# DIGITAL MANUFACTURING PLATFORMS FOR CONNECTED SMART FACTORIES

# D7.2 Detailed Pilot Specifications and Pilot Sites Preparation

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| Deliverable Id : | **D7.2** |
| Deliverable Name : | Detailed Pilot Specifications and Pilot Sites Preparation |
| Status : | **FINAL** |
| Dissemination Level : | **PU** |
| Due date of deliverable : | **31/12/2020** |
| Actual submission date : | **28/04/2021** |
| Work Package : | **WP7** |
| Organization name of lead contractor for this deliverable : | **Philips** |
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**Abstract:**

Specifications for each pilot, including details on the technical architecture and the use of the pilot systems


Co-funded by the Horizon 2020 Programme of the European Union

# Contents



  

# History

| Version | Date | Modification reason | Modified by |
|---|---|---|---|
| 0.1 | 16/11/2020 | Start new document from D7.1 | J. Wortel |
| 0.2 | 17/11/2020 | Added available content | J. Wortel |
| 0.3 | 22/12/2020 | Added new available content | J. Wortel |
| 0.4 | 26/01/2021 | Added Abbreviations | J. Greidanus |
| 0.5 | 28/01/2021 | Added last missing pilot content | J. Wortel |
| 1.0 | 28/04/2021 | Final version for submission | J. Greidanus |

# 1 Executive Summary

This document gives overview of all Pilots regarding specifications and preparations. The pilots have got a central location in the Qu4lity project. It is area where requirements, architecture, knowledge regarding ZDM have to show their real potential. By implementing the needed items to fulfil the needs within the Pilots.

The QU4LITY project demonstrates its data-driven ZDM product and related services in a combination of five strategic ZDM plug & control lighthouse equipment pilots as well as nine production lighthouse facility pilots.

*Pilot #1: PHILIPS OneBlade shaving unit production line*
*Pilot #2: SIEMENS SIMATIC Products Quality Improvements*
*Pilot #3: CONTI Autonomous Quality in PCB Production for Future Mobility*
*Pilot #4: WHR Dryer Factory Holistic Quality Platform*
*Pilot #5: Zero defect and Autonomous Quality in Machinery Building for Capital Goods sector*
*Pilot #6: KOL's Real-time injection moulding process monitoring-control*
*Pilot #7: THYS Quality Management of Steering Gear based on Acoustic control*
*Pilot #8: AIRBUS Trade space framework for Autonomous Quality Manufacturing Systems' Design*
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*Pilot #10: RiaStone Autonomous Quality ZDM for "Ceramic tableware Single-firing*
*Pilot #11: PRIMA Additive Manufacturing Pilot Adaptive Control Technology*
*Pilot #12: Danobat Digital Machine for zero-defects at high precision cutting/grinding*
*Pilot #13: FAGOR Zero-Defects Manufacturing Digital Press Machine*
*Pilot #14: GF Digital machine and part twins for zero defect manufacturing*

Besides global planning, agreed way of working, for each pilot relevant information is summarized in this document:

- General description of each pilot
- Involved partners per pilot
- Current state
- Future state
- Detailed plan
- Expected results
- Preparatory results

# 2 Introduction

Task T7.1 will undertake all preparatory steps needed prior to deploying the pilot system and commencing pilot operations in the various pilot sites. For each one of the pilots, this includes the following activities:

(i) Organizing site visits in the factories and engaging all relevant stakeholders (i.e. production quality managers, factory IT managers, business managers, factory workers and more);
(ii) Collecting and analysing samples of the data that will be used in the pilots;
(iii) (Producing very detailed specifications for each pilot, including details on the technical architecture and the use of the pilot systems;
(iv) (Training stakeholders and pilot participants on the use of the pilot systems;
(v) Performing a pre-deployment of each one of the pilot systems in lab environments or pilot lines inside the factory;
(vi) Providing feedback on the results of the pre-deployment and preparing for the actual deployment.

These activities will be organized by each one of the pilot sites under the leadership of the pilot manager. Nevertheless, the task leader will also set some common standards regarding the timing, organization and implementation of the above-listed activities at the pilot sites. This will facilitate uniform reporting and comparability of the results. As part of the centralized coordination of the preparation processes, the task will identify commonalities and differences of the various pilots, including opportunities for reusing components and maximizing value for money. In this chapter, you will find generic information about the QU4LITY project including the pilots as well as the relation between task T7.1 and task 2.1.

## 2.1 About QU4LITY

The QU4LITY project aims to achieve Zero Defect Manufacturing through Autonomous quality. An ambitious objective with much unclear and different views on how- and even if it is achievable. Although manufacturing in Europe is already highly automated, the current production processes still require a lot of human involvement such as: machine operators, maintenance engineers, suppliers, and management.

QU4LITY will demonstrate, in a realistic, measurable, and replicable way an open, certifiable and highly standardised, SME-friendly and transformative shared data-driven ZDM product and service model for Factory 4.0 through 5 strategic ZDM plug & control lighthouse equipment pilots and 9 production lighthouse facility pilots. QU4LITY will also demonstrate how European industry can build unique and highly tailored ZDM strategies and competitive advantages (significantly increase operational efficiency, scrap reduction, prescriptive quality management, energy efficiency, defect propagation avoidance and improved smart product customer experience, and foster new digital business models; e.g. outcome-based and product servitisation) through an orchestrated open platforms ecosystem, ZDM atomized components and digital enablers (Industry 4.0 digital connectivity & edge computing package, plug & control autonomous manufacturing equipment, real-time data spaces for process monitoring & adaptation, simulation data spaces for digital process twin continuity, AI-powered analytic data spaces for cognitive digital control twin composable services, augmented worker interventions, European quality data marketplace) across all phases of product and process lifecycle (engineering, planning, operation and production) building upon the QU4LITY autonomous quality model to meet the Industry 4.0 ZDM challenges (cost and time effective brownfield ZDM deployment, flexible ZDM strategy design & adaptation, agile operation of zero defect processes & products, zero break down sustainable manufacturing process operation and human centred manufacturing).

## 2.2 Pilots within QU4LITY

As aforementioned, the QU4LITY project demonstrates its data-driven ZDM product and related services in a combination of five strategic ZDM plug & control lighthouse equipment pilots (green) as well as nine production lighthouse facility pilots (orange). An overview of the pilots is presented in figure X, followed by a short description of each pilot.

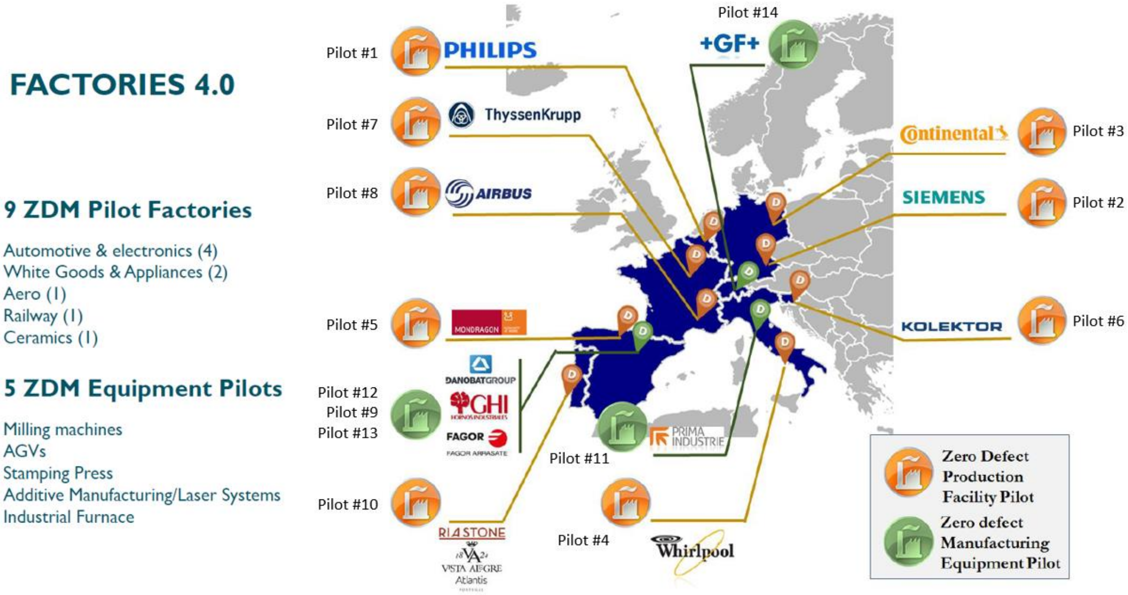


Figure 1: An overview of pilots' part of the QU4LITY project

*Pilot #1: PHILIPS OneBlade shaving unit production line*
*Pilot #2: SIEMENS SIMATIC Products Quality Improvements*
*Pilot #3: CONTI Autonomous Quality in PCB Production for Future Mobility*
*Pilot #4: WHR Dryer Factory Holistic Quality Platform*
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**Pilot #1: PHILIPS OneBlade shaving unit production line**

PHILIPS has recently developed a new male grooming device called OneBlade. The OneBlade is undergoing a phased worldwide introduction, started in 2016. PHILIPS is currently developing new production lines with increased capacity to meet the increased market demand. To remain competitive, there is a clear need to improve PHILIPS productivity by improving three main metrics: Time to market, Production costs and Product/component quality. An increase of component quality will have a positive effect on production costs and time to market.

Pilot participants: TTT, SINTEF, FHG-IPA, FHG-ISST, TNO

**Pilot #2: SIEMENS SIMATIC Products Quality Improvements**

At Amberg, Siemens' Digital Factory Division is manufacturing its SIMATIC products. Core of the manufacturing process is the production of the circuit boards, which are later on assembled with the housing parts to form the final product.

The overall objective is the introduction of AQ control loops for testing improvement and thus for overall production efficiency, while at the same time further raising the quality rate of finished products. This shall be achieved by implementing a closed control loop approach via the deep analysis of process data and the implementation of digital twins for products and production. Data from control loops throughout the manufacturing lines are to be collected and analysed via data mining and machine learning techniques, allowing to systematically identifying faulty products and the respective failure causes, providing the base for the intended improvements. By means of quality forecasting and simulation, (production) control decisions shall be derived at an early stage if quality deviations occur, thus avoiding further added value in ok products.

Pilot participants: IPS, TUBS, ATOS

**Pilot#3: CONTI Autonomous Quality in PCB Production for Future Mobility**

The production of automotive electronics for future mobility is based on automated lines that secure highest quality and output. For the production and assembly of respective PCBs an effective ZDM approach and availability is paramount. Key features, such as "product/component quality", "cost control" and "time-to-market" for multi-millions of products outline the situation in the automotive industry at the brink of a new economic scenario and govern the global competitiveness.

As to Equipment Data Collection and Communication, it is obvious that:

(i) Sensing and combining data from a variety of sources is essential to enable a progressive approach. Setting a standard for data formats in shop floor communication, such as "Bluetooth 4.0 for Autonomous Quality" is crucial, aiming at achieving an independent format for machine communication;

(ii) Autonomous quality control loops, as well as recognition a management of unstructured data for several production lines all over Europe requires establishing an "EU-Cloud "for safe, secure and trustworthy data processing;

(iii) The adoption of Big Data technology in supervisory and strategic decision-making actions on production lines and the full supply grid are the gateway to immediate reaction to problems.

The pilot supports the realization of a ZDM Scenario for multi-stage production lines through introduction of deep analysis and decision-making control loops, for capturing, communicating, secure storing and visualizing real-time holistic data on products, material, equipment, environment, human actions; in relation to quality control and processes. Essential KPIs, such as FPY, OEE, MTBF/MTTR, PPM and Control loop time throughout the supply network will be fully taken into account.

Pilot participants: ATB, ATOS, EPFL, FHG, SINTEF, TUBS, VTT

**Pilot #4: WHR Dryer Factory Holistic Quality Platform**

Whirlpool is opening a green field plant in Lodz/Poland. The white good that will be produced there is Dryer. Digitalizing the Factory, we want to reach a holistic approach to ZDM considering the full product lifecycle: from Product Design to Customer Service, cycling back to Product Design.

The pilot will leverage the outcomes of a previous research project (NMBP FP7 GRACE) and will integrate the QU4LITYdigital enablers and platforms (through the APIs) and the AQ control loops. The main innovation will be represented by the introduction in production of MPFQ model fused with AQ control loops: Functional Integration and Correlation between Material, Quality, Process and Appliance Functions.

This innovative way to control quality and model data inherent to quality will be the fundamental approach that will lead to the vision of holistic Quality system.

In addition, it will be deployed AQ reference implementations to address unresolved problems in the vertical integration of data management (from data gathering to visualization and decision-making), enabling a holistic vision to be achieved.

The production process to build a Clothes Dryer comprises many stages; combination of automatic equipment and manual operation and all along the production process several Quality Stations are installed to perform gauge, to detect defective parts, filter them out or repair them. The main stages of the production process (Drum Line, Heat Pump, Side Fabrication, Main Assembly, Functional Test, ZHQ Area and Reliability Test) will be equipped with a Quality Gate, i.e., station to perform gauges and pass/fail test on product as well as Process monitoring means (OEE, SPC, Andon). All these data sources will be integrated in the experiment, providing a comprehensive view of the production process.

Pilot participants: ENG, POLIMI, TTS, Synesis, NXT

**Pilot #5: Zero defect and Autonomous Quality in Machinery Building for Capital Goods sector**

The goal of MONDRAGON Corporation roadmap for the coming years, as a global business group, is to change the structure of the businesses, leading their evolutions towards higher added value and developing new activities in leading sectors. Machinery Building for Capital Goods is a main industrial division within the Corporation providing high quality –high performance solutions based on smart technology in a wide variety of sectors (automotive, aerospace, energy, railway, oil &gas, capital goods, white goods, etc.). Danobat Group, Fagor Arrasate, and other leading corporate brands represent a benchmark in machines, solutions and advanced services in the area of Machine Tools.

Given the strategic importance of the Machine Tools industry, and in the context of QU4LITY, MONDRAGON proposes two process pilots in the Machinery Building for Capital Goods scenario; two realities that can be complementary in many customers' value chains:

Use Case MONDR1:
Multistage zero-defect manufacturing railway axles production line: Manufacturing Processes with Cutting/Grinding Machinery, leaded by DANOBAT (DAN). The objective of MONDR1 pilot is to reach zero defects in the production line of axles that includes forging, heat treatment, machining (roughing and finishing), finishing stages (painting and protecting), as well as in-process and final inspection and verification operations. During this multi-stage process, several deviations or process variability may cause geometry and quality defects that cause both extensive rework operations and part scrap.

The technologies and the control loops provided by QU4LITY will make it possible to achieve observability of the product, process and resource states, throughout the system stages.

Use Case MONDR2:
Zero-Defects Manufacturing digital Hot Stamping process: Manufacturing Processes with Hot Stamping Machinery, leaded by FAGOR. The objective of this MONDR2 pilot is to reach zero defects in the hot stamping cooling temperatures, transfer speed, loss of temperature in the transfer or settings of press and identifying exactly the process developed in the manufacturing of the parts.

Pilot participants: MON, DAN, FAGOR, GHI, ATLAS, CEA, SINTEF, EPFL, VTT, FHG-ISST

**Pilot #6: KOL's Real-time injection moulding process monitoring-control**

Kolektor (KOL) is known as the world's largest manufacturer of commutators, the second largest European manufacturer of slip rings and the second largest European manufacturer of plastic-bonded magnetic products. Injection moulding is enabling technology for production of all these parts. The scope of this pilot project will be a production line where Kolektor produces one type of products. The aim of this pilot is to detect, possibly predict, and remove the cause of the process failure as soon as possible, ideally in real-time. In the process of real-time process monitoring, we are planning to:

(i) Collect moulding process parameters;
(ii) Monitor environmental parameters;
(iii) Inspect moulding tool and moulded parts;
(iv) Introduce AQ control loops at the operational level.

Based on the collected data and by applying control loops, advanced analytics and artificial intelligence methods we will better understand the moulding process and will be able to detect anomalies and failures as soon as possible. Because of the geometry of a moulding tool and number of cavities, it is not possible to inspect all cavities at once. Therefore, we are planning to use robots to perform complex moves required for inspection. We would like to study if it is possible to automate the removal of root cause of the bad parts being produced (like cleaning the cavity with dry ice).

Pilot participants: JSI, FhG-ISST, CEA, VC

**Pilot #7: THYS Quality Management of Steering Gear based on Acoustic control**

The current context of the automotive sector leads to continuous improvement. For all customers, the quality of THSYS products passes by an acoustic comfort. Therefore, a large part of THYS production requires acoustic control.

Today, to make an acoustic control on our steering gears, a workstation uses accelerometers to measure the noise caused by the mechanical linkages and is able to determine if the product respect the acoustic limits. In case of defect, there is a need to identify which component from the assembly is responsible of the acoustic defect, so, that after a specific treatment and analysis of the signal, component as the root cause can be isolated.

Pilot participants: CEA, AIT

**Pilot #8: AIRBUS Trade space framework for Autonomous Quality Manufacturing Systems' Design**

During the early phase of an aircraft program, Industrial Architects are evaluating different industrial scenarios and trade-offs. Interesting findings, include:

(1) Manufacturing Processes are not enough agile and not enough flexible in order to answer to the complex and competitive environment and to the incessant changes needed concerning both the performance (need to improve the ramp-up) and the product (change of MSN) on the assembly lines;

(2) Engineering, Manufacturing & support processes are still considered in a sequential approach. For solving part of the problems, Product Line and Co-design concepts needs to be tackled. A Model-based systems engineering (MBSE) approach where the Industrial System is seen as a System like any other (in parallel of the Aircraft) will allow to structure and optimise the development of Industrial System and to perform trade-offs efficiently.

Model based System Engineering, Trade Space exploration and Multi Skill optimization are common capabilities in Engineering Systems; often in the context of "Design to Aircraft Performance". The Engineering process and the Digital solutions are not enough supporting Design to Manufacturing Value.

This leads to late design loops, rework and the end extra costs for Airbus and for the customers.

The use case involves multiple engineering options and sites and at least one Airbus supplier; keeping in mind the need to deploy the solution at a large scale and at a low cost for Airbus and the suppliers.

The pilot will demonstrate applicability of the approach to design an industrial system at high level (Supplier network, Factories, Machines and processes) for near Zero-Defect Manufacturing. By taking the Industrial System as a whole, Autonomous Quality control loops will be integrated at the pertinent points. Also, the easy reconfiguration of manufacturing process will be compliant with AQ concepts. AQ for ZDM will also ensure to keep the right quality level as a target. Case focus aero structure design –with composite or metallic machining and assembly process using robots or humans.

Pilot participants: SIEMENS, EPFL, FHG-IAO, VC

**Pilot #9: GHI Real-time cognitive hot stamping furnace 4.0**

Hot stamping is a process increasingly used in the automotive sector. Motivated by the current demands of the light vehicle development, hot stamping will become a critical manufacturing process in future factories 4.0. Current limitations in hot stamping zero defect manufacturing relate to the fact that control algorithms in the furnace are related to the parameters of the furnace but are not able to infer the impact of those furnace-heating parameters in the actual heat distribution of the part to be later stamped in the press. Closed loop quality control on the furnace heating control in relation to the press stamping parameters such as spring bass, press, frequency and mould & die ware out. Zero defect manufacturing in these systems will be related to the development of smart connected furnaces with ability for real-time connected and smart closed loop monitoring & control.

Hot stamping process is currently responsible for the manufacturing of crash-relevant parts within the car body structure, a critical part with strong requirements on the car safety. One of the usual reasons why this phenomenon occurs is related to the difficulty to distribute the temperature of the piece homogeneously in the stamping process. In order to provide them with an austenitisation temperature of about 900-

950 °C, the parts must first pass through a furnace, which is composed of its corresponding control system. However, most of these devices perform a control on the temperature obtained in different points of the furnace, but not on the temperature experienced by the pieces as a result of the heating process. Therefore, GHI aims at developing ZDM solutions based on implemented improvements (sensor and data analysis, AQ control loops) in the furnace that will provide a more accurate control of the temperature of the pieces and therefore, a more optimized quality for such critical parts.

Pilot participants: INNO, SQS, TID, TTT, ENG/ATOS

**Pilot #10: RiaStone Autonomous Quality ZDM for "Ceramic tableware Single-firing"**

RiaStone (RST) is part of "Visabeira Industria" a sub-holding of the "Visabeira Group" conglomerate. RST manufactures the IKEA worldwide supply of "Dinera", "Fargrik" and "Flitighet" tableware families, being these products fabricated through an innovative Industrial ceramics production process: tableware automated single firing. RST needs to improve its Overall Production Effectiveness (OPE) KPI; from ~92%, to the improvement goal of reaching OPE 99%. This requires new approaches to production, promoting better and innovative defect management and production control methods, consistent with the integration of ZDM processes, namely in-line inspection technologies, and integration of tools for autonomous, automatic, smart system decision making.

In order to achieve the required improvement goals, RST will apply a systems-level strategy consisting in the integration of new inline inspections systems and QA control loops into the current production line. In parallel new in-line automation components will be implemented that will automatically remove detected defective parts from the production lines; enabling the introduction of recycling and re-using of raw materials into the production line for a new defect-free production cycle.

Pilot participants: KOL, UNP, AIT, SYN

**Pilot #11: PRIMA Additive Manufacturing Pilot Adaptive Control Technology**

Prima Industry is a world leader manufacturer of laser machines for metal components. Prima has recently started with a new activity in Additive Manufacturing systems, investing in both technologies of metal powder bed and direct energy deposition. The scope of this use case is to enhance process monitoring and control for producing metal components and make Additive process more productive and robust.

The next generation of manufacturing systems will be based on advanced processes, where additive manufacturing (AM) leads the technology trend. If AM has done a first quantum leap shifting from prototyping to production, the second relevant leap is now directed to make series production a reality. Next Generation of AM systems go towards a cost-effective solution by embracing a more robust process and higher process quality. To reach this aim, it is important to improve monitoring and control aspects towards process reliability and ZDM in terms of part dimension, surface roughness, part quality. Improving the real time monitoring and closed loop control can lead to reduce development time, enhance part quality and reduce waste and cost of production.

In this pilot, additive manufacturing machines for powder bed and direct deposition will be considered to enhance process control for producing metal components. Traditional solutions and new concepts of machines will be considered to test new edge devices for process control, towards a ZDM result, and to work on data management and analytics to implement the whole manufacturing process by a platform and control loop approach. In laser-based additive manufacturing, production time has a great influence on the economic efficiency of the production process. To increase the productivity but also reliability of such processes, a zero-defect AM strategy is targeted. Starting from modular devices for real time detection of the process, it will be possible to collect data, deploy new parameters to adapt the machine control to the actual task and communicate data at management level, where not only the single machine is considered; approach will consider both new systems and new concepts of machines in parallel with AQ control loops.

Pilot participants: FHG-ISST/ILT/IGD, TTS

**Pilot #12: Danobat Digital Machine for zero-defects at high precision cutting/grinding**

ZDM strategy in High Precision Machining in Danobat HG--LG external cylindrical horizontal grinding machine is based on a fully sensorized machine in its critical components. Machine condition monitoring and data analytics will be the foundation of Danobat and Ideko´s approach for ZDM at machining level.

In grinding machines, the rotating spindles and machine axis condition monitoring are the main concerns regarding ZDM. The main problems in spindles are rotor unbalance, rotor misalignment, motor electrical problems, front bearing damage, rear bearing damage, motor demagnetization and geometric accuracy. Regarding machine axes condition, guideways (stick-slip and friction) and servo drives mechanic chains (ball screw, power transmission, backlash, electrical problems) face condition issues that have impact on the machining process and consequently on quality of work pieces.

The pilot of Danobat ZDM grinding machine will use grinding machine operational data to relate machine-use with evolution of machine components condition. The analytics and the applied AQ control loops on ZDM grinding machine will be based on combination of load distribution map for different time-periods and for different part programs, a positioning distribution map and a rotating speed and feed rate (load vs. speed ranges maps) map.

Pilot participants: IDEKO, ATLANTIS, SINTEF, EPFL

**Pilot #13: FAGOR Zero-Defects Manufacturing Digital Press Machine**

FAGOR has a long experience in delivering manufacturing lines (machine-tools & the whole automation solution) as well as providing the building blocks of such lines (press machines). Press machine is the product par excellence of FAGOR. A press machine is composed by 2 rigid platforms (head and base), a bed, a ram, a mechanism and other surrounding components that guarantee the full automation and process control (temperature, pressure, etc.).

The pilot proposed in QU4LITY project is framed within the process of continuous improvement of FAGOR R&D strategy. The development of this project will allow FAGOR to offer to its customers a more accuracy, competitive and productive press machines that can take part in a production line. All the improvements performed at press machine level will directly improve the production line where it is integrated with. The development of this project will facilitate the increase of the level of sales. The technological development together with the quality, constitute the great bet of FAGOR to achieve its objective of customer satisfaction.

The objective of this project is to reach zero defects manufacturing process collecting press machine critical parameters and identifying exactly the process developed in the manufacturing of pieces. Traditional zero defects approaches propose the analysis of such parameters isolated from the rest of the process where the machine is integrated. Whereas these approaches try to maximize the efficiency of the process by maximizing the efficiency of the parts, it fails to maximize the efficiency of the overall system. Such process has a great complexity from the point of view of the acquisition, measurement and transmission of the parameters and variables. In addition to that, the integration of the data from other parts of the system at machine level should be valuable.

Pilot participants: VTT, FHG-ISST

**Pilot #14: GF Digital machine and part twins for zero defect manufacturing**

Current barriers to high accuracy in manufacturing in multi-technology and automated cells are related to limitations in data aggregation to either machining processes or machine health scopes. Zero defect manufacturing in these systems will be therefore possible by taking into account in the planning stage how the machine mechanics evolve towards states where deviations are more likely to occur, where failures might damage the part or the machine, or where uncertainties are introduced by maintenance, repairing or any other uncontrolled factor in the chain.

The pilot will address the challenge by setting up a first digital system for detecting, diagnosing, and fully compensating deviations on accuracy, productivity and sustainability of a machining cell based on the aggregation of information from milling and EDM machinery health, process performance and geometrical part characterisation, using AQ control loops and a common data space for making possible a realistic information integration from different types of hardware & software coexisting at different end-users factories, and targeting fully automated, zero defect manufacturing.

  

Pilot participants: EPFL, UNIM, MGEP

## 2.3 Relation Between Task T7.1 and other tasks

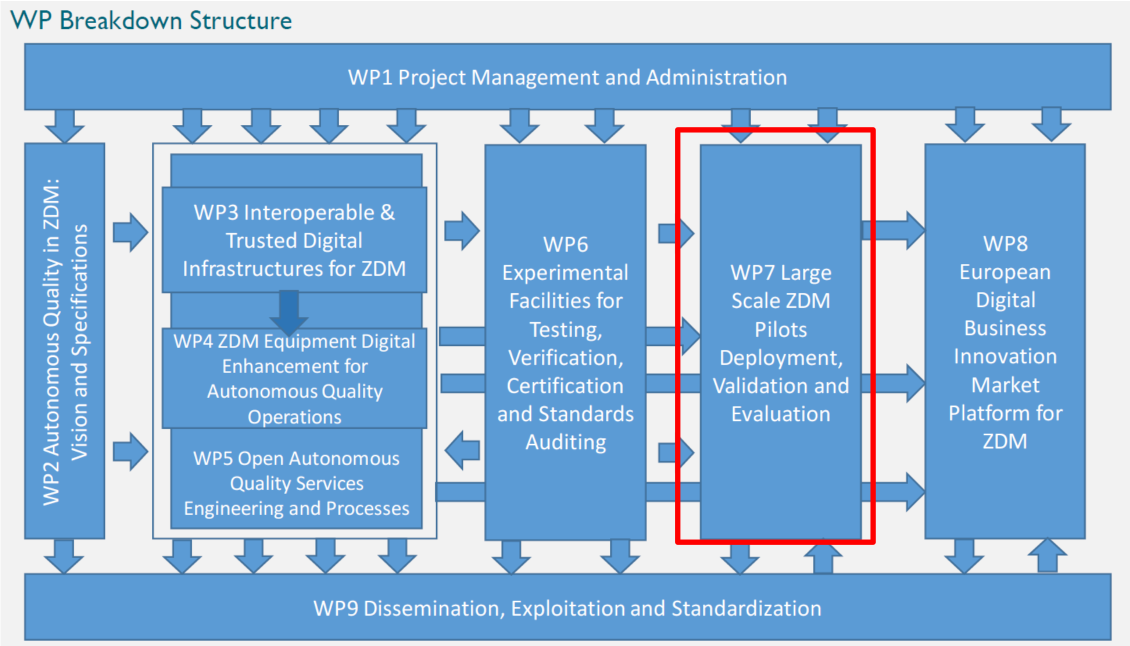


Figure 2: Visualization of the relation between the tasks

As figure 2 shows, Work Package 7 with all the Pilots is in the middle of all work packages. The goal is to use/implement for example:

- Requirements from Pilots and developed in another WP's
- Available (new) knowledge
- New and existing architecture

From the different work packages into the Pilots. To guide this in a common way in the Pilots one way harvesting of information is being deployed which is accessible for all other WP's to check/investigate and find mismatch and/or opportunities to add value. Within the Qu4lity project all involved partners have this responsibility.

Innovalia as overall Pilot responsible created the Table of Content for the Trail Handbook structure.

This deliverable is using the Trial handbook to harvest all the documentation required to fulfil the requirements and to create an overall view on site specifications and preparations.

Example: Chapter 1 Trail Handbook:

**Content**

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Figure 3 Table of Content of Trail Handbook Chapter 1

Deliverables of Task 7.1 are requirements for Pilot/Partners to deliver within the Trail Handbook. These elements are being used to build up this deliverable and to have overall view.

# 3 KPI's Used in Pilots and How to Measure

The pilot providers part of the QU4LITY project uses a wide variety of Key Performance Indicators (KPI's) to track their performance. While some are being monitored during the manufacturing process, others are measured at the (end) customer. Since every company has their own set of KPI's, the definitions for the most important ones (i.e. OEE, PPM, and FPY) are defined below.

### OEE

The OEE or 'Overall Equipment Effectiveness' is a rating figure providing information about the functioning of a machine. In general, the OEE is less than one and a measure providing information about the availability and effectiveness of equipment and machines during operating time. To calculate the OEE, the following three key figures are used: OEE = Availability (Productivity) x Performance (Effectiveness) x Quality

### PPM

PPM or 'Parts Per Million' indicates the number of nonconforming parts in the process, expressed in parts per million. Although Cpk and Ppk are the most commonly used metrics for process capability, they measure how the process is performing only in relation to the specification limit that is closest to the process mean. Therefore, they evaluate only one side of the process curve, and do not directly indicate how the process performs on the other side of the process curve.

To get a clearer indication of how the process is performing on both sides of the process curve, it is possible to use other indices, such as PPM. PPM < LSL indicates the number of nonconforming parts less than the lower specification limit. PPM > USL indicates the number of nonconforming parts greater than the upper specification limit. PPM Total indicates the total number of nonconforming parts outside of both specification limits. By comparing PPM values before and after a process improvement, it is possible to get a concrete sense of how much a process improvement has actually reduced the number of nonconforming parts on both sides of the process curve.

### FPY

FPY or 'First Pass Yield' is an indicator that gauges the production and quality performance of a Manufacturing group, based on the number of good vs. defective units produced. FPY can be a good measure of a company's progress in continuous improvement efforts, since continuous improvement is often concentrated on the reduction of inefficiencies and waste. Relatively low values for this KPI may suggest that the Manufacturing function is using flawed materials for its production inputs, has ineffective manufacturing processes or is utilizing faulty machinery. A low value for FPY will lead to high scrap costs and rework costs. An FPY that is constantly fluctuating indicates that the company does not have reliable manufacturing processes in place and may not be able to meet demand or fulfil customer orders on a consistent basis. FPY is also one of the components of Overall Equipment Effectiveness Quality (OEE-Q).

  

# 4 QU4LITY Pilots

## 4.1 Introduction

The methodology used to support the development of the pilot and gather the relevant information in order to fulfil the reporting of the project in the most efficient way is the Trial Handbook approach. This methodology is based on the analysis and adaptation of Requirements Engineering techniques and methodologies carried out in FITMAN[1] and successfully applied in MIDIH and BOOST4.0. the methodology has proved to be very effective to pull off a considerable number of pilots.

Each pilot in the project will keep a Handbook to collect the information needed to perform all tasks dealing with the QU4LITY trial implementation.

Each Pilot will write and be responsible for its own deliverables and the gathered information, however in order to better coordinate and align the development of activities inside the 14 pilots, the handbook will provide a common structure to gather and present data. This approach will also:

- Facilitate the work within the different trial factories
- Prevent overlapping among tasks
- Avoid duplication of efforts
- Ensure the schedule accomplishment

The specific procedure to gather the information in chapter has therefore followed the following steps:

1. Conceptual design. Approach discussion and agreement: In this stage, we developed an initial idea to attempt the data gathering and define a first version of the questionnaires that was discussed with the rest of the work packages 1 and 2 participants. After an initial agreement, we planned a schedule for a review and second release of the questionnaires.
2. Classifying and categorizing the content: In this phase, we discussed, analysed, and reviewed the content we need to include in the questionnaires and the format of the different paragraphs to achieve a certain degree of harmonization and quality.
3. Creation of the chapter template: After the classification and categorization of the content that the template had to contain, we develop a final version of it and delivered to the Pilots. We also planned remote meetings with all the team members for each one of Pilots, to ensure accomplishment of schedule and effectiveness.
4. Template and Interview schedule: We finally entered in an iterative phase where interaction with the trials was done to assure understanding, length, coherency and quality of the information delivered. This phase holds the delivery and feedback of templates and remote meeting for final adjustments, corrections and fulfilment of required information.

The templates of the chapters have been completed after several meeting among the stakeholders involved in the process, where a careful analysis of the relevant information to be collected has been carried out. These meetings had the purpose to

[1] FITMAN is a FI-PPP Phase II project, developing and applying Future Internet (FI) technologies to manufacturing industries.

clarify the different contributions to the pilot development and to fine-tune further refinements in the elicitation process. The collected information is incorporated into a master document.

## 4.2 Pilot reporting

As explained in the previous section, all information related with the pilots is gathered in the Trial Handbook (TH). Each pilot will deliver a TH that is subdivided into different chapters. At present, in QU4LITY there are 4 completed chapters. The number of chapters depends on the development of the project, based on our previous experiences, QU4LITY will probably have 5 chapters.

The TH is the main source of information for deliverables. Below, we show a table with the deliverables that have been already issued or will be issued in the first year, all of them have taken or are going to take information from the first three chapters of the TH.

| Chapters | Deliverables |
|---|---|
| 1,2 | D2.1, D2.3, D2.5, D2.7, D2.11, D4.1, D7.1 |
| 1,2,3 | D2.2, D2.4, D3.1, D3.3, D3.5, D3.7, D3.9, D3.11, D4.3, D4.5, D6.1 |

Figure 4 Deliverables related to chapters.

## 4.3 Pilots' technologies


To realize the goals that this project intends to achieve, QU4LITY enable platform and system composition, collaboration, traceability and visibility across product, process and factory lifecycle, QU4LITY is supported by 4 pillars:

**Pillar 1 – Trusted time sensitive ZDM composition middle wares**, which allow for vertical and horizontal integration, distributed real-time control and orchestration and allow to build coordinated big data-driven and AI-powered ZDM strategies from any level product-process-factory).

**Pillar 2 – Self-adaptive instant ZDM infrastructures** which allow for aggregation of the ZDM control loops and allow time-sensitive digital automation pipelines to be deployed seamlessly (quickly, flexibly, gradually) and extended across hybrid (public & private) clouds, the edge (physical nodes or Telecom Operator managed infrastructures) and HPC GPU-powered infrastructures.

**Pillar 3 – Collaborative Deep ZDM Services,** which extends current digital engineering, planning, operations, manufacturing capabilities with descriptive, predictive and prescriptive prognosis capabilities.

**Pillar 4 – Human-centric Big Data Visualisation,** enables the integration of the human by supporting the development and integration of smart visualization mobile/wearable apps. This is done by offering ZDM-specific services for data handling and visualization.

QU4LITY pilots have been carefully selected to ensure that manufacturing industry (SME & large industry) can implement AQ feedforward and feedback control loop with digital ZDM platforms both for brownfield equipment and manufacturing processes as well as greenfield industry 4.0 processes. The table below shows where each of the 14 pilots will implement AQ quality control loops, demonstrating that these quality control loops are applicable in many sectors and over all phases of AQ lifecycle:

- Engineering
- Commissioning
- Operation
- Collaboration

| Autonomous Quality (AQ) Control Loops | Engineering | | Planning & Management | | Operations | | Connected Production | |
|---|---|---|---|---|---|---|---|---|
| | Plug & produce Equipment | ZDM Production Facility | Plug & produce Equipment | ZDM Production Facility | Plug & produce Equipment | ZDM Production Facility | Plug & produce Equipment | ZDM Production Facility |
| Augmented human centred decision control loop services | | Whirlpool | DANOBAT | KOLEKTOR | PRIMA | Philips RIASTONE | | CONTINENTAL |
| Multi-stage ZDM deep analysis control loop services | | AIRBUS | DANOBAT | Philips , SIEMENS, ThyssenKrupp | GHI PRIMA | Philips, RIASTONE, KOLEKTOR | +GF+ | CONTINENTAL |
| ZDM orchestration & simulation-based composition control loops | | Whirlpool | MONDRAGON | SIEMENS | GHI PRIMA | RIASTONE | +GF+ | |
| ZDM Embedded intelligence & real-time control loop services | FAGOR | | DANOBAT | ThyssenKrupp | | KOLEKTOR | +GF+ | |
| QU4LITY Digital Platform Capabilities | Design for product/process performance | | Prescriptive CPPS Commissioning | | Self-learning brownfield adaptive digital production | | Collaborative multi-level production quality control | |

Figure 5. Pilot technologies

## 4.4 Overall Planning

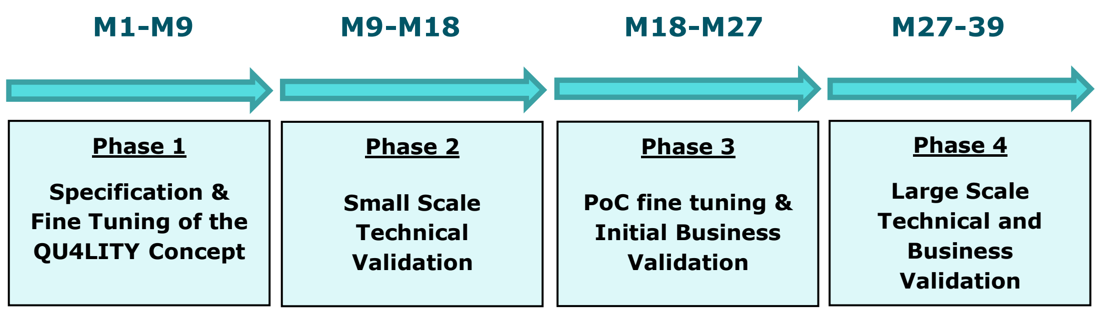


Figure 6 Main phases

### Phase I (M1-M9)

- Scope & Goals: Detailed definition of the QU4LITY concept terms of ZDM innovations and requirements, determine goals, start writing the first two chapters from the TH.
- Infrastructures: Lab prototypes; Mock-Ups of components.
- Stakeholders Engagement: Consortium Members (including factory workers & manufacturers´ employees) and External Stakeholders (i.e. EFRA, National manufacturing Initiatives AIOTI, etc.).

### Phase 2 (M9-M18)

- Scope & Goals: For month nine the first two chapters of the TH must already be written, detailed pilots Specifications, define KPIs, implementation planning drafts, prototypes of the digitally enhanced ZDM equipment and processes, prototypes test in small scale facilities, update general goals and start writing chapter 3.
- Infrastructures: Lab Deployment; Small Scale Deployments in testbed and/or pilot lines in the factory.
- Stakeholders Engagement: Consortium members (Manufacturers, solution providers, solution integrators) – Notably project team members

**Phase 3 (M18-M27)**

- Scope & Goals: For month eighteen chapter 3 must be written, pilots result available, ZDM prototype improvement, functionality enhancements using more advanced versions of the digital enablers, detailed implementation planning and defined architecture for each Pilot.
- Infrastructures: Full deployment in testbed and factory pilot lines.
- Stakeholders Engagement: Consortium members (Manufacturers, solution providers, solution integrators including workers in testbeds and in the pilot lines of the manufacturers and testbed participants).

**Phase 4 (M27-M39)**

- Scope & Goals: This phase will focus on the production of the final version of digitally enhanced ZDM equipment and processes, as well as on the final version of the pilot systems. The final outcomes and integrated prototypes will be released and the individual ZDM components and the pilots will be validated through factory deployments. This phase will conclude the technical validation of the project developments, while also focusing on their business validation with a clear outlook towards their sustainable deployment in the factories and their wider use as part of the virtualized DIH ecosystem of the project.
- Infrastructures: Full deployment in factories (pilot lines & production lines).
- Stakeholders Engagement: Consortium members (Manufacturers, solution providers, solution integrators); Participants to the project´s multi side market platform.

# 5 Pilot 1: PHILIPS; OneBlade shaving unit production line

## 5.1 Pilot 1: *Philips*; Current state

The production line in scope at Philips is producing the cutting element for the OneBlade. Processes used for this are:

- Over moulding
- µAssembly of parts
- µWelding/joining of parts
- Pad Printing
- In-line testing

Due to confidentiality details about the production line is not listed but put in Trail Handbook Chapter 1 and 2.

### Weaknesses and Bottlenecks

Table 1: Pilot 1, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY *At processes (manufacturing) level and business level* |
|---|---|---|---|
| IDS architecture not compatible with other developments / existing solutions | There is a risk that other developments made within this pilot do not follow the reference architecture of IDS and thus are incompatible. This would cause that certain applications could not be deployed and run within in the proposed data space approach. | Support in applying the IDS reference architecture by FHG-ISST. | N/A |

## 5.2 Pilot 1: *Philips*; Future state

Based on partners involved in the Philips Pilot, the following contribution of technology is being made:

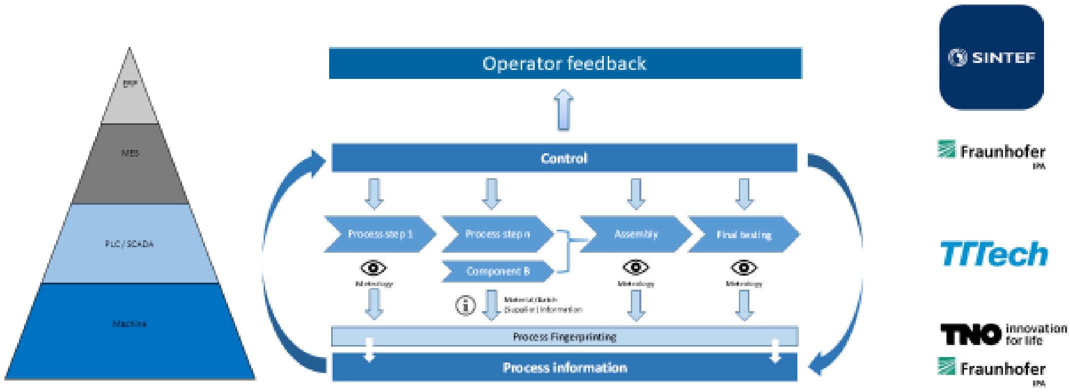


Figure 7: Philips pilot-case and (main) partners

The main goal of QU4LITY for PHILIPS is to realize a holistic system that:

- can raise early warning signals based on early indicators and trends from process signals and dimensional CTQs that are still acceptable on component level but will lead to Fall of Rate on the finished good in the current quality framework
- can suggest feed-forward or feed-backward controls to neighbouring process stations, which might have an influence on the dimensional CTQ that is under observation
- increases OEE A and P by helping the operator to take correct process adjustment decisions,
- reduces Fall Off Rate (FOR) by learning from unknown data interactions.

With these elements the next step in autonomous quality/production can be made:

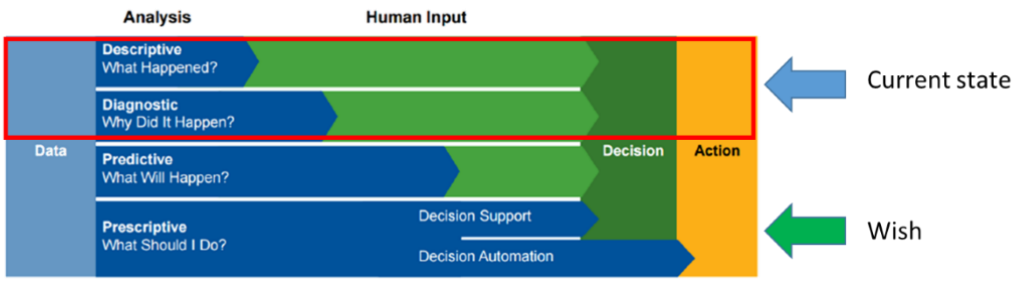


Figure 8: From Descriptive to Prescriptive

How to reach future goal of what to improve:

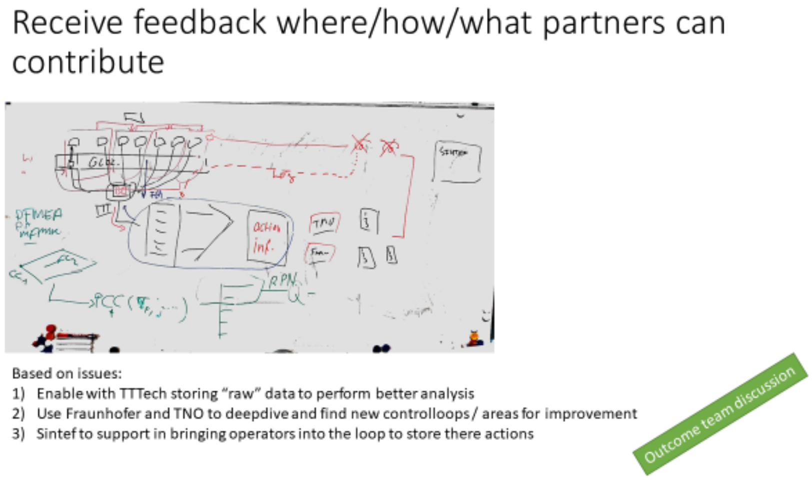


Figure 9: Added contribution of partners to Philips pilot

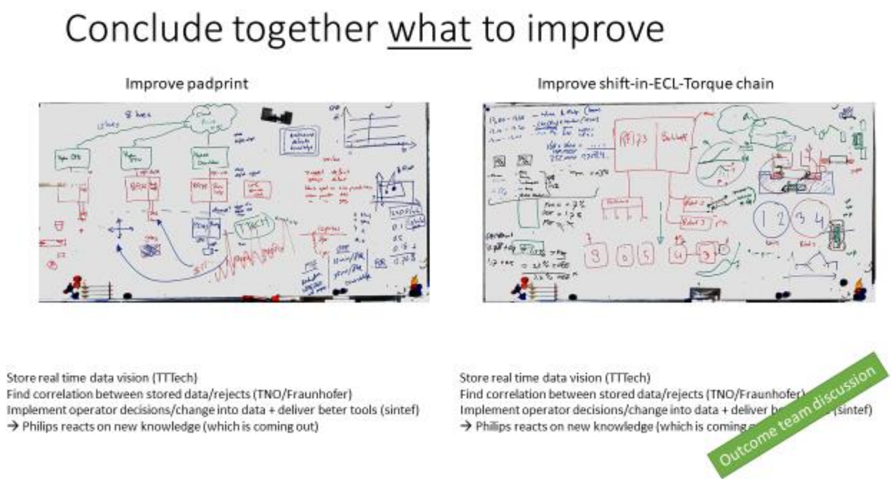


Figure 10: Philips pilot-case and (main) partners

Basically figure 7 and 8 show the added value of the partners to use their knowledge to improve the OneBlade production on 2 Pillars:

1. Improve Pad print
2. Improve assembly step

These 2 pillars are based on the pareto and partners the biggest contributors to make next step in decision based Autonomous Quality.

## 5.3 Pilot 1: *Philips*; Detailed plan

Table 2: Pilot 1. Philips Detailed Plan

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| **1** | Define goal | Set-up kpi matrix | Wk1920 | Pilot owner | Done |
| **2** | Indentify | Get familiar to production line and data | Wk2020 | *PArtners* | *Done* |
| **3** | Analysis of goal | Find correlations within realtime data | *Wk2052* | *Partners* | *Running* |
| **4** | *Set-up improvements* | *Base don find correlations set-up w.o.w. to test in line* | *Wk2110* | *Partners* | *Not running* |
| **5** | *Test solution* | *Measure results* | *Wk2152* | *Pilot* | *Not running* |

## 5.4 Pilot 1: *Philips*; Expected results

Table 3: Pilot 1. Philips; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION<br>*Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | OEE-A | Availibility of equipment. Less FOR = increased OEE-A | [%] | 80 | 87 |
| **2** | OEE-P | Performance- Deviation on cycletime | [%] | 98 | 99 |
| **3** | OEE-Q | Quality- Fall Off Rate | [%] | 95 | 98.5 |
| **4** | Operator Load | Number of operators to perform activities | [FTE] | 2.5 | 2 |
| **5** | OEE-overall | N/A | [%] | 75 | 85 |

## 5.5 Pilot 1: *Philips*; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 5.5.1 Pilot 1: *Philips*; Analysis of sample data

Sintef performed interviews with operators

TNO has investigated raw picture data

Fraunhofer has analysed raw robot data, shift-in (force-way measurements) to find relationships to predict Torque

TTTech has delivered Edge device for in-process control, this device is being installed

### 5.5.2 Pilot 1: *Philips*; Pre-deployment results

Sintef delivered information to put "soft" part of organization also in daily management structure. Nowadays the KPI's are hard technical related. Other topic is to use digital tools for operator- whiteboard sessions. People claim they are more digital oriented at home compared to work floor.

Seems to be relationship to predict torque with use of in-line data. Needs to be more explored (Fraunhofer)

AI vision algorithm developed by TNO (WP3) seems to filter bad rated parts compared to installed algorithm. Advantage can be when product print is changing to catch-up development speed in traditional algorithm development. Test-case currently in progress.

### 5.5.3 Pilot 1: *Philips*; Stakeholder-training Logbook

No results yet, as the implementation is not far enough to train stakeholders.

# 6 Pilot 2: SIEMENS; Control Products Quality Improvements

## 6.1 Pilot 2: SIEMENS; Current state

In the considered production line, electronic components are manufactured automatically and tested for functional defects using multiple test stations, including optical inspections, inner circuit tests and X-ray machine. Significant process steps are the solder paste printing of the circuit board, the placement of the electronic elements and the (reflow) heating process (compare Figure 11) before assembly. For ensuring high product quality, several quality tests are integrated into the manufacturing line. Today, each of these quality tests is conducted in order to test the result of the previous manufacturing steps. From the overall setup of the manufacturing environment, ICT and X-Ray testing are placed in a testing area, decoupled from the actual manufacturing lines. The X-ray test has a comparatively high process time, is carried out as a batch process and represents the line bottleneck, since currently a 100%-testing is conducted. Since the purchasing of further X-ray machines is associated with high costs, other solutions and approaches have to be generated.


Figure 11: Schematic overview of the manufacturing process

### Weaknesses and Bottlenecks

Table 4: Pilot 2, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY *At processes (manufacturing) level and business level* |
|---|---|---|---|
| Data Availability | Limited access to measurement data (due to limited access to third-party systems) | Manufacturing, Technical Support | Limitations / Inability to improve with chosen approach. |

## 6.2 Pilot 2: SIEMENS; Future state

Current activities performed in the factory in Amberg are a collection of product and test data, storage and management of these data for quality scouting, with web service and graphical report extraction. Specifically, for this trial, the focus is on one specific manufacturing line including solder printing, placement of electronic components and reflow soldering. Within this manufacturing line several test stations are installed for automated test of every panel. The solder printing inspection is an optical inspection of the solder paste printed on the panels. The automatic optical inspection is currently located after the reflow oven. Within the trial it will be additionally located before the reflow oven. The electronic pads are then tested by in-circuit test and x-ray.

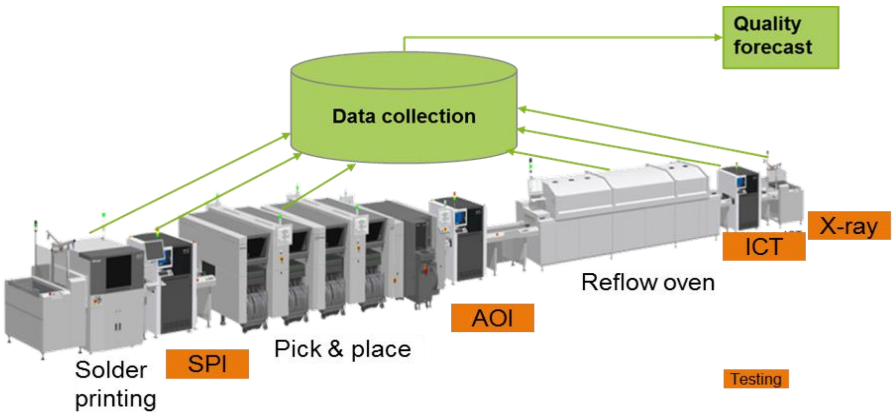


Figure 12: Manufacturing line for panel production and test data acquisition

For this trial, the acquired test data will be analyzed regarding quality classification. In every test a part could pass or fail. Failed parts must be reworked, if possible, and brought back to the process. Sometimes parts are classified as failed even if they are good (false positive). This effect will be analyzed by machine learning algorithms and, if necessary, adopted in classification parameterization. Additionally, the fact of 100% testing, means every panel is tested automatically, with bottleneck in out of the line test stations will be addressed in setting up failure prediction models for quality forecast. This will be supported by data analysis of pre reflow AOI. With all these data analysis and process optimization activities economical evaluation will be included to support decisions in-process and configuration changes. For the development of these applications, the main steps are data availability/access, data processing, and model development. The developed applications should be deployed on Edge devices.

## 6.3 Pilot 2: SIEMENS; Detailed plan

Table 5: Detailed plan Siemens Pilot

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| **1** | Define goal | Set-up kpi matrix | Pilot owner | M9 | Done |
| **2** | Concept Development | Refine concept for implementation | All | M9 | Done |
| **3** | Data Availability Estimation | Identify necessary data, and determine which data is already available for initial working | Pilot Owner | M11 | Done |
| **4** | Data Capture and Sharing | Capture additional data as required by concept and begin to share with development Partners | Pilot Owner | M18 | Done |
| **5** | Prototype Implementation of Concepts | Based on initial data shared, development partners to show PoC for RM | Development Partners | M22 | In Progress |

| | | | | | |
|---|---|---|---|---|---|
| **6** | Concept Development | Based upon initial PoC feedback, continue development of concepts for integration in Pilot | Development Partners | M27 | Planned |
| **7** | Integration In Pilot | Integration of concept implementations within the pilot, including calibration of modules. | All | M33 | Planned |
| **8** | Execution in Pilot | Utilized Concepts will be demonstrated in the Pilot | All | M39 | Planned |

## 6.4 Pilot 2: SIEMENS; Expected results

Through innovative algorithms and statistical methods, possible data sources for predictive quality control can be identified and evaluated. Moreover, by cooperation of all project partners, the realization of data access and acquisition along the whole process chain can be realized.

With a focus on algorithms and methodology, a use case-specific algorithm is going to be implemented and validated to maintain high prediction accuracy. By applying sophisticated algorithms and methods on the acquired data, systematic failure root cause detection supported by data analytics can be implemented. In addition, improved knowledge of machine states/maintenance requirements for neuralgic points can be implemented through the desired solution path within this pilot.

Concerning the ecological and economic operation of a factory, data analytics tools in combination with simulation approaches can contribute to improved throughput, bottleneck-reduction, or both for the production line. Through the optimization of the processes, production execution on organization and logistic level can be optimized by reducing the amount of material within the system, the lead times, or both.

Table 6: Pilot 2. SIEMENS; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Current value | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | OEE | Measured as false positives rate, actual value is considered confidential | ppm / % | N/A | improve false positive rate by 20% |
| **2** | FPY | Measured as false positives rate, actual value is considered confidential | ppm / % | N/A | improve false positive rate by 20% |

## 6.5 Pilot 2: SIEMENS; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 6.5.1 Pilot 2: SIEMENS; Analysis of sample data

Test data from several months (txt and csv files) were structured and uploaded in a common data base model and analyzed regarding correlation. Involved Partners are TU Dortmund and TU Braunschweig.

### 6.5.2 Pilot 2: SIEMENS; Pre-deployment results

First results show a correlation of decision parameters in quality classification and are deployed as decision tree for a first test stand. These results must be validated now. Main contributor here is TU Dortmund.

### 6.5.3 Pilot 2: SIEMENS; Concept for test strategy assessment

Working on concept for failure propagation module and test strategy assessment service. Main contributors are TU Braunschweig and Siemens Corporate Technology

# 7 Pilot 3: CONTI; Autonomous Quality in PCB Production for Future Mobility

## 7.1 Pilot 3: CONTI; Current state

The production of automotive electronics for future mobility is based on automated lines that secure highest quality and output. For the production and assembly (Figure 13) of respective PCBs an effective zero-defect approach and availability is paramount.

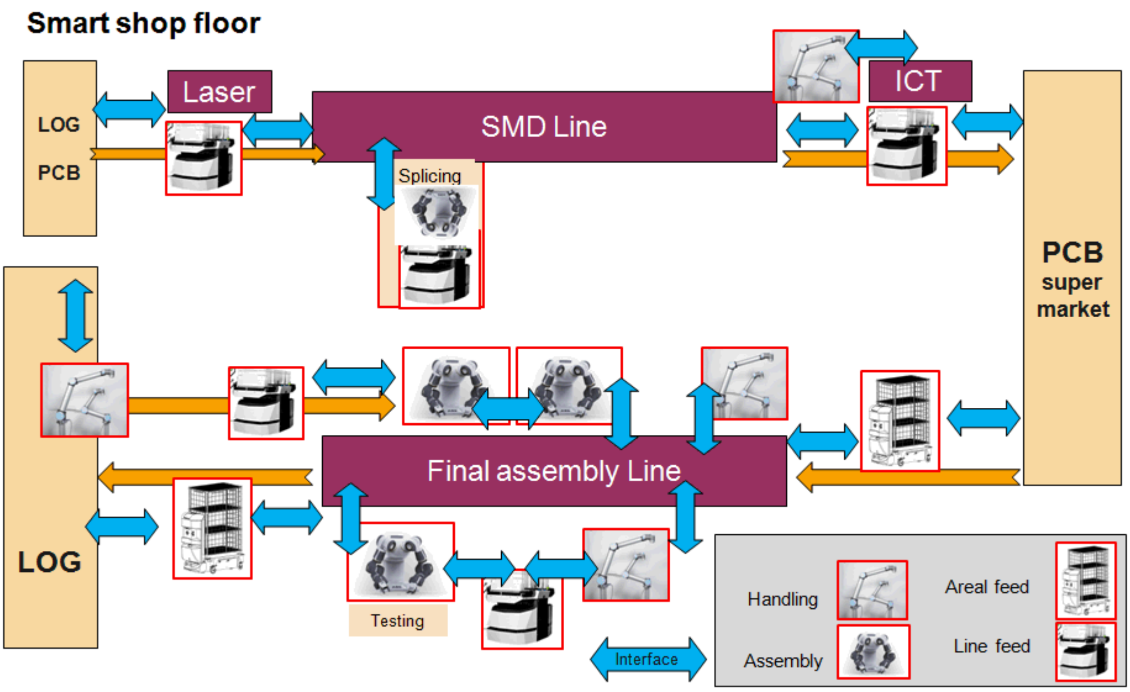


Figure 13: Continental's PCB production combining a SMD with a final assembly line

The challenges, which result from the emerging autonomous driving and electro-mobility call for a step-change in quality of electronic components and systems, as well as regarding reactivity to product and market changes whilst keeping the stringent cost constraints in focus. Key features, such as "product/component quality", "cost control" and "time-to-market" for multi-millions of products outline the situation in the automotive industry at the brink of a new economic scenario and govern the global competitiveness. As to Equipment Data Collection and Communication it is obvious that:

- sensing and combining data from a variety of sources is essential to enable a progressive approach. Setting a standard for data formats in shop floor communication, such as **"Bluetooth 4.0 for Autonomous Quality"** is crucial, which aims at achieving an independent format for machine communication

- autonomous recognition and management of unstructured data for several production lines all over Europe requires the establishment of an **"EU-Cloud"** for safe, secure and trustworthy data processing
- the adoption of **Big Data technology** in supervisory and strategic actions **on production lines and the full supply grid** are the gateway to immediate reaction to problems
- the **next generation of shop floor Visualization Management** will be a steppingstone to advance beyond current line boards and trend charts in order to visualize quality relevant data which cannot be naturally sensed by operators

## 7.2 Pilot 3: CONTI; Future state

- Builds on real-time Data Mining in Production Systems and communication (via Bluetooth 4.0 for Autonomous Quality) to provide early indicators and trends from process signals
- Enables "Big Data in Zero Defect Production", which facilitates the creation of new applications that span over the whole value chain, i.e. data acquisition and extraction, data analysis, data storage, data visualization and usage in a "safe "Cloud storage" environment
- Allows Digital Modelling & Zero-Defect Strategies an suggest feed-forward or feed-backward of quality data along the supply chain
- Enacts the physical interpretation and initiation of real-time reaction plans via innovative shop floor visualization management increasing OEE by helping the operator to take correct process adjustment decisions

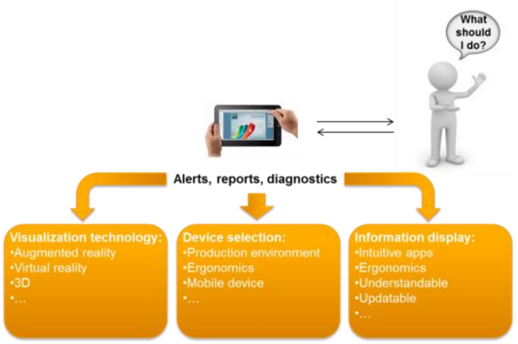


Figure 14: Visual impression of alerts reports and diagnostics to user

## 7.3 Pilot 3: CONTI; Detailed plan

Table 7: Detailed plan Continental Pilot

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| **1** | Define Target BP1 – BP4 | Agree on contribution to the pilot from all partners | TUBS<br>ATOS<br>Sintef<br>ATB<br>PACE<br>IAO | Pilot owner | done |

| | | | | | |
|---|---|---|---|---|---|
| **2** | Establish connectivity BP1 | Collect Data form individual Equipment in Continenal Factory | TUBS ATOS | Pilot owner | ongoing |
| **3** | Establish connectivity BP2 | Provide Access to external Partners to Continental Manufacturing Datalake | Sintef ATB | Pilot owner | Done |
| **4** | *Analytics BP2* | *First Analytics results provided to plant Ingolstadt.* | *Conti, Sintef, ATB* | *Pilot owner* | *Done* |
| **5** | *On site investigation* | *Plant visit at plant Karben* | *TUBS* | *Pilot Owner* | *Upcoming in August* |
| **6** | *Concept definition BP3* | FhG provided concept to support BP2 with user oriented workplace design. | *IAO* | *Pilot owner* | *done* |
| 7 | *On site visit* | *Plant visit at plant Karben* | *IAO* | *Pilot Owner* | *Upcoming* |
| 8 | *Use case validation BP4* | 1st use cases in place in Plant Ingolstadt. AR solution supporting maintenance, change over and training of operators in the plant. | *PACE* | *Pilot owner* | *ongoing* |

## 7.4 Pilot 3: CONTI; Expected results

Table 8: Pilot 3. CONTI; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | PPM | PPM related (errors at end user / Field Call Rate risk etc) | [ppm] | >10 | <1 |

## 7.5 Pilot 3: CONTI; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 7.5.1 Pilot 3: CONTI; Analysis of sample data

(Short conclusion on what has been found during analysis)

BP1:

- 1st wave: analyze dependencies between ICT / FKT and AOI shows potential.
  - Karben is providing data from PRiME – MES in order to start an 1st investigation
  - Explaning the structure and fields to be done
- 2nd wave: extend the data with SPI as a source of generating fails of ICT / FKT
  - Data collection from the equipment and possible link of data from the different data sources to be investigated

BP2:

- Focus was on identification of outliers as suspicious events.
- Correlation was found between two outliers and previous test measurement data.
- No significant differences between customer returns and random units.
- Findings only linked to a small subset of tests. More experiments are planned on different subsets of test.

BP3:

- Focus was on identification of data to be consumed by possible users at the newly to be designed workplace.

BP4:

- Time to learn and operate maintenance and Training actions was reduced. Operator satisfaction increased. Less risk for failure confirmed.

Relevant questions:

What has been analysed, how, involvement of partners and outcome/conclusion

### 7.5.2 Pilot 3: CONTI; Pre-deployment results

(Short conclusion what has be done, involvement/contribution partners, hardware/software, training etc.)

BP1: Investigation was done on data, that is so far used for ZDM enabling. During and on-site visit in Plant Karben several data source were identified, that are so far unused for analytics. It was clarified how a data access could be organised and how analytics should happen in order to contribute to the ZDM strategy.

BP2: As part of a lot release application, that should enable a risk evaluation before shipments are finally leaving the plant, relevant data sets were analysed. Data come from Plant Ingolstadt, were safety relevant ADAS products are being manufactured. Plant Quality management could see benefit from the activities so far.

BP3: linked to BP2 the data could now be provided for usage in BP3. The surrounding of a newly designed workplace can be worked on now, as it is clear, which data has to be consumed at the workstation.

BP4: Several use cases have been documented as videos. The videos are basis for AR environments, that will be enriched using WEAVR from Pace. First trials already happened at Plant Ingolstadt.

### 7.5.3 Pilot 3: CONTI; Stakeholder-training Logbook

The training logbook related to the training of stakeholders and pilot participants on the use of the pilot systems can not be completed yet, as the pilot is not advance far enough to create training materials.

# 8 Pilot 4: WHR; Dryer Factory Holistic Quality Platform

## 8.1 Pilot 4: WHR; Current state

The pilot will leverage the outcomes of a previous research project (NMBP FP7 GRACE) and will integrate the QU4LITY digital enablers and platforms (through the open APIs) and the AQ control loops. The main innovation will be represented by the introduction in production of MPFQ model fused with AQ control loops: Functional Integration and Correlation between Material, Quality, Process and Appliance Functions. This innovative way to control quality and model data inherent to quality will be the fundamental approach that will lead to the vision of holistic Quality system.

Also, it will deploy AQ reference implementations to address unresolved problems in the vertical integration of data management (from data gathering to visualization and decision making), enabling a holistic vision to be achieved.

The production process to build a Clothes Dryer comprises many stages: the combination of automatic equipment and manual operation and all along the production process several Quality Stations are installed to perform gauge, to detect defective parts, filter them out or repair them.

Quality data are still managed as islands and with poor correlation between business processes and locations. This is mainly due to a lack of a common and holistic semantic model able to represent concepts at different stages of the product lifecycle:

1. Lack of a common and a holistic semantic model able to represent concepts at different stages of the product lifecycle;
2. Lack of standard methods and tool to gather, store and share data;
3. Lack of flexible and user-friendly analytical tools;
4. Lack of a comprehensive way to share results or data analysis and link them to business priorities.

The full potential of data generated at each gate is not exploited yet and any attempt of using the data are currently requiring a strong specialization and specific knowledge of each gate. Moreover, time-consuming activities are needed to query database and manually correlate and analyse data.

The new installed drier factory in Lodz is based on an integrated approach for shop-floor Quality management. However, a further step of integration could be made available at a higher level of vertical integration (e.g. through chain business processes) and horizontal (to other related processes or factories).

### Weaknesses and Bottlenecks

Table 9: Pilot 4, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY *At processes (manufacturing) level and business level* |
|---|---|---|---|
| Data reliability (IMECH) | Reliability of data coming from personnel | Manufacturing | • Organizational changes (HR and business level)<br>• Process automation<br>• Training on best practice of data reliability |
| Model Accuracy (IMECH) | Large number of variables can influence model accuracy | Manufacturing, Technical support | • Training on big data approach<br>• Training on best practice of data reliability |
| Data protection (IMECH) | Protection of production and market data in terms of cybersecurity and in terms of anonymization | Manufacturing, Others (IT) | • Changes in corporate information systems<br>• Training on best practice of cybersecurity<br>• Training on best practice of data anonymization |
| Data integration (IMECH) | Integration of data coming from several department and from the market | Technical support,<br><br>Others (IT) | • Changes in corporate information systems<br>• Training on best practice of data integration |

## 8.2 Pilot 4: WHR; Future state

Expected Outcomes:

- A common and holistic semantic model able to represent concepts at different stages of product lifecycle;
- Standard methods and tool to gather, store and share data;
- Trustworthy digital continuity and data management;
- Flexible and user-friendly analytical tools - Human-centric big data visualization;
- Comprehensive way to share results among different management roles;
- Equipment and process simulation and optimization solution as major leverage towards the efficient realization of complex first-time-right parts;
- Implementation of a closed loop over the manufacturing process between digital and real domains.

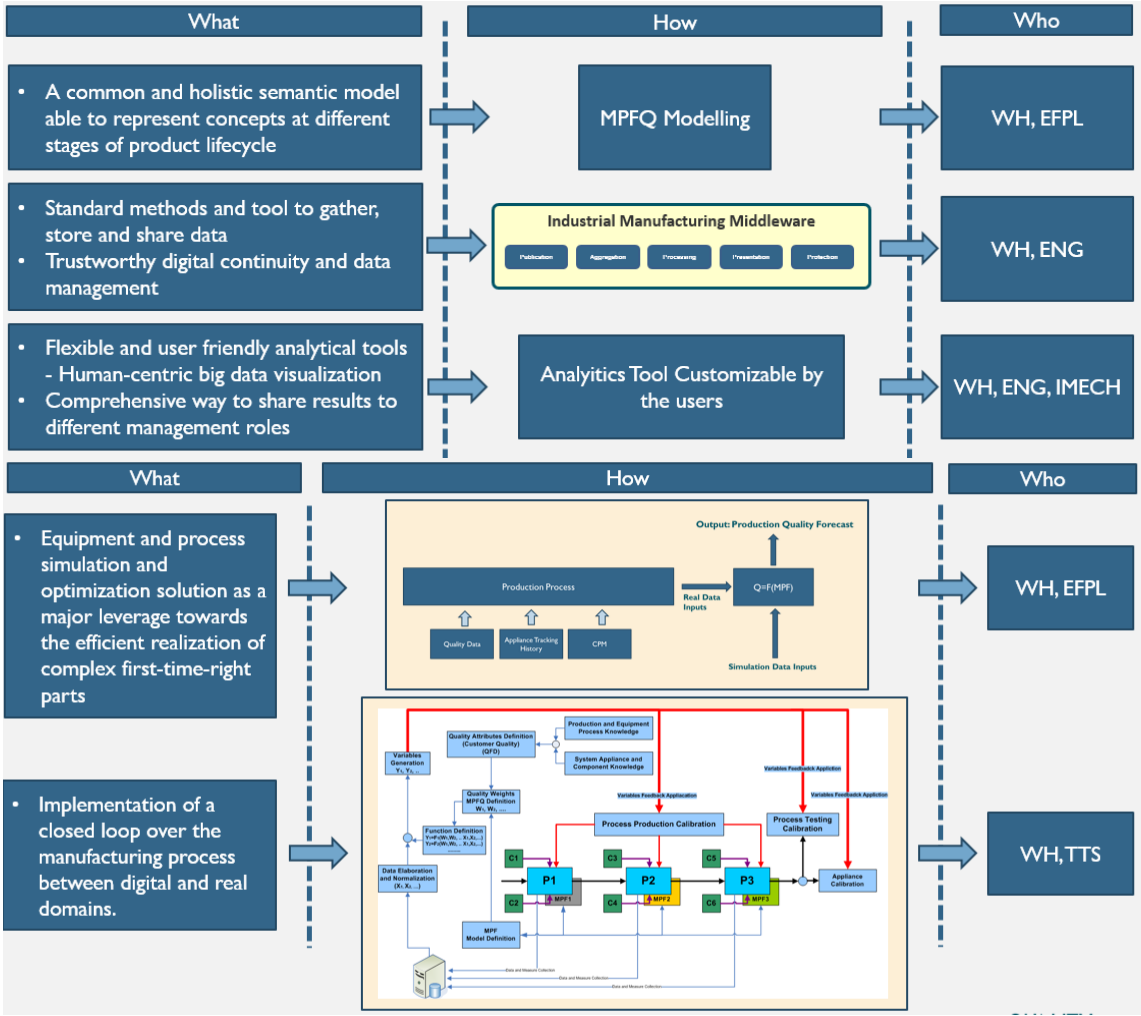


Figure 15: TO-BE state and partnership

MPFQ Model:

- Manufacturing is the only point of integration between the concepts and the reality
- Manufacturing is the only point in which the Customer Domain is brought into reality and satisfied (or dissatisfied)
- Future Manufacturing concept need to better integrate these two distinct processes

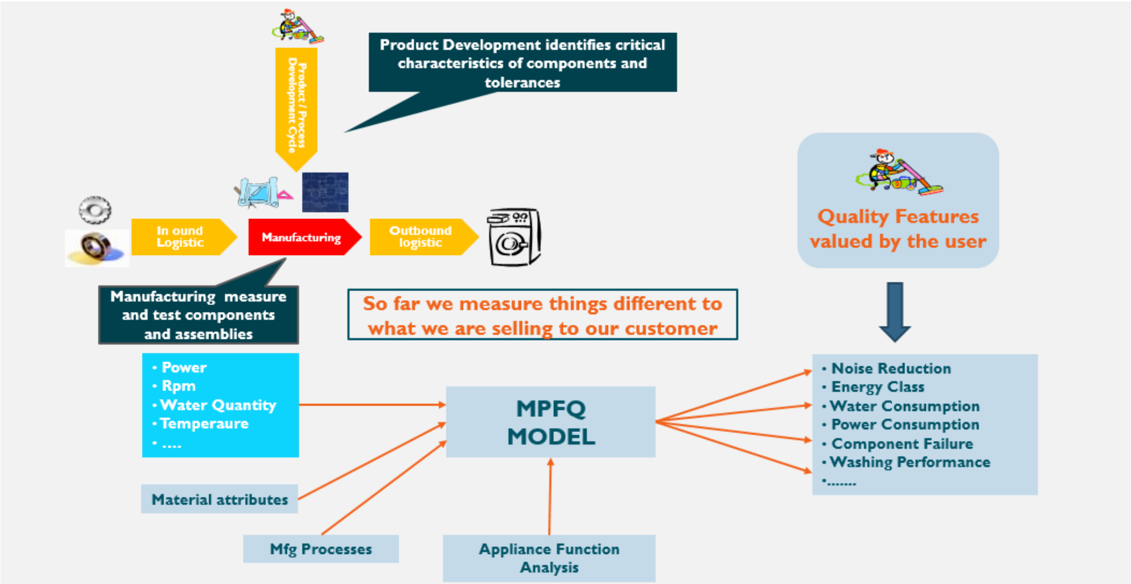

Figure 16: pilot approach

The MPFQ-model is an acronym combined by the first characters of the four main elements:

- **M**aterial - as a collective term for everything that is needed to produce a certain product or product component. This may include raw materials, pre-products, consumables, operating supplies, product components and assemblies.
- **P**rocess - meaning production processes processing and transforming materials into the final goods by using machines, tools and human labour. This process is defined within the plant engineering.
- **F**unction - meaning product feature and functions as distinguishing characteristics of a product item. This is mostly focused on functionalities as specific task, action or process the product is able to perform, but may also include other features like performance etc.
- **Q**uality - measured as the degree of conformance of final product functions and features to customer requirements.

Every material, production process and product function/feature can be described by its technical characteristics and a collection of measured data. The processes can be additionally described as a sequence of process steps and their parameter setups. Product functions and features additionally contain performance indicators. These performance indicators may be evaluated by analysing and computing measured data from the materials forming this function, the process realizing the function or even by the directly measured data from the function measuring.

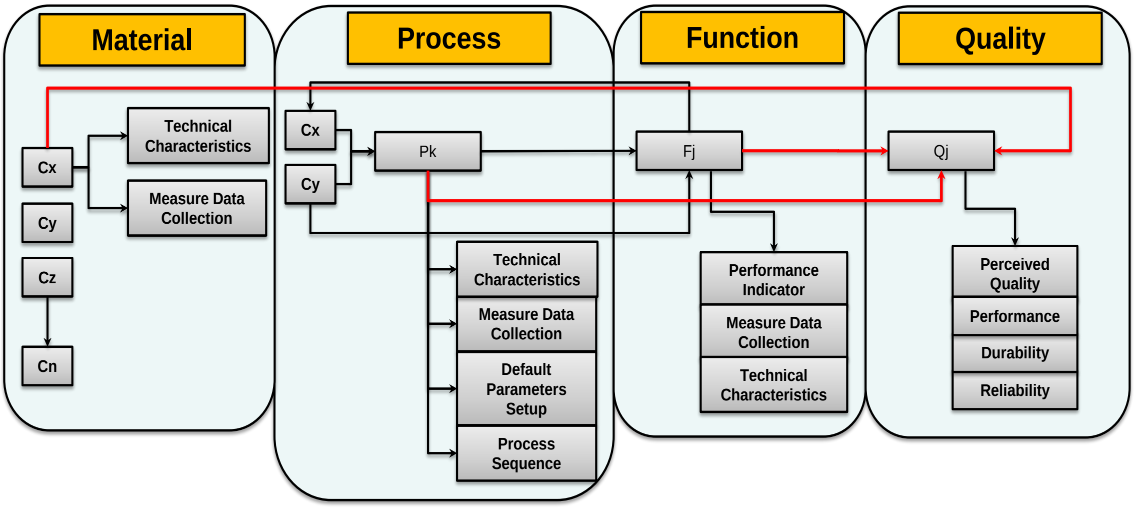


Figure 17: MPFQ Model

Expected Impact:

- **First Pass Yield,** (FPY= 1- (#defects / #units produced)) - it allows to assess the capability of the Production to filter defective products along the process so to avoid their delivery to the market.
- **SIR** (# calls / units produced) - it measures the quality of the product in the market. It can be measured both in different period of the product lifetime, to separate problems arisen in the manufacturing stage from design problems.
- **Q** (defect severity/product sampled) - it allows to statistically forecast how the product will perform on the market. It is based on full check performed on statistical sample ranging from 3% to 5% of the production.

## 8.3 Pilot 4: WHR; Detailed plan

1) Trial Preparation: MPFQ Model developlemt, Assembly Processs Mapping

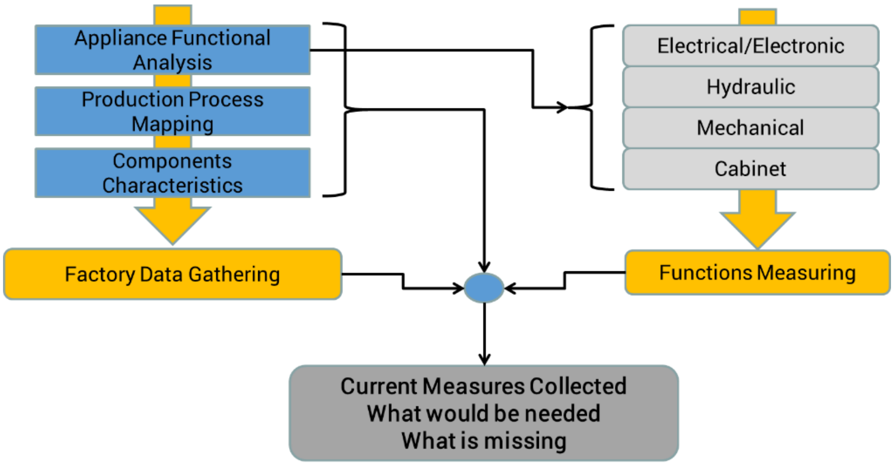


Figure 18: Assembly process mapping

2) Trial Preparation: Industrial Manufacturing Middelware Design and Implemenation

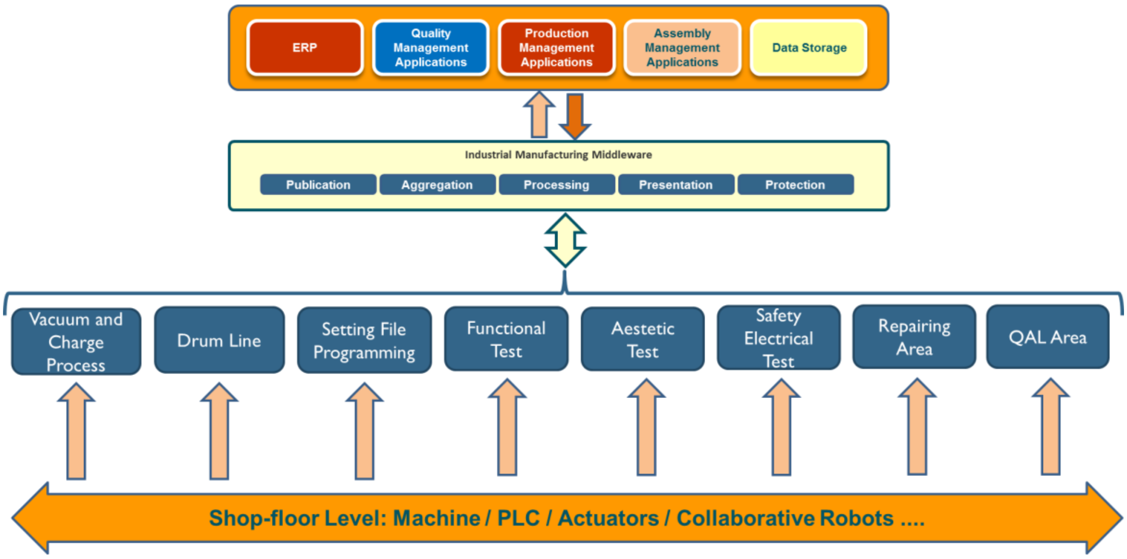


Figure 19: Industrial Manufacturing Design and Implementation

3) Trial Preparation: Quality Performance Indicatior Design by Analitics Methods

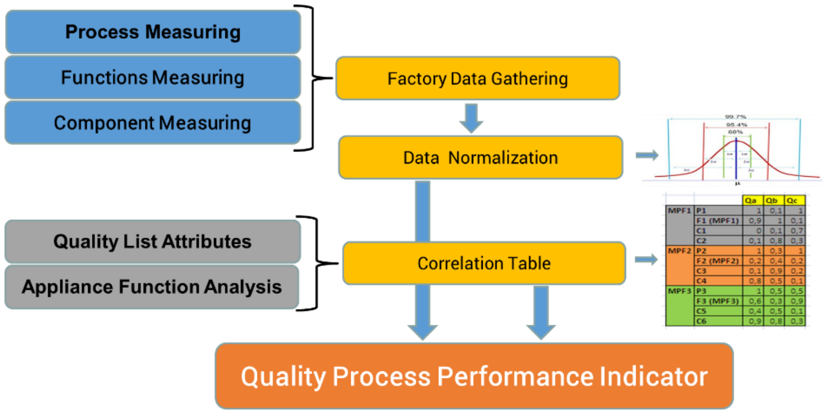


Figure 20: Quality Performance Indicator Design

4) Trial Implementation:
   a. Automatic Data Collection
   b. Data Normalization and the Cloud DB Stored
   c. Data Analitically Elaborated in according to the MPFQ Modelling
   d. Data shared to different plant users in according to the role and theirs activity
      i. Quality Manager
      ii. Quality Process Leader
      iii. Testing Engineer
      iv. Central Quality Team

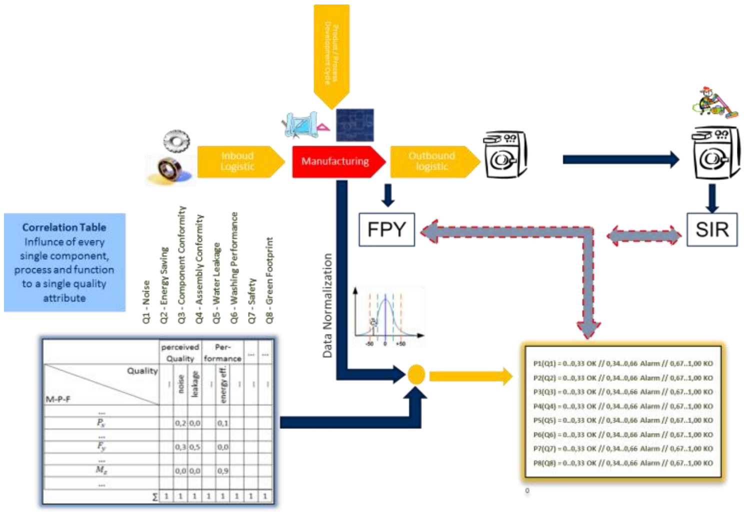


Figure 21: Trial Implementation

5) Trial Implementation: Autonomous Quality Feedback:
   a. Production Process Calibration
   b. Testing Process Calibration

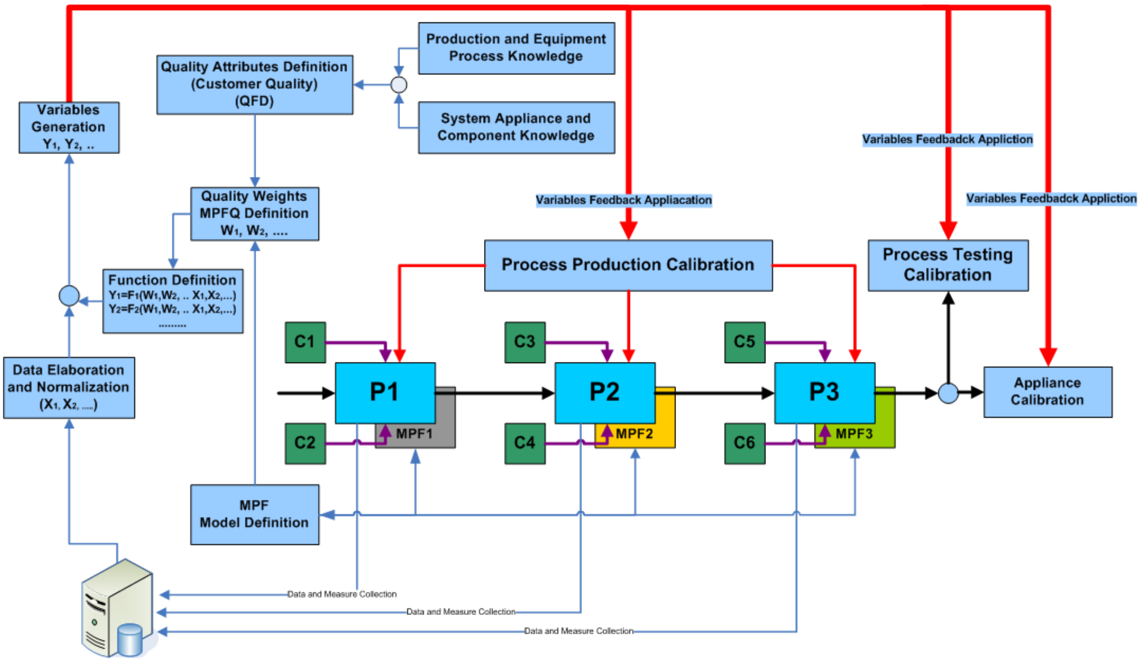


Figure 22: Autonomous Quality Feedback

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| **1** | *Lodz plant production mapping* | | *WH, TTS, Intellimech* | | *Done* |
| **2** | *MPFQ modelling and definition of the architectural project design* | | *WH, EN, TTS, Intellimech* | | *Done* |
| **3** | *Ontology and DB design* | | *WH, EN, TTS* | | *Done* |
| **4** | *Cockpit Design* | | *WH, TTS* | | *On-going* |
| **5** | *Data Plant Collection* | | *WH, EN* | | *Done* |
| **6** | *Drum Line: data analytics elaboration* | | *Intellimech* | | *On-going* |
| **7** | *Data Server Project Repository* | | *EN* | | *On-going* |

Table 10: Pilot 4, WHR; Detailed plan

## 8.4 Pilot 4: WHR; Expected results

Table 11: Pilot 4, WHR; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | **1** | **FPY** (1- (#defects / #units produced)) | it allows to assess the capability of the Production to filter defective products along the process so to avoid their delivery to the market | (#defects / #units produced)) | N/A |
| **2** | **2** | **SIR** | it measures the Quality of the product in the market. Can be measured both in different period of the product lifetime, to separate problems arisen in the manufacturing stage from design problems | (# calls / units produced) | N/A |
| **3** | **3** | **Q** | it allows to statistically forecast how the product will perform on the market. It is based on full check performed on statistical sample ranging from 3% to 5% of the production | (defect severity/product sampled) | N/A |

## 8.5 Pilot 4: WHR; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 8.5.1 Pilot 4: WHR; Analysis of sample data

The Lodz factory has a data collection and management architecture that made it possible to have a clear and easy vision of how the project could have evolved. The data coming from different, but structured, silos are representative of all the essential processes for the production of dryers, this allowed us to define a process modelling process in accordance with the evolution of the MPFQ model that was in line with expectations of the autonomous quality. Data integration was filtered through the evolution of the data ontology defined in the GRACE project.

### 8.5.2 Pilot 4: WHR; Pre-deployment results

Once the key concepts on which to set up the activities had been defined, the team moved accordingly, in practice:

- Definition of the MPFQ model based on the mapping of the production process
- Ontological evolution of the process data and its transposition into a relational DB
- Definition of the operational cockpit configurable according to the stakeholders
- Collection of process data and processing in the project relational DB
- DRUM line: analytical evolution between process measurements and quality data

### 8.5.3 Pilot 4: WHR; Stakeholder-training Logbook

Stakeholders were presented with the project in its entirety and its potential, in particular the elements that they can use to improve efficiency in the production and use of the plants. The processed data, the configurability of the information collected and displayed, the interconnection between product and process information are all elements that represent a better way of reading what happens during the production process, avoiding waste of time and improving overall operations.

# 9 Pilot 5: MON; Zero defect and Autonomous Quality in Machinery Building for Capital Goods sector

## 9.1 Pilot 5: MON; Current state

**SCENARIO 1 – Manufacturing processes with cutting/grinding machinery**

The multi-stage production line of axles is represented in the Figure below. The process chain includes forging, heat treatment, machining (roughing and finishing), finishing stages (painting and protecting), as well as in process and final inspection and verification operations. The assembly of one axle and two wheels results in a wheelset. During this multi-stage process, several deviations or process variability may cause geometry and quality defects that cause both extensive rework operations and part scrap.

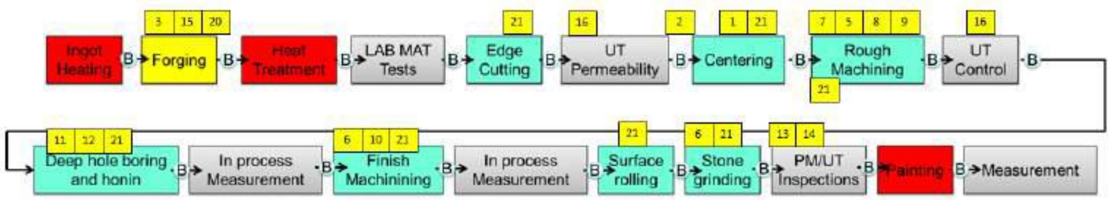


Figure 23: Axle production line

The processes in the production line are grouped in:

- Upstream processes that influence the machining
- Centring, part assignment, adaptive machining
- Critical process monitoring
- Data engineering
- Root cause analysis, data analytics
- NDT optimization
- System optimization

Within these processes there are numbered actions mapped to the general process chain above. The table below details the whole process, actions, description, solution type, actions derived, location and defects affected to be implemented by QU4LITY platform.

### Weaknesses and Bottlenecks

Table 12: Pilot 5, SCENARIO 1, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY *At processes (manufacturing) level and business level* |
|---|---|---|---|
| Data access and quality | The availability and quality of the data is a real issue in production plants. Data gathering systems are sometimes disconnected for different reasons. In addition, high sampling frequencies may produce bottlenecks in the machine and consequently online monitoring services may be lagged | DANOBAT | N/A |
| Limited fieldbus connectivity | The savvy box as data gateway lacks industrial real-time control capabilities and integrates the capabilities of industrial automation controllers or PAC devices via modbus. The load balancing between PAC and Savvy Box is another issue to be handled. In this context, the adoption and implementation of IEC-61499 distributed control can be an important enhancement | DANOBAT | N/A |
| Push information services | The information delivery services provided the technology provider are pull services. Push services like ticket based notifications will enhance the usage of the platform. | DANOBAT | N/A |
| Data exchange | In addition to the API Rest data exchange services provided there is a need of extending the data exchange services to OPC-UA standard. Moreover, and IDS compliant data exchange is an important enhancement in terms of standardization. | DANOBAT | N/A |
| AI | The implementation of embedded analytics in the edge or cloud tier of the platform is in an initial stage of development. The implementation of tools and methods jointly with the hardware resources is an important task to be accomplished within the scope of the project | DANOBAT | N/A |
| Poor RUL estimation results | RUL highly depends on the provided data and the selected distribution. If the data are not enough or not appropriate or the selected distribution | DANOBAT | N/A |

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY *At processes (manufacturing) level and business level* |
|---|---|---|---|
| | does not fit the data correctly the RUL estimations will be far from the actual behaviour. | | |
| Integration of devices not compatible with the existing proprietary solutions | Legacy industrial protocols are most of the time proprietary which slow down the availability of a certain class of sensors or IoT devices | DANOBAT | N/A |
| Accuracy of time synchronization | A certain level of data correlation analysis is impossible if the production rhythm is faster than the time synchronization solution selected, e.g., production rhythm in the order of the millisecond and time synchronization in the order of the second. | DANOBAT | N/A |
| Remote control of actuators | Without end-to-end control data delay guarantee, it is impossible to ensure reliable and performant remote control of actuators | DANOBAT | N/A |
| Converters-Interoperability-Standardization | The main weakness is the large number of standards, data models and protocols available in the field. | DANOBAT | N/A |
| LKS and IDEKO Big Data platforms are based in Hortonworks but both are different versions | Work is needed to deal with the differences of each version. Similar but different. | DANOBAT | N/A |
| Hardware is different in both platforms | Performance issues could happen | DANOBAT | N/A |

**SCENARIO 2 – Manufacturing Processes with Hot Stamping Machinery**

The pilot proposed in QU4LITY project is framed within the process of continuous improvement of FAGOR ARRASATE R&D strategy. The development of this project will allow FAGOR ARRASATE to offer to its customers a more accuracy, competitive and productive hot stamping lines and a greater degree of sophistication with respect to what the market currently offers. The development of this project will facilitate the increase of the level of sales.

  

Autonomous Quality in hot stamping process, allows to implement augmented human centred decision control loop, by analysing automatically not only the process settings and in-process sensor data but also data generated from the context of such process. Such analysis should serve to propose new process settings with the aim of reducing defective manufactured parts. The proposed new settings are dynamic (requires dynamic learning) because the manufacturing process admits variability such as different input formats or changes in the die of press machine.

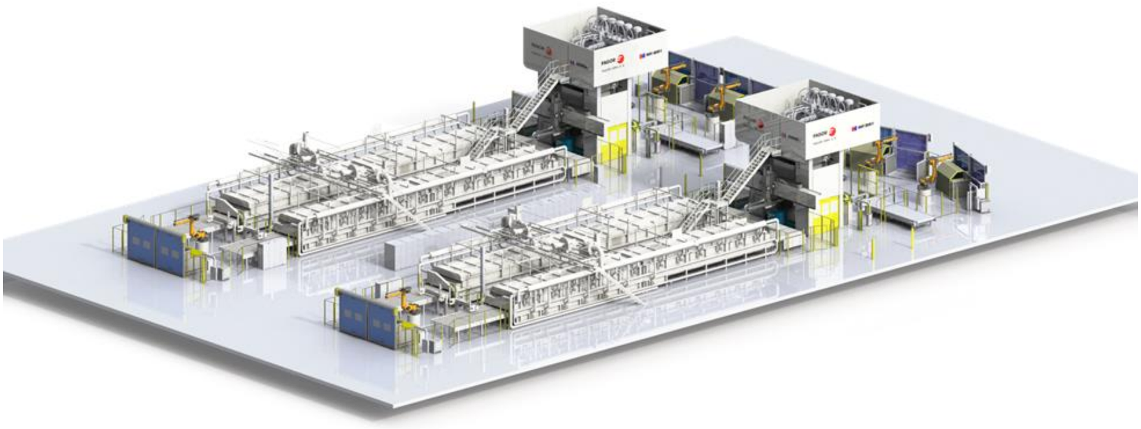

Figure 24 Hot Stamping Press Line

### SCENARIO 2 - Weaknesses and Bottlenecks

Table 13: Pilot 5, SCENARIO 2, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY *At processes (manufacturing) level and business level* |
|---|---|---|---|
| Data sources | -Integration of several data sources that each have own data format | FAGOR, IKERLAN | Due to lack of standardization, may be time consuming. |
| Reference architecture | -Integration of other developments made within this pilot do not follow the reference architecture of IDS and thus are incompatible. | FAGOR, IKERLAN | This would cause that certain applications could not be deployed and run within the proposed data space approach. |
| CPS Data | -Integrity of the CPS data could be compromised during the data flow from the generation, to the consumption. | FAGOR, IKERLAN | This would cause to producing bad optimizations or software in the control loop. |
| CPS Multiple measures | -Handling of the CPS Multiple measures are retrieved from CPS in real time. | FAGOR, IKERLAN | Such quantity of data could be big, causing an |

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY *At processes (manufacturing) level and business level* |
|---|---|---|---|
| | | | unintentional denial of service. |
| Data analytics | -During operation, analytics are realized in order to optimize manufacturing. | FAGOR, IKERLAN | If the time needed to analyse the data is longer that the response time needed to close the control loop, it can become useless. |
| The platform that will provide the converters for the use case is not core to the use case | It is an extra element providing additional interoperability capabilities. The platform does not condition the correct functioning of the use case. The main weakness is the large number of standards, data models and protocols available in the field. | MGEP | The implementation of all to all converters will be a major challenge. Correct selection of the most relevant is of most importance. |
| Different nature of standards and protocols | Conditions such as data frequency collection or availability of complete data may harm the correct mapping between protocols and standards. Again, fine selection of most relevant technologies is essential. | MGEP | N/A |
| Difficulty of testing the converters | A final issue identified is the difficulty of testing the converters against all major platforms in the market (Mindsphere, AWS, Google Cloud, Azure). | MGEP | In some case licenses and payment are required and this is not always feasible. |
| Datafabric architecture based in standards but adaptation needed | Datafabric Authenticator should be adapted to the Industry 4.0 Platform used. | LKS | Need to evaluate if an integration with current LDAP servers is needed. |
| Integration with current user repositories | N/A | LKS | N/A |

## 9.2 Pilot 5: MON; Future state

### SCENARIO 1 – Manufacturing processes with cutting/grinding machinery

The multi-stage ZDM platform proposed in QU4LITY for MONDRAGON - DANOBAT in Manufacturing Processes with Cutting/Grinding Machinery machine level trial in the Danobat Railway Systems (DRS) provides a basis to deploy the specific contents of the solution and serve as pilot cases to demonstrate the applicability of the solution to different multi-stage lines. The reference architecture for multi-stage systems on which the solution proposed by QU4LITY grounds on five major pillars, which are described in the following.

**Comprehensive Data Acquisition System**,

Combining sensor signals with numerical control (NC) system information will allow us to collect information related to product or process towards the development of the ZDM solution. Therefore, a secure communication between the real time sensing devices and the acquisition system and assurance that the measured sensor signals are correlated correctly with the information from the CNC system, are contemplated. Different numerical controls exist for machine tools (e.g. Heidenhain, Siemens, etc.), therefore, the main objective of this task will be to guarantee the communication between the platform and the NC.

The target parameters are based on the requirements of the models to be used and the data sources available to fulfil these requirements have been identified. the data obtained are gathered and treated so the most informative variables are found by means of quantitative, descriptive and visual techniques. The most relevant information is permanently monitored and stored in a static or dynamic way

The data groups that are considered as target for the analysis include (i) workpiece quality data, gathered by inspection technologies, (ii) process data, gathered from in-process sensors, (iii) and machine state data, gathered by the production monitoring system.

**2 Management Platform**

Such platform stores and updates the acquired data in a structured and formalized way. A cloud infrastructure stores data using and running the algorithms developed. The data storage uses both relational and non-relational databases. The purpose of the database is to collect historical data and activity reports in order to harvest insights. The algorithm runtime uses high availability cloud infrastructure able to process data in real-time with minimum delay. A data lake is used for the structuring of the data needed for the project purposes. Edge capabilities and local visualization possibilities are also be taken into account in the pilot use case.

Converters-Interoperability-Standardization: It is an extra element providing additional interoperability capabilities. The platform does not condition the correct functioning of the use case.

Fine selection of most relevant technologies is essential and ensures compatibility with the different nature of standards and protocols. Conditions such as data frequency collection or availability of complete data are coordinated for the correct mapping between protocols and standards.

**Data correlation**

Correlation is used to carry out the development and implementation of statistical models based on advanced data analytics and artificial intelligence techniques, in order to characterize the significant defect correlations among product, process and resource data, at different stages.

Physical and statistical models adapted to the practical problems at hand are used. We also use the models developed in machine pilot levels to implement algorithms that support a mechanistic model for near-future machine condition prediction. The condition prediction combines non-linear parameters with self-learning capabilities so it can automatically adapt to better fit the target parameters after each measurement.

**Cyber Physical Systems (CPS)**

The railway pilot line is turned into a cyber physical system through its connection to a system engineering platform, aiming to avoid the generation and propagation of defects. State-based models of the resources which compose the pilot line have been developed. Advanced but consolidated, general purpose statistical techniques are used to obtain an output state model representing the dynamic behaviour of the equipment in the axles production line, by characterizing all their possible states. Each resource state model is composed to obtain state-based models at process stage level. A set of state-based models, one for each stage in the system, represents the transformation applied by each stage on the incoming flow. integrated model of the whole system by state composition techniques through a modular approach, able to capture the dynamics of the workpiece flow in the multi-stage process chain. This is used lately in the DSS tool

An advanced automation framework for the line as a high-level automation system commands and orchestrates different elements of a lower level of automation. IT is a heterogeneous ecosystem embodied in a software-based automation platform that is created to enable high-level control of low-level devices and sub-systems. Normally, all control tasks are performed by field devices (PLC) at the shop-floor level. In this distributed architecture, this methodology becomes obsolete as upper level management systems gain access to a broader range of information, allowing them to overcome the limitations established by local decision making.

**Decision Support System**

The system engineering platform provides information about the incoming part history in the previous stages and is used to issue alarms on the specific variation mode of the part, before the process. With these inputs, a model-based approach is used to adjust the controllable variables at the next correlated stage to avoid the generation of defects while processing the part under the identified variation mode. To reduce complexity, a predefined discrete set of alternative process parameter sets will be designed and validated for each part variation mode combination.

This is done in a sensitivity analysis by recalculating outcomes under alternative assumptions to determine the impact of a variable. It useful for determination of the influence of process parameters on the ZDM objective of the pilot case. This technique is applied on the State based models developed and issues parameters to be adjusted on the working line.

  

After the processing, if one or more product key quality characteristics is outside the specification limits imposed by design, defect propagation avoidance policies will be triggered. They mainly consist in CPSs for correcting the defect before it reaches the final manufacturing stage in the process-chain. The selection of the most suitable selective inspections, part flow control, and defect correction policies is based on the analysis of the impact of the action managing the trade-off between quality and productivity, at system level.

The results are communicated to the advanced automation framework that commands the actions to be taken to correct and prevent possible failures.

**SCENARIO 2 – Manufacturing Processes with Hot Stamping Machinery**

The future scenario, focused in zero defects manufacturing, will have the objective of reduction of defective parts and breakdowns of FAGOR hot forming process machines by the implementation of an efficient and flexible condition-based monitoring and data analytics service Platform.

To achieve the main objective, it will early detect malfunctions on the press machine, peripherals or its components that may lead to a breakdown. In this hot forming line, a breakdown supposes a rejection of parts. For this purpose, the press machine and the peripherals will be monitored remotely, and real time data will be collected. Concretely, this data will be processed, stored in the Platform, and analysed according to a set of predefined indicators (KPIs) and process instances. As a result of this condition-based monitoring, the Platform will be able to trigger an alarm when an error occurs, i.e. when a KPI is exceeded or reached.

Digital Platforms Involved in this pilot are:

**Fagor DAS (Data Acquisition System)** is responsible of sampling data from the sensors via PLCs. Using industrial protocols, such as OPC-UA, DAS system gathers data provided by the sensor in real time. In the deployed scenarios more than 80 relevant variables are sampled with sampling frequencies between 2 milliseconds and 5 minutes. After this data is gathered, it is analysed, compacted and stored in an SQL Server. Such data can be visualized via a tool called Visual Stamp. Visual Stamp provides information related to channels, off centred loads, maintenance, alarms, trends and historic.

The main objective of the DAS application is the acquisition of data from an industrial process for subsequent sending or processing. In other words, it consists of a tool that links the data obtained in a process with storage systems.

**Fagor's monitoring platform, FALink-MAP (Fagor Arrasate Link Machine Platform)**, is composed by two systems, the former that is executed in the manufacturing plant (on premise) and the latter that is executed in the cloud. The data captured in plant via on premise (local view), is uploaded and aggregated in the cloud part (global view).

In FALink-MAP the data acquired is shown in different graphs. For instance, any stroke can be traced and analysed as shown on the image below. The strokes in green are considered good, the orange ones come with advises and the red ones are bad strokes (due to lack of parallelism for example). The user will be able to navigate on the platform and keep track of the key parameters, such as loads, oil and temperature.

Also, if something isn´t working properly, the platform will show any alerts to the user, making the tracking of the key parameters easier.

The cloud infrastructure is responsible of the reception (data ingestion), the processing (data analysis) and the storage. This infrastructure is supported via **IKCLOUD infrastructure**. Once the data is persisted, it is possible to visualize manufacturing information such as status and historic data, reports, comparison of multiple manufacturing lines (global view), etc. through a modern Web application (responsive & reactive HTML5 app). This application makes possible to monitor platform information such as uptime, communication status, throughput, etc.

## 9.3 Pilot 5: MON; Detailed plan

Table 14: Detailed plan Mondragon Pilot

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| **1** | Phase 1 - Specification & Fine Tuning of the QU4LITY Concept | *Specifications of the pilot, Architecture Analysis*<br>*IIoT definition, Variables and Possible Data Set*<br>*Analysis of Digital Enablers and Enhancement* | *MON, FARR, IKERLAN, DANOBAT, IDEKO, MGEP* | Pilot owner | Done |
| **2** | Phase 2 - Proof-of-Concept and Minimum Viable Product Implementation and Validation | *Architecture Design,*<br>*IIoT design*<br>*Key Variables*<br>*Digital Enhancement and Digital Enabler Connectors and Initial Data Sets -*<br>*IDS Metadata,*<br>*Connectivity, Interoperability and Broker development* | *MON, FARR, IKERLAN, DANOBAT, IDEKO, MGEP, ATLANTIS, FHG* | Pilot owner | DONE |
| **3** | Phase 2 - Proof-of-Concept and Minimum Viable Product Implementation and Validation | *KPIs*<br>*Feedback methodology*<br>*First predictions and data analytics* | MON, FARR, IKERLAN, DANOBAT, IDEKO, MGEP, ATLANTIS, FHG | Pilot owner | *ALMOST DONE* |
| **4** | Phase 3 - Technical Validation and Initial Business Validation | *Data analytics second iteration*<br>*Improvements in Connectivity, Interoperability and Message Broker*<br>*HMI*<br>*IDS connectors and Data Sharing*<br>*Predictions*<br>*KPIs*<br>*FIRST and SECOND Approach for ZDM AQ*<br>*Business plan definition* | MON, FARR, IKERLAN, DANOBAT, IDEKO, MGEP, ATLANTIS, FHG | MON, FARR, IKERLAN, DANOBAT, IDEKO, MGEP, ATLANTIS, FHG | Ongoing |

| | | | | | |
|---|---|---|---|---|---|
| | | *Feedbacks from PILOT* | | | |
| **5** | Phase 4 - Large Scale Technical Validation and Business Validation | *FINAL interactive HMI*<br>*Final TUNE large scale technical validation*<br>*Fine tune integration*<br>*Business final*<br>*FINAL Approach for ZDM AQ*<br>*Final Feedback report* | MON, FARR, IKERLAN, DANOBAT, IDEKO, MGEP, ATLANTIS, FHG | MON, FARR, IKERLAN, DANOBAT, IDEKO, MGEP, ATLANTIS, FHG | M36-M39 |

## 9.4 Pilot 5: MON; Expected results

### SCENARIO 1 – Manufacturing processes with cutting/grinding machinery

Table 15: Pilot 5 Scenario 1: MON; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | OEE of production line (efficiency, downtime, rejects etc) | N/A | N/A | N/A | -15% production costs;<br>-20% defective axles;<br>-25% rework time;<br>-20% waste reduction; -10% |

### SCENARIO 2 – Manufacturing Processes with Hot Stamping Machinery

Table 16: Pilot 5 Scenario 2: MON; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Current value | Future expectedvalue |
|---|---|---|---|---|---|
| 1 | OEE of production line (efficiency, downtime, rejects etc) | Measuring next parameters (Cycle time, Force, Temperature, Energy consumption, Water consumption, Oil condition etc), OEE will be measure. | N/A | N/A | -10% improve in-service efficiency due to the reduction of unscheduled machine downtimes and increase of RUL (Remaining Useful Life) through a better tracking of critical machine parameters and possible failure prediction.<br>-15% increase of line production availability.<br>-Up to 10% reduction of machine downtime because of on-line data processing and alerting.<br>-15% increase of line energy efficiency, controlling on-line all the energy consumed. |

## 9.5 Pilot 5: MON; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 9.5.1 Pilot 5: MON; Analysis of sample data

There are two different datasets from automotive manufacturing line and railway manufacturing line.

From railway manufacturing line which there are 3 grinding machines there have been detecting anomalies in the in the sensorial input due to neural analysis, specifically Long Short-Term Memory (LSTM). For that analysis, the SMART MAINTENANCE PLATFORM from ATLANTIS was used.

For the analysis there have been provided Training Data considering those characteristics

- 39 PCs (36 normal, 3 acoustic anomaly class)
- PC duration: ~23secs
- Sampling rate: 2ms
- Number of Sensors: 10

The analysis has been carried out by ATLANTIS with the collaboration of IDEKO Research centre, DANOBAT and MONDRAGON

From automotive manufacturing the principal variables which affect to the process have been identified. Around 100 variables have been considered for The Hot Stamping process. The realization of that analysed has been carried out by FAGOR, IKERLAN, MON, MGEP and VTT. Customer has been preparing the system for the first analysed which will be carry out at the beginning of the next year.

### 9.5.2 Pilot 5: MON; Pre-deployment results

The common architecture for gathering data has been developed considering interoperability for multiple manufacturing production lines which involved multiple industrial devices (Press and grinding Machines, Oven, stacker). Furthermore, IoT edge industrial platform has been needed to connect to a "message broker platform" which there are an analysis of the alarms derived from specific thresholds.

On the other hand, messages for "message broker platform" have been carried out considering the specification of Asset Administration Shell initiative.

The implementation has been carried out considering Docker, Node-Red, Rabbit-MQ and OPC-UA and MQTT protocols. SAVVY IoT and FA-LIN Platform have been stabilised for monitoring production lines.

Finally, the consideration of data sharing will be developed taking advantage of International Data Space Connectors. For that developed, semantic analysis providing meta-data of the variables needed has been provided.

The analysis of the data has required the help of the ATLANTIS and VTT experience which have developed previous requirements and needed analysis.

MGEP, DANOBAT, FAGOR, IDEKO, IKERLAN, MONDRAGON, ATLANTIS, VTT and FHG are the principal partners related to the pre-deployment results.

### 9.5.3 Pilot 5: MON; Stakeholder-training Logbook

The implementation of ZDM approach should be implemented once the second data analysis has been carried out. That it is clear is that there is a definition of the process which limits and thresholds has been established.

# 10 Pilot 6: KOL; Real-time injection moulding process monitoring-control

## 10.1 Pilot 6: KOL; Current state

Injection moulding is widely used manufacturing process for producing parts by injecting molten material into a mould (injection tool). Injection moulding can be performed with different materials such as elastomers, thermoplastic and thermosetting polymers. Material (heated, melted) for the part is injected into a tool cavity, where it cools and hardens to the configuration of the cavity. Injection moulding is widely used for manufacturing a variety of parts, from the smallest components to entire body panels of cars. Depending on tool design one injection cycle can produce one or many (even more than 100) products.

Parts to be injection moulded must be very carefully designed to facilitate the moulding process; the material used for the part, the desired shape and features of the part, the material of the mould, and the properties of the moulding machine must all be taken into account.

The scope of this pilot project will be a production line where we produce one type of products. Anomalies anywhere during the moulding process may degrade the quality of moulded parts. Currently we are not able to detect these failures in real time. As a consequence, we may produce many false parts before even knowing this. Without real-time information about the production process, it is also impossible to correct and optimize the process.

While the process is running acquire the relevant data and the exact acquisition time so the data from various sensors and stages can be paired together.

(I.) The moulding matrix goes to the place for the process to start
(II.) (II.a) The moulding process starts.
(III.) (II.b) The moulding process is running.
(IV.) (II.c) The moulding process is venting.
(V.) (II.d) The moulding process is running.
(VI.) (II.e) The moulding process finishes.
(VII.) (II.f) Excess material is removed from the cell.
(VIII.) (II.g) The moulding matrix leaves to moulding cell.
(IX.) (III.a) The moulding matrix arrives to the dropout zone.
(X.) (III.b) The moulding matrix unlocks the locking mechanism.
(XI.) (III.d) The moulding matrix drops the product on the tray.

### Weaknesses and Bottlenecks

Table 17: Pilot 6, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY *At processes (manufacturing) level and business level* |
|---|---|---|---|
| Liquid plastic properties in the supply channel are currently unknown | The state of the liquid plastic in the injection channels can vary modifying he injection result. Measures such as temperature, pressure, flow speed or air bubbles in the liquid plastic can greatly influence the quality of the moulded parts. | Manufacturing | Aim to reduce our non-Quality costs: a reduced number of defectives parts will increase productivity. Possibly the production speed can be increased by better knowledge of all process parameters. |
| IDS architecture not compatible with other developments | There is a risk that other developments made within this pilot do not follow the reference architecture of IDS and thus are incompatible. This would cause that certain applications could not be deployed and run within in the proposed data space approach. | Support in applying the IDS reference architecture by FHG-ISST. | N/A |
| Availability of CAD models to create the virtual layout and the digital twin | Machine providers are reluctant to provide the CAD data of their equipment due to IPR limitations. Nevertheless, Visual Components provides alternative parametric models that can be used to get the most realistic virtual layout | 3D simulation and visualization | The availability of the real CAD will provide more realism in the simulation, but the parametric models available at Visual Components should be good enough for the simulation of the pilot. |
| Data Availability | Different systems are involved in the pilot which require interact with the simulation. It should be clarified data serialization, communication interfaces and priorities. | 3D simulation and visualization | More accurate results |

## 10.2 Pilot 6: KOL; Future state

While the process is running acquire the relevant data and the exact acquisition time so the data from various sensors and stages can be paired together.

(I.) The moulding matrix goes to the place for the process to start
(II.a) The moulding process starts.
(II.b) The moulding process is running.

- Acoustic sensors are collecting and analysing data
- Transfer of data to MES

(II.c) The moulding process is venting.
(II.d) The moulding process is running.

- Acoustic sensors are collecting and analysing data
- Transfer of data to MES

(II.e) The moulding process finishes.
→Signal VISION to start the acquisition process.
(II.f) The termal vision camera acquires data.
←Signal MACHINE to continue normal process.
(II.g) Excess material is removed from the cell.
(II.h) The moulding matrix leaves to moulding cell.
(III.a) The moulding matrix arrives to the dropout zone.
(III.b) The moulding matrix unlocks the locking mechanism.
→Signal VISION to start the acquisition process.
VISION → ROBOT: Start the acquisition process.

- For I. to IV.:
- Robot moves to place i
- Camera acquires visual information at place i
- Return results to VISON.

←Signal MACHINE to continue normal process.
(III.c) The moulding matrix locks the locking mechanism.
(III.d) The moulding matrix drops the product on the tray.

## 10.3 Pilot 6: KOL; Detailed plan

Table 18: Detailed Plan Kolektor Pilot

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| **1** | First Integration | Preparation and planning; initial integration | All | Pilot owner | Done |
| **2** | Prototype learning and testing | Simulation and ReconCell implementation; partial deployment | All | Pilot owner | Ongoing |
| **3** | Prototype validation and data collection | Upgrading and data collection; learning of error prediction | All | Pilot owner | Future |

| | | | | | |
|---|---|---|---|---|---|
| **4** | Final evaluation and deployment | Final deployment; evaluation | All | Pilot owner | Future |

## 10.4 Pilot 6: KOL; Expected results

Table 19: Pilot 6: KOL; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | Quality | Validation of products and processes is carried out at all stages of development and production, from the technological concept to the industrialization phase. The production process uses several procedures and technologies to evaluate the quality of the produced parts with the main ones being SPC (Statistical Process Control) of all components and the finished product and an electrical test of the connection terminals. 100% Inline optical inspection is also a part of some of the production lines. The goal of the quality assurance is to optimize and lower the current PPM rejection rate. | PPM | N/A | N/A |
| **2** | OEE | OEE-overall | % | 60 | 70 |
| **3** | Scrap rate | Produced parts not suitable to be shipped to the customer. | % | 5 | 4 |

## 10.5 Pilot 6: KOL; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 10.5.1 Pilot 6: KOL; Analysis of sample data

Until now, the feasibility and the usability of the proposed Pilot have been studied, with effort directed also in the integration of various components (injection moulding line, visual inspection system, robot, simulation environment, etc). The pre-injection moulding assembly dataset was acquired and analysed. Initial simulation results on the ReconCell test-platform have been obtained.

### 10.5.2 Pilot 6: KOL; Pre-deployment results

The partners have invested effort in the planning of the Pilot, which has been modified due to the COVID-19 lockdown and subsequent market changes, which have forced Kolektor to change the production line.

Kolektor has prepared the new production line and is currently in the process of deployment of the line and visual inspection elements to the line. Assembly check dataset was acquired in the laboratory environment.

Production line is experimentally connected to Sinapro.IIoT - part of MES/MOM system. The first tests of data acquisition from the injection moulding machine and Cell-1 were performed. The data access interface has been prepared and tested on similar production equipment.

JSI has developed a simulation to determine the feasibility and possible robot motion planning autonomy to guide the in-hand camera for visual quality inspection. JSI is collaborating with Kolektor in the process of integrating the robot control with Kolektor's vision system software (KIS).

### 10.5.3 Pilot 6: KOL; Stakeholder-training Logbook

Complete Kolektor Pilot solution has not yet been deployed and stakeholders have not been trained yet.

# 11 Pilot 7: THYS; Quality Management of Steering Gear based on Acoustic control

## 11.1 Pilot 7: THYS; Current state

Currently, product quality checks are only considered at the end of the production line at a system level with no or only limited control strategies during assembly. Individual part defects are therefore challenging to detect and to identify. The multi-level zero defect manufacturing platform considered in the QU4LITY project intends to overcome this limitation by consecutively performing quality checks on a part level and applying adequate control strategies if necessary. Real-time adaptation of the assembly line parameters could be used to achieve the ZDM ambition of this project. The multi-level ZDM platform proposed in the QU4LITY project will be the basis to prove its applicability of the solution on different multi-level production lines. We indent to implement a data acquisition system distributed on various points on the production line to collect and synchronize data from different kind of sensors. These include in-process sensor data, data from the production monitoring system as well as operator data. The solution will allow observability of the product during assembly stages. The overall goal is to provide defect correlations among parts at different stages. HMIs could be used to inform the operator and to take action if necessary.

**Weaknesses and Bottlenecks**

Table 20: Pilot 7, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| Quality check at the end of the production line | Product quality checks are only considered at the end of the production line at a system level with no or only limited control strategies during assembly. Individual part defects are therefore challenging to detect and to identify. | Manufacturing | Aim to reduce our non-Quality costs: an emphasis on the defective component would allow reintroducing back into production all the other components instead of losing the entirety which may be costly. It would also save time by not reintroducing defective components for cross-testing and avoiding any off-line diagnostic operation. |
| The identified algorithms are not appropriate for the produced data. | When tested, the resulting models of the algorithms fail to predict with sufficient accuracy the target variable (RUL) | (to be completed) | (to be completed) |
| Limited or no availability of data from the production machinery | In order to predict and identify possible machinery "misbehaviour" data from masynery sensors would be required. (to be completed) | (to be completed) | (to be completed) |

## 11.2 Pilot 7: THYS; Future state

The solution has to be implemented without interfering the production lines, indeed, the trial implementation cannot limit the performance of the line and has to work as a plug & play device to improve the overall effectiveness of the line.

The main benefit of the proposed acoustic measurement technique is an in-situ quality check after a screwing process step in the steering column use-case. Any deviation from the pre-defined quality limit is treated immediately by an associated "control step", i.e. tightening or loosening and replacing the screws between the motor and the steering column module. This should reduce the defect rate.

Another expected result is to make the system easily and quickly reconfigurable for future products to expand it to other machines and generalize this acoustic control method. This will be partially archived by applying the Distributed Data Analytics framework, which provides the ability to dynamically route the various data streams or persisted data to the appropriate algorithmic engines to produce the desired results.

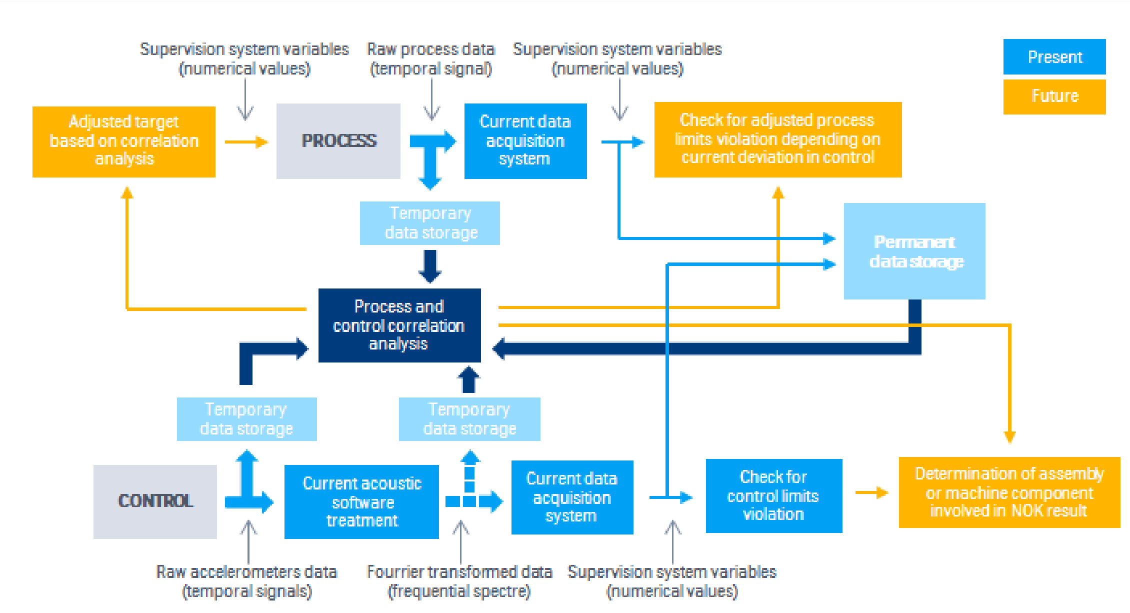


Figure 25: Process map Thyssen Pilot

## 11.3 Pilot 7: THYS; Detailed plan

Table 21: Detailed Plan Thyssen Pilot

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| **1** | Specification & Fine Tuning | *Global process dataset analysis* | *INTRA* | *12/2019* | *Done* |
| **2** | | *Non-intrusive sensors definition* | *ALL* | *01/2020* | *Done* |
| **3** | | *Prototype development* | *CEA* | *03/2020* | *Done* |
| **4** | | *Specific root causes process dataset analysis* | *INTRA* | *07/2020* | *Done* |

| | | | | | |
|---|---|---|---|---|---|
| **5** | Small Scale Technical Validation | *Integration of non-intrusive sensors on line* | *THYSS* | *09/2020* | *Done* |
| **6** | | *Prototype test on production line* | *CEA* | *08/2020* | *Done* |
| **7** | POC | *Additional fine-tuning on FFLOR/WP6* | *CEA* | *09/2020* | *Not needed* |
| **8** | | *Additional asset data analysis* | *INTRA* | *10/2020* | *Technical issues* |
| **9** | | *POC migration on another Use-case* | *THYSS* | *12/2020* | *In Progress* |
| **10** | | *Knowledge transfer of the POC to Pilot* | *ALL* | *01/2021* | *In Progress* |
| **11** | | *Adjustment of traceability feature to new use-case environment* | *ALL* | *02/2021* | |
| **12** | Large Scale Technical and Business Validation | *Mutualization of final hardware on modules* | *THYSS* | *12/2020* | *Delayed* |
| **13** | | *Analysis on multiple assets dataset* | *INTRA* | *12/2020* | *Delayed* |
| **14** | | *Additional assets taken into account for AI correlation (depends on data availability for ThyssenKrupp)* | *INTRA* | *03/2021* | |
| **15** | | *Design of live parameters suggestion monitor for production line end-users (depends on data availability for ThyssenKrupp)* | *CEA* | *04/2021* | |
| **16** | | *Provide gateway for autonomous correlation rules definition* | *INTRA* | *05/2021* | |
| **17** | | *Optimize preliminary work to merge CEA and INTRA POCs into one single system* | *ALL* | *06/2021* | |
| **18** | | *Mutualization of the new system on several production lines* | *ALL* | *12/2021* | |

## 11.4 Pilot 7: THYS; Expected results

Table 22: Pilot 7: THYS; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | OEE | production line (efficiency, downtime, rejects etc) | % | OOE=60% (EA=60% / QR=98%) | OOE=80% (EA=80% / QR=100%) ; |
| **2** | PPM | Rework parts | k [pcs] | 15 | 5 |

## 11.5 Pilot 7: THYS; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 11.5.1 Pilot 7: THYS *Presta*; Analysis of sample data

QARMA was able to determine that setting only 4 variables (out of about 90) to certain values in the intervals specified in any one of 67 combinations, leads to at least 3 products in the run that do not pass the acoustic tests. These are parameter combinations to avoid.

### 11.5.2 Pilot 7: THYS *Presta*; Pre-deployment results

The first tests of non-intrusive communication with the production line PLC proved to be functional. The main advantage of this is to allow algorithms and routines to interact with a single interface regardless of the machine used, this gives a large flexibility and allows a quick implementation.

One remaining challenge is to run algorithms on production line without precise part-to-part traceability but only with time stamps.

### 11.5.3 Pilot 7: THYS *Presta*; Stakeholder-training Logbook

Not available.

# 12 Pilot 8: AIRBUS; Trade space framework for Autonomous Quality Manufacturing Systems' Design

## 12.1 Pilot 8: AIRBUS; Current state

During the early phase of an aircraft program, Industrial Architects are evaluating different industrial scenarios and trade-offs. Interesting findings, include:

- Manufacturing Processes are not enough agile and not enough flexible in order to answer to the complex and competitive environment and to the incessant changes needed concerning both the performance (need to improve the ramp-up) and the product (change of MSN) on the assembly lines.
- Engineering, Manufacturing & support processes are still considered in a sequential approach.
- Most of the time, decisions are taken by optimizing alternatives proposed by Architects based on their experiences and judgments.
- Some interesting & innovative areas are not explored because the way of working does not consider a systematic exploration based on multiple parameters considerations
- No integrated way of managing trade off studies

**Weaknesses and Bottlenecks**

Table 23: Pilot 8, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br><br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| Large Data handling and complexity | N/A | VIS | The large data types from different sources and formats as well complexity are required in the pilot. It will be required to serialize and organize according to the use to manage and avoid bottlenecks. |
| Communication between different systems | N/A | VIS | Different systems are involved in the pilot which require interact with the simulation. It should be clarified data serialization, communication interfaces and priorities. |
| Design validation of production systems and processes for most efficient productivity and highest quality in time and cost | N/A | Siemens | Using digital twin simulation-based production assistant in KPI evaluation and process optimization. Setting up a simulation model (MBSE) as plant companion needs automated model generation and synchronization, used in design exploration as well as process time optimization and zero-defect manufacturing. |

## 12.2 Pilot 8: AIRBUS; Future state

For solving part of the problems, Product Line and Co-design concepts needs to be tackled. A Model-based systems engineering (MBSE) approach where the Industrial System is seen as a System like any other (in parallel of the Aircraft) will allow to structure and optimise the development of Industrial System and to perform trade-offs efficiently.

Model based System Engineering, Trade Space exploration and Multi Skill optimization are common capabilities in Engineering Systems; often in the context of "Design to Aircraft Performance". The Engineering process and the Digital solutions are not enough supporting Design to Manufacturing Value. This leads to late design loops, rework and the end extra costs for Airbus and for the customers.

## 12.3 Pilot 8: AIRBUS; Detailed plan

Table 24: Detailed plan Airbus Pilot

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| **1** | Define goal | Set-up kpi matrix | Wk1920 | Pilot owner | Done |
| **2** | *Define scenario* | *Define process and objective of demonstration* | | Pilot owner | Done |
| **3** | *Define prototype* | *Define implementation framework* | | *FH* | *On-going* |
| 4 | *MVP 0 - Methods, ontologies & data models* | *Define application ontology following upper-level ontology, and define data models to integrate elements that impact process quality* | | *All* | *On-going* |
| **5** | *MVP 1 - Local semantic integration* | *Implement semantic models based on the scenario* | | *All* | *Planned* |
| **6** | *MVP 2 - Simple trade-off scenario simulation* | *Simulate two different scenarios, i.e. semi-automated and manual assembly, demonstrating a first stage of semantic integration.* | | *All* | *Planned* |
| **7** | *MVP 3 - Global methods & ontologies* | *Extend the adopted methods and ontology* | | *All* | *Planned* |
| **8** | *MVP 4 - Global semantic integration* | *Extend the scope of the semantic model to cover more processes* | | *All* | *Planned* |
| **9** | *MVP 5 - Complex trade-off scenario simulation* | *Simulate more complex trade-off scenarios* | | *All* | *Planned* |
| **10** | *Pilots' Evaluation and Stakeholders' Feedback* | *Evaluate the implementation results and collect Stakeholders' Feedback* | | *All* | *Planned* |

## 12.4 Pilot 8: AIRBUS; Expected results

Table 25: Pilot 8: AIRBUS; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | Leadtime | lead time often represents the time it takes to create a product and deliver it to a consumer | N/A | N/A | N/A |
| **2** | Costs | Costs represents the sum of costs of all resources consumed in the process of making a product: direct materials cost, direct labour cost and manufacturing overhead. | N/A | N/A | N/A |
| **3** | Reliability & Capability | Quality of being trustworthy or of performing consistently well | N/A | N/A | N/A |
| **4** | Feasibility | state or degree of being easily or conveniently done | N/A | N/A | N/A |
| **5** | Working conditions & Labour Efficiency | Environment that influence the satisfaction of employees | N/A | N/A | N/A |
| **6** | Flow efficiency | Flow Efficiency examines the two basic components that make up your lead time: working time and waiting time | N/A | N/A | N/A |
| **7** | Footprint | Industrial footprint | N/A | N/A | N/A |
| **8** | Quality level | Products quality level | N/A | N/A | N/A |

## 12.5 Pilot 8: AIRBUS; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 12.5.1 Pilot 8: AIRBUS; Analysis of sample data

Data analysis has not started yet, which is planned to begin after digital models and ontologies are defined.

### 12.5.2 Pilot 8: AIRBUS; Pre-deployment results

The application scenario has been refined by narrowing the scope to one station of the airplane assembly line. The implementation framework and enabling technologies have been defined. Three technology providers will provide corresponding components as described in previous sections and in CH3. Currently Airbus is working on the definition of behavioural models and at the mean time supporting the development of semantic models together with FHG and EPFL. Besides, VISUAL has started the development of 3D simulation models of the assembly process.

### 12.5.3 Pilot 8: AIRBUS; Stakeholder-training Logbook

The pilot is not advanced far enough to provide stakeholder training materials.

# 13 Pilot 9: GHI; Real-time cognitive hot stamping furnace 4.0

## 13.1 Pilot 9: GHI; Current state

This pilot is focused on the GESTAMP facilities located in Bizkaia, Spain. Here, an installation for hot stamping ("L line") is located since 2016, including a rolling beam furnace, suitable for the treatment of steel alloy blanks for simultaneously stamping them in a press. The blanks in this kind of furnace are placed crosswise very close to each other inside each batch along the furnace to increase the useful heating area.

The main components of this 'L' line installation are: Rolling Beam Furnace 'L', with a production capacity of 7.400 kg/h, and loading and unloading system with tables and machines to that end.

The inner lining of the furnace, the door and the roof consists of bio-fiber modules with low thermal inertia, conferring the furnace a great insulating power. The furnace hearth is composed by layers of insulating bricks and panels.

In the top and bottom of one of the furnace walls, gas fired radiant tubes (ceramic tubes above the blanks, metallic ones placed below) are installed, including heat recovery systems for better energy efficiency. For radiant tubes, specifically designed recuperative burners are installed and managed by the PLC.

Inside the furnace there are several mechanisms: rolling beams supported on rollers, and elevation beams supported on frames, which are responsible for moving the blanks along the furnace.

The corresponding loading and unloading tables are supplied together with the furnace, including blank centring devices and mechanisms to allow the customer's feeder to pick up the treated and centred hot blanks.

The process variables are controlled automatically by the PLC. An operator panel serves as an interface for data entry by operator.

A typical cycle consists of a progressive heat up of the blanks while they advance through the furnace, reaching the desired temperature in the final zone. The maximum attainable is 950°C.

The blanks that may be processed in this furnace should be made from an Al-Si coated boron steel alloy material, and each of the batches of blanks is composed of one (1) to eight (8) blanks simultaneously introduced inside the furnace.

The furnace has the capacity to use dry air as protective atmosphere. To prevent hydrogen embrittlement in the Al-Si coated blanks, the furnace atmosphere is monitored throughout the whole process with a dew point analyser, and thus introducing new protective atmosphere if required. To do this, it has the corresponding analyser and a control loop in the PLC.

A total of 5 atmosphere injection points are incorporated in the furnace with a dosage control of the dry air based on the dew point temperature through a manual precision adjustment valve each in order to be able to adjust the exact amount of dry air being introduced in the furnace.

The dew point of the protective dry air atmosphere is monitored by a small sample taken continuously from the furnace. The sensor analyses the air samples, obtaining an accurate and fast reading from the atmosphere, which will act to inject the necessary dry air. There are 3 sampling points inside the furnace, at different places to cover the whole atmosphere.

### Weaknesses and Bottlenecks

Table 26: Pilot 9, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| Little information known about the process | Defective material (especially, billets with cracks) is above reasonable levels | Manufacturing | Product non-complying with the specifications leads to economic loss and problems spreading downline in the production chain. |
| Time spent to identify the root cause of a quality issue | When an issue occurs, the time to identify where it comes from is significant, currently, because it is based on exclusion reasoning | Manufacturing | This can lead to high equipment stoppage times, which affect all manufacturing, logistics (stocks), management and business layers. |

## 13.2 Pilot 9: GHI; Future state

To solve the problem related to crack formation on the manufacturing process, GHI aims at developing ZDM solutions based on implemented improvements (sensor and data analysis) in the furnace that will provide a more accurate control and which will allow a greater vigilance of premature rupture of radiant tubes that can cause H2O filtration into the furnace atmosphere, which on contact with the parts can cause cracks and cracks to appear.

To solve the problem related to whole system control, Zero-defect manufacturing in these systems will be related to the development of smart connected furnaces with ability for real-time connected and smart closed loop monitoring & control.

The following components will be implemented:

- A **common data space**, for furnace and hot stamping installation related information secured, standardised and referenced.
- **A high-speed edge-powered furnace control platform** allowing connected control in real-time of furnace parameters and stamping process.
- A **cognitive digital twin data and deep streaming analytics framework** for real-time analysis of large data in motion streams and smart learning engines for correlation of part defects, press parameters and optimum furnace parameter selection (heating parameters, heating curve, energy consumption).
- A **big data simulation-based framework**, able to correlate large heating control data, furnace heating curve profiles with part heating profiles and temporal temperature variations in the hot stamping process.
- **Semantic data models for the furnace operation information** for automated integration of the austenitization process information into learning algorithms and furnace edge control platforms.

## 13.3 Pilot 9: GHI; Detailed plan

Table 27: Detailed plan GHI pilot

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| **Task 1** | PHASE I - Specification and fine Tuning of the Qu4lity concept | Analysis of the specifications of the pilot | GHI | M4 | Done |
| **Task 2** | PHASE I | Define the smart (AQ vision) solution to be implemented | INNO & GHI | M12 | Done |
| **Task 3** | PHASE I | Definition of the HW & SW solution requirements | GHI | M9 | Done |
| **Task 4** | PHASE I | Study of the Dataset, Metadata and key variables to be analysed | GHI | M9 | Done |

| | | | | | |
|---|---|---|---|---|---|
| **Task 5** | PHASE I | Architecture Design & Description | INNO & GHI | M15 | Done |
| **Task 6** | PHASE I | Initial exploitation and business plan. KPIs definition. | GHI | M12 | Done |
| **Task 7** | PHASE II - PoC and MVP Implementation and Validation | IIoT & HW integration | GHI | M16 | Done |
| **Task 8** | PHASE II | First furnace data gathering tests | GHI | M14 | Done |
| **Task 9** | PHASE II | First Furnace Data Analytics | GHI | M20 | On progress |
| **Task 10** | PHASE II | HMI (Beyond Platform) customization | GHI | M22 | On progress |
| **Task 11** | PHASE II | First furnace data visualizations on Beyond Platform | GHI | M22 | On progress |
| **Task 12** | PHASE II | First parts quality control measurements | INNO | M22 | On progress |
| **Task 13** | PHASE II | First iteration KPI measurement and feedback | GHI | M23 | Not Started |
| **Task 14** | PHASE III - Technical Validation and Initial Business Validation | Data sharing solution description & implementation | GHI, SQS & GHI | M29 | Not Started |
| **Task 15** | PHASE III | Furnace Data analytics 2º iteration | GHI | M27 | Not Started |
| **Task 16** | PHASE III | Definition of the parts QC dataset to be shared | INNO | M26 | Not Started |
| **Task 17** | PHASE III | Improvements on the Beyond Customization | GHI | M30 | Not Started |
| **Task 18** | PHASE III | Second iteration KPI measurement and feedback | GHI & INNO | M30 | Not Started |
| **Task 19** | PHASE IV - Large Scale Technical Validation and Business Validation | Final fine tune integration of the whole solution | GHI & INNO | M34 | Not Started |
| **Task 20** | PHASE IV | Validation of the IDS compliance data sharing system | SQS | M36 | Not Started |
| **Task 21** | PHASE IV | Testing and validation of the final scenario | GHI | M36 | Not Started |
| **Task 22** | PHASE IV | Final iteration KPI measurement and feedback | GHI & INNO | M39 | Not Started |
| **Task 23** | PHASE IV | Final exploitation & Business plan | GHI & INNO | M39 | Not Started |

## 13.4 Pilot 9: GHI; Expected results

Table 28: Pilot 9: GHI; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | Reduce defective | Reduce defective parts manufacturing, especially crack formation on parts on the hot stamping process. | % | 0 | 30 |
| **2** | Energy consumption | Reduce energy consumption of the plant | % | 0 | 5 |
| **3** | Productivity | Increase on the number of manufactured parts. | % | 0 | 5 |
| **4** | Failures detection | Fast detection of root cause of quality problem | % | 0 | 30 |
| **5** | Decision making | Improve decision making efficiency thanks to the analysis & visualization tools. | % | 0 | 15 |
| **6** | Reduce costs | Reduce furnace operational costs | % | 0 | 5 |

## 13.5 Pilot 9: GHI; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 13.5.1 Pilot 9: GHI; Analysis of sample data

As it has been commented on section 4.1, GHI has begun to analyse the evolution of the parameters and evaluating the impact of each variable in the modelling of the process. With this, GHI has been able to identify some of the critical direct variables that affect the proper hot stamping furnace operation, but also other indirect variables that must be calculated by correlating other parameters. Through this analysis, several operative scenarios have been studied with the intention to identify the worst-optimized operational steps.

On the other hand, Innovalia has been analysing which would be the critical points of the piece that must always be controlled through dimensional quality control of those named parts.

### 13.5.2 Pilot 9: GHI; Pre-deployment results

On behalf of GHI, coming from the data analysis they have been working on, valuable information for improvements and optimizations of the hot stamping process has been gained as for example:

- A lack of heating power in the first areas of the furnace.
- There's some heterogeneity on the furnace temperature.
- The high impact produced by small stops on the line.
- Inability to maintain the dew point on the furnace.

### 13.5.3 Pilot 9: GHI; Stakeholder-training Logbook

Since the integration of the solutions provided by both Innovalia and SQS in the GHI platform has not yet been carried out, specific training has not yet been required.

However, during this second period, several meetings and trainings are planned so that GHI can understand and use the added value that product quality information can provide in its technology, in addition to the knowledge about how industrial data can be exchanged in a safe and secure way.

# 14 Pilot 10: RiaStone; Autonomous Quality ZDM for "Ceramic tableware Single-firing

## 14.1 Pilot 10: RiaStone; Current state

The new single firing process developed by RiaStone requires higher quality produce levels, to be delivered by the pre-oven production chain, in order to assure that when the pre-firing produce reaches the firing oven, the produce can be fired without being heat distorted due to existing pre-firing defects

At system production level when defects mentioned above occur, detection is done through human observation, therefore causing large lots of defective products running through the production line.

The main implementation axis will consist in the integration of new inline inspections systems and QA control loops into the current production line in the most critical production steps:

| Stages | Process name | Short Description |
|---|---|---|
| 1 | Iso-Static pressing | At this Stage the main ceramic structure is formed through the pressing of specific pastes, into the main tableware format |
| 2 | Abrasive trimming finishing and edging | The raw main tableware produce is processed in a six-stage edging, trimming and finishing table |
| 3 | Pre-cure warehousing | The finished main tableware produce is grouped and stored for a six-hour drying cure period in a fully automated storing facility |
| 4 | Glaze preparation | The glazing is mixed through the chemical composition of a precipitate that includes water, colouring agents, glass powder, and mixture stabilizers |
| 5 | Tableware Glazing | The finished main tableware produce enters an in-line spray glazing chamber where it is sequentially sprayed |
| 6 | Pre-firing product Grouping | The glazed tableware produce is grouped in heat resistant trolley tables |
| 7 | Oven Single Firing | Grouped tableware trolleys are sequentially inserted in the Firing Ovens where they cure during eight hours at 1400-degree celsius |
| 8 | Quality Control inspection | Finished tableware trolleys are disassembled into individual finished products and go through visual control inspection |
| 9 | Sorting and Packing | Finished tableware that is graded as being "A" quality is assemble into Tableware sets |
| 10 | Warehousing | Finished tableware sets are store into the warehousing area, ready for dispatching |
| 11 | Logistic Dispatching | Logistic dispatching is performed to one of the IKEA worldwide logistic distribution Hubs |

Figure 26: Production steps RiaStone

Ria Stone production Lines have the latest state of the art automation equipment from the most relevant automation manufacturers such as Lippert, Siemens, Festo, SEW-Eurodrive, Omron, Kuka, and others.

The main Ria Stone Automated production line equipment is:

- 10x Raw Matter ceramic paste storing Silos;
- 19x Iso-Static Oleo-pneumatic cold presses;
- 23x KUKA flexible manufacturing Robots;
- 8x Pre-Oven Glazing Lines;
- 3x Kiln Grouping Lines;
- 3x High Capacity Firing Kilns;
- 8x Sorting Lines;
- 3x Packing Lines;
- 1x Automated green ware Warehouse.
- 1x Automated Warehouse.

### Weaknesses and Bottlenecks

Table 29: Pilot 10, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| **Failure detection and remediation** | Lack of decision-making based on real-time data. | Manufacturing | Detection and remediation are based in worker experience and composed of mainly manual corrective actions. |
| **Human based Production control system** | All business rules that manage how the manufacturing process is performed | Manufacturing | The production control system is adjusted only through machine inputs by the workforce and based in operator experience |

## 14.2 Pilot 10: RiaStone; Future state

Riastone has received an up-scope request from IKEA to extend and increase, the present Contractual Scope up to 2026, increasing the number of contracted to be produced tableware parts to 48 Million pieces per year.

For that goal to be achieved, Riastone acted on two complementary fields:

a) Quantity: Riastone addressed the required production ramp-up through a new factory expansion, that has installed one (1) new production line with a forecasted additional output of +18 Million Tableware pieces per year
b) Quality: Riastone has the urgent need to implement new ZDM systems in order to improve its Overall Production Effectiveness (OPE) Key performance

Indicator, presently RiaStone has an OPE of ~92%, with the goal of reaching a running OPE of 95%.

In order to accommodate IKEA´s new production up scope and quality requirements Riastone will implement a holistic transformation of its production process, focused on the implementation of better and innovative production quality control, and defect management and control, consistent with the integration of Zero-defect Manufacturing and shop floor automation approaches to its processes, namely:

Isostatic Pressing:

- Shop floor automation Implementation through an In-line ZDM digital control Loop with enhanced inspection capabilities, automated Press regulation, and decision capabilities for production handover to alternate presses
- Technologies to be implemented for ZDM system integration– Product QC, inline artificial vision inspection, edge computing, and AI

Glaze application:

- Shop floor automation Implementation through an In-line ZDM digital control Loop with enhanced inspection capabilities, and automated glazing viscosity regulation.
- Technologies to be implemented for ZDM system integration – Product QC, inline artificial vision inspection, edge computing, and AI

Riastone will interconnect the newly implemented ZDM production loops with both the existing FMS, and MES production management platforms, in order to collect process data, and make available relevant information for Production management and KPI dashboard-based visualization.

## 14.3 Pilot 10: RiaStone; Detailed plan

The details plan, including milestones, site visits, stakeholder map, and plan for training will be added in a subsequent release of this document (i.e. M18).

Table 30: Detailed plan Riastone Pilot

| Actions | Task | Who | Schedule | Status |
|---|---|---|---|---|
| Phase 1 | | | | |
| Task 1.1 | Definition of the requirements regarding the data to extract from the database | RIA | Jul-20 | **Done** |
| Task 1.2 | Definition of the communication protocol to gather the data from the cloud | RIA | Jul-20 | **Done** |
| Phase 2 | | | | |
| Task 2.1 | Compilation of Isostatic presses data dumps in a MSSQL Server (June 2020 | RIA | Jul-20 | **Done** |

| | | | | |
|---|---|---|---|---|
| Task 2.3 | Definition of DataBlock (DB) with all relevant process data, allowing access to other visualization/processing components | RIA/SYN/INTRA | Jul-20 | **Done** |
| Task 2.4 | Definition of the dedicated server to host the solution | RIA/SYN/INTRA | January 2021 - July 2021 | **Done** |
| Task 2.5 | Transposition of QU4LITY ontology into a relational DB | INTRA | July 2020 - January 2021 | Ongoing |
| Phase 3 | | | | |
| Task 3.1 | Test and fine-tuning of the PoC | RIA/SYN/INTRA | January 2021 - July 2021 | Pending |
| Task 3.2 | Extension of support to EOLT, ESA and Tracking databases | RIA/SYN/INTRA | January 2021 - July 2021 | Pending |
| Phase 4 | | | | |
| Task 4.1 | Integration of the dedicated server with the IT infrastructure of the RiaStone Factory. | RIA/SYN/INTRA | September 2021 | Pending |
| Task 4.2 | Deploy and test (July 2021 | RIA/SYN/INTRA | December 2021 | Pending |

## 14.4 Pilot 10: RiaStone; Expected results

Table 31: Pilot 10: RiaStone; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | OPE | Increase the Overall Production Effectiveness KPI | % OPE Algorithm | 92% | 95% |
| **2** | FPY | Increase the overall First Pass Yield KPI | % FPY Algorithm | 92% | 98% |
| **3** | Firing Oven efficiency | Through the use of the new ZDM systems, 100% of the produce introduced in the firing oven will present zero defects | N/A | N/A | N/A |
| **4** | Raw material Reuse | Defective products detected through the new ZDM systems in the production lines, will be reused | Reuse % | 50% | 70% |

## Pilot 10: RiaStone; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 14.4.1 Pilot 10: RiaStone; Analysis of sample data

During this period RIA provided two data dumps containing real process data, including data payloads and Meta-data originated in the factory shop floor in BP1 and BP2 to Intrasoft

Using the provided data Intrasoft initiated data parsing tests, in order to configurate a functional data parsing algorithm, allowing for the information to be processed in the Instrasoft ML Toolkit.

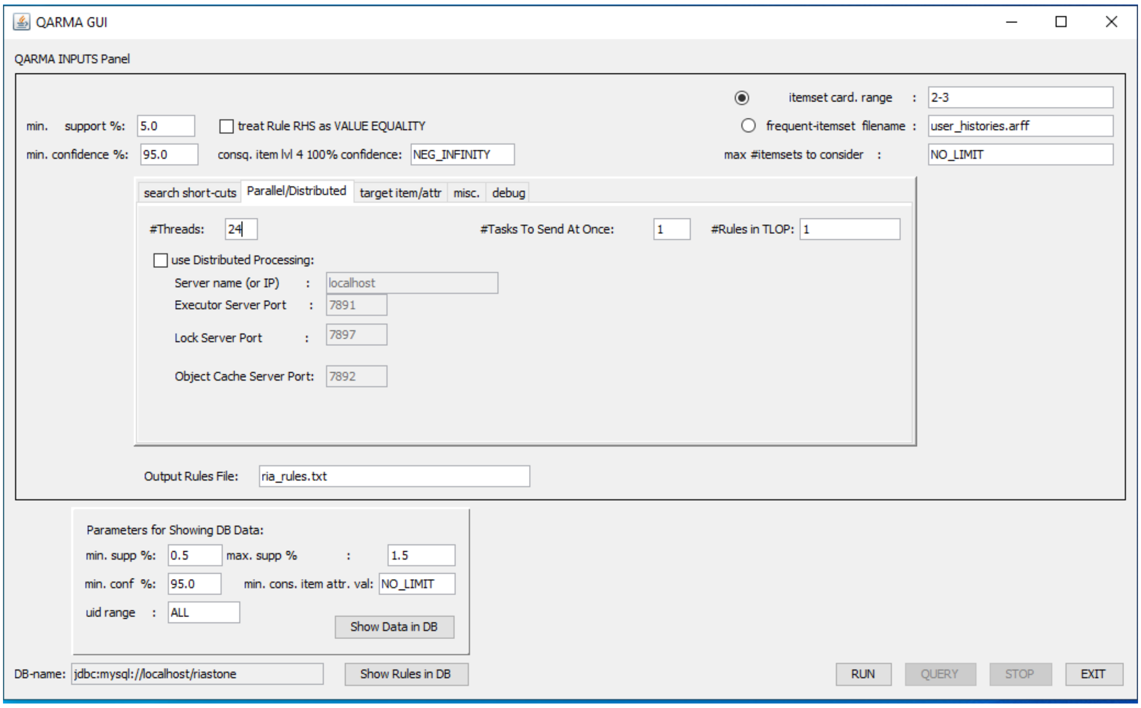


Figure 27: RiaStone - Intrasoft Quarma screen capture

Intrasoft started experimenting with ML algorithms contained in the Intrasoft Qarma ML Toolkit with the parsed data already structured, and homogenised through the data parsing algorithm, achieving significant preliminary results

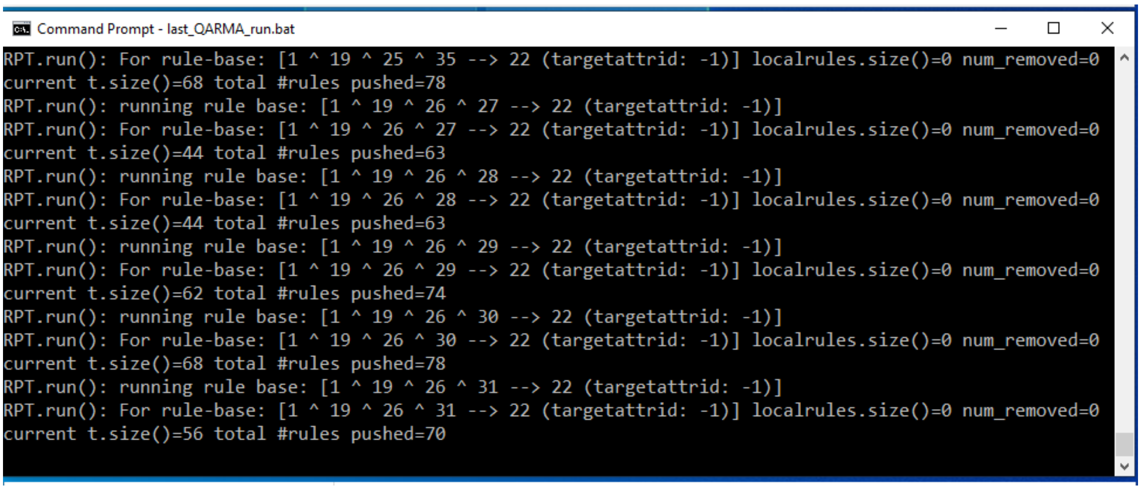


Figure 28: RiaStone - Quarma image

The processed volume of the data was enough to achieve results even without a target variable, the Intrasoft Qarma Tool used unsupervised learning techniques, being successful in the discovery of quantitative association rules, that determined how some variable values affected other variable values in the dataset.

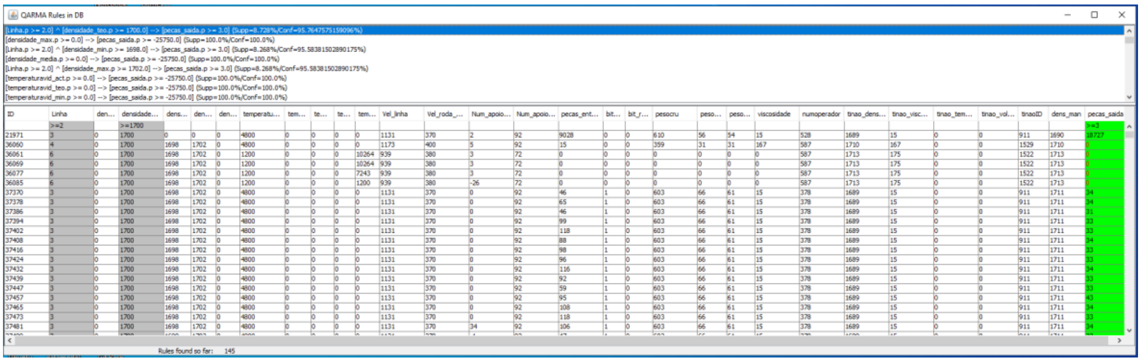

Figure 29: RiaStone - dataset

The quantitively discovered rules, and the discovered associations were correctly mapped into the processed data and confirmed by the RiaStone Shop floor process engineers.

### 14.4.2 Pilot 10: RiaStone; Pre-deployment results

Main Pilot Focus 2# - Implementation of Ai ML Algorithms 4 defect detection through artificial cognitive vision.

| Actions Taken |
|---|
| AQL System Conception |
| i. Comprehensive analysis of RiaStone AQL, High Level and Low Level requirements |
| ii. System architecture definition |
| *1. General system architecture* |
| *2. Communications architecture* |
| *3. Local and centralized processing architecture* |
| *4. Database architecture* |
| *5. Basic functional requirements of the physical systems of Artificial Vision Systems* |
| *6. Requirements of the necessary energy systems* |
| *7. Development of system RAMS* |
| iii. Definition of COTS equipment and components of the Artificial Vision Systems |
| iv. coordination of the preliminary project execution for the installation and assembly of Artificial Vision Systems, at POC locations 1 & 2 |
| LAB POC tests |
| i. Definition of POC Tests matrix to confirm compliance with the Functional requirements of the system |
| ii. Definition of the preliminary list of Artificial Vision Systems component equipment, i.e. models of required optical sensors, as well as local processing units. |
| iii. Process of Acquisition of COTS elements |
| iv. Conducting POC Tests matrix |
| v. Analysis of POC Test Results Vs System Requirements |
| vi. Confirmation of compliance with the RiaStone requirements List |
| vii. Definition of the final list of equipment components of the Artificial Vision Systems Sub |
| Definition of Artificial Vision Systems Locations |
| i. Physical definition at the two implementation points of Artificial Vision Systems |
| ii. Definition of the general architecture of implementation for each Artificial Vision System |
| *1. Definition of support infrastructures needed at 2x points of implementation* |

| |
|---|
| *2. Cable fixing and routing systems* |
| *3. Delivery points and data communication* |
| *4. Physical configuration of the HMI station (Human Machine Interface)* |
| iii. Review of preliminary projects |
| iv. Delivery of final projects for the implementation of Artificial Vision Systems |
| v. Acquisition of the basic elements that constitute each Artificial Vision Systems system: |
| *1. Optical sensors according to technical specification* |
| *2. Local Computing Nodes according to technical specification* |
| *3. Local interaction system with line operators (HMI interface) according to the technical specification* |
| *4. Industrial assembly accessories, and support structures necessary for the implementation of all equipment and component elements of Artificial Vision Systems* |
| *5. Shading chambers according to technical specification* |
| *6. Controlled light sources according to technical specification* |

Pilot Focus 3# - Implementation of functional POCs that enable AQL Loop aligning all pilot partner contributions

| Actions To Be Taken |
|---|
| **Software Development of the Inspection, Conformity Control and Quality Control System "DICS" (Defect Identification and Classification Software)** |
| i. Development of artificial intelligence and “Machine Learning” algorithms |
| ii. Operationalization an operational version of the DICS with installation and operationalization in the 2 locations of the production line, |
| *1. Initial image collection services Artificial Vision Systems, and DICS systems with a minimum total of between three thousand (3000) and five thousand (5000) images.* |
| *2. Delivery of them in a software tool to classify “non conformities” typologies, to the RiaStone product Quality teams;* |
| *3. Sinalization of any non conformities that are found, whether these are frequent and common or not* |
| *4. Human Classification of remaining images by the product quality teams* |
| *5. Incorporation into the DICS database,* |

| iii. Preliminary system start |
|---|
| *1. Defect detection and validation by DICS and the the operator, or reclassification of the defect category found;* |
| *2. Detection of new defects and validation by the operator with reclassification of the category of defect found* |

### 14.4.3 Pilot 10: RiaStone; Stakeholder-training Logbook

The training logbook related to the training of stakeholders and pilot participants on the use of the pilot systems is not yet available.

# 15 Pilot 11: PRIMA; Additive Manufacturing Pilot Adaptive Control Technology

## 15.1 Pilot 11: PRIMA; Current state

Nowadays additive manufacturing is still very dependent from the operator on the machine and takes continuous tuning, also during the process, because this as a very high dependency on geometry and building strategies defined by the engineers.
The process will be affected also by the orientation and supports of the part and by initial defined machine parameters.

**Typical issues:**

- Burns on deposited layer
- Thermal distortions due to incorrect design of supports
- Damaged recoater (discontinuity lines on powder bed)
- Today solutions:
- Visual inspection and manual correction during process

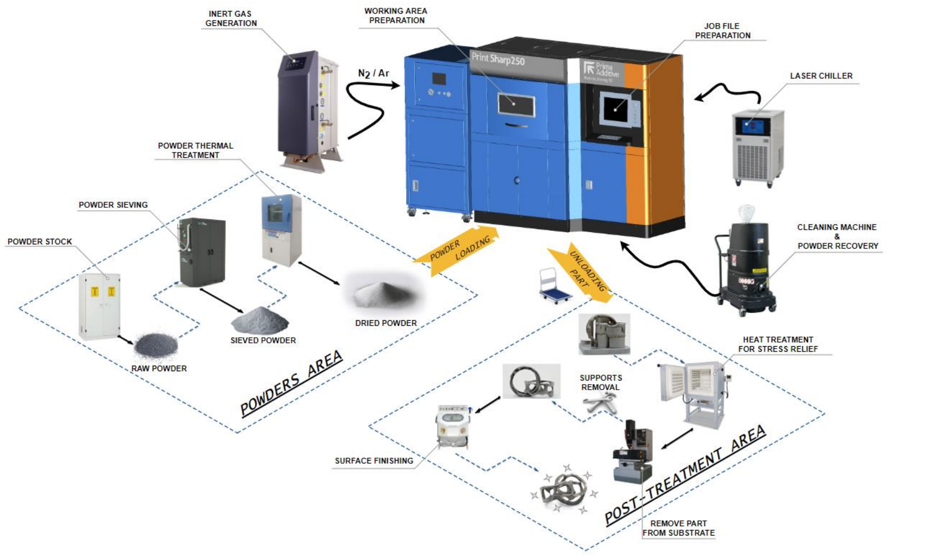


Figure 30: Overall SOA production phase's scheme

In laser-based additive manufacturing, production time has a great influence to the economic efficiency of the production process. To increase the productivity but also reliability of such processes, a zero-defect AM strategy is targeted.

The zero-defect approach in additive manufacturing addresses the following problems:

- The time-consuming build processes need to stop if a critical defect is detected during the process. Thus, in-process monitoring is suggested for fast and reliable real-time defect detection which leads to:
    - Less powder, energy and machine time consumption;

- Less quality assurance procedures (in defect case);
- Bad process conditions can be readjusted through adaptive process control
- Laser – based AM is currently used in high-tech industrial applications where 100% quality inspection is applied to achieve zero defect components
    - Potentially saves NDT procedures by replacing them with in-line quality assurance
- The high connectivity to the factory environments enables fast adaption to process changes and high-performance analytics through HPC for faster production decision and reliable process models.

To allow an autonomous quality assurance system which decides whether to cancel or continue the production process, different sources of information are required. Besides collecting machine data to observe the quality and maintenance states of the production line, in line process information is crucial to achieve constant product quality and ZDM.

In industry, laser-based manufacturing processes mostly are controlled with statistical process control. In some cases, measurement signals are used to indirectly predict product quality. If these signals remain within a certain tolerance, quality of the product is assumed. Nearly all those applications require statistical process control in addition to the signal analysis. The process of the laser-matter interaction is so complex, that a single sensor solution did not yet succeed to identify robust criteria for zero defect product quality. Some solutions have been demonstrated at lab level, which still suffer on the lack of analytics performance.

The methods currently used for monitoring and controlling laser-based AM processes enable the establishment of correlations of single measurement signals. The required quality is obtained by applying tolerance bands based on statistical evaluation. These methods cannot exploit the advantages multi-dimensional sensor data.

### Weaknesses and Bottlenecks

Table 32: Pilot 11, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| Lack of simulation (TTS) | Simulation allows to predict in advance possible errors in setting up machine parameters and/or part program | Manufacturing | Lack of simulation causes longer time to set up the machine before fabricating a part<br>Lack of simulation impacts negatively on time needed to discover possible cause of failures in producing a part |

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| Pipeline for generating AR content (VTT) | To be able to benefit from AR, all the content displayed in the AR tool must have location reference. Also, some content like 3D models might need to be optimized for AR presentation on devices with limited hardware capabilities. | Technical Support | Steps required for generating AR content must be integrated to e.g. training processes. Optimization of e.g. 3D models can already be integrated to product design processes. |
| Multiple AR presentation devices (VTT) | Since there isn't a single AR device suitable for all the different scenarios, the complete AR system will be based on multiple devices. This causes some complexity for managing all the devices running on various platforms (UWP, iOS, Android etc.) | Technical Support | Technical support must have the required skills to manage various types of AR presentation devices. End users might require some basic training to be able to get most out of the AR technology. |
| ZDM DSS rule thresholds initialization difficulty (ATLAS) | The initial thresholds of the specified rules are too low or two high. Hence, the ZDM DSS delays converging to most appropriate rule thresholds based on the use feedback. | Technical | N/A |
| ZDM DSS wrong false/true positive classification (ATLAS) | User feedback can be subjective, hence the ZDM DSS might be mistakenly trained and misclassify some predictions to the wrong class (true/false positive). | Technical | N/A |
| Correlation-based process monitoring (FHG-ILT) | It is possible that even with a large number of different sensor signals, the correlation between defects/quality and measurement signals is not sufficient to meet user requirements. | Manufacturing | No cost reduction due to full NDT; |
| Missing integration into shop floor environment, data | The system needs also to be integrated into the shop floor environment | Manufacturing; Management | Part quality related data are not accessible from the superior |

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| lakes and cloud solution due to undefined interfaces on both sides. (FHG-ILT) | and cloud-based data lakes to unfold advantages compared to a stand-alone process monitoring system. | | quality assessment system in the factory |

## 15.2 Pilot 11: PRIMA; Future state

In this pilot, Powder Bed additive manufacturing machines will be considered to enhance process control for producing metal components. Traditional solutions and new concepts of machines will be considered to test new edge devices for process control, towards a ZDM result, and to work on data management and analytics to implement the whole manufacturing process by a platform approach. In this scenario it will be possible to work on:

- Modular edge device for real-time AI - data analysis and metrics exploitation
- AR/ VR visualization and open platform
- Simulation framework
- Edge computing and fog integration
- Industrial data space
- ZDM strategy at factory level

The ambition is to create a modular monitoring and control system that can be used with many different sensors and process models. The models need to be adaptable to the actual task, be it for a specific geometry or dedicated material processing conditions.

Real-time process and machine signals need to be analysed in by machine-learning algorithms to find structures and pattern related to the required key quality indicators (critical defects per track, distortion, keeping of dimensions).

The system will be also connected to a higher-level factory data interface which allows to exchange process information and reassign the production strategy based on additional factory conditions.

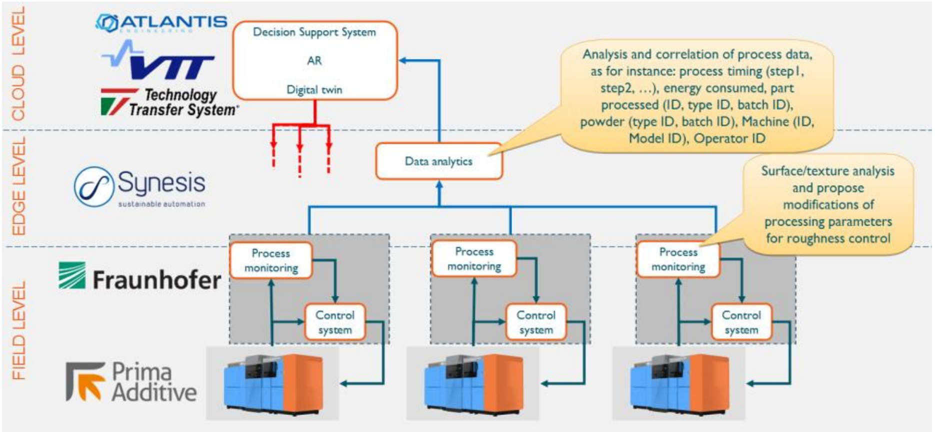


Figure 31: Overall scheme of the pilot scenario with partners involved

## 15.3 Pilot 11: PRIMA; Detailed plan

Table 33: Detailed plan Prima Pilot

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| Task 1.1 | Final Specification of machine enhancement | Definition of the specifications for the machine | PRIMA | Pilot owner | Done |
| Task 1.2 | Final Specification of the proof of concept | Definition of the specifications for the test phases | PRIMA | Pilot owner | Done |
| Task 1.3 | Software and Architecture initial design | Design a first structure for the software that will be developed | PRIMA | Pilot owner | Done |
| Task 2.1 | Sensor system installation | New sensors installation for process monitoring | ILT | Pilot owner | On going |
| Task 2.2 | SW implementation at Edge level | Software installations in the pilot machine | PRIMA | Pilot owner | On going |
| Task 2.3 | First test cycle and data collection | Test cycles under identical conditions will be launched periodically at the machine, collected by the machine and analysed by the experts | PRIMA | Pilot owner | Not started |
| Task 2.4 | Continuous data collection | Selected parameters from the machine will be collected continuously for analysis | PRIMA | Pilot owner | Not started |
| Task 2.5 | Simulation and analytics results | Through expert analysis of continuous data and periodical test the first conclusions and results for ZDM will be achieved | PRIMA | Pilot owner | Not started |
| Task 3.1 | Second Data Analytics | Second version of digital enhancement based on Data Analytics | PRIMA | Pilot owner | Not started |
| Task 3.2 | Architecture improvements | Development and implementation of improvements on architecture and software derived from the second version of the ZDM enhancements | PRIMA | Pilot owner | Not started |
| Task 3.3 | Final data collection and validation | Last round of data collection that will be used for the final evaluations | PRIMA | Pilot owner | Not started |

| | | | | | |
|---|---|---|---|---|---|
| Task 3.4 | KPI and results evaluation | Selection of suitable KPIs and final results evaluation | PRIMA | Pilot owner | Not started |

## 15.4 Pilot 11: PRIMA; Expected results

Table 34: Pilot 11: PRIMA; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Current value | Future expected value |
|---|---|---|---|---|---|
| **1** | Maintenance costs reduction | Thanks to AR, operators will be able to handle maintenance tasks | N/A | N/A | N/A |
| **2** | Training enhancement | AR will enhance and make more effective the training for new operators | N/A | N/A | N/A |
| **3** | Increase OEE | Increase OEE by recommending process adjustments to the operator, predicting and preventing failures, as well as operation beyond the optimal and/or accepted conditions. | N/A | N/A | N/A |
| **4** | Reduction of FAR (False Alarm Rate) | Taking advantage of the feedback mechanism will be possible to convey the knowledge from the shop floor back to the system | N/A | N/A | N/A |
| **5** | Safer workplace | AR will warn operators about safety equipment and hazardous material | N/A | N/A | N/A |

## 15.5 Pilot 11: PRIMA; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 15.5.1 Pilot 11: PRIMA; Analysis of sample data

The first data analysis was focused on the data from .epi file, an outcome file coming from a proprietary software dedicated to the Prima Additive machine, and the definition of job file .epi: the file was made legible for the interpretation of machine processes and time estimation, so that together with TTS there could be the possibility to develop a Time estimation software thanks to the data contend in the pre process file, but also could be useful for other partners in the pilot to understand the main parameters and steps that the machine will perform during the process.

### 15.5.2 Pilot 11: PRIMA; Pre-deployment results

First results for Prima pilot coming from the Time estimation software developed by TTS, that is capable to estimate and optimize the production processes based on the production needs.

The second result come from the AR app, developed by VTT, that is capable to recognize the machine and its components, so to give suggestions and indications to the operator about switches, buttons and so on.

### 15.5.3 Pilot 11: PRIMA; Stakeholder-training Logbook

The training logbook related to the training of stakeholders and pilot participants on the use of the pilot systems is not available yet.

# 16 Pilot 12: Danobat; Digital Machine for zero-defects at high precision cutting/grinding

## 16.1 Pilot 12: Danobat; Current state

The DANOBAT machines are currently equipped with Danobat Data System technology. It enables data communication from the machine, to the owner and to the machine tool supplier. The most difficult part of this digitalization process started by Danobat, is creating a value proposal based on these technologies. This will be built upon the client business scenarios that will be used to define their needs, and the value that Danobat can incorporate to its proposal.

With the aim of supplying machines and solutions that assure a Zero-Defect Manufacturing, DANOBAT will need to develop Smart solutions that can avoid any failure, following the concept of Autonomous quality.

Reducing machine tool downtime and assuring quality are important aspects for the customers of machine tool builders. Quality, however, heavily depends on the condition of the equipment. Digitalization and the permanent, remote monitoring of machinery condition makes it possible to reduce downtimes through the early detection of possible problems prior to asset failure. This is achieved by implementing predictive maintenance.

Currently many condition issues on the machine are detected afterwards, they appear when a quality matter is detected on the machining parts or a machine component is damaged, causing even machine stoppage. These problems are fixed by machine adjustment or changing programs or machining process parameters.

The only way to avoid future problems is by preventive maintenance or machine adjustment actions. These are carried out either by the machine owner itself or external services which are sometimes delivered by DANOBAT.


Figure 32 Danobat machine and main components

### Weaknesses and Bottlenecks

Table 35: Pilot 12, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| Data access and quality | The availability and quality of the data is a real issue in production plants. Data gathering systems are sometimes disconnected for different reasons. In addition, high sampling frequencies may produce bottlenecks in the machine and consequently online monitoring services may be lagged | N/A | N/A |
| Limited fieldbus connectivity | The savvy box as data gateway lacks industrial real-time control capabilities and integrates the capabilities of industrial automation controllers or PAC devices via Modbus. The load balancing between PAC and Savvy Box is another issue to be handled. In this context, the adoption and implementation of IEC-61499 distributed control can be an important enhancement | N/A | N/A |
| Push information services | The information delivery services provided the technology provider are pull services. Push services like ticket-based notifications will enhance the usage of the platform. | N/A | N/A |
| Data exchange | In addition to the API Rest data exchange services provided there is a need of extending the data exchange services to OPC-UA standard. Moreover, and IDS compliant data exchange is an important enhancement in terms of standardization. | N/A | N/A |
| AI | The implementation of embedded analytics in the edge or cloud tier of the platform is in an initial stage of development. The implementation of tools and methods jointly with the hardware resources is an important task to be accomplished within the scope of the project | N/A | N/A |

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| Poor RUL estimation results | RUL highly depends on the provided data and the selected distribution. If the data are not enough or not appropriate or the selected distribution does not fit the data correctly the RUL estimations will be far from the actual behaviour.<br><br>A key aspect of the RUL analysis is the selection of the most appropriate distribution the better fits (explains) the data. For the fitting process, there are lots of testing methods that examine the goodness-of-fit of various distributions (e.g. there is a python module named Fitter , which automatically find the best fitting distribution examining the MSE of up to 80 distributions). However, there is no optimal approach to find the best-fitted distribution. There is a chance that the selected distribution partially fits the data, hence the estimation made for RUL might not be close to the actual behaviour of the equipment. To mitigate this weakness, a combination of more than one fitting procedures will be applied, increasing the confidence for the used distribution. | N/A | N/A |

## 16.2 Pilot 12: Danobat; Future state

DANOBAT competes in a totally globalized sector. The players in the machine tool sector are more and more, big manufacturers that are able to develop cutting edge technologies and also count on big production volumes that give them economic advantages. To keep the pace is this dynamic and hard sector, DANOBAT has always worked in niche markets, where its long-term experience makes a difference when offering highly technological and customized products. Technology combined with machining process knowledge, ensures the client the best solution for their machining with the best cost per part ratio. A zero-defect manufacturing is the objective of the DANOBAT machine, that must guarantee the availability and process quality expected at the machining plant by the end user.

New business models are coming to the machine tool sector. Servitization is a term that has been used in the manufacturing sector for a long time, pay-per-use is starting to spread from just a few industries, like electricity or phones, to more traditional sectors. The technologies of IoT and Industry 4.0 paradigms are setting a technological basis for these new business models development.

Machine tool contracts have been including for several year OEE commitments from the manufacturer. Recently some end users have also started thinking on pay-per-use contracts when buying a machine. The machine tool manufacturer has then to ensure not only availability but also productivity (so quality).

Historically, machine tool manufacturers have not had any information of the machine behaviour once they were working at the customer facilities. Maintenance actions by the machine tool supplier, where mainly started by a customer's call and where mainly related to corrective actions, once the failure had already happened.

The DANOBAT machines are currently equipped with Danobat Data System technology. It enables data communication from the machine, to the owner and to the machine tool supplier. The most difficult part of this digitalization process started by Danobat, is creating a value proposal based on these technologies. This will be built upon the client business scenarios that will be used to define their needs, and the value that Danobat can incorporate to its proposal.

With the aim of supplying machines and solutions that assure a Zero-Defect Manufacturing, DANOBAT will need to develop Smart solutions that can avoid any failure, following the concept of Autonomous quality.

Reducing machine tool downtime and assuring quality are important aspects for the customers of machine tool builders. Quality, however, heavily depends on the condition of the equipment. Digitalization and the permanent, remote monitoring of machinery condition makes it possible to reduce downtimes through the early detection of possible problems prior to asset failure. This is achieved by implementing predictive maintenance.

Currently many condition issues on the machine are detected afterwards, they appear when a quality matter is detected on the machining parts or a machine component is damaged, causing even machine stoppage. These problems are fixed by machine adjustment or changing programs or machining process parameters.

The only way to avoid future problems is by preventive maintenance or machine adjustment actions. These are carried out either by the machine owner itself or external services which are sometimes delivered by DANOBAT.

## 16.3 Pilot 12: Danobat; Detailed plan

Table 36: Detailed plan Danobat Pilot

| ID | Topic | Task | Who | Plan | Status (30 jun20) |
|---|---|---|---|---|---|
| **T1.1** | Initial specifications | Define initial specifications for the digital enhancements on the machine pilot | *Danobat Ideko* | Pilot owner Third party | Done |
| **T1.2** | *Specifications of proof of concept* | *Define the scope of the proof of concept* | *Danobat Ideko* | Pilot owner Third party | Done |
| **T1.3** | *Software architecture initial design* | *Design a first structure for the software that will be developed* | *Danobat Ideko* | Pilot owner Third party | Done |
| T1.4 | *Analysis and design f digital enables and enhancement* | *Analysis of the architecture and is interactions with the other digital enables in the project that also work on Danobat Machine* | *Danobat Ideko* | Pilot owner Third party | Done |
| **T1.5** | *Initial Exploitations, Dissemination and Business Plan* | *First steps for the development of the exploitation plan that also involves dissemination and business plan* | *Danobat Ideko* | Pilot owner Third party | Done |
| **T2.1** | *Specifications on Digital enhancements and CPS enablement* | *Continue on the development of the use case and pilot based on the learnings and requirements that arise on the MVP implementation* | *Danobat Ideko* | Pilot owner Third party | Done |
| **T2.2** | *Installation* | *Hardware and software installations in the piltot machine* | *Danobat Ideko* | Pilot owner Third party | Done |
| **T2.3** | *Validation of initial design* | *The design of the enhancements will be validates through periodical revisions and meetings during the implementation phase* | *Danobat Ideko* | Pilot owner Third party | Done |
| **T2.4** | *Test cycles data collection and analysis* | *Test cycles under identical conditions will be launched periodically at the machine, collected by the machine and analysed by the experts* | *Danobat Ideko* | Pilot owner Third party | *On going* |
| **T2.5** | *Continuous data collection and analysis* | *Selected parameters from the machine will be collected continuously for analysis* | *Danobat Ideko* | Pilot owner Third party | *On going* |
| **T2.7** | *First simulations and analysis results* | *Through expert analysis of continuous data and periodical test the first conclusions and results for ZDM will be achieved* | *Danobat Ideko* | Pilot owner Third party | *On going* |
| **T2.8** | *KPIs* | *Selection of suitable KPIs and gathering of current values* | *Danobat Ideko* | Pilot owner Third party | *On going* |
| **T3.1** | *Diagnosis second iteration* | *Improvement and automatization phase for diagnosis and ZDM functions* | *Danobat Ideko* | Pilot owner | Not Started |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Third party | |
| **T3.2** | *Second version Data Analytics* | *Second version of digital enhancement based on Data Analytics by Atlantis* | *Danobat Ideko Atlantis* | Pilot owner Third party | Not Started |
| **T3.3** | *Improvements architecture and Digital enablers* | *Development and implementation of improvements on architecture and software derived from the second version of the ZDM enhancements* | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T3.4** | *KPI* | *Selected KPIs values update* | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T3.5** | *Business Plan definition* | *Definition of the business plan* | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T3.6** | *Feedbacks from pilot* | *Collect feedbacks about the implementation from pilot users* | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T3.7** | *First and Second approach for ZDM AQ* | | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T4.1** | *Final ZDM machine solution running in* | *Start-up phase for the developed solutions in continuous pilot working conditions* | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T4.2** | *Fine Tune large scale validation* | *Fine tune the development and the installation during the start-up phase* | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T4.3** | *Fine tune integration* | *Fine tune the integration with all digital enablers involved and also with demands from other work packages* | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T4.4** | *Business Final* | *Develop the final Business Plan* | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T4.5** | *Final approach for ZDM AQ* | | *Danobat Ideko* | Pilot owner Third party | Not Started |
| **T4.6** | *Final feedback report* | *Develop a final report of feedback from users* | *Danobat Ideko* | Pilot owner Third party | Not Started |

## 16.4 Pilot 12: Danobat; Expected results

ZDM strategy in the Danobat grinding machine is based on a fully sensorized machine in its critical components. Machine condition monitoring and data analytics will be the foundation of Danobat and Ideko's approach for ZDM at machining level.

The objective is to digitally upgrade machines in order to enable more proactive and intelligent operations in identifying and remedying defects.

In grinding machines, the rotating spindles and machine axis condition monitoring are the main concerns regarding ZDM. The main problems in spindles are rotor unbalance, rotor misalignment, motor electrical problems, front bearing damage, rear bearing damage, motor demagnetization and geometric accuracy. Regarding machine axes condition, guideways (stick- slip and friction) and servodrives mechanic chains (balls crew, power transmission, backlash, electrical problems) face condition issues that have impact on the machining process and consequently on quality of workpieces.

The pilot of Danobat ZDM grinding machine will use operational data to relate machine use with evolution of machine components condition. The analytics and the applied AQ control loops on ZDM HG will be based on combination of load distribution map for different time periods and for different part programs, a positioning distribution map and a rotating speed and feed rate (load vs speed ranges maps)

Digital technologies transform machine tools into intelligent assets, which are able to collect and communicate real-time information about themselves and their surroundings, thus enhancing transparency in the production process.

Any problem at the machine will be previously detected, warnings will be sent to the machine, the final user or/and to the machine tool manufacturer so that failures will be avoided before they occur.

The main concept to identify machine condition is what we call the “fingerprint”. It is a reference pattern of the behaviour of the main components of the machine. This pattern will be changing over time, the intelligence incorporated at different points of the software architecture will analyse these changes. There could be different causes for the change: it is a new normal situation related to production circumstances, it is a symptom to be further analysed, it is a clear deterioration and actions must be taken whether directly by the machine or by a service technician in a planned period in time.

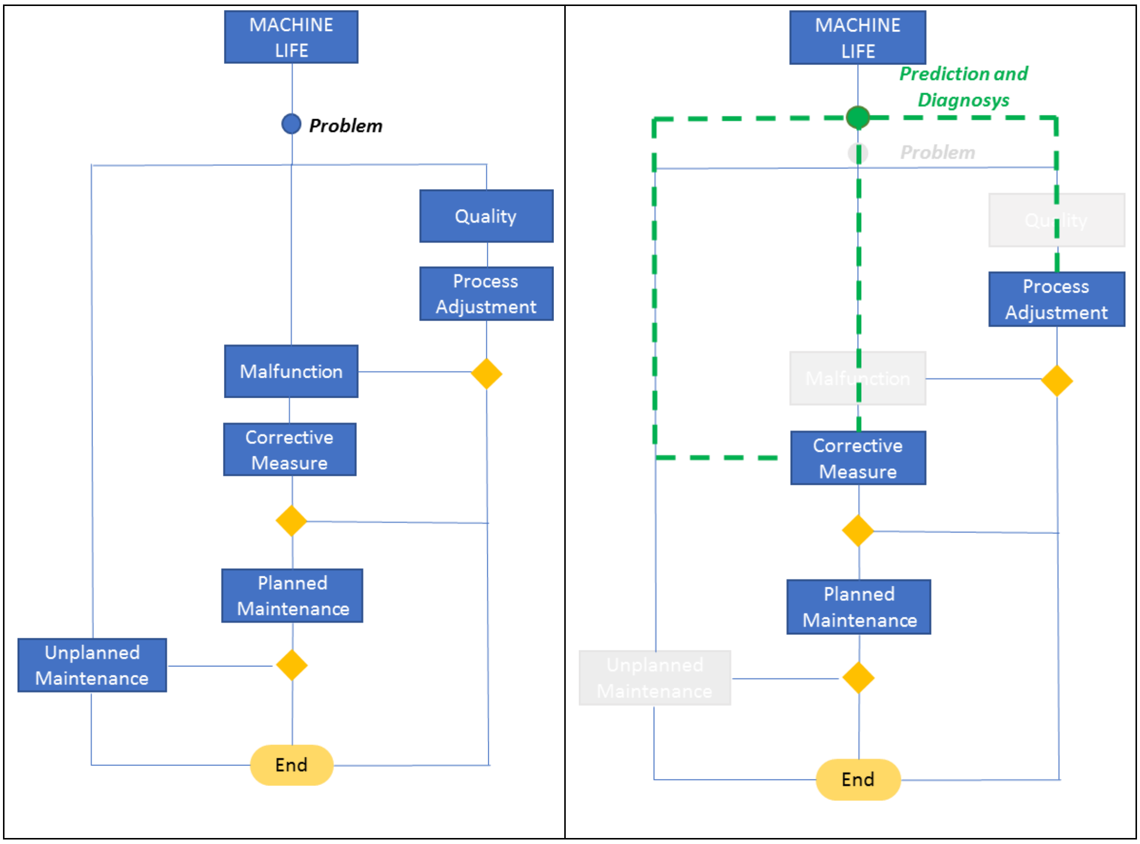


Figure 33:Current vs Future Business Scenario

Table 37: Pilot 12: Danobat; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | | Efficient maintenance service by receiving warnings from the machine instead of having to actively enter and manually analyse machine behaviour | N/A | N/A | N/A |
| **2** | | Develop better machines, more customized offers and new functionalities on the digitized and intelligent machines, based on actual data | N/A | N/A | N/A |
| **3** | | To increase the adoption of the smart and predictive solutions at their customers plants and increase the market share of the solutions. | N/A | N/A | N/A |
| **4** | | Improve competitiveness by developing more reliable machines and processes | N/A | N/A | N/A |

## 16.5 Pilot 12: Danobat; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 16.5.1 Pilot 12: Danobat; Analysis of sample data

A preliminary data analysis has been done by DANOBAT and IDEKO using data gathered from the grinding machine regarding condition test cycles and machining processes. It is expected to collect more test cycles and process data during this year. The data has allowed the elaboration of the first condition reports on the machine and some analysis of the machining process conditions.

In the collaboration with Atlantis r we focused only on the sensors and data that are related to the Z2 axis (i.e. regulating wheel in Figure 1), as it was reported as the most failure prone. The sensors measurements that are taken into consideration are listed on Table 38.

Table 38: Utilized Sensor Measurements

| Sensor Measurements | Description |
|---|---|
| Engine Intensity (A) | Ampère consumption by the axis engine |
| Load (%) | % of KW consumed by the motor over its rated power |
| Position (mm) | Position of the wheel |
| Power (kW) | Power consumption by the axis |
| Speed (mm/min) | Advance speed of the axis |
| Temperature (°C) | Measured temperature |

The frequency of data collection for each sensor is one measurement per second, which produces a big volume of data to be processed. As the RUL estimation should be applied at runtime, we have implemented two data aggregation policies in order to shrink the data volume size.

### 16.5.2 Pilot 12: Danobat; Pre-deployment results

The data collection has allowed the testing of the communication a processing of time series data in the developed digital infrastructure. The data is pre-processed at the edge, sent to our cloud for some processing and generation of reports on condition of key components and customized visualization and alarms. This data is also prepared and shared with Atlantis for analysis.

The data gathered has been useful to test and identify the most promising algorithms for the RUL estimations. It has also enabled the selection of key indicators for the purposes of machine condition diagnosis.

### 16.5.3 Pilot 12: Danobat; Stakeholder-training Logbook

No specific training actions has been conducted yet.

# 17 Pilot 13: FAGOR; Zero-Defects Manufacturing Digital Press Machine

## 17.1 Pilot 13: FAGOR; Current state

Nowadays, the machinery monitoring and maintenance process is quite reactive and manual. After installing a press machine or a forming line, FAGOR ARRASATE does not continuously collect machine/component data or monitor communications from multiple sources, customers and equipment types, neither from manufactured part quality parameters.

In case of machine-level (i.e. press machine, transfer system) or component-level (i.e. hydraulic cylinder) error, the customer telephones the FAGOR TAS (Technical Assistance Service) member with instructions to commence answering. The TAS team maintains a spreadsheet to track customer issues requiring on-site intervention and minor remote checking, or doubts clarification. At this point, it is possible to transfer the issue from the TAS team to the specialized developer team. If necessary, the responsible for resolving the issue can also make a team viewer remote connection to see online status or can even ask for a video record. Through remote connection, the developer or TAS member responsible for collecting and repairing the error cause can access machine-level and component-level logs, accessing the SCADA HMI (Human Machine Interface) and Programmable Logic Controller (PLC). In this current scenario, some errors can be fixed remotely, however, most of them require an onsite intervention.

The use case selected for this scenario is a Hot forming press. Hot forming or press hardening is a process of metal forming which allow to form high strength parts through a quenching of boron steels heated above 950ºC.

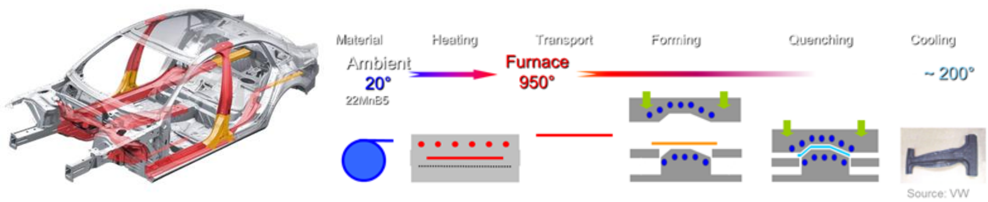


Figure 34 Hot Stamping Process in Automotive sector

Close cooperation between FAGOR ARRASATE, furnace manufacturers and die-makers offer the possibility of having turnkey solutions to manufacture a wide range of workpieces for automotive sector (A pillars, B pillars, front panels or any other high strength parts).

**PRESS**

It is the product par excellence of FAGOR ARRASATE. Until now, due to its functional flexibility, a hydraulic press has been used to fulfil this function. The main characteristic of this process is that, unlike the trajectory that is necessary in the forming of cold steels, in Hot Stamping the press has to approach the mould as quickly as possible, to form the piece to a moderate speed, stay in the Bottom Dead Centre during the process of cooling and tempering the piece and finally remove from the mould also at fast speed.


Figure 35: Press

### Weaknesses and Bottlenecks

Table 39: Pilot 13, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| Data sources | -Integration of several data sources that each have own data format | FAGOR, IKERLAN | Due to lack of standardization, may be time consuming. |
| Reference architecture | -Integration of other developments made within this pilot do not follow the reference architecture of IDS and thus are incompatible. | FAGOR, IKERLAN | This would cause that certain applications could not be deployed and run within the proposed data space approach. |
| CPS Data | -Integrity of the CPS data could be compromised during the data flow from the generation, to the consumption. | FAGOR, IKERLAN | This would cause to producing bad optimizations or software in the control loop. |
| CPS Multiple measures | -Handling of the CPS Multiple measures are retrieved from CPS in real time. | FAGOR, IKERLAN | Such quantity of data could be big, causing an unintentional denial of service. |
| Data analytics | -During operation, analytics are realized in order to optimize manufacturing. | FAGOR, IKERLAN | If the time needed to analyse the data is longer that the response time needed to close the control loop, it can become useless. |

## 17.2 Pilot 13: FAGOR; Future state

The future scenario, focused in zero defects manufacturing, will have the objective of reduction of defective parts and breakdowns of FAGOR hot forming press by the implementation of an efficient and flexible condition-based monitoring and data analytics service Platform.

To achieve the main objective, it will early detect malfunctions on the press machine or its components that may lead to a breakdown. In a hot forming line, a breakdown in the press, supposes a rejection of parts. For this purpose, the press machine will be monitored remotely, and real time data will be collected. Concretely, this data will be processed, stored in the Platform, and analysed according to a set of predefined indicators (KPIs) and process instances. As a result of this condition-based monitoring, the Platform will be able to trigger an alarm when an error occurs, i.e. when a KPI is exceeded or reached.

## Digital Platforms Involved

### FAGOR DAS

Fagor DAS (Data Acquisition System) is responsible of sampling data from the sensors via PLCs. Using industrial protocols, such as OPC-UA, DAS system gathers data provided by the sensor in real time. In the deployed scenarios more than 80 relevant variables are sampled with sampling frequencies between 2 milliseconds and 5 minutes. After this data is gathered, it is analysed, compacted and stored in an SQL Server. Such data can be visualized via a tool called Visual Stamp. Visual Stamp provides information related to channels, off centred loads, maintenance, alarms, trends and historic.

The main objective of the DAS application is the acquisition of data from an industrial process for subsequent sending or processing. In other words, it consists of a tool that links the data obtained in a process with storage systems.

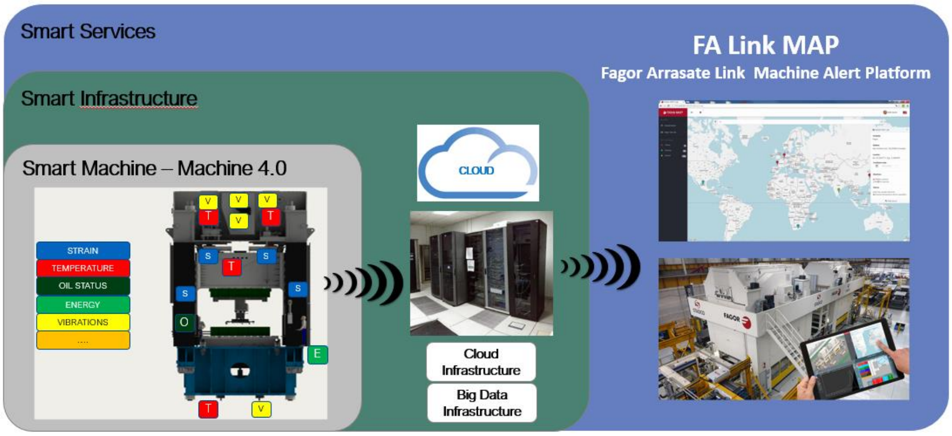


Figure 36: FAGOR FAlink-MAP, from sensor to cloud

### FAGOR FAlink-MAP

Fagor's monitoring platform, FALink-MAP (Fagor Arrasate Link Machine Platform), is composed by two systems, the former that is executed in the manufacturing plant (on premise) and the latter that is executed in the cloud. The data captured in plant via on premise (local view), is uploaded and aggregated in the cloud part (global view).

In FALink-MAP the data acquired is shown in different graphs. For instance, any stroke can be traced and analysed as shown on the image below. The strokes in green are considered good, the orange ones come with advises and the red ones are bad strokes (due to lack of parallelism for example). The user will be able to navigate on the platform and keep track of the key parameters, such as loads, oil and temperature.

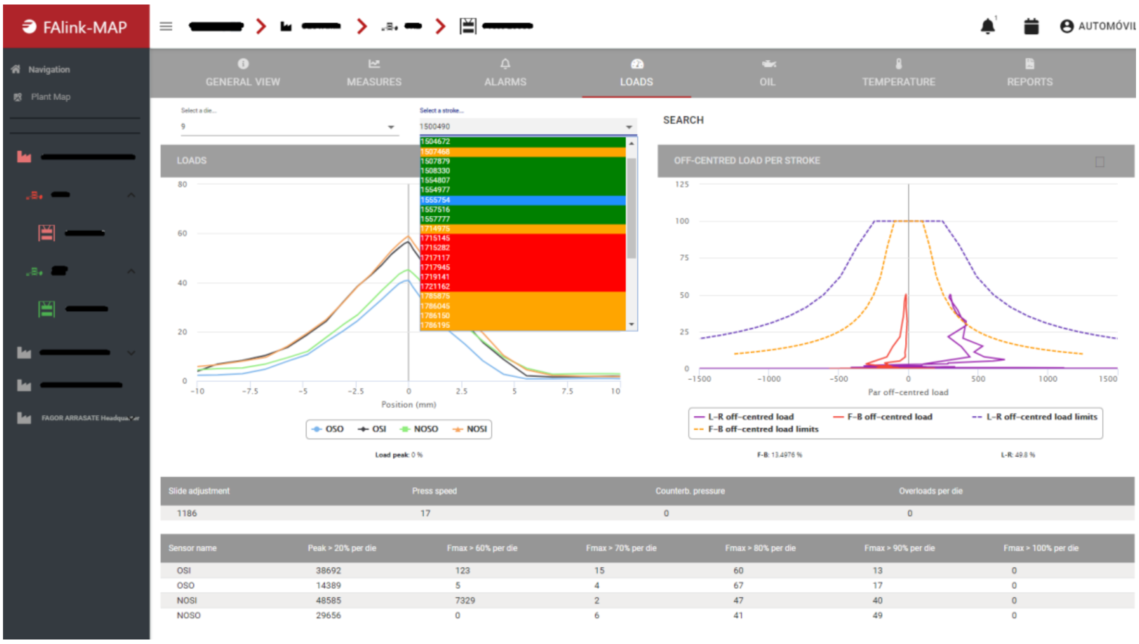

Figure 37: FAlink-MAP

Also, if something isn´t working properly, the platform will show any alerts to the user, making the tracking of the key parameters easier.

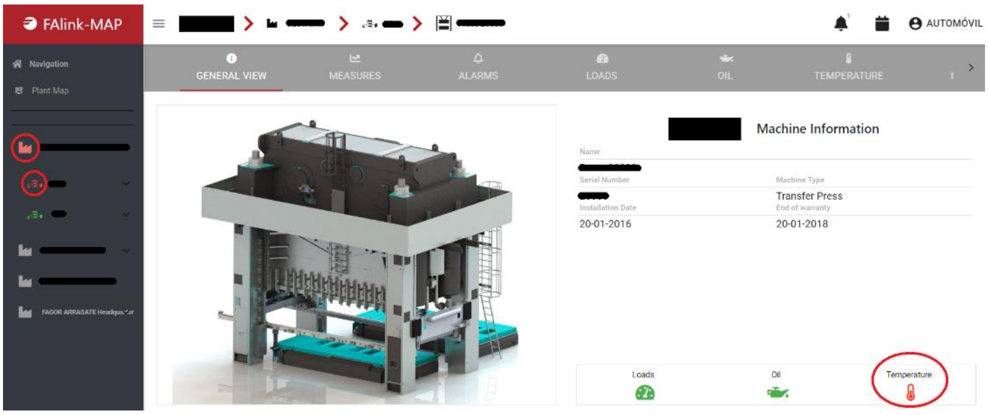

Figure 38: FAlink-MAP 2

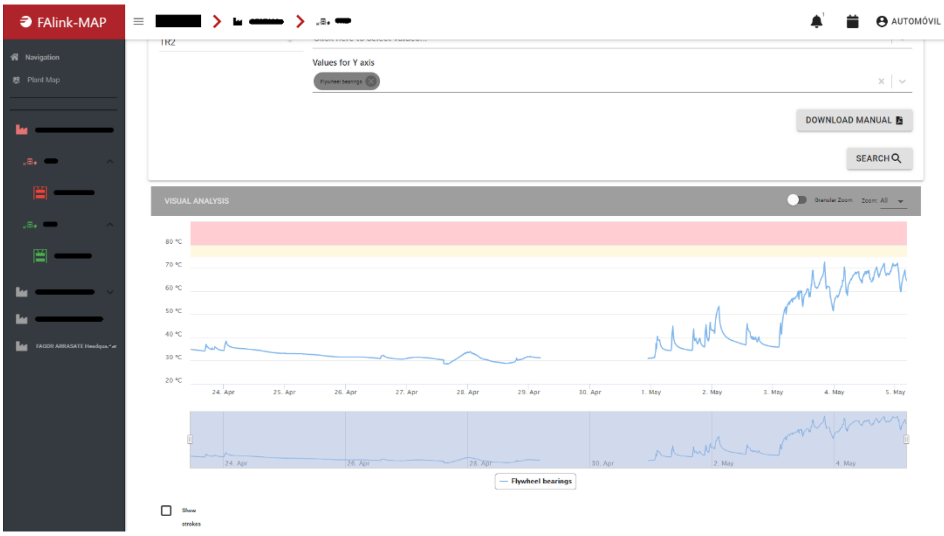


Figure 39: FAlink-MAP alert

**Cloud**

The cloud infrastructure is responsible of the reception (data ingestion), the processing (data analysis) and the storage. This infrastructure is supported via IKCLOUD infrastructure (for more details, see IKERLAN's IKCLOUD private cloud infrastructure). Once the data is persisted, it is possible to visualize manufacturing information such as status and historic data, reports, comparison of multiple manufacturing lines (global view), etc. through a modern Web application (responsive & reactive HTML5 app). This application makes possible to monitor platform information such as uptime, communication status, throughput, etc.

## 17.3 Pilot 13: FAGOR; Detailed plan

Table 40: Detailed plan Fagor Pilot

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| 1 | *Phase 1* | *Specification & Fine Tuning of the QU4LITY Concept* | *Pilot partners* | *(M1-M9)* | *Done* |
| 2 | *Phase 2* | *Proof-of-Concept and Minimum Viable Product Implementation and Validation* | *Pilot partners* | *(M9-M18)* | *On progress* |
| 3 | *Phase 3* | *Technical Validation and Initial Business Validation* | *Pilot partners* | *(M18-M27)* | *On progress* |
| 4 | *Phase 4* | *Large Scale Technical Validation and Business Validation* | *Pilot partners* | *(M27-M39)* | *Not started* |

## 17.4 Pilot 13: FAGOR; Expected results

Reduction in defective parts. Monitoring the input material properties, measures during the transformation process (e.g. temperature variations in the oven, alignment of dies, etc.), and output piece properties; it will be possible to detect which process are critical and should be controlled exhaustively.

Reduction in set-up time. Current market demands innovative products with short lifetime cycles (e.g. new car models every X years). In most cases this leads to the production of new piece types. When a production of a new piece type is started, the production parameters need to be set using a trial/error process. Using ZDM algorithms, this process should be shortened leading also to a reduction in waste and scrap.

Reduction difficulties during assembly of parts. The quality of the product is the sum of their parts. Accumulated deviations can produce defective products even when their parts met their quality parameters. Data sharing between the producers of the different parts should favour the reduction of waste and improve the quality of the overall product leading to a better final customer satisfaction and branding engaging.

Below are listed the expected results that will be achieved at the end of the project:

- Production optimization. Aggressive machine configurations (ultrafast movement of dies, increment in the pressure made by dies) can lead to an improvement on the production at expenses of lower quality pieces and reduction in the machine lifetime. Conservative machine configurations (slow movement of dies) can lead to an improvement of the quality of the pieces at the expenses of a slower production. Searching a balance between the quality and performance will lead to a sustainable production.

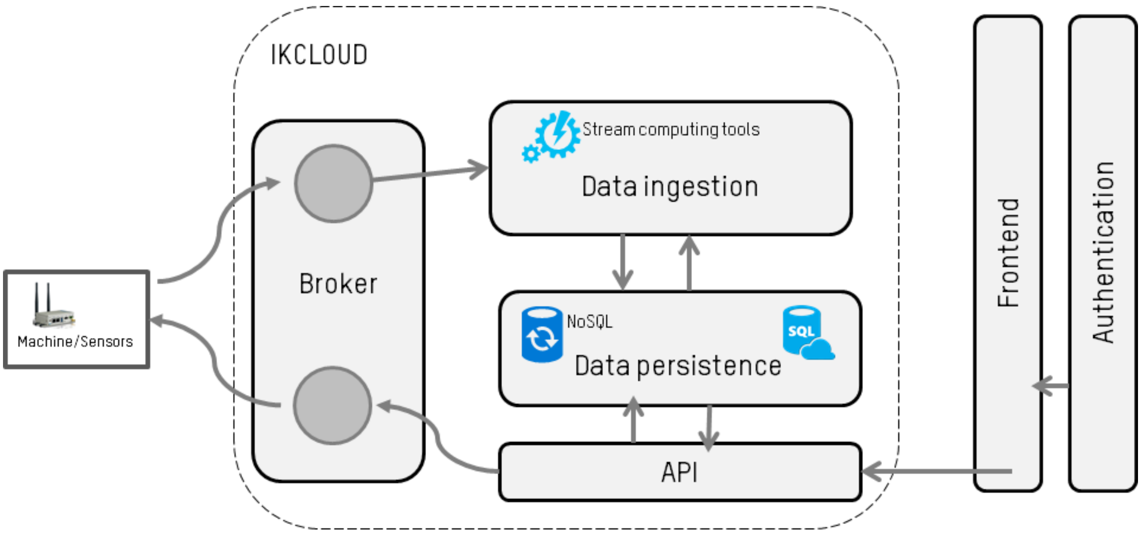


Figure 40: IKERLAN IKCLOUD architecture

The future scenario will have a cloud component which will be capable of dealing with near to real-time response for the operation of the machine, based on IKERLAN IKCLOUD ® (Figure 40: IKERLAN IKCLOUD architecture

. The cloud will collect measurements from many components of the process of the part building. It will store the information in timeseries databases, both for traceability and the data analysis. The latter one will allow to have tools for the predictive maintenance, using Machine Learning techniques.

Measuring next parameters (Cycle time, Force, Temperature, Energy consumption, Water consumption, Oil condition etc), the objective is to achieve next KPIs:

- 10% improve in-service efficiency due to the reduction of unscheduled machine downtimes and increase of RUL (Remaining Useful Life) through a better tracking of critical machine parameters and possible failure prediction.
- 15% increase of machine availability.
- Up to 10% reduction of machine downtime because of on-line data processing and alerting.

Table 41: Pilot 13: FAGOR; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Current value | Future expected value |
|---|---|---|---|---|---|
| 1 | OEE of production line (efficiency, downtime, rejects etc) | Measuring next parameters (Cycle time, Force, Temperature, Energy consumption, Water consumption, Oil condition etc), OEE will be measure. | N/A | N/A | -10% improve in-service efficiency due to the reduction of unscheduled machine downtimes and increase of RUL (Remaining Useful Life) through a better tracking of critical machine parameters and possible failure prediction.<br>-15% increase of machine availability.<br>-Up to 10% reduction of machine downtime because of on-line data processing and alerting. |

## 17.5 Pilot 13: FAGOR; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 17.5.1 Pilot 13: FAGOR; Analysis of sample data

A preliminary data analysis has been done by IKERLAN using data gathered from one press machine. Although the current volume of gathered data is quite low, it is expected to collect more data from other press machines in the forthcoming months. It should be noted that delays in data collection have been experienced due to the COVID. Nonetheless, the data that is currently available has been useful for performing some preliminary tasks such as data exploration to analyse the structure of the data to understand it and to automate pre-processing steps for future incoming data. Moreover, the data has aided in identifying the most relevant variables using machine learning algorithms along with the experience of the operators. Finally, it has been possible to generate some preliminary models to test potential alternatives regarding the final model.

### 17.5.2 Pilot 13: FAGOR; Pre-deployment results

The first result for the FAGOR pilot refers to the connection between FAGOR's digital platform and the ikCloud+ module developed by IKERLAN to prepare the raw data for machine learning purposes. Several tests have been successfully conducted in which raw data has been extracted from FAGOR's database and saved into HDFS after being formatted.

The second results coming from the preliminary analysis of the data conducted by IKERLAN, is that some valuable insights have been obtained regarding the relevance of the variables and about which are the most promising algorithms to generate the machine learning models.

### 17.5.3 Pilot 13: FAGOR; Stakeholder-training Logbook

Since the solution provided by IKERLAN has not been yet fully integrated within FAGOR's platform, no specific training actions has been conducted. Nevertheless, several meetings have been arranged to discuss which are the best integration strategies, besides reporting on the progress being made during the developing phase by both FAGOR and IKERLAN.

# 18 Pilot 14: GF; Digital machine and part twins for zero defect manufacturing

## 18.1 Pilot 14: GF; Current state

The current automated solutions integrate GF milling, electro-erosion (EDM), measurement systems and automation systems, including Fanuc robots and dedicated GF software. The current systems require however extensive tests before operations and demand intensive maintenance in order to sustain productivity, which currently increases costs and presents high barriers for market development in the mould and die and aerospace segments.

Automation systems (robots and tool changers)

Automation systems are integrated in the cell and manage the execution stage of the manufacturing process. GF automation systems integrate robots (multi-axes, up to 750 Kg), the Workshop Manager automation software control. They support the interfaces with MES and ERP systems as well as other quality information and control systems. The system doesn’t integrate advanced interfaces with CAD-CAM and simulation systems which could be updated with the information coming from the various stages of the process.

MES and ERP systems

Current interfaces with MES and ERP systems have been developed between the GF Workshop Manager and SAP and MES such Siemens Mindsphere, Vimana, Factorywiz and Forcam. The integrated system does not integrate information on variances of the process in automated way. Human intervention is needed for defining schedules for maintenance and process execution as well as for the preparation of all CNC codes with the existing interfaces.

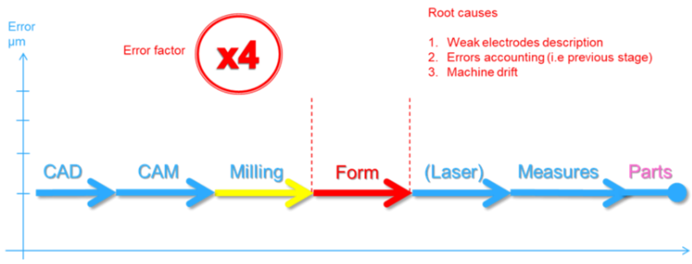


Figure 41: Current interface

Current GF trial scenario and issues in accuracy for mould and die manufacturing with automated cells

### Weaknesses and Bottlenecks

Table 42: Pilot 14, Weakness and Bottlenecks

| WEAKNESS & BOTTLENECKS | DESCRIPTION | PARTNER | IMPACT IN THE COMPANY<br>*At processes (manufacturing) level and business level* |
|---|---|---|---|
| Heterogeneous data sources | Constraints for integration | Manufacturing | N/A |
| No maintenance annotation | Limited options of data analytics | Manufacturing | N/A |
| Lack of data | No history recorded | N/A | N/A |
| No pattern clearly identified | Difficulties to extract pattern for defining predictive models | N/A | N/A |

## 18.2 Pilot 14: GF; Future state

With respect to the current present scenario in mould manufacturing the GF pilot will address the main weaknesses identified in the manufacturing chain at the level of Electro-erosion (EDM) process integration as well as data aggregation and analytics exploitation from all stages of the process, including the CAD CAM preparation, Milling and Measurement of parts, in order to get a stable zero-defect manufacturing process reaching accuracy levels allowing the automated mould assembly.

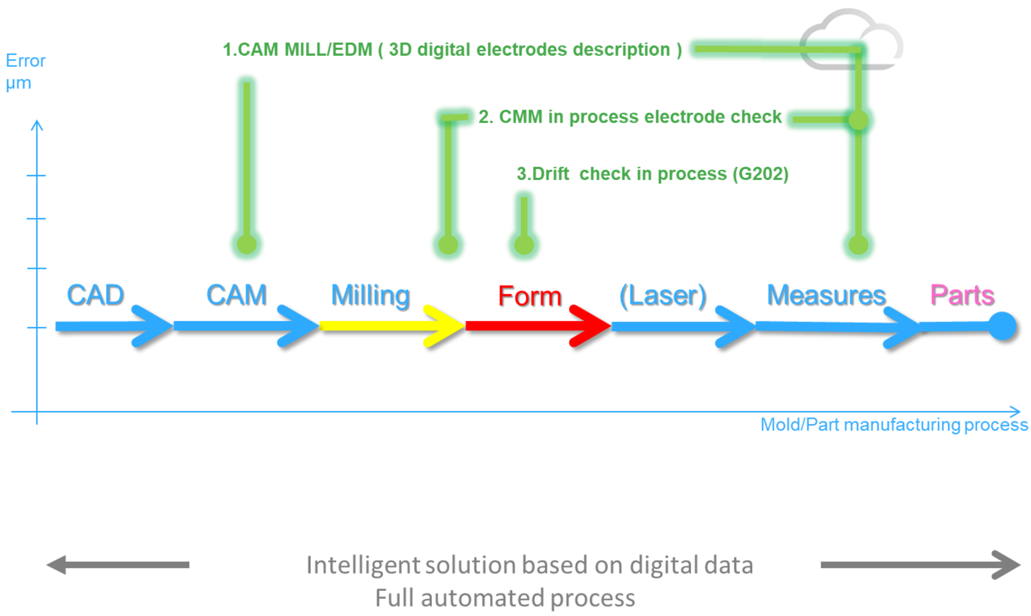


Figure 42: Desired interface

A similar solution will be developed for the particular case of Milling in aerospace component manufacturing, where dedicated surface quality measures will be additionally integrated into the common data space for reaching the required surface integrity for such applications. The detailed solution and future scenario architecture are described in the following diagrams.

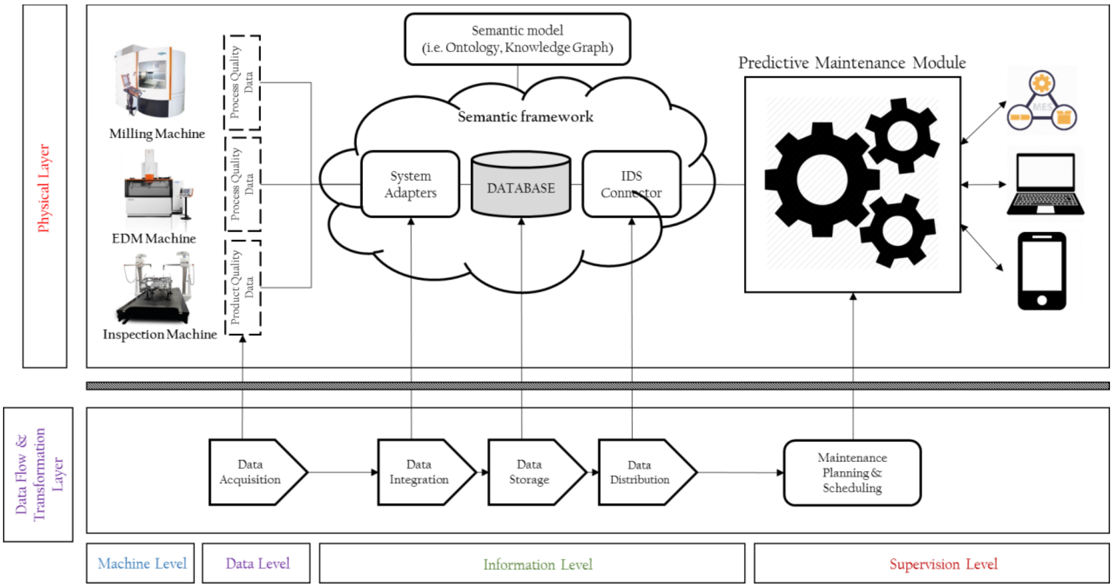


Figure 43: Architecture desired state

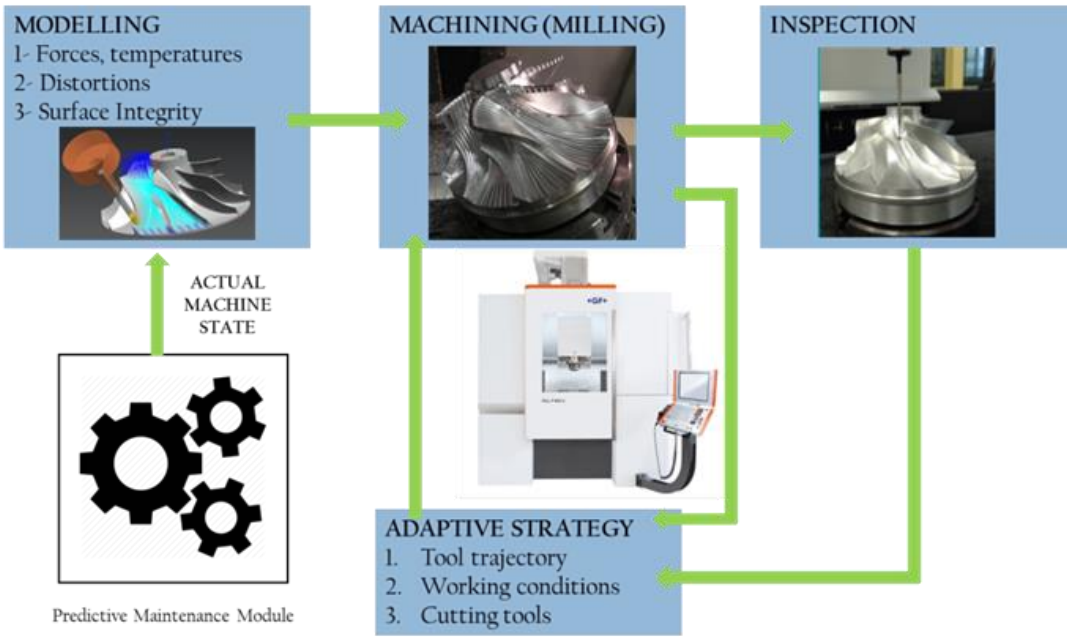


Figure 44: Process desired state

Inspection tasks will involve mainly measuring distortions and roughness when executing the inspection program in M3, a CNC program is generated.

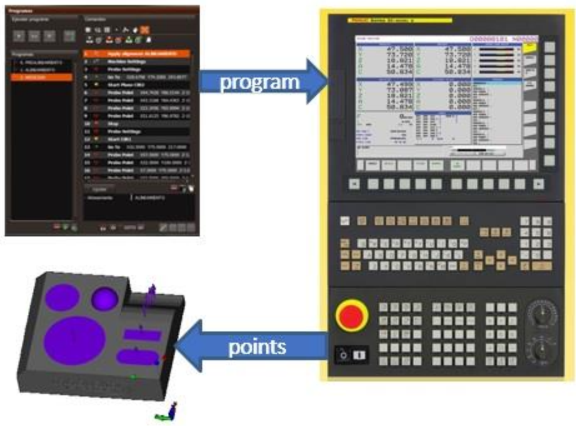


Figure 45: Generalized scheme of M3MH+Machine Tool interaction

When running the CNC program, the probe points are required. This information can be exchanged in several ways:

- Manual file transfer;
- Shared folder;
- Serial channel;
- Proprietary communications protocol.

In the case of the machine tool verification of the integration the operation would include the following steps:

1. The program designed for the operation of the machine in online mode is transferred to the control CNC and selected automatically.
2. It goes to automatic mode and the cycle start button is pressed. The spindle (the stylus rotation on itself) will be placed in its reference position but the machine will not move.
3. Execute the desired task in M3.
4. At the end of the previous task, the loaded program will continue executing waiting for the next part, without having to modify anything in the CNC.
5. In case of alarm, it will be reset, trying to find out what the problem is, reconnecting the machine in M3, going into automatic mode and starting the cycle again.

## 18.3 Pilot 14: GF; Detailed plan

Table 43: GF detailed plan

| ID | Topic | Task | Who | Plan | Status |
|---|---|---|---|---|---|
| 1 | Define goal | Set-up kpi matrix | Wk1920 | Pilot owner | Done |
| 2 | *Phase 1 - Specification and Fine Tuning of the QU4LITY Concept* | *Specification of the pilot* | *GF Unimetrik EPFL MON* | *(M1-M9)* | *Done* |
| 3 | *Phase 1 - Specification and Fine Tuning of the QU4LITY Concept* | *Pilot architecture* | *GF Unimetrik EPFL MON* | *(M1-M9)* | *Done* |
| 4 | *Phase 1 - Specification and Fine Tuning of the QU4LITY Concept* | *Varibales and Data sets* | *GF Unimetrik EPFL MON* | *(M1-M9)* | *Done* |
| 5 | *Phase 1 - Specification and Fine Tuning of the QU4LITY Concept* | *KPI definition* | *GF* | *(M1-M9)* | *Done* |
| 6 | *Phase 1 - Specification and Fine Tuning of the QU4LITY Concept* | *Initial exploitation and business plan* | *GF* | *(M1-M9)* | *Done* |
| 7 | *Phase 2 - Data acquisition and PoC implementation* | *IIoT* | *GF* | *(M9-M18)* | *Done* |
| 8 | *Phase 2 - Data acquisition and PoC implementation* | *Data acquisition for modules* | *GF MON* | *M9-M18)* | *In progress* |
| 11 | *Phase 2 - Data acquisition and PoC implementation* | *Data analytics for different modules* | *GF EPFL* | *M9-M18)* | *In progress* |
| 12 | *Phase 2 - Data acquisition and PoC implementation* | *Initial PoC modules* | *GF MON* | *M9-M18)* | *In progress* |
| 13 | *Phase 2 - Data acquisition and PoC implementation* | *First feedback modules* | *GF EPFL Unimetrik MON* | *M9-M18)* | *Not started* |
| 14 | *Phase 3 - PoC fine tuning, Technical Validation and Initial Business Validation* | *Fine Tuning and Validation Modules* | *GF EPFL Unimetrik MON* | *(M18-M27)* | *Not started* |
| 15 | *Phase 3 - PoC fine tuning, Technical Validation and Initial Business Validation* | *Validation Cockpit optimizer* | *GF* | *(M18-M27)* | *Not started* |
| 16 | *Phase 3 - PoC fine tuning, Technical Validation and Initial Business Validation* | *Validation Anomaly Detector* | *GF EPFL* | *(M18-M27)* | *Not started* |
| 17 | *Phase 3 - PoC fine tuning, Technical Validation and Initial Business Validation* | *Validation Predictive Maintenance* | *GF MON* | *(M18-M27)* | *Not started* |
| 18 | *Phase 4 - Large Scale Technical and Business Validation* | *Final Tuning modules* | *GF EPFL Unimetrik MON* | *M(27-M39)* | *Not started* |
| 19 | *Phase 4 - Large Scale Technical and Business Validation* | *Business Final* | *GF* | *M(27-M39)* | *Not started* |
| 20 | *Phase 4 - Large Scale Technical and Business Validation* | *Final Report* | *GF EPFL Unimetrik MON* | *M(27-M39)* | *Not started* |

## 18.4 Pilot 14: GF; Expected results

Table 44: Pilot 14: GF; Expected Results

| ID | BUSINESS Indicators | DESCRIPTION *Give a detailed description of the indicators* | Unit* | Currentvalue | Future expectedvalue |
|---|---|---|---|---|---|
| **1** | Part accuracy | Part accuracy in terms of minimum and maximum deviations with respect to geometric 3D model. | N/A | N/A | N/A |
| **2** | CpK | Part CpK value of the tolerances in drawing dimensions, roughness, integrity | N/A | N/A | N/A |
| **3** | Surface integrity | Surface integrity in terms of number of defects, affected layer, micro-hardness, residual stresses. | N/A | N/A | N/A |
| **4** | Machine component reliability | Estimated machine component lifetime, failure probability, number of failures per component, defect rate per component. | N/A | N/A | N/A |
| **5** | Machining cost | Machining cost indicators: machining time, tool lifetime, maintenance costs | N/A | N/A | N/A |
| **6** | Productivity | Productivity: OEE, lead time (delay from design to manufacturing), production capacity, human to machine ratio (for assessing effectiveness of cognitive system in assimilating human expertise) | N/A | N/A | N/A |

## 18.5 Pilot 14: GF; Preparatory results

This section provides the results related to the preparations for the deployment of QU4LITY systems as part of the pilot, including the pre-deployment of these QU4LITY systems. First, the results related to the analysis of sample data are discussed followed by the results related to the pre-deployment. The section ends with a brief evaluation of the stakeholder training including the stakeholder-training logbook.

### 18.5.1 Pilot 14: GF; Analysis of sample data

Digital infrastructure implementation has been completed, with EDGE and Digital HUB connected to GF Milling and EDM machines and delivering first set of data for further data collection campaigns.

A dedicated GF Milling machine is being prepared for the data collection campaign, delays for this implementation are related to COVID crisis. After completion of this phase the data collection will start. A specific part has been designed and machining tests have been done by Mondragon University. Sensor data has been defined with EPFL for the analytics phase.

Unstructured data collection has been done for EDM machines and a preliminary analytics model has been developed for the estimation of machining time, necessary for the implementation of the Cockpit optimiser application. The accuracy of the predictions is within expectations of the customers.

  

### 18.5.2 Pilot 14: GF; Pre-deployment results

Data acquisition tests have been successful and various machines have already been connected to the new infrastructure. Data characteristics have been validated and proven to be adapted to requirements for analytics on process optimisation and predictive maintenance of Milling machines. EDM data has been compiled and first analytics results on machining time estimation provide sufficient accuracy for advanced optimising applications. Compensation algorithms for high accuracy automated manufacturing using both technologies have been designed and will be implemented on real systems during the deployment phase.

### 18.5.3 Pilot 14: GF; Stakeholder-training Logbook

Involvement of main stakeholders, key customers, has been done through dedicated Design Thinking campaigns. 2 key customers in the mould and die industry have been contacted and interviews have been carried on for integrating their views on the overall solution architecture. Similarly, dedicated parts have been defined for the aerospace segment which will be the focus of the milling use case led by Mondragon University.

## List of Figures

# List of Tables



  

## List of Abbreviations

| | |
|---|---|
| AI | Artificial Intelligence |
| AIC | Automotive Intelligence Center |
| AOG | Aircraft On Ground |
| API | Application Programming Interface |
| AQ | Autonomous Quality |
| ARENA2036 | Active Research Environment for the Next Generation of Automobiles 2036 |
| ASF | Automotive Smart Factory |
| AWA | Augmented Worker Application |
| CAD | Computer Aided Design |
| CAE | Computer-Aided Engineering |
| CAM | Computer-Aided Manufacturing |
| CDF | Cumulative Distribution Function |
| CEA | COMMISSARIAT AL ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES |
| CMM | Coordinate Measurement Machine |
| CPS | Cyber-Physical System |
| DIH | Digital Innovation Hub |
| EIS | Environmental Impact Statement |
| EOL | End Of Lifetime |
| ERP | Enterprise Resource Planner |
| FAR | False Alarm Rate |
| FFLOR | Future Factory LORraine |
| FPY | First Pass Yield |
| FOR | Fall Off Rate |
| FTE | Full Time Equivalent |
| GTM | Go To Market |
| I4.0 | Industry 4.0 |
| ICT | Information Communication Technology |
| IDSA | International Data Space Association |
| IMECH | Consorzio Intellimech |
| IoT | Internet of Things |
| IP | Intellectual Property |
| IRR | Internet Rate of Return |
| IT | Information Technology |
| JSI | Jozef Stefan Institut |
| JSON | JavaScript Object Notation |
| KPI | Key Performance Index |
| MBD | Model Based Definition |
| MBE | Model-based Enterprise |
| MES | Manufacturing Execution System |
| MGEP | Mondragon Goi Eskola Politeknikoa |
| MIMOSA | Machinery Information Management Open System Alliance |

| | |
|---|---|
| MOM | Manufacturing Operation Management |
| MQTT | MQ Telemetry Transport |
| MRD | Market Requirements Document |
| MVP | Minimum Viable Product |
| ND | No Defect |
| NIST | National Institute of Standards and Technology |
| NPV | Net Present Value |
| NTF | No Trouble Found |
| O&M | Operation and Maintenance |
| OEE | Overall Equipment Effectiveness |
| OMG's UML | Object Management Groups Unified Modelling Language |
| OPC-UA | Open Platform Communications – Unified Architecture |
| PCC | Principle Control Centre |
| PIS | Performance Indicator System |
| PLC | Programmable Logic Controller |
| PMS | Production Management System |
| PoC | Proof of Concept |
| POLIMI | Polytechnic of Milan |
| PPM | Parts Per Million |
| PRISM | Project Risk Identification, Selection and Management model |
| QIF | Quality information Framework |
| R&D | Research & Development |
| RA | Reference Architecture |
| RAMI | Reference Architecture Model Industry |
| REST | REpresentational State Transfer |
| ROI | Return On Investment |
| RoSF | Regions of Smart Factories |
| RUL | Remaining Useful Lifetime |
| SCADA | Supervisory Control And Data Acquisition |
| SMACC | Smart Machines and Manufacturing Competence Centre |
| SME | Small and Medium Enterprise |
| TEA | Techno - Economic Assessment |
| TEF | Technological Experimental Facility |
| TRL | Technology Readiness Levels |
| UMATI | Universal machine technology interface |
| V&V | Verification & Validation |
| VDI | The Association of German Engineers |
| VDMA | The German Mechanical Engineering Industry Association |
| VR | Virtual Reality |
| W3C DCAT | World Wide Web Consortium Data Catalog Vocabulary |
| W3C ODRL | World Wide Web Consortium Open Digital Rights Language |

| | |
|---|---|
| XML | eXtended Markup Language |
| XSLT | eXtensible Stylesheet Language Transformations |
| ZDM | Zero Defect Manufacturing |

# 19 Partners

INTELLIMECH CONSORZIO PER LA MECCATRONICA
SIEMENS
Atos
AIRBUS
MONDRAGON
NXT CONTROL
ATB Institut für angewandte Systemtechnik Bremen GmbH
Continental
RIASTONE
UNIMETRIK METROLOGY AND CALIBRATION
Technology Transfer System
EPFL
SQS
FAGOR FAGOR ARRASATE
TTTech Ensuring Reliable Networks
tu technische universität dortmund
thyssenkrupp
Jožef Stefan Institute Ljubljana, Slovenia
PRIMA INDUSTRIE
eit Digital
ENGINEERING
PACE a TXT company
innovalia ASSOCIATION
Telefonica
Synesis sustainable automation
ghi
UNPARALLEL
DANOBAT
POLITECNICO MILANO 1863
Whirlpool CORPORATION
VTT
VISUAL COMPONENTS
ASTI
Fraunhofer
cea
INTERNATIONAL DATA SPACES ASSOCIATION
PHILIPS
ATLANTIS
aic AUTOMOTIVE INTELLIGENCE CENTER
KOLEKTOR
INTRASOFT INTERNATIONAL
SINTEF
+GF+
Technische Universität Braunschweig
TNO innovation for life
European Research Programme Consulting
TTTech industrial