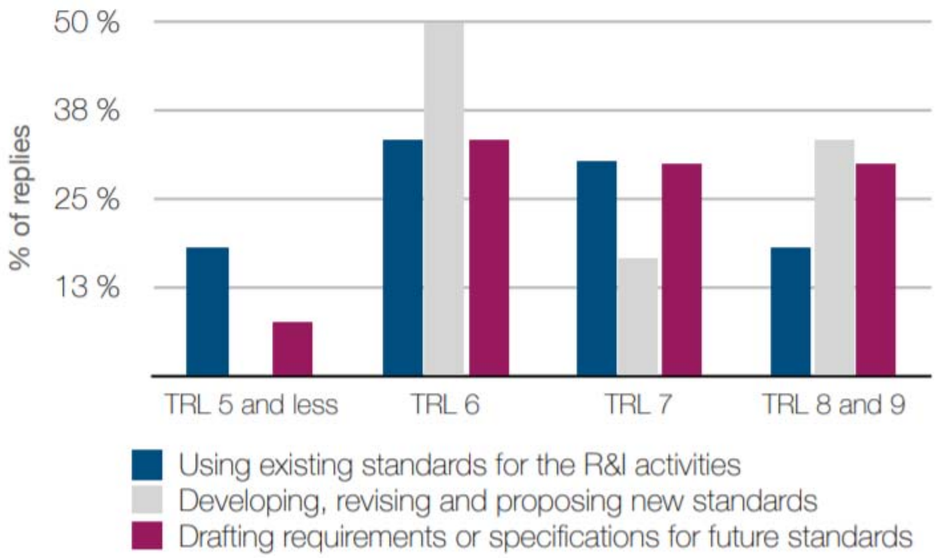

Figure 54 Source: Key findings of a study on the contribution of standardisation to European Framework Programme for research and innovation - FP7 & H2020, BRIDGIT2 project.

The above-mentioned pilots' requirements analysis, see section 4, was aimed at identifying existing implemented standards and a first analysis on standardisation needs to be addressed by RECLAIM. The following standardisation, Table 17, needs has been identified.

Table 17 Links between standardisation and TRL activities.

STANDARDISATION LINKS TO TRL ACTIVITIES
Terminology, Key Performance Indicators & Metrics
▪ Identify a cross sectoral and cross technology standardized definition of Remanufacturing and Refurbishment, as a starting point to spot a circular economy strategic approach for large machinery equipment. ▪ Define an interoperable and cross value chain set of KPIs to standardized remanufacturing metrics and measurement methods. ▪ Standardized and interoperable definition of damage should be put in place. ▪ A design and project life cycle approach should be implemented, to integrate circular economy and remanufacturing approach since the design of machinery. ▪ KPIs should be differentiated whether they apply to existing or new machinery.
Safety & Health
▪ Obsolescence of machinery makes it difficult to comply with existing safety standards and regulation. ▪ Remanufactured and refurbished machine should be compliant with existing regulation on safety of machinery and CE declaration.

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Quality, socially responsible and environmental management
▪ Define a "remanufacturing" management system along all product life cycle and internal organisation system. ▪ Integrated circular economy and remanufacturing approach in existing environmental management system. ▪ Enhance a remanufacturing management system with external stakeholder (suppliers, RTO, clients, maintenance operators ...) involved in product value chain. ▪ Adopt a socially responsible framework to measure the impact of remanufacturing within the value chain phase. ▪ Define a standardized remanufacturing toolbox to support strategic decision.
Skills & Competence
▪ Define standardized and written skills framework for remanufacturing operator. ▪ Standardized skills framework for internal workers and guidelines to manage relation with external stakeholders.

Such findings will be the starting point for a wider standardisation state of the art analysis and complemented by standardisation need assessment.

Table 18 RECLAIM Pilots existing standardization gap.

STANDARDIZATION GAP/PROBLEM	IMPACT ON THE PILOT	TYPE OF NEED
PILOT#1 Home Appliance Manufacture		
CE-Declaration of Conformity not sufficiently implemented. Monitoring system traceability.	Market, Regulatory and the machine can't be sold, Loss of efficiency and measurements of working part.	Process and Metrics.
PILOT#2 Shoemaking Industry		
Cultural barrier. No knowledge on standards.	Market, Regulatory, Technology and Process.	Terminology, KPIs, Metrics, Safety, Quality and env. Management, Skills and competence.
PILOT#3 Woodworking Production Line		
Anticipate machine turn down.	Quality management, process, product.	Metrics, process.

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PILOT#4 Friction Welding Machines		
Standards on safety not sufficiently implemented	Technology, process	Safety
Hydraulic collet system - Wear out at sealing	Technology, process	Technology
Welding stroke too slow	Process	Process, Market
Sensors and actuators difficult to mount	Process	Process, Technology
No standardized database of type of damage	Process	Metrics, terminology, KPIs
PILOT#5 Home textile Manufacture		
Pressure transmitter - measurement of liquid	Process	Technology
Liquid level controller	Process	Process
Residual moisture sensor	Process, technology, market/product	Process, product

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9 Conclusion.

The D2.2, RECLAIM Use Cases Definition & Operational Requirements #1 is the first approach of the consortium understand the production lines from five different manufacturing company's really different but with a similar problem: the obsolescence and ageing of machinery relevant for the production continuity and the need to incorporate them into the Industrial Internet of Things and the Digitalization.

RECLAIM scenarios for the demonstration and validation of the Physical and Digital tools are a good representation of the overall manufacturing sector at Europe. The consortium has on board companies manufacturing small and major household and domestic appliances with automatic and robotised production lines, representing the good manufacturing sectors. The manufacturing of artisan product with a minimum integration of automatized lines and very specific old and customized machines, with high quality standards and at the top of products portfolio in its category, is also represented at RECLAIM. This sector began its modernization at the storage and logistic of the plant, and currently, its challenge is focus on the smartization of their machines and production line. As much as these machines are old, as much as the factory owner would like to monitor and supervise them to extend their production life, because of their singularity. In this sense, RECLAIM offer non-intrusive Smart IoT sensors to monitor their correct functioning along the machine life. Traditional sectors like the furniture manufacturer with a good reputation worldwide because their creativity and quality, as well as the footwear artisan sector, it is the result of combining modern production line with traditional ones develop based in the cultural heritage and the artisan knowledge. The nexus between these two worlds, modern and traditional, could be merge into digitalization by the use of new algorithms and sensor fusion. Or the original equipment manufacturer sector might have new business opportunities by new combination of flexible industrials smart sensor, controllers and data modelling for the servitization of the data to offer more customizes services and machines to their customers including their re-usability of the equipment's. And, sector were the robustness and the eco-sustainability are in the focus of government and users, the digitalization could bring them the opportunity to achieve these important goals by the implementation of physical and software smart sensor to have the correct decision support tools. Important sectors for European and national economies, like the textile, specifically, home textiles, where its production has been directed to countries with lower production costs. The implementation into real scenarios of smartization tools could bring them the necessary competitiveness to restore their relevance into European economy. Also, even more in the present global situation, these tools will made them competitive because they are necessary for the Europe resilience and sustainability.

The scenario defined in its first version will continue in constant evolution to incorporate the advances that the technological partners in close collaboration with the industrial ones will perform in the following months going in depth into more detailed and precise scenarios and its elements.

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20 https://www.iso.org/iso-14001-environmental-management.html
21https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:39280&cs=192F4B877617B102A749830A8B801600A
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23https://www.cen.eu/work/Sectors/Mechanical_machines/Pages/MechanicalengineeringGeneral.aspx
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27https://www.iso.org/standard/46418.html
28Machinery Directive 2006/42/EC
29https://www.cenelec.eu/dyn/www/f?p=104:110:1753583005748601::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258025,43747,25
30https://www.cenelec.eu/dyn/www/f?p=104:30:1362735602906801::::FSP_ORG_ID,FSP_LANG_ID:1258161,25
31https://www.iecee.org/dyn/www/f?p=106:49:0::::FSP_STD_ID:5275
32https://www.namur.net/en/recommendations-and-worksheets/current-nena.html
33https://webstore.ansi.org/standards/isa/ansiisas8202011999
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37https://www.cenelec.eu/dyn/www/f?p=104:110:805577227201701::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258289,60994,25
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40https://www.cencenelec.eu/standards/DefEN/Pages/default.aspx
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43https://www.iso.org/committee/5915511/x/catalogue/p/1/u/0/w/0/d/0
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46https://www.iso.org/standard/35996.html?browse=tc

47https://www.iso.org/standard/39189.html?browse=tc
48https://www.iso.org/standard/51528.html?browse=tc
49https://www.iso.org/standard/52259.html?browse=tc
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51 Key findings of a study on the contribution of standardisation to European Framework Programmes for research and innovation - FP7 & H2020 – Bridgit2 project

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Annex 1.- Requirements Matrix

A.1.1 Pilot#1A Gorenje

USE CASE REQUIREMENTS				Problem	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
Pilot	Productive Process	Machine	Parts			Classification	If Other is selected write a little explanation		
Pilot#1 A Gorenje	A Robot cell	Welding cell (table, control unit)	Actual parts recognition with label	Failures, wrong parts…	Bad parts reduction	Electronical	SW (laser printing code)	3	3
			Sensors, SW for robot, manual control	Failures, wrong position for welding, wrong parts…	Bad parts reduction	Software	Electrical, electronical	5	5
		Hole cutting	Punch cylinder, sensors	Better efficiency, reduce of complexity	Better efficiency, bad parts reduction	Mechanical	SW, electrical	4	4
		2 Presses	Hydraulic valves Control unit Tools	Worn out	Increase of prod. quality, bad parts reduction	Mechanical	Electrical, electronical	3	4
		4 robots (1, 2, 3, 10)	Grippers for all robots, robot 2, welding control unit for robot 2	Worn out	Better quality	Mechanical	Electrical, SW	4	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	Mechanical	Electrical, SW	3	4
		Double bending	Protective sensors	Crash	Better efficiency	Mechanical	Electrical	2	3
		Spot welding	Welding cell (table, control unit)	No repetability, failures, wrong position for welding	Better efficiency, less time loosing of tool changing	Mechanical	Electrical, SW	3	3
			Electrodes with click system	No repetability, failures, wrong position for welding		Mechanical	Electrical, SW	2	3
			New insert of tool	Bad quality	Improving of function	Mechanical	Electrical, SW	2	3
		Seam welding	Drive unit	Bad welding quality	Better efficiency, better quality	Mechanical	SW	3	4
			Sensor for welding parameters			Electrical	SW	3	4
			Welding control unit			Electrical	SW	3	4
		Cooling water system	Dirty work environment	Bad working condition, bad water quality, dirty, too big water consumption	Lower water consumption	Mechanical	Mechanical	2	3
	C Robot cell	Hydraulic agregate	Hydraulic agregate	Worn out	Better production quality	Mechanical	Mechanical	3	4
			Control unit	Worn out	Better production quality	Electrical	Mechanical	3	4
		Tightness control system	Manual	Bad quality	*New system needed*	Electronical	SW, electrical	4	4
		Double bending	Protective sensors	Crash	Better efficiency	Mechanical	Electrical	2	3
	D Robot cell	Ovens (4. pieces)	Control unit and regulators	Electrical unpredictable shutdown the machine	Better efficiency	Electrical	SW	3	4
		Support for bending bitumen	Jigs for support bitumen	Bad quality	Bad parts reduction	Mechanical	Mechanical	3	3
		Cooling system after insulation	Transport system	Too slow	Better efficiency	Mechanical	Electrical, SW	2	2
		4 robots (12,13,14,15)	Grippers and robots	Worn out	Better quality	Mechanical	Electrical, SW	4	5
	E Robot cell	Measurement system	Measurement equipment	No output data	Better quality	Software	Mechanical, electrical	3	3
	Outer Bottom cell	Robot	Gripper	Worn out	Better quality	Mechanical	Electrical, SW	4	5
		Welding table	Table	Position of parts	Better efficiency	Mechanical	Mechanical	2	3
	All cells	PLC upgrade	Control units	Update	Parameters and parts	Software	Electrical, electronical	4	5
		CE - Declaration of Conformity	CE for all changed and new integrated equipment	Safety reason	Under Low	Mechanical	Other - documentation for all in Slovenian language	5	6

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A.1.2 Pilot#1B Gorenje

USE CASE REQUIREMENTS				Problem	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
Pilot	Productive Process	Machine	Parts			Classification	If Other is selected write a little explanation		
Pilot#1 B (MORA)	1.Spraying cabine	1.1 Aplication technology of enamelling powder		worn out - new delivery from specific company		Electronical		5	6
						Software		5	6
						Mechanical		5	6
						Electrical		5	6
		1.2 Chain conveyor		worn out		Mechanical		5	6
								5	6
								5	6
		1,3 Hangers for parts		worn out		Mechanical		5	6
	2. Furnace	Furnace with new temterature insulation, new gas burners and tubes		worn out - new delivery from specific company		Mechanical		5	6
								5	6
								5	6
								5	6
	3. Traceability	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	Electronical		4	5
			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	Electronical		4	5
								4	5
		Aplication (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	Electronical		4	5
			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	Electronical		4	5
		Equippment 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	Electronical		4	4

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A.1.3 Pilot#2 Fluchos

USE CASE REQUIREMENTS				Problem	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
Pilot	Productive Process	Machine	Parts			Classification	If Other is selected write a little explanation		
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	1.1.1 Incorrect temperature	The material does not fit the last shape	Other	Thermal	4	5
				1.1.2 Power consumption	Deviations in the average consumption	Electrical		3	3
			1.2 Hot pressing	1.2.1 Low pneumatic pressure	Unplanned downtime	Mechanical		5	5
				1.2.2 Rubber fatigue	Breakage of membranes	Mechanical		5	5
				1.2.3 High membrane pressure	Breakage of membranes	Mechanical		5	6
				1.2.4 Vibrations	Unplanned downtime	Mechanical		4	3
				1.2.5 Temperature of the material	Material damage	Other	Thermal	4	3
			1.3 Cooling	1.3.1 Incorrect temperature	The material does not keep its shape	Other	Thermal	4	5
				1.3.2 Power consumption	Deviations in the average consumption			3	3
				1.3.3 Coolant gas leaks	Unsuitable temperature	Electrical		4	5
			1.4 Cold pressing	1.4.1 Low pneumatic pressure	Unplanned downtime	Mechanical		5	5
				1.4.2 Fatigue	Breakage of membranes	Mechanical		5	5
				1.4.3 High membrane pressure	Breakage of membranes	Mechanical		5	6
				1.4.4 Vibrations	Unplanned downtime	Mechanical		4	3
				1.4.5 Temperature of the material	Lack of quality	Other	Thermal	4	3
	Forming of upper parts of the shoes, through pressure and thermal treatments	2. Forming machine for rear parts. Rotostir	2.1 Engine	2.1.1 Power Consumption	Deviations in the average consumption	Electrical		4	5
				2.1.2 Carbon Footprint	Environmental	Electrical		3	5
			2.2 Hot deforming	2.2.1 Membrane Pressure	Breakage of membranes	Mechanical		4	5
				2.2.2 Temperature of the material	Lack of quality and bad shape of the material	Mechanical		4	5
	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		4	3
				2.2.3 Incorrect average speed	Operation time decreasement	Mechanical		3	5
				2.2.4 Incorrect acceleration	Operation time decreasement	Mechanical		3	5
				2.2.5 High actuators temperature	Unplanned downtime	Other	Thermal	5	4
			3.3 Cutting tool (spin)	2.3.1 Tool wear	Material tearing	Mechanical		4	4
				2.3.2 Tool temperature	Material damage, tool wear	Other	Thermal	4	4
			3.4 Leather clamping (suction)	2.4.1 Power consumption	Deviations in the average consumption	Electrical		3	3
				2.4.2 Low pneumatic pressure	Lack of quality - precision	Mechanical		3	5

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A.1.4 Pilot#3 Podium

USE CASE REQUIREMENTS				Problem	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
Pilot	Productive Process	Machine	Parts			Classification	If Other is selected write a little explanation		
Podium - Carpenty kitchen manufacturing	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				
			Elevation	Different heights stable collision risk	Breakdown and downtime				
			Recharge	Battery maintenance and recharge control	if the battery breaks no longer works				
	Cutting	Automatic loading	Loading rollers						
			Robot automation	Loads only the material that is given to it without any system	Automatic storage? With system for the remains ?		With an automatic warehouse there would no longer be any need for handling by elevator and the organizational system of spare parts is also managed by the program		
			Vacuum	Regular maintenance	Does not hold the panel				
		Homag HKL Horizontal panel saw X + Y cutting machine	Panel progress	Entry side inlet port is 2100mm, larger panels to be optimized differently					
			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				
			software	Incompatible / obsolete	Manual programming				
			Print Labels and Scanners?	Compatibility with other production management programs	Direct label bonding system?		Label with relevant information for the entire production including transport		
		Holzma HPP11 "out of series" cuts	Panel progress				This machine is used		
			Cuttig blade				Only for non-optimized and unplanned material cuts.		
			PC + eletronics						

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USE CASE REQUIREMENTS				Problem	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
Pilot	Productive Process	Machine	Parts			Classification	If Other is selected write a little explanation		
Podium - Carpenty kitchen manufacturing	**Edgebander**	IMA	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				
			Milling machine	Sharpening	Quality of cutting		Optimised aluminium cutters for more precision and longer cutting life with diamond (already updated)		
			Laser	Visible junction, temperature ?	FINAL quality visible joint		Had to install pump with dehumidifier to dry the air entering the laser device		
			Glue PU	Tank pressurization	Avoids the daily cleaning of the element				
				Substitution glue - colour	Replacement complicated				
				Too much glue / too little	Final cleaning and edge hold		Edge-dependent variation		
			Handling chain	Automatic thickness and speed regulation of the piece			Fixed and regulated speed for the system		
				The piece is not held well	Roller cleaning				
			Edge pressing						
			Edge storage / Edge						
				Edge quality (supplier)	Visible joint (see white line)				
			Edge cutting	Setting	Cut length imperfection				
			Edge milling	Setting					
			Edge edging	Regular maintenance					
			Glue sraper	Regular maintenance					
			Scraper	Regular maintenance					
			Cleaning	Regular maintenance					
			Electronic control panel	Suffers the summer heat	Additional air conditioner				
		Automated return	Robot automation	Turning device	Data loss problems (PC) - due to lowering of maintenance				
			Rollers	Supported by conveyor belts					
		Homag	Scanner	Compatibility with other production management programs	Panel passage control and CNC program management				
			Milling machine	Sharpening	Quality of cutting				
			Glue PU	Pressurization tank					
				Too much glue / too little	Final cleaning and edge hold				
				Substitution glue - colour	Easy to replace				
			Handling chain	Automatic thickness setting					
			Edge pressing	Regular maintenance					
			Edge storage	Regular maintenance					
			Edge cutting	Regular maintenance					
			Edge milling	Regular maintenance					
			Edge edging	Regular maintenance					
			Glue sraper	Regular maintenance					
			Scraper	Regular maintenance					
		Return rollers	Rollers	supported by conveyor belts					

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USE CASE REQUIREMENTS				Problem	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
Pilot	Productive Process	Machine	Parts			Classification	If Other is selected write a little explanation		
Podium - Carpenty kitchen manufacturing	Drilling machine	Drilling machine fronts MAW	Scanner	Is not there at the moment	Compatibility with other production management programs				
			Milling	Yes					
			Drilling	Yes					
			Hardware insertion	Yes					
			Software	Incompatible / obsolete	Manual programming				
		Drilling machine Bremen	Scanner	With current labels works, for the programming of the whole production would be to see	Compatibility with other production management programs				
			Milling	Yes					
			Drilling	Yes					
			Hardware insertion	Yes					
			Plugs	Yes					
		Homag special CNC	Scanner	Yes	Incompatibility of use for the current system				
			Cutting	Yes					
			Milling	Yes					
			Drilling	Yes					
			Edging	Yes					
	Assembly	Weighing caissons	Press	Bottleneck					
			Rollers	Yes					
			Automated assembly		Scan label to read box size?				
		Drawer assembly	Grass structure	Assembly of drawers and pull-outs					
			Blum structure	Yes					
			PC for itemized list reading						
		Final assembly	Rollers	Yes					
			PC reading						
			Scan labels						
	Packaging	Automatic film coating	Film automation	Yes					
			Scanner -Check to PC ?	Yes	Compatibility with other production management programs				
		Hardware packaging	Scanner -Check to PC ?	Yes	Compatibility with other production management programs				
				with cardboard boxes					
				with protective film					
		Final storage	Via transpalett						
			Loading platfomr truck	Elevator					
			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?				
			Scanner Hollenstein	Hollenstein load control	What and when did he upload				

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A.1.5 Pilot#4 Harms & Wende

USE CASE REQUIREMENTS				Problem	Certification	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
Pilot	Productive Process	Machine	Parts				Classification	If Other is selected write a little explanation		
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		Machine cannot be used	Electrical		5	3
			1.1.2 Spindel	No prediction on wear-out		Sudden break-downs	Mechanical		5	2
			1.1.3 Motor/converter	No prediction on wear-out; not state of the art (servo technology preferred)		Sudden break-downs	Electrical		5	5
			1.1.4 PLC	No standard HWH component, connection to standard HWH technology not possible		Does not fit well in HWH portfolio; double work	Electronical		4	5
			1.1.5 Panel	Outdated, panel not available anymore		Machine cannot be sold	Electronical		4	3
			1.1.6 HMI	Old technology, not state of the art		Machine cannot be sold	Software	HMI Software needs to be replaced	4	5
			1.1.7 Remote maintenance/monitoring	Remote monitoring "just in case" and very restricted		Potential malfunctions cannot be detected in advance	Electronical	Software. Cloud-based approach required	4	5
			1.1.8 Valves	Very slowly; suffer from wear; no maintenance possible		Higher machine downtimes	Mechanical		4	4
			1.1.9 Hydraulic collet system	Wear out at sealing		Downtime	Mechanical			4
		1.2 General friction welding machine (RSM 410)	1.2.1 Similar to 1.1							
			1.2.2 Welding stroke	Stroke too slow						1
		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						
			1.3.2 Similar to 1.1							

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A.1.6 Pilot#5 Zorluteks

USE CASE REQUIREMENTS				Problem	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
Pilot	Productive Process	Machine	Parts			Classification	If Other is selected write a		
Pilot#5Textile Manufacturer	BLEACHING PROCESS	Bleaching Machine	1. Preparation of bleaching recipe	Excess or low caustic concentration	Hydrogen peroxide activates at pH 11-12. Otherwise, bleaching operation does not run which affects whiteness of fabric.			2	5
				High hydrogen peroxide concentration	It lowers to strength of fabric.			2	5
				Low hydrogen peroxide concentration	Bleaching does not occur suitably which has an effect on whitness.			2	5
				Unsufficient stabilizer concentration	It leads to decomposition of peroxide bleaching liquor and degradation of cellulose. This also affect whiteness and fabric strength.			2	5
				Unsufficient wetting agent concentration	Hydrophilicity affects negatively which prevents spreading of chemicals on te fabric surface. This also affect whiteness of fabric.			1	5
				Unsufficient sequestering agent concentration	Metal ions which could not be removed by sequestering agent result decomposition of peroxide bleaching liquor which affects whiteness and fabric strength of fabric.			1	5
			2. Pre-washers (Desize Wash)	Low temperature	It is hard to remove desizing agents at low temperature which affects whiteness of fabric			3	4
				Low pH	It is hard to remove desizing agents which affects whiteness of fabric			1	3
				High pH	It lowers to strength of fabric.			2	3
				Failure at valves for water supply	It prevents recycling of water inside the washers which has an negative effect on both cleaning of fabric and pH of the washers			4	4
				Lack of pH sensor	It affects both whiteness and strenght of the fabric.			1	2
				Failure at bearings	It affects movement of the fabric inside the bleachig machine.			1	1
				Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleaching process totally.			5	6
				Low roller pressure before bleaching chemical trough	Excess water on the fabric lead to decrease concentration of chemical mixing unit			5	5
			3.Chemical mixing unit & Bleaching chemical trough	Failure at dosing system	If chemical amount is not sufficient, reactions can not take place properly which affects whiteness of fabric			5	6
				Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleaching process totally.			5	6
				Lack of pH sensor	It affects both whiteness and strenght of the fabric.			1	2
				High roller pressure after chemical trough	It causes removing sheer amount of chemical on the fabric surface which affects whiteness.			5	5

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USE CASE REQUIREMENTS				Problem	Effect	Type of Problem		Severity (1-5)	Priority (1-6)
Pilot	Productive Process	Machine	Parts			Classification	If Other is selected write a		
Pilot#5Textile Manufacturer	**BLEACHING PROCESS**	Bleaching Machine	4. Steamer	Low steamer temperature	If temperature is not high enough for the activation of reactions, bleaching operation can not take place appropriately. It causes removing sheer amount of chemical on the fabric surface which affects whitenes.			4	6
				High steamer temperature	It results diminishing fabric strength.			4	5
				Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleaching process totally.			5	6
				Low steamer timing	Reactions can not take place properly which affects whiteness of fabric.			4	6
				High steamer timing	It results diminishing fabric strength.			4	6
				Failure at tempeature sensor	Temperature level can not be controlled. When temperature level is out of bonds, it affects whiteness.			5	5
			5. Washing Baths	Low pH	It is hard to remove bleaching chemicals on the fabric surface which has an negetive effect on whiteness			2	3
				High pH	It lowers to strength of fabric.			2	3
				Lack of pH sensor	It affects both whiteness and strenght of the fabric.			1	2
				Failure at electrical wirings	Pumps, engines, sensors and so on do not work which affects bleaching process totally.			5	6
				Failure at valves for water supply	It prevents recycling of water inside the washers which has an negative effect on both cleaning of fabric and pH of the washers .			4	4
				Failure at bearings	It affects movement of the fabric inside the bleachig machine			1	1
				Low temperature	It is hard to remove caustic on the fabric surface at low temperature which affects whiteness.			2	3
			6.Neutralizing Compartment	Lack of pH sensor	It affects both whiteness and strenght of the fabric.			1	2
				Excess or low concentration of acid	It affects pH of the fabric.			2	3
			7. Drying Unit	Failure at tempeature sensor	Temperature level does not not be controlled. It affects whiteness.			5	5
				Failure at moisture sensor	Moisture level, which has a significant importance for the next processes, doesn't be controlled.			4	4
				Failure to perform regular cleaning	Condensing steam and dirtiness in the drying unit lead to tenacious stains on the fabric surface.			3	4
				High temperature	Color of fabric turn yellow.			4	5

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Annex 2.- Technologies Matrix

TECHNOLOGIES MATRIX	
TECHNOLOGIES	**COMMENTS/SHORT DESCRIPTION**
Temperature Sensors – Thermocouple	A loop that (a) is made of two thermojunctions connected together and (b) is operated by maintaining a temperature difference between the two thermojunctions.[2] The resultant electric current in the loop is a function of the temperature difference between the two junctions and the materials used to make the junctions. A calibrated thermocouple can be used to measure the temperature difference between the two junctions. If the temperature of one junction is known, the temperature of the other can be calculated. Thermocouples are used to measure the temperature of thermal equipment, such as a furnace, an electric motor, or an internal combustion engine. They might operate up to 1700 ºC, offering high resistance over impacts and easy to deploy.
Temperature Sensors – Thermal resistor	Temperature can be measured with resistance temperature detectors, RTDs, or using thermistors or thermal resistor, thermally sensitive semiconductors fabricated from metal oxide semiconductor material[3] encapsulated in a glass or epoxi bead. Thermally sensitive resistors, have very high sensitivity, making them extremely responsive to changes in temperature. Thermistors also have a low thermal mass that results in fast response times, but they are limited by a small temperature range (compared to RTDs), up to 300ºC.

2. Weik M.H. (2000) thermocouple. In: Computer Science and Communications Dictionary. Springer, Boston, MA
3. (2007) Thermistor. In: Gooch J.W. (eds) Encyclopedic Dictionary of Polymers. Springer, New York, NY

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	Because thermistors are resistive devices, an excitation current should be supplied to them, reading then the voltage across their terminals. Thermistor output signals are typically in the millivolt range, making them susceptible to noise. Lowpass filters are commonly used in thermistor data acquisition systems to effectively eliminate high frequency noise in thermistor measurements. Thermistor are cheap sensor solution to control low temperatures.
Fluxgate sensor	Fluxgate sensors are typically ring cores of a highly magnetically permeable alloy around which are wrapped two coil windings: the drive winding and the sense winding. Some sensors will also have a third feedback winding, if the sensor is to operate in closed loop. A non-invasive method to diagnose AC motor efficiency and should not require opening the terminal box. They are able to give accurate information on the consumed energy without direct measurement of the voltage or the speed. It possible to achieve a complete energy diagnosis: the working time, the temperature, the number of starts, the effective torque, the power and so the speed and, at last, the efficiency.[4] The major difficulty is to separate the influence of the currents flowing in the end-winding connections from the effect of the air gap field. They are easy to install and to combine with IoT communication solutions.
Hall effect sensors	Magnetic sensors that convert magnetic or magnetically encoded information into electrical signals for processing by electronic circuits based in hall effect. Hall effect: a steady current is flowing in a steady magnetic field, electromotive forces are developed which are all right angles both to the magnetic force and to the current and are proportional to the product of the intensity of the current, the magnetic force and the sine of the angle between the directions of these quantities.[5] The linear relationship between the Hall voltage and the applied magnetic field makes Hall effect devices ideally suited to magnetic sensing applications.
Magneto-resistive sensors	The transversally directed Hall effect that there is a longitudinal resistance effect, or the Gaussian effect, occurs on semiconductor wafers. The sensor devices exploiting this effect are known as magnetoresistors. The magnetoresistor tends to be shorter

4. Farid Zidat et al. Non Invasive Sensors for Monitoring the Efficiency of AC Electrical Rotating Machines Sensors (Basel). 2010; 10(8): 7874–7895
5. (2007) Hall effect. In: Gooch J.W. (eds) Encyclopedic Dictionary of Polymers. Springer, New York, NY

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	and squatter, and represents a very low electrical resistance, where it is necessary to connect a large number of serial devices to achieve values in the kΩ range. They are usually supplied in the dual-configuration form in voltage-divider circuits, differential magnetoresistors, to reduce their temperature dependency. The required magnetic initial-tension is supplied by a small permanent magnet. The magnetoresistors are a high signal level which is usually in the volts range. This means that amplification is unnecessary, as well as the local electronic circuitry and the associated protective measures which would otherwise be needed.[6]
Pressure sensors	Pressure is defined as force per unit area that a fluid exerts on its surroundings and measured in the SI unit for pressure is the Pascal (N/m2), but other common units of pressure include pounds per square inch (psi), atmospheres (atm), bars, inches of mercury (in Hg), and millimetres of mercury (mm Hg).[7] A pressure measurement can be described as either static or dynamic. The pressure in cases where no motion is occurring is referred to as static pressure. Often the motion of a fluid changes the force applied to its surroundings. Such a pressure measurement is known as a dynamic pressure measurement. A pressure measurement can further be described by the type of measurement being performed. There are three types of pressure measurements: absolute, gauge and differential. - Absolute pressure measurement is measured relative to a vacuum, often the abbreviation psia (pounds per square inch absolute) is used to describe absolute pressure. - Gauge pressure is measured relative to ambient atmospheric pressure , similar to absolute pressure, the abbreviation psig (pounds per square inch gauge) is often used to describe gauge pressure. - Differential pressure is similar to gauge pressure, but instead of measuring relative to ambient atmospheric pressure, differential measurements are taken with respect to a specific reference pressure, also, the abbreviation psi

6. Robert Bosch GmbH (2014) Sensor measuring principles. In: Robert Bosch GmbH (eds) Bosch Automotive Electrics and Automotive Electronics. Bosch Professional Automotive Information. Springer Vieweg, Wiesbaden
7. Definition from DELIVERABLE D3.1. at ActiPPTSens G.A.: 255909 lead by TECNALIA.

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	(pounds per square inch differential) is often used to describe differential pressure. Pressure Sensors: - Piezoresistive sensors - Capacitive sensors - Piezoelectric sensors
Piezoresistive sensors	Piezoresistive sensors were among the earliest micromachined silicon devices and exhibit an exceptionally large change in resistivity. They are used for commercial and researcher applications to produce increasingly complex piezoresistive strain gauges, pressure sensors, accelerometers and force/displacement sensors, including many commercially successful products. The need for smaller, less expensive, higher performance sensors helped drive early micromachining technology, a precursor to microsystems or microelectromechanical systems (MEMS). Today, piezoresistive sensors comprise a substantial portion of the MEMS sensors market and are found in everything from automobiles to smartphones to interstellar probes. All piezoresistive sensors operate upon the principle of a mechanical load deforming a sensor structure. In silicon sensors the deformation is transduced into a resistance change by embedding a doped resistor in the structure. The resistance change is converted to a voltage signal using a measurement circuit, typically a Wheatstone bridge. The signal is conditioned by amplifiers and filters before it is acquired. Depending on the physical quantity being measured, the physical form of the sensor will vary.[8]
Piezoelectric sensors	Sensors based on the principle of piezoelectricity discovered by the Curie brothers where an electrical voltage was generated when they compressed or stretched quartz, piezoelectric effect. This effect is reversible, meaning that quartz can be lengthened or shortened when an electrical voltage is applied. Piezoelectricity refers to the material's ability to exhibit this piezoelectric effect. [9]

8 J. C. Doll and B. L. Pruitt, Piezoresistor Design and Applications, Microsystems and Nanosystems, Springer Science+Business Media New York 2013.
9 Piezoelectric Sensors. Andreas JanshoffClaudia Steinem. Springer Series on Chemical Sensors and Biosensors book series (SSSENSORS, volume 5)

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	Piezoelectric sensors measure the electrical charge by utilizing piezoelectric materials that include Barium titanate, Lead zirconate titanate, quartz, PVdF (including its copolymers) and many others. Piezoelectric sensor are being developed to be immune to dust, dirt, grime, and liquids, and can work in high temperatures and humidity levels. Therefore, growing applications in semiconductor industry acts as one of the major driver for position sensor market. Piezoelectric sensor market is experiencing a healthy growth rate over the few years due to increasing demand for the smart devices.
	Applications:
	- **Physical properties sensing :**
	  ▪ **Temperature**
	  ▪ **Displacement**
	  ▪ **Deformation**
	  ▪ **Stress**
	  ▪ **Strain**
	  ▪ **Pressure**
	  ▪ **Vibration**
	- **Transducers :**
	  ▪ **Concentration**
	  ▪ **pH**
	  ▪ **Molecules**
	  ▪ **Organic substances**
	  ▪ **Functional groups**
	  ▪ **Displacement**

Limit switches sensors	Presence Sensing is the act of detecting the presence or absence of an object with a contact or non-contact sensing device. The sensors then produce an electrical output signal that can be used to control equipment or processes. Mechanical limit switches are contact sensing devices widely used for detecting the presence or position of objects in industrial applications. The term limit switch is derived from the operation

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	of the device it-self. As an object (or target) makes contact with the operator of the switch, it eventually moves the actuator to the "limit" where the electrical contacts change state. Through this mechanical action, electrical contacts are either opened (in a normally closed circuit) or closed (in a normally open circuit). Inductive proximity, capacitive proximity, and photoelectric sensors perform this same process through noncontact sensing.[10]
Detection of Vibration by Piezoelectric sensors	Piezoelectric sensors might detect vibrational states links with structural status and functioning of machines and their components.
Infrared temperature sensors	Infrared temperature sensors sense electromagnetic waves in the 700 nm to 14,000 nm range. While the infrared spectrum extends up to 1,000,000 nm, IR temperature sensors do not measure above 14,000 nm. These sensors work by focusing the infrared energy emitted by an object onto one or more photodetectors. These photodetectors convert that energy into an electrical signal, which is proportional to the infrared energy emitted by the object. Because the emitted infrared energy of any object is proportional to its temperature, the electrical signal provides an accurate reading of the temperature of the object that it is pointed at. The infrared signals are passed into the sensor through a window made out of a specialty plastic. While plastic normally does not allow infrared frequencies to pass through it, the sensors use a form that is transparent to particular frequencies. This plastic filters out unwanted frequencies and protects the electronics inside the sensor from dust, dirt and other foreign objects.[11]
Gas sensor for coolant leaks	Gas sensor to detect low ppm or bpp gas concentration to about leaks in the gas coolant circuit of the machines.

10. The Basics of Limit Switches. EATOM. https://www.eaton.com/ecm/idcplg?IdcService=GET_FILE&allowInterrupt=1&RevisionSelectionMethod=LatestReleased&noSaveAs=0&Rendition=Primary&dDocName=PCT_1549250
11. https://www.surecontrols.com/infrared-temperature-sensors/

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	One of the main extended technology is based in resistivity changes in the semiconducting material due to gas molecules adsorption in the surface of the sensing materials. A large number of sensors and material are under development or implemented into commercially available solutions and sensing chips.
Absolute encoders	An absolute encoder generates information about the position, angle, and number of revolutions in type-specific angular increments. Based on the resolution, each code pattern forms a unique reference that is determined with each revolution using the code disc. There is no need for a reference run after power is applied. A single-turn encoder measures the absolute rotation within a single revolution, whereas a multiturn encoder additionally provides the number of revolutions. An absolute encoder is easy to control and can provide position and hence velocity and acceleration data. Very useful to know tool position, acceleration and velocity data.[12]
Platform for Digital Twin reconfiguration and analytics execution (called DINASORE) and platform for cyber physical production system graphical design and deployment.	Digital Twin technology based in python that is used to interface with physical components, process its data and send it to information systems. Additionally, it is possible to design and deploy a machine to machine communication to build a cyber physical production system. This cyber physical system design is based on a IEC61499 industrial standard where blocks are used to graphically program the dynamics of CPPS. As the digital twin is built using python, the last artificial intelligence methods can be used.
Edge device	This is a physical component capable to be connected to the existing sensors and actuators to enable to integration as a digital twin in the cyber physical production system.

12. https://www.sick.com/ag/en/glossary/absolute-encoder/g/p505244#:~:text=z-,Absolute%20encoder,in%20type%2Dspecific%20angular%20increments.&text=A%20singleturn%20encoder%20measures%20the,provides%20the%20number%20of%20revolutions.

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Component Models in Cyber Physical Production System	Strategies to establish a communication between multiple digital twins independently of the programming language being c/c++, java or python (and others to be integrated). This allows for a more flexible orchestration of the cyber physical production system where a more heterogeneous and specific functionalities can be used.
Transparent Cyber Physical Production Systems	Assuming there will exist some devices at the edge level as a first phase of data processing before synchronization with information systems and cloud, the proposed technology facilitates / optimizes the distribution of processing software among edge devices / digital twin. This way, according to the processing and memory capabilities of physical devices, processing software can be optimally (and sub-optimally) distributed among the network, being transparent to the user where the software is actually running.
Algorithms for quality prediction and process parameter optimization	Algorithms to predict the final product quality in a specific machine based on the parameters used for the process. These methods are based in data, where both parameters and final quality should exist in order to train machine learning models, both regression and classification. Ultimately, based on the quality predictive model it is possible to estimate future machine parameters if a new product needs to be yielded.
Anomaly Detection	Techniques to find abnormal behaviours that deviate from normal process conditions to raise warnings and find root causes for the problem.
Degradation models	Machine learning based models to model the degradation patterns of certain components, and based on this, calculate the KPIs to classify machine's health.
Microprocessor	Several definitions could be applied to microprocessor[13]: 1.A central processing unit (CPU) mounted on a single chip, i.e., on an integrated circuit chip, such as an optical integrated circuit (OIC). 2. An arithmetic, logic, or control unit constructed on a single large-scale integrated (LSI) circuit chip.

13. Weik M.H. (2000) microprocessor. In: Computer Science and Communications Dictionary. Springer, Boston, MA.

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	3. A processor that executes microcodes or microprograms. 4. A processor that is constructed of microelectronic circuits or microoptical circuits
Wireless communication	Wireless communication generally works through electromagnetic signals that are broadcast by an enabled device within the air, physical environment or atmosphere. The sending device can be a sender or an intermediate device with the ability to propagate wireless signals. The communication between two devices occurs when the destination or receiving intermediate device captures these signals, creating a wireless communication bridge between the sender and receiver device. Wireless communication has various forms, technology and delivery methods including: ▪ Satellite communication ▪ Mobile communication ▪ Wireless network communication ▪ Infrared communication ▪ Bluetooth communication Although all of these communication technologies have different underlying architecture, they all lack a physical or wired connection between their respective devices to initiate and execute communication.[14]
Battery-Operated	Powering solutions to provide the necessary electrical power to the sensor or the communication network when not electrical network is available.
Energy Harvesting	The need to develop autonomous systems within the framework of Industry 4.0 is a security and operating challenge for systems, which must be taken into account from the initial design phases. The replacement of batteries or charging of devices are processes that affect the security, usability, integrability and cost of the devices. Energy Harvesting technologies are a real and feasible alternative that

14. https://www.techopedia.com/definition/10062/wireless-communications.

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	enable power to be harvested and provided, ranging from a few micro-watts that a sensor may need to dozens of watts that a computer may need. Energy harvesting is the process of collecting energy from the environment and transforming it into electrical energy for immediate use or for storage.[15] The harvesting sources are: ▪ Mechanical (vibration, deformation, etc.) ▪ Thermal (temperature, gradients) ▪ Radiofrequency ▪ Solar (sun, indoor lighting The main Energy Harvesting systems are based in: ▪ Magnetic materials ▪ Piezoelectric materials ▪ Thermoelectric materials ▪ Dielectric materials
Smart piezoelectric Structures	Operational, mechanical and vibrational monitoring of structurers and components at the machines or the process manufacturing line by implemented piezoelectric low-cost sensors. Due to their electromechanical coupling with the structure, these sensors provide accurate information of the strains and force of the structure during it normal operation to avoid the mal functioning of the components.
Fiber optic distributed temperature sensor (DTS)	Fiber optic distributed sensors are a unique technology with attractive application due to its potential for long-distance measurement, explosion proof, resistant corrosion, free maintenance, light weight, and extreme durability.[16]

15. Presentation of Dra. Nieves Murillo from TECNALIA. https://www.youtube.com/watch?v=GBdrsxANI7c
16. ukuzawa, T., Shida, H., Oishi, K. et al. Performance improvements in Raman distributed temperature sensor. Photonic Sens 3, 314-319 (2013).

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	The Raman distributed temperature sensor (DTS) has been successfully adopted in the oil & gas fields for monitoring the progress of the steam-assisted extraction process, inflow profile, injectivity profile of the injection well, etc. For these applications, the Raman DTS must be robust under 1) harsh environments (no electric power, wide operation temperature range, and corrosive gases) and 2) high temperature (~600℃) measurement, resulting in the temperature measurement error.
Softsensors	The softsensor concern with the problem of availability of information provided by measurements in plants either when sensors become unavailable or when they have not been installed. [17]The solution to this problem is approached by means of soft sensors, i.e., systems replacing the missing measurement (primary measurement) with an estimation or prediction of the missing measurement based on the other measurements (secondary measurements) correlated with the primary measurement. But also in the context of monitoring a tooling with integrated sensors and actuators, model-based indirect measurements (also called) allow estimating parameters and states of the mechanical system without the need to install additional sensors. Indirect measurements are widely used in control systems and in applications that aim to know the condition of the components of the systems. The information provided by these monitoring systems, opens the possibility of monitoring systems without the need to install additional physical sensors. These virtual or soft sensors can provide information on the state of the system and the process, as long as there is a joint model in which the mechanical and electrical subsystems are coupled. Currently, there are commercial sensor solutions that allow measuring physical quantities by installing additional sensors and can then use this information to implement advanced monitoring and control of the assembly process systems. However, introducing new sensors increases the cost of the machine, being these sensors susceptible to failure. The use of this type of estimation techniques replaces the introduction of new sensors in the system, thus reducing the costs associated with the purchase and installation of the same and reducing the failures due to their drift / miscalibration or breakage.

17. González G. (2010) Soft Sensing. In: Sbárbaro D., del Villar R. (eds) Advanced Control and Supervision of Mineral Processing Plants. Advances in Industrial Control. Springer, London.

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	Model-based virtual sensing involves knowing and represent the dynamic behaviour of the monitored system. Virtual sensors extract information about the parameters, states and disturbances of the monitored system.

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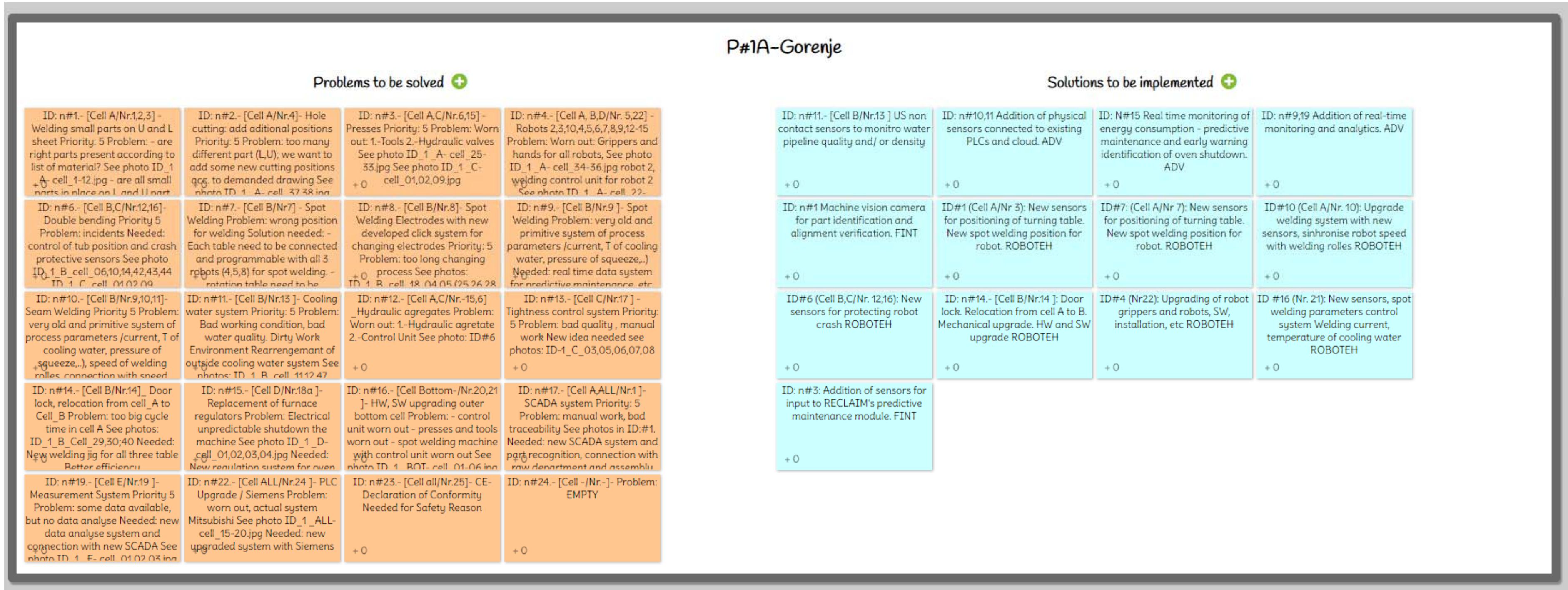
Annex 3.- IdeaBoardz Panels

A.3.1: Pilot#1A: Gorenje



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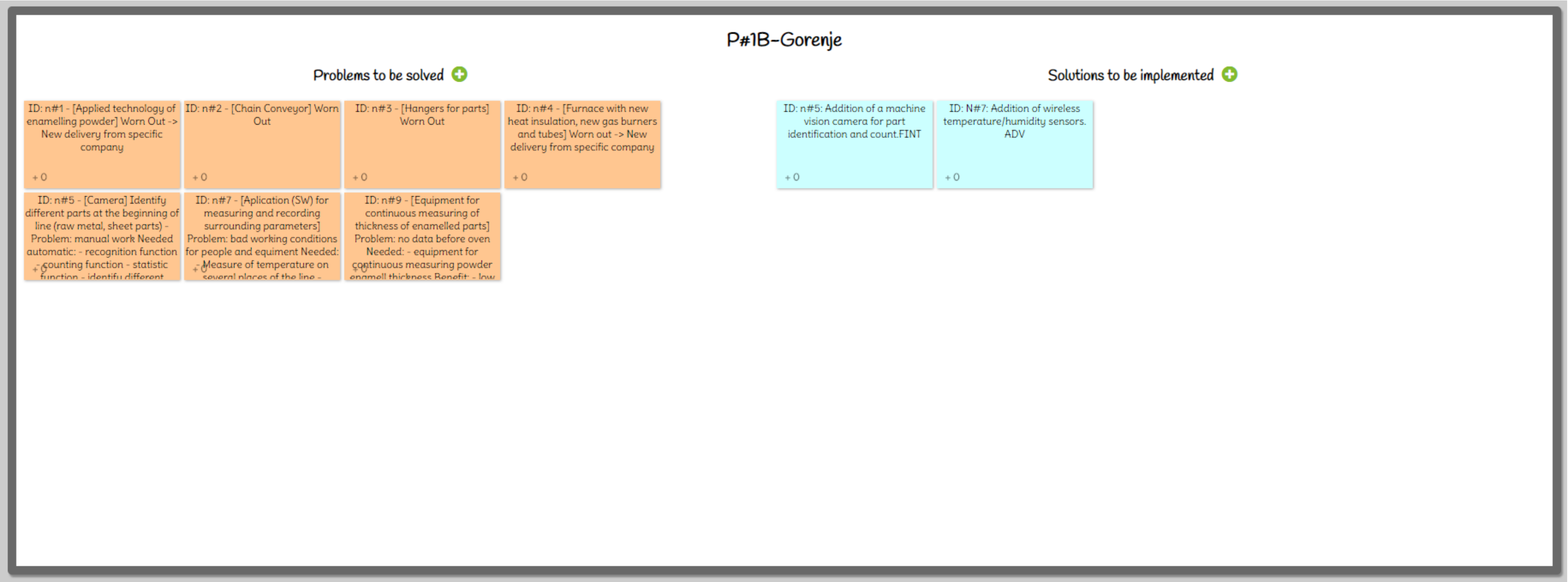
A.3.2: Pilot#1B: Gorenje



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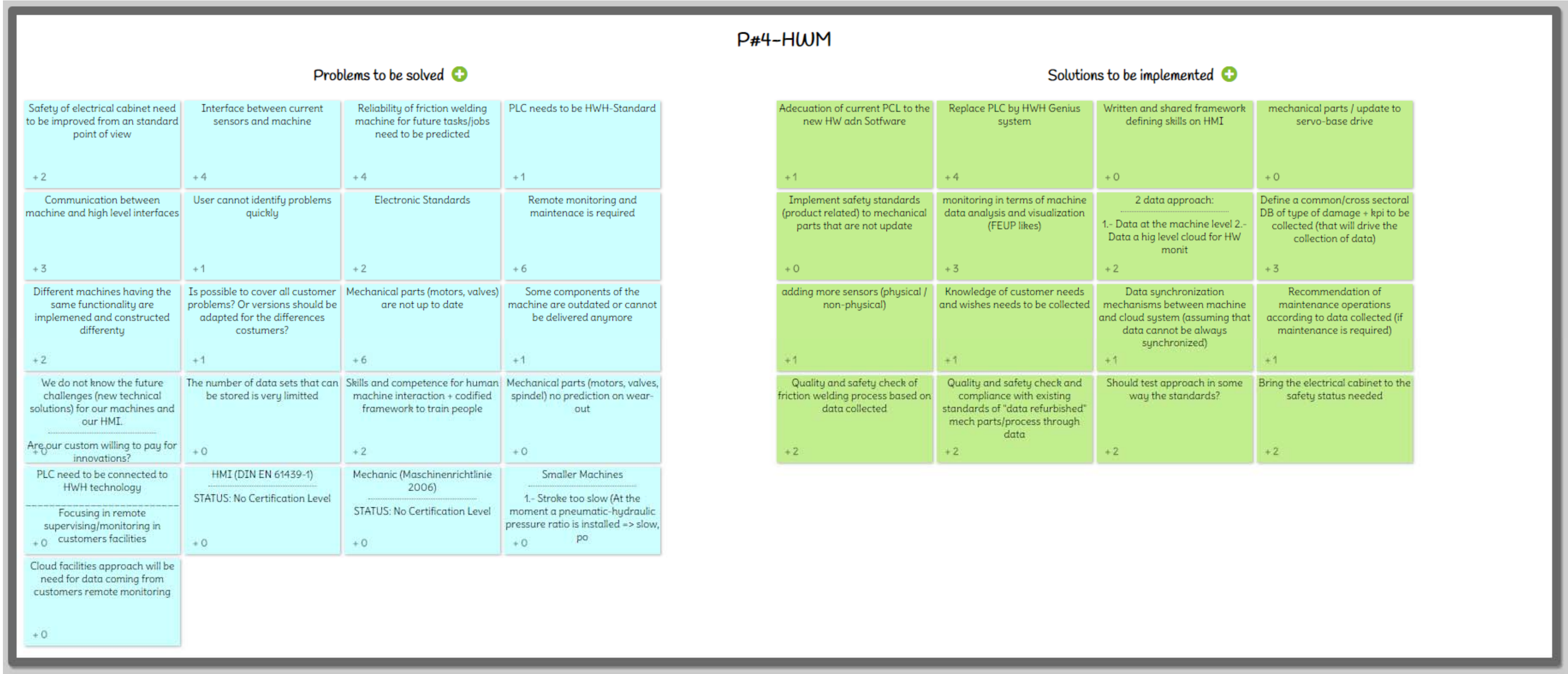
A.3.3: Pilot#4: Harms & Wende



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Annex 4.- Requirements and standards state of the art

STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
EN 13306:2010	This European Standard specifies general guidelines for the technical documentation to be supplied with an item, before it is ready to be put into service, in order to support its maintenance. The documentation of information to be established within the operational phase of an item, in order to support the maintenance requirements	Maintenance	Cross sector	Terminology, KPI, documentation
EN 15341:2019	This document lists Key Performance Indicators (KPIs) of the Maintenance Function and gives guidelines to define a set of suitable indicators, to appraise and to improve effectiveness, efficiency and sustainability in the maintenance of the existing physical assets either industrial, infrastructures, facilities, civil buildings or transportation systems, etc. in the framework of the external and internal influencing factors.	Maintenance	Cross sector	KPI
EN 17007:2017	This European Standard provides a generic description of the maintenance process. It specifies the characteristics of all the processes, parts of maintenance process, and establishes a maintenance model to gives guidelines for defining indicators. This European Standard is applicable to all organizations (company, institution, agency, etc.) in charge of maintaining physical assets. The purpose of the breakdown into processes and the representation of their inter-relationships is to help maintenance personnel, and particularly management at different levels to identify the actions to be taken in order to meet the overall objectives set by Management in terms of maintenance; delegate responsibilities ensuring the realization of the actions with the required performance levels; for each process, clearly determine a) the necessary inputs and their origin; b) the required results and their intended uses monitor and quantitatively assess the performance obtained at various levels of the breakdown into processes; - improve the collection and the distribution of data. This standard does not cover software maintenance itself but applies to items containing software.	Maintenance	Cross sector	KPI, process (general)

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
EN 13269:2016	This European Standard provides guidance on the preparation of private contracts for maintenance work. It can be applied to cross-border as well as national company/maintenance contractor relationships; the whole range of maintenance services including planning, management and control in addition to maintenance operations; every type of item with the exception of computer software unless the software has to be maintained as an integral part of, and together with, technical equipment. It does not: provide standard forms for maintenance contracts; determine rights and obligations between company and maintenance contractor; provide rules for agreements with public administrations.	Maintenance	Cross sector	Private contract
CWA 17492:2020	The document contains a methodology detailing the machine/deep learning techniques that should be employed, through the different steps to be followed, with the aim to predict industrial processes or equipment drifts and trigger alarms and potentially help to improve overall equipment effectiveness or the workshop performances. NOTE The triggered alarms are related to the process in such a way a small deviation affecting the production can be detected in advance, but these alarms are not related to safety. This document can be used as a guide by: - Manufacturing plant managers: it contains two examples of real use cases that show the possibilities offered by machine/deep learning techniques applied to the control and optimization of manufacturing processes and to the predictive maintenance of plant machinery; - Data Scientists: The actual use cases shown reflect the problems they will face when applying these techniques in an industrial environment, which has its own characteristics.	Maintenance	Cross sector	Process, methodologies
EN ISO 9001:2015	Quality management system when an organization: a) needs to demonstrate its ability to consistently provide products and services that meet customer and applicable statutory and regulatory requirements, and b) aims to enhance customer satisfaction through the effective application of the system, including processes for improvement of the system and the assurance of conformity to customer and applicable statutory and regulatory requirements. All the requirements of ISO 9001:2015 are generic and are intended to be	Quality management	Cross sector	Management, organization, KPI

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
	applicable to any organization, regardless of its type or size, or the products and services it provides.			
EN ISO 9000:2015	ISO 9000:2015 describes the fundamental concepts and principles of quality management which are universally applicable to the following: organizations seeking sustained success through the implementation of a quality management system; customers seeking confidence in an organization's ability to consistently provide products and services conforming to their requirements; organizations seeking confidence in their supply chain that their product and service requirements will be met; organizations and interested parties seeking to improve communication through a common understanding of the vocabulary used in quality management; organizations performing conformity assessments against the requirements of ISO 9001; providers of training, assessment or advice in quality management; developers of related standards. ISO 9000:2015 specifies the terms and definitions that apply to all quality management and quality management system standards developed by ISO/TC 176	Quality management	Cross Sectoral	Management, organization, terminology
EN ISO 19952:2005	ISO 19952:2005 defines terms used in the footwear industry, in English, French, Spanish and Italian. The terms and their definitions are listed alphabetically in English. In the annexes, all the terms are listed alphabetically in English, French, Spanish and Italian, so that the user of this International Standard can easily find the corresponding definition and the equivalent terms in the different languages. ISO 19952:2005 is intended to facilitate communication in the footwear sector	Terminology	Footwear	Terminology
EN ISO 11111 series	ISO 11111-1:2016 specifies safety requirements for frequently occurring hazards common to the types of textile machinery and the hazards of certain machine elements covered by ISO 11111 2 to ISO 11111 7. The standard series is complemented by the type C standards ISO 9902 (all parts) with respect to noise emission measurement and ISO 23771 with respect to measures for the reduction of noise emissions. ISO 11111-1:2016 is applicable to machinery plant and related equipment intended to be used in the textile industry for the following purposes: - opening, cleaning, blending, carding, preparation	Safety	Textile machinery	Terminology, methods, safety

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
	subsequent to carding, spinning and other processing of fibres (staple and filament) and other materials to form yarn or nonwoven material (including felts); - winding, doubling, twisting, texturing, etc., of yarns and the processing of yarns preparatory to weaving and knitting; - weaving, knitting, lace-making and similar utilization of yarn, etc., to form fabric; - forming of braid, cord, strand, rope, twine, net, etc., except take-up reels of stranding and laying machinery; - processing, including the pre-treatment, bleaching, dyeing, printing and finishing of fibre, yarn, fabric, braid, cord, etc., and final assembly for dispatch; - piece-dyeing of made-up goods; - finishing of warp and weft knitting, including hosiery, other than assembly of the finished product (e.g. sewing); - manufacturing of carpets by weaving, tufting and other processes.			
EN ISO 22301:2019	Requirements to implement, maintain and improve a management system to protect against, reduce the likelihood of the occurrence of, prepare for, respond to and recover from disruptions when they arise. The requirements specified in this document are generic and intended to be applicable to all organizations, or parts thereof, regardless of type, size and nature of the organization. The extent of application of these requirements depends on the organization's operating environment and complexity. This document is applicable to all types and sizes of organizations that: a) implement, maintain and improve a BCMS; b) seek to ensure conformity with stated business continuity policy; c) need to be able to continue to deliver products and services at an acceptable predefined capacity during a disruption; d) seek to enhance their resilience through the effective application of the BCMS.	Resilience	Cross sectoral	Terminology, management
UNE EN 1845:2008	This European Standard applies to footwear moulding machines which are intended for use in the shoe industry for the production of footwear and footwear components. These machines are: - direct-on sole moulding machines (see Figures 1, 2 and 3); - unit sole and footwear component moulding machines (see Figures 4 to 10); - full shoe and boot moulding machines (see Figure 11). This European Standard applies also to the mentioned machines when used for other products than footwear and footwear components, as far as these products require no other changes than a different mould.	Safety	Footwear, machine	Safety Requirements

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
UNI EN 931:2010	This standard is applicable to lasting machines used in the footwear manufacturing industry, namely: Adhesive fore part lasting machines; Hand operated adhesive side lasting machines; Adhesive seat lasting machines; Adhesive seat and side lasting machines; Hand operated tack/staple side lasting machines; Tack seat lasting machines; Tack seat and side thermocement lasting machines; Tack heel seat and thermocent side lasting machines; Tack heel seat and thermocent + tack side lasting machines; This standard does not apply to lasting machines which process granular thermocement.	Safety	Footwear, machine	Safety Requirements, Safe by design
UNI EN 12653:2010	This standard is applicable to nailing machines used in the footwear manufacturing industry, namely: heel attaching machines; heel nailing machines; gang nailing machines	Safety	Footwear, machine	Safety Requirements; safe by design
UNI EN 930:2010	This standard applies to the following machines which are intended to work material for the manufacture of footwear: - Automatic and manual roughing, scouring and polishing machines; - Automatic and manual edge contour trimming machines.	Safety	Footwear, machine	Safety Requirements, safe by design
UNI EN 13457:2010	This document applies to splitting, skiving, edge trimming, strip cutting, cementing and cement drying machines used in the manufacture of footwear, leather and imitation leather goods and other related components. This document specifies safety requirements for construction, transport, installation, adjustment, setting, teaching or process change-over, operation, cleaning, maintenance, decommissioning, dismantling and disposal for machines. It takes account of intended use , foreseeable misuse, component and system failure.	Safety	Footwear, machine	Safety requirements
UNI EN 12387:2010	Tent applies to the following machines including their additional equipment intended for the repair of footwear, leather and imitation leather goods as well as for the manufacture and repair of orthopaedic shoes hereafter called "Shoe Repair Machines": Polishing machines; Trimming machines; Scouring machines; Finishing machines; Orthopaedic finishing machines; Heel and sole press; Activating unit - Adhesive; Orthopaedic vacuum moulding press; Orthopaedic presses; Extraction equipment; Powered ranging device; Edge inking or staining machines; Mechanism for stationary nailing and stapling tools.	Safety	Footwear, machine	Safety Requirements

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
	These machines can be standing alone or combined in a modular system for shoe repairs or the production of orthopaedic shoes including the lasts.			
UNI EN 12044:2010	This European Standard is applicable to shoe and leather presses used in the manufacture of footwear, leather and imitation leather goods and other related components. These machines are: Sole attaching presses (open and closed types); Sole and insole moulding machines; Back part moulding machines; Backer, lining and toe puff attaching presses; Ironing presses; Marking, stamping, labelling and embossing machines; Stitch marking machines; Upper preforming machines; Automatic shoe and leather presses; Premoulding machines for thermoplastic counters and counter forming machines; Integrated manufacturing systems; Presses with mobile stations and rotary configuration; Folding presses; Activating presses; Relasting and last slipping machines; Top piece attaching presses; Leather button covering machines. Cutting and punching machines; Eyelet, hook and decorative nail attaching machines; Presses used for shoe repair and orthopaedic works	Safety	Footwear, machine	Safety requirements for construction, transport, installation, adjustment, setting, teaching or process change-over, operation, cleaning, maintenance, decommissioning, dismantling and disposal for machines
UNI EN 12545:2009	This noise test code specifies common requirements necessary to carry out efficiently and under standardised conditions the determination, declaration and verification of the noise emission characteristics of the following leather and imitation leather goods and footwear manufacturing machinery: - Cutting and punching machines (EN 12044); - Roughing, scouring, polishing and trimming machines (EN 930); - Footwear moulding machines (EN 1845); - Lasting machines (EN 931); - Nailing machines (EN 12653); - Modular shoe repair equipment (EN 12387); - Shoe and leather presses (EN 12203); - Splitting, skiving, cutting, cementing and cement drying machines (EN 13457). Common requirements given in this standard are complemented by specific requirements on noise given in the above-mentioned C-type standards.	Safety	Footwear, machine	Noise test

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
EN ISO 14001:2015	ISO 14001:2015 specifies the requirements for an environmental management system that an organization can use to enhance its environmental performance. ISO 14001:2015 is intended for use by an organization seeking to manage its environmental responsibilities in a systematic manner that contributes to the environmental pillar of sustainability. ISO 14001:2015 helps an organization achieve the intended outcomes of its environmental management system, which provide value for the environment, the organization itself and interested parties. Consistent with the organization's environmental policy, the intended outcomes of an environmental management system include: · enhancement of environmental performance; · fulfilment of compliance obligations; · achievement of environmental objectives. ISO 14001:2015 is applicable to any organization, regardless of size, type and nature, and applies to the environmental aspects of its activities, products and services that the organization determines it can either control or influence considering a life cycle perspective. ISO 14001:2015 does not state specific environmental performance criteria. ISO 14001:2015 can be used in whole or in part to systematically improve environmental management. Claims of conformity to ISO 14001:2015, however, are not acceptable unless all its requirements are incorporated into an organization's environmental management system and fulfilled without exclusion.	Environmental management	Cross sector	Implementation, management and LCA
EN ISO 14004:2016	ISO 14004:2016 provides guidance for an organization on the establishment, implementation, maintenance and improvement of a robust, credible and reliable environmental management system. The guidance provided is intended for an organization seeking to manage its environmental responsibilities in a systematic manner that contributes to the environmental pillar of sustainability. This International Standard helps an organization achieve the intended outcomes of its environmental management system, which provides value for the environment, the organization itself and interested parties. Consistent with the organization's environmental policy, the intended outcomes of an environmental management system include: - enhancement of environmental performance; - fulfilment of compliance obligations; - achievement of environmental objectives.	Environmental management	Cross sector	Implementation, Management, LCA

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	The guidance in this International Standard can help an organization to enhance its environmental performance and enables the elements of the environmental management system to be integrated into its core business process. NOTE While the environmental management system is not intended to manage occupational health and safety issues, these can be included when an organization seeks to implement an integrated environmental and occupational health and safety management system. ISO 14004:2016 is applicable to any organization, regardless of size, type and nature, and applies to the environmental aspects of its activities, products and services that the organization determines it can either control or influence, considering a life cycle perspective. The guidance in this International Standard can be used in whole or in part to systematically improve environmental management. It serves to provide additional explanation of the concepts and requirements. While the guidance in this International Standard is consistent with the ISO 14001 environmental management system model, it is not intended to provide interpretations of the requirements of ISO 14001.			
EN ISO 14005:2019	Guidelines for a phased approach to establish, implement, maintain and improve an environmental management system (EMS) that organizations, including small and medium-sized enterprises (SMEs), can adopt to enhance their environmental performance. The phased approach provides flexibility that allows organizations to develop their EMS at their own pace, over a number of phases, according to their own circumstances. Each phase consists of six consecutive stages. The system's maturity at the end of each phase can be characterized using the five-level maturity matrix provided in Annex A. This document is applicable to any organization regardless of their current environmental performance, the nature of the activities undertaken or the locations at which they occur. The phased approach enables an organization to develop a system that ultimately satisfies the requirements of ISO 14001. The guidance does not cover those elements of specific systems that go beyond ISO 14001 and it is not intended to provide interpretations of the requirements of ISO 14001.	Environmental management	Cross sector	Implementation, management and LCA

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
EN ISO 14040:2006	It describes the principles and framework for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14040:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies. It does not describe the LCA technique in detail, nor does it specify methodologies for the individual phases of the LCA. The intended application of LCA or LCI results is considered during definition of the goal and scope, but the application itself is outside the scope of this International Standard. ISO 14044:2006 specifies requirements and provides guidelines for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14044:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies.	Environmental management	Cross sector	Principles, framework, methodology of LCA and LCI
EN ISO 14044:2006	ISO 14044:2006 specifies requirements and provides guidelines for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14044:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies.	Environmental management	Cross sector	Environmental requirement
EN ISO 14046:2016	It specifies principles, requirements and guidelines related to water footprint assessment of products, processes and organizations based on life cycle assessment (LCA). ISO 14046:2014 provides principles, requirements and guidelines for conducting and reporting a water footprint assessment as a stand-alone assessment, or as part of a more comprehensive environmental assessment. Only air and soil emissions that impact water quality are included in the assessment, and not all air and soil emissions are included. The result of a water footprint	Environmental management	Cross sector	Water footprint

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	assessment is a single value or a profile of impact indicator results. Whereas reporting is within the scope of ISO 14046:2014, communication of water footprint results, for example in the form of labels or declarations, is outside the scope of ISO 14046:2014. It defines terms of fundamental concepts related to environmental management, published in the ISO 14000 series of International Standards.			
EN ISO 14050:2010	It defines terms of fundamental concepts related to environmental management, published in the ISO 14000 series of International Standards.	Environmental management	Cross sector	Terminology
EN ISO 13854:2019	Enabling the user (e.g. standard makers, designers of machinery) to avoid hazards from crushing zones. Minimum gaps relative to parts of the human body and is applicable when adequate safety can be achieved by this method. ISO 13854:2017 is applicable to risks from crushing hazards and is not applicable to other possible hazards, e.g. impact, shearing, drawing-in. For impact, shearing, drawing-in hazards, additional or other measures are to be taken	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, crushing zones
EN 547-1:1998+A1:2008	Specifies the dimensions of openings for whole body access as applied to machinery as defined in EN 292-1. It provides the dimensions to which the values given in EN 547-3 are applicable. Primarily for non-mobile machinery, there may be additional specific requirements for mobile machinery. Dimensions for passages are based on the values for either the 95th or the 99th percentile of the expected user population. Values for the 99th percentile apply to emergency egress routes. The anthropometric data given in EN 547-3 originate from static measurements of nude persons and do not consider body movements, clothing, equipment, machinery operating conditions or environmental conditions. This European Standard shows how to combine the anthropometric data with suitable allowances to take these factors into account. Situations where people are to be prevented from reaching a hazard are dealt with in EN 294.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, human body, access zone
EN 547-2:1998+A1:2008	Specifies the dimensions of openings for access as applied to machinery as defined in EN 292-1. It provides the dimensions to which the values given in EN 547-3 are applicable. Values for additional space requirements are given in annex A. Primarily for non-mobile machinery, there may be additional specific requirements for mobile	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, human body, access zone

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
	machinery. Dimensions for access openings are based on the values for the 95th percentile, whereas reach distances are based on the values for the 5th percentile, in each case the least favourable body dimension of the expected user population being used as a basis. The same considerations apply to the location of access openings. The anthropometric data given in EN 547-3 originate from static measurements of nude persons and do not consider body movements, clothing, equipment, machinery operating conditions or environmental conditions. This European Standard shows how to combine the anthropometric data with suitable allowances to take these factors into account. Situations where people are to be prevented from reaching a hazard are dealt with in EN 294.			
EN ISO 13851:2019	Safety requirements of a two-hand control device (THCD) and the dependency of the output signal from the actuation by hand of the control actuating devices. This document describes the main characteristics of THCDs for the achievement of safety and sets out combinations of functional characteristics for three types. It does not apply to devices intended to be used as enabling devices, as hold-to-run devices or as special control devices. This document does not specify with which machines THCDs shall be used. It also does not specify which types of two-hand-control device shall be used for a specific application. Moreover, while guidance is given, it does not specify the required distance between the THCD and the danger zone (see 8.8). This document provides requirements for design and guidance on the selection (based on a risk assessment) of THCDs including the prevention of defeat, the avoidance of faults and verification of compliance. NOTE 1 A THCD only offers protection for the person using it. NOTE 2 For specific machines, the suitability of a two-hand control as a suitable protective device can be defined in a type-C standard. If such a standard does not exist or is not appropriate, the risk assessment and determination of suitable protective measures is the responsibility of the manufacturer of the machine. This document applies to all THCDs, independent of the energy used, including: — THCDs which are fully assembled for installation; — THCDs which are assembled by the machine manufacturer or integrator. This	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, two hand control devices

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
	document is not applicable to THCDs manufactured before the date of its publication.			
EN842:1998+A1:2008	Criteria for the perception of visual danger signals in the area that people are intended to perceive and to react to such a signal. It specifies the safety and ergonomic requirements and the corresponding physical measurements and subjective visual check. It also provides guidance for the design of the signals to be clearly perceived and differentiated as described in 5.3 of EN 292-2:1991. This European Standard does not apply to danger indicators: - Presented in either written or pictorial form; - Transmitted by data display units. This European Standard does not apply to special regulations such as those for public disaster and public transport.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, visual signals
EN 894-1:2000+A1:2008	Design of displays and control actuators on machinery. It specifies general principles for human interaction with displays and control actuators, to minimise operator errors and to ensure an efficient interaction between the operator and the equipment. It is particularly important to observe these principles when an operator error may lead to injury or damage to health.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, ergonomic, human display interaction
EN 894-2:2000+A1:2008	Guidance on the selection, design and location of displays to avoid potential ergonomic hazards associated with their use. It specifies ergonomics requirements and covers visual, audible and tactile displays. It applies to displays used in machinery (e.g. devices and installations, control panels, operating and monitoring consoles) for occupational and private use. Specific ergonomics requirements for visual display terminals (VDTs) used for office tasks are given in the standard EN ISO 9241.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, ergonomic, human display interaction
EN 894-3:2000+A1:2008	Guidance on the selection, design and location of control actuators so that they are adapted to the requirements of the operators, are suitable for the control task in question and take account of the circumstances of their use. It applies to manual control actuators used in equipment for occupational and private use. It is particularly important to observe the recommendations in this European Standard where operating a control actuator may lead to injury or damage to health, either directly or as a result of a human error.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, ergonomic, human display interaction

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
EN 894-4:2010	Ergonomic requirements for the location and arrangement of displays and control actuators in order to avoid hazards associated with their use. This European Standard applies to displays and control actuators for machinery and other interactive equipment (e.g. devices and installations, instrument panels, control and monitoring consoles). This European Standard is not applicable to the location and arrangement of displays and control actuators which are manufactured before the date of its publication as EN.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, ergonomic, human display interaction, requirements
EN 981:1998+A1:2008	To reduce risks associated with misinterpretation of visual and auditory danger signals, a system of danger and information signals is specified taking into account the different degrees of urgency. Applicable to all danger and information signals which have to be clearly perceived and differentiated as specified in 5.3 of EN 292-2:1991, by other requirements or by the work situation, and to all degrees of urgency - from extreme urgency to an ALL CLEAR situation. Where visual signals are to be complementary to sound signals, the signal character is specified for both. It does not apply to certain fields covered by specific standards or other conventions in force (international or national); in particular, fire alarms, medical alarms, alarms used in the field of public transport, navigation signals and signals for special fields of activity (for example, military). When new signals are being planned, however, this European Standard should be considered in order to avoid inconsistency. For auditory signals, the system of signal character is a guideline for a signal language based on message categories which are classified according to urgency. Certain characters are specified for purposes which require safe and rapid recognition. Certain categories allow possibilities for variants, e.g. control and warning signals at workplaces where the signalling is intended for personnel with specific training. For visual signals, the established meanings of the safety colours are not affected by this European Standard. For different needs, complementary meanings have been assigned to the signals by timed patterns, and in a very few cases by alternating colours.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, danger information signals
EN 1037:1999+A1:2008	Requirements for designed-in means aimed at preventing unexpected machine start-up (see 3.2) to allow safe human interventions in danger zones (see Annex A). It applies to unexpected start-up from all types	Safety (Directive 2006/42/EC of	Industrial Machinery	Safety, requirements,

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	of energy source, i.e.: - power supply, e.g. electrical, hydraulic, pneumatic; - stored energy due to, e.g. gravity, compressed springs; - external influences, e.g. from wind. It does not specify performance levels or safety integrity levels for safety-related parts of control systems. While available means to prevent unexpected start-up are identified, this document does not specify the means for the prevention of unexpected machine start-up for specific machines. NOTE A type-C standard can define the required means for the prevention of harm arising from unexpected start-up. Otherwise, the requirements for a specific machine need to be determined by risk assessment outside the scope of this document.	17 May 2006 on machinery)		unexpected start up
EN ISO 7731:2008	Specifies the physical principles of design, ergonomic requirements and the corresponding test methods for danger signals for public and work areas in the signal reception area and gives guidelines for the design of the signals. It may also be applied to other appropriate situations. ISO 7731:2003 does not apply to verbal danger warnings (e.g. shouts, loudspeaker announcements). ISO 9921 covers verbal danger signals. Special regulations such as those for a public disaster and public transport are not affected by this International Standard.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, test methods, daner sinals
EN ISO 10218-1:2011	ISO 10218-1:2011 specifies requirements and guidelines for the inherent safe design, protective measures and information for use of industrial robots. It describes basic hazards associated with robots and provides requirements to eliminate, or adequately reduce, the risks associated with these hazards. It does not address the robot as a complete machine. Noise emission is generally not considered a significant hazard of the robot alone, and consequently noise is excluded from the scope of ISO 10218-1:2011. It does not apply to non-industrial robots, although the safety principles established in ISO 10218 can be utilized for these other robots	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery, Robots	Safety, robots, requirements
EN ISO 10218-2:2011	It specifies safety requirements for the integration of industrial robots and industrial robot systems as defined in ISO 10218-1, and industrial robot cell(s). The integration includes the following: the design, manufacturing, installation, operation, maintenance and decommissioning of the industrial robot system or cell; necessary information for the design, manufacturing, installation, operation, maintenance and decommissioning of the industrial robot system or	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery, Robots	Safety, robots, robos cell, requirements

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	cell; component devices of the industrial robot system or cell. It describes the basic hazards and hazardous situations identified with these systems, and provides requirements to eliminate or adequately reduce the risks associated with these hazards. It also specifies requirements for the industrial robot system as part of an integrated manufacturing system. It does not deal specifically with hazards associated with processes (e.g. laser radiation, ejected chips, welding smoke). Other standards can be applicable to these process hazards.			
EN ISO 12100:2011	It specifies basic terminology, principles and a methodology for achieving safety in the design of machinery. It specifies principles of risk assessment and risk reduction to help designers in achieving this objective. These principles are based on knowledge and experience of the design, use, incidents, accidents and risks associated with machinery. Procedures are described for identifying hazards and estimating and evaluating risks during relevant phases of the machine life cycle, and for the elimination of hazards or sufficient risk reduction. Guidance is given on the documentation and verification of the risk assessment and risk reduction process. ISO 12100:2010 is also intended to be used as a basis for the preparation of type-B or type-C safety standards. It does not deal with risk and/or damage to domestic animals, property or the environment.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, design, terminology, principles
EN ISO 12100:2011	It specifies basic terminology, principles and a methodology for achieving safety in the design of machinery. It specifies principles of risk assessment and risk reduction to help designers in achieving this objective. These principles are based on knowledge and experience of the design, use, incidents, accidents and risks associated with machinery. Procedures are described for identifying hazards and estimating and evaluating risks during relevant phases of the machine life cycle, and for the elimination of hazards or sufficient risk reduction. Guidance is given on the documentation and verification of the risk assessment and risk reduction process. ISO 12100:2010 is also intended to be used as a basis for the preparation of type-B or type-C safety standards. It does not deal with risk and/or damage to domestic animals, property or the environment.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, design, terminology, principles

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EN ISO 13849-1:2016	ISO 13849-1:2015 provides safety requirements and guidance on the principles for the design and integration of safety-related parts of control systems (SRP/CS), including the design of software. For these parts of SRP/CS, it specifies characteristics that include the performance level required for carrying out safety functions. It applies to SRP/CS for high demand and continuous mode, regardless of the type of technology and energy used (electrical, hydraulic, pneumatic, mechanical, etc.), for all kinds of machinery. It does not specify the safety functions or performance levels that are to be used in a particular case. This part of ISO 13849 provides specific requirements for SRP/CS using programmable electronic system(s). It does not give specific requirements for the design of products which are parts of SRP/CS. Nevertheless, the principles given, such as categories or performance levels, can be used. NOTE 1 Examples of products which are parts of SRP/CS: relays, solenoid valves, position switches, PLCs, motor control units, two-hand control devices, pressure sensitive equipment. For the design of such products, it is important to refer to the specifically applicable International Standards, e.g. ISO 13851, ISO 13856-1 and ISO 13856-2. NOTE 2 For the definition of required performance level, see 3.1.24. NOTE 3 The requirements provided in this part of ISO 13849 for programmable electronic systems are compatible with the methodology for the design and development of safety-related electrical, electronic and programmable electronic control systems for machinery given in IEC 62061. NOTE 4 For safety-related embedded software for components with PLr = e, see IEC 61508?3:1998, Clause 7.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety related part of control system, terminology, requirements
EN ISO 13849-2:2013	It specifies the procedures and conditions to be followed for the validation by analysis and testing of the specified safety functions, the category achieved, and the performance level achieved by the safety-related parts of a control system (SRP/CS) designed in accordance with ISO 13849-1.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety related part of control system, validation, test
EN ISO 13850:2016	It specifies functional requirements and design principles for the emergency stop function on machinery, independent of the type of energy used. It does not deal with functions such as reversal or limitation of motion, deflection of emissions (e.g. radiation, fluids),	Safety (Directive 2006/42/EC of	Industrial Machinery	Safety, requirements, emergency stop

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	shielding, braking or disconnecting, which can be part of the emergency stop function. The requirements for this International Standard apply to all machines, with exception to: - machines where an emergency stop would not reduce the risk; - hand-held or hand-operated machines. NOTE The requirements for the realization of the emergency stop function based on electrical/electronic technology are described in IEC 60204-1.	17 May 2006 on machinery)		
EN ISO 13855:2010	It establishes the positioning of safeguards with respect to the approach speeds of parts of the human body. It specifies parameters based on values for approach speeds of parts of the human body and provides a methodology to determine the minimum distances to a hazard zone from the detection zone or from actuating devices of safeguards. The values for approach speeds (walking speed and upper limb movement) in ISO 13855:2010 are time tested and proven in practical experience. ISO 13855:2010 gives guidance for typical approaches. Other types of approach, for example running, jumping or falling, are not considered in ISO 13855:2010. Safeguards considered in ISO 13855:2010 include: - electro-sensitive protective equipment, including light curtains and light grids (AOPDs), and laser scanners (AOPDDRs) and two-dimensional vision systems; - pressure-sensitive protective equipment, especially pressure-sensitive mats; - two-hand control devices; - interlocking guards without guard locking.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, safeguards
EN ISO 13857:2008	It establishes values for safety distances in both industrial and non-industrial environments to prevent machinery hazard zones being reached. The safety distances are appropriate for protective structures. It also gives information about distances to impede free access by the lower limbs (see Annex B). This document covers people of 14 years and older (the 5th percentile stature of 14-year-olds is approximately 1 400 mm). In addition, for upper limbs only, it provides information for children older than 3 years (5th percentile stature of 3-year-olds is approximately 900 mm) where reaching through openings needs to be addressed. NOTE 1 It is not practical to specify safety distances for all persons. Therefore, the values presented are intended to cover the 95th percentile of the population. Data for preventing lower limb access for children is not considered. The distances apply when sufficient risk reduction can be achieved by distance alone.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, distances

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	Because safety distances depend on size, some people of extreme dimensions will still be able to reach hazard zones even when the requirements of this document are met. Compliance with the requirements in this document will prevent access to the hazard zone. Nevertheless the user of this document is advised that it does not provide the required risk reduction for every hazard (e.g. hazards related to machine emissions such as ionizing radiation, heat sources, noise, dust). The clauses covering lower limbs apply on their own only when access by the upper limbs to the same hazard zone is not foreseeable according to the risk assessment. The safety distances are intended to protect those persons trying to reach hazard zones under the conditions specified (see 4.1.1). NOTE 2 This document is not intended to provide measures against reaching a hazard zone by climbing over (see ISO 14120:2015, 5.18).			
EN ISO 14118:2018	Requirements for designed-in means aimed at preventing unexpected machine start-up (see 3.2) to allow safe human interventions in danger zones (see Annex A). ISO 14118:2017 applies to unexpected start-up from all types of energy source, i.e.: - power supply, e.g. electrical, hydraulic, pneumatic; - stored energy due to, e.g. gravity, compressed springs; - external influences, e.g. from wind. ISO 14118:2017 does not specify performance levels or safety integrity levels for safety-related parts of control systems. While available means to prevent unexpected start-up are identified, this document does not specify the means for the prevention of unexpected machine start-up for specific machines. NOTE A type-C standard can define the required means for the prevention of harm arising from unexpected start-up. Otherwise, the requirements for a specific machine need to be determined by risk assessment outside the scope of this document.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, design, prevention, unexpected start up
EN ISO 14119:2014	It specifies principles for the design and selection independent of the nature of the energy source of interlocking devices associated with guards. It covers the parts of guards which actuate interlocking devices. It does not necessarily provide all the specific requirements for trapped key systems. ISO 14119:2013 provides measures to minimize defeat of interlocking devices in a reasonably foreseeable manner.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, design, interlocking devices

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
EN ISO 14119:2014	It specifies principles for the design and selection independent of the nature of the energy source of interlocking devices associated with guards. It covers the parts of guards which actuate interlocking devices. It does not necessarily provide all the specific requirements for trapped key systems. ISO 14119:2013 provides measures to minimize defeat of interlocking devices in a reasonably foreseeable manner.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, design, interlocking devices
EN ISO 14120:2016	It specifies general requirements for the design, construction, and selection of guards provided to protect persons from mechanical hazards. ISO 14120:2015 indicates other hazards that can influence the design and construction of guards. ISO 14120:2015 applies to guards for machinery which will be manufactured after it is published. The requirements are applicable if fixed and movable guards are used. This International Standard does not cover interlocking devices. These are covered in ISO 14119. ISO 14120:2015 does not provide requirements for special systems relating specifically to mobility such as ROPS (rollover protective structures), FOPS (falling-object protective structures), and TOPS (tip over protective structures) or to the ability of machinery to lift loads.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, requirements, guards
EN ISO 14122-1:2016	It gives general requirements for access to stationary machines and guidance about the correct choice of means of access when necessary access to the stationary machine is not possible directly from the ground level or from a floor. It is applicable to permanent means of access which are a part of a stationary machine, and also to non-powered adjustable parts (e.g. foldable, slidable) and movable parts of fixed means of access. NOTE 1 "Fixed" means of access are those mounted in such a manner (for example, by screws, nuts, welding) that they can only be removed by the use of tools. ISO 14122-1:2016 specifies minimum requirements that also apply when the same means of access is required as the part of the building or civil construction (e.g. working platforms, walkways, ladders) where the machine is installed, on condition that the main function of that part of the construction is to provide a means of access to the machine. NOTE 2 Where no local regulation or standards exist, this part of ISO 14122 can be used for means of access which are outside the scope of the standard. It is intended that this part of ISO 14122 be used with a	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, access, stationary machine

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	relevant access-specific part of ISO 14122. The ISO 14122 series as a whole is applicable to both stationary and mobile machinery where fixed means of access are necessary. It is not applicable to powered means of access such as lifts, escalators, or other devices specially designed to lift persons between two levels. ISO 14122-1:2016 is not applicable to machinery manufactured before the date of its publication. For the significant hazards covered by this part of ISO 14122, see Clause 4.			
EN ISO 14122-2:2016	It gives requirements for non-powered working platforms and walkways which are a part of a stationary machine, and to the non-powered adjustable parts (e.g. foldable, sliding) and movable parts of those fixed means of access. NOTE 1 "Fixed" means of access are those mounted in such a manner (for example, by screws, nuts, welding) that they can only be removed by the use of tools. ISO 14122-2:2016 specifies minimum requirements that also apply when the same means of access is required as the part of the building or civil construction (e.g. working platforms, walkways) where the machine is installed, on condition that the main function of that part of the construction is to provide a means of access to the machine. NOTE 2 Where no local regulation or standards exist, this part of ISO 14122 can be used for means of access which are outside the scope of the standard. It is intended that this part of ISO 14122 be used with ISO 14122-1 to give the requirements for walking platforms and walkways. The ISO 14122 series as a whole is applicable to both stationary and mobile machinery where fixed means of access are necessary. It is not applicable to powered means of access such as lifts, escalators, or other devices specially designed to lift persons between two levels. ISO 14122-2:2016 is not applicable to machinery manufactured before the date of its publication.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, requirements, walkways
EN ISO 14122-3:2016	It gives requirements for non-powered stairs, stepladders and guard-rails which are a part of a stationary machine, and to the non-powered adjustable parts (e.g. foldable, slidable) and movable parts of those fixed means of access. NOTE 1 "Fixed" means of access are those mounted in such a manner (for example, by screws, nuts, welding) that they can only be removed by the use of tools. ISO 14122-3:2016 specifies minimum requirements that also apply when the same means	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, requirements, stairs, stepladders and guardrails

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
	of access is required as the part of the building or civil construction (e.g. stairs, stepladders, guard-rails) where the machine is installed, on condition that the main function of that part of the construction is to provide a means of access to the machine. NOTE 2 Where no local regulation or standards exists, this part of ISO 14122 may be used also for means of access which are outside the scope of the standard. It is intended that this part of ISO 14122 be used with ISO 14122-1 to give the requirements for steps, stepladders and guard-rails. The ISO 14122 series as a whole is applicable to both stationary and mobile machinery where fixed means of access are necessary. It is not applicable to powered means of access such as lifts, escalators, or other devices specially designed to lift persons between two levels. ISO 14122-3:2016 is not applicable to machinery manufactured before the date of its publication			
EN ISO 14122-4:2016	It gives requirements for fixed ladders which are a part of a stationary machine, and to the non-powered adjustable parts (e.g. foldable, slidable) and movable parts of fixed ladder systems. NOTE 1 "Fixed" means of access are those mounted in such a manner (for example, by screws, nuts, welding) that they can only be removed by the use of tools. ISO 14122-4:2016 specifies minimum requirements that also apply when the same means of access is required as the part of the building or civil construction (e.g. fixed ladders) where the machine is installed, on condition that the main function of that part of the construction is to provide a means of access to the machine. NOTE 2 Where no local regulation or standards exists, this part of ISO 14122 may be used also for means of access which are outside the scope of the standard. It is intended that this part of ISO 14122 be used with ISO 14122-1 to give the requirements for fixed ladder systems. The ISO 14122 series as a whole is applicable to both stationary and mobile machinery where fixed means of access are necessary. It is not applicable to powered means of access such as lifts, escalators, or other devices specially designed to lift persons between two levels. ISO 14122-4:2016 is not applicable to machinery manufactured before the date of its publication.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, requirements, fixed ladder

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STANDARD	SUMMARY	NEED	SECTOR	KEYWORDS
EN ISO 20607:2020	It specifies requirements for the machine manufacturer for preparation of the safety-relevant parts of an instruction handbook for machinery. This document: — provides further specifications to the general requirements on information for use given in ISO 12100:2010, 6.4.5; and — deals with the safety-related content, the corresponding structure and presentation of the instruction handbook, taking into account all phases of the life cycle of the machine. NOTE 1 The strategy for risk reduction at the machine is given in ISO 12100:2010, Clause 6, and includes inherently safe design measures, safeguarding and complementary risk reduction measures as well as information for use. NOTE 2 Annex A contains a correspondence table between ISO 12100:2010, 6.4, and this document. NOTE 3 Information for conception and preparation of instructions in general is available in IEC/IEEE 82079-1. This document establishes the principles which are indispensable to provide information on residual risks. This document does not address requirements for declaration of noise and vibration emissions. This document is not applicable to machinery manufactured before the date of its publication.	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, guidelines, handbook
EN 60204-1:2018	It applies to electrical, electronic and programmable electronic equipment and systems to machines not portable by hand while working, including a group of machines working together in a co-ordinated manner. The equipment covered by this part of IEC 60204 commences at the point of connection of the supply to the electrical equipment of the machine. This sixth edition cancels and replaces the fifth edition published in 2005. It constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition: - added requirements to address applications involving power drive systems (PDS); - revised electromagnetic compatibility (EMC) requirements; - clarified overcurrent protection requirements; - requirements for determination of the short circuit current rating of the electrical equipment; - revised protective bonding requirements and terminology;	Safety (Directive 2006/42/EC of 17 May 2006 on machinery)	Industrial Machinery	Safety, electrical equipment, requirements

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	- reorganization and revision to Clause 9, including requirements pertaining to safe torque off of PDS, emergency stop, and control circuit protection; - revised symbols for actuators of control devices; - revised technical documentation requirements; - general updating to current special national conditions, normative standards, and bibliographical references.			

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