QU4LITY

DIGITAL MANUFACTURING PLATFORMS FOR CONNECTED SMART FACTORIES

D2.2 Analysis of User Stories and Stakeholders' Requirements (Final Version)

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Abstract: This report will collect, document and analyze requirements regarding the excellence in ZDM. The requirements will be collected and analyzed based on a variety of different modalities, including direct interactions with stakeholders, focus groups, collection of questionnaire-based feedback, documentation of user stories reflecting the viewpoints of different users' networks.

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HISTORY

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Executive Summary

This deliverable of the QU4LITY project is the documentation of the process to complete Task 2.2: User Stories and Analysis of Stakeholders' Requirements.

As described in the Grant Agreement: *This task will collect, document and analyse requirements regarding the excellence in ZDM. The requirements will be collected and analysed based on a variety of different modalities, including direct interactions with stakeholders (i.e. manufacturers and their employees, quality management experts, providers of ZDM solutions, digital manufacturing solutions integrator), focus groups, collection of questionnaire-based feedback, documentation of user stories reflecting the viewpoints of different users (e.g., maintenance workers & engineers, production quality managers), as well as review of relevant project's and initiatives (e.g., projects of the 4ZDM cluster, H2020 FoF-09 projects on maintenance etc.). Interactions with stakeholders will be facilitated by the partners' business networks, including clusters, associations (e.g., EFFRA) and DIHs where the consortium partners' play a leading role.*

The requirements and user stories were gathered using different steps. First a questionnaire was created to get a better overview of the situation at the partners involved to define the scope. We will see an evolution in the flexibility and modularity of factory processes (autonomous transportation & logistics, plug & produce modular assembly cells, human & robot collaboration, digital factory) that will be linked to an increased ability for manufacturing equipment and manufacturing processes to make autonomous decisions supervised and assisted by the expertise and knowledge of human workers.

The next step was gathering the high-level requirements from the industrial pilots and other relevant projects and initiatives. This resulted in an overview of project descriptions and inputs for the QU4LITY project. Analysing these requirements and the ones from other sources the conclusion was that the requirements should be described on a lower level and mapping on the technology work packages was needed. For this purpose, an additional questionnaire was prepared using a set of eliciting questions and a template for user stories.

The answers of the questions were processed by the work packages resulting in a mapping of the low-level requirement on technologies used by the pilots. The user stories were combined with the requirements. Although the user stories are close to the requirements, they serve a different purpose. The user stories describe the solution from the viewpoint of the owner/user and are input for the realization phase. The LL requirements describe the knowledge and guidance that will be delivered by the technology providers to support the development. As such D2.2 will provide the structure and content needed for all relevant parts of the QU4LITY project.

1 Introduction

The Zero Defect Manufacturing (ZDM) concept has been articulated for more than forty years ago as an element of quality management and has been gradually adopted as a quality optimization discipline in the manufacturing chain, e.g. (Cesar, 2012), (Gabler, Osterreicher, Bosk, & Nowak, 2007), (Myklebust, 2013).

Manufacturers have been deploying various ZDM solutions targeting different aspects of quality control and production processes, such as factory automation, condition monitoring, supply chain optimization, and predictive maintenance. Despite these deployments, ZDM adoption is still painful, as it is directly associated with a complex and time-consuming engineering ramp up phase, while involving multi-stage processes that span multiple production systems. Hence, large enterprises have to deal with many complex ZDM processes at scale, while SMEs lack the knowledge, skills and equity capital to invest in sophisticated digital manufacturing solutions in general and holistic ZDM solutions in particular.

To retain European manufacturing competitiveness and to ensure manufacturing excellence, there is an urgent need to ensure industry in general and SMEs in particular access to Pan-European open large-scale experimentation facilities and pilot demonstrations of data-driven zero-defect manufacturing strategies for "connected smart" Factories 4.0. This is clearly stated in the European Factories of the Future Association (EFFRA) recommendations on "Factories 4.0 and Beyond" (Sept 2016) and the Second Stakeholder's Forum on Digitizing European Industry (March 2018).

The Digitising European Industry (DEI): Working Group 2 (August 2017)[1], the European Roundtable of Industrialists (August 2016)[2], and EC Communication (April 2016)[3] all stress the strategic importance of EU industry to drive and coordinate global standards development for Industry 4.0. The EU industry must lead the development of interoperable, composable, open digital manufacturing platforms federated over a trusted European Data Space for ensuring European Industry 4.0 competitiveness, "since it is unlikely that a single industrial (data) platform will achieve a position of total dominance".

At the EFFRA Connected Factories workshop hold in Brussels (5,6 February 2018) and the EC/EFFRA Digital Manufacturing Platforms for Connected Smart Factories workshop (October 2017), priorities for Digital Manufacturing Platform research and innovation priorities were established by digital manufacturing platform and manufacturing experts. These did nothing but reinforce the importance of democratising ZDM strategy implementation through the development of a European universal, open and flexible digital model for ZDM in the Factory 4.0 for fast and cost-effective customization to a wide variety of manufacturing processes in a resilient, efficient and sustainable factory that can be generally applied across industry. This should be independent of manufacturing sector, business development strategy, factory size and region of operation.

[1]https://ec.europa.eu/futurium/en/system/files/ged/dei_wg2_final_report.pdf
[2]https://www.ert.eu/sites/ert/files/ert_benchmarking_report_2016_-_final_-_bookmarked_version.pdf
[3] http://eur-lex.europa.eu/legal-content/TXT/?uri=CELEX:52016DC0180

However, the key question remains, how could such transformative and general lighthouse ZDM model be developed for the Factory 4.0?

With DT-ICT-07-2018-2019 (IA) EFFRA called for European industry to get together in a strategic alliance to develop the digital platform that will leverage optimized and sustainable manufacturing (excellence), including advanced human-in-the-loop workspaces, for the autonomous factory. The QU4LITY project is the response to this challenge.

This report (Deliverable D2.2) reflects the outcome of WP Task T2.1 as described in the QU4LITY Grant Agreement. Deliverable D2.2 collects, documents and analyses the requirements towards the ZDM solution that will be delivered by the QU4LITY project.

In this chapter a general description of the overall QU4LITY project goals, an explanation of Autonomous Quality Control. Chapter 2 explains the Autonomous Quality vision, which is the base of the QU4LITY project. In Chapter 3 is an overview of the design and implementation of the IT and OT architecture. The fourth Chapter describes the relation between WP2, Task T2.1 and other tasks in QU4LITY. The methodology, tools and approach that were used to collect requirements can be found in Chapter 5. In Chapter 6 the various stakeholders can be found, followed by chapter 7: The requirements from the industrial partners, clustered as input for the technology work packages. This deliverable concludes with Chapter **Error! Reference source not found.** Containing set of r equirements for Work packages 2, 3, 4 and 5.

This document will serve as input for the further development of the QU4LITY project.

2 About QU4LITY

QU4LITY will demonstrate, in a realistic, measurable, and replicable way an open, certifiable and highly standardized, 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 through an orchestrated open platforms ecosystem, ZDM atomized components and digital enablers.

As described in the report: "QU4LITY Vision & Autonomous Quality (AQ) Model" (O. Lazaro, 2020) which is part of the D2.4 deliverable of Task T2.2 we will see an evolution in the flexibility and modularity of factory processes (autonomous transportation & logistics, plug & produce modular assembly cells, human & robot collaboration, digital factory) that will be linked to an increased ability for manufacturing equipment and manufacturing processes to make autonomous decisions supervised and assisted by the expertise and knowledge of human workers. Those autonomous manufacturing processes will see and deploy different levels of human-AI collaboration. According to Industry 4.0 classification, QU4LITY will address the implementation of processes and manufacturing equipment up to Autonomy Level 4 – see Figure 1. Where processes will run autonomously, and the human is only involved to supervise and intervene in emergency situations.

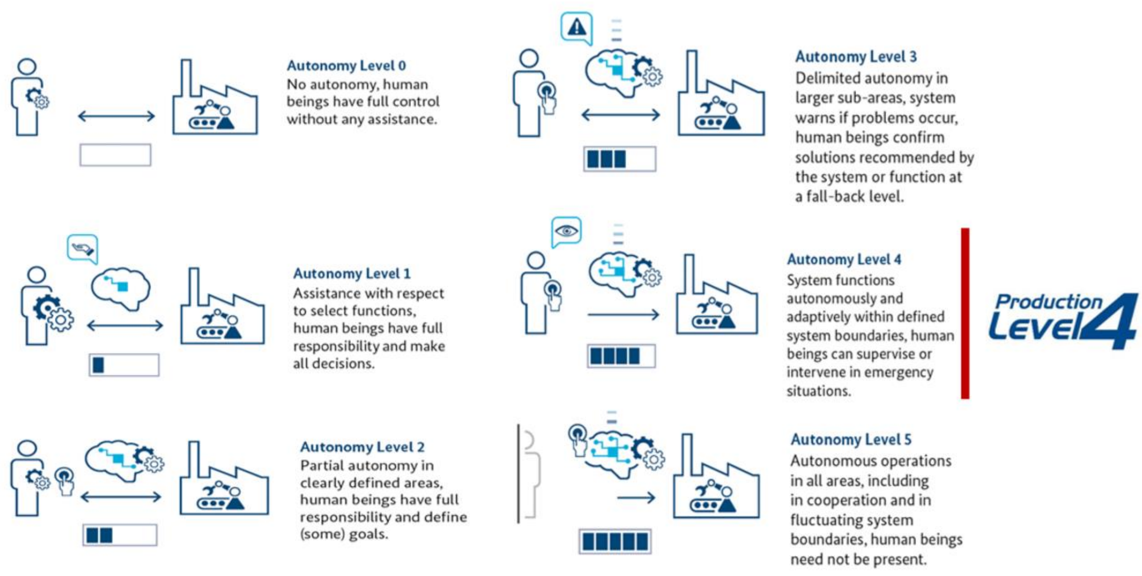

Figure 1: Autonomous manufacturing processes autonomy levels.

The QU4LITY autonomous quality model will 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).

QU4LITY will deliver competitive advantages that should significantly increase operational efficiency, scrap reduction, prescriptive quality management, energy efficiency, defect propagation avoidance and improved smart product customer experience. It should also foster new digital business models; e.g. outcome-based and product servitisation through an orchestrated open platforms ecosystem, ZDM atomized components and digital enablers across all phases of product and process lifecycle (engineering, planning, operation and production).

Proposed Digital enablers to be covered are 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 and European quality data marketplace. A full description of the QU4LITY Vision and KPI’s can be found in the deliverable D2.4: “Autonomous Quality Vision for ZDM and Quality Management Excellence (version II)” (Eleftheriadis, et al., 2019).

3 QU4LITY Reference Architecture (D2.11)

As described in the QU4LITY Vision & Autonomous Quality (AQ) Model the adoption of the QU4LITY autonomous quality model by the QU4LITY pilots demands that pilots need to reconcile and design pilot activities under a unified framework that supports an Autonomous Quality (AQ) control workflow. This workflow is described in the former mentioned document.

In parallel to the development, deployment and set-up of information flows, cognitive services and self-adaptive manufacturing equipment, the QU4LITY autonomous quality model considers the design and implementation of the IT and OT integrated digital infrastructure leveraging the reliable and high-performance networking, storage, computing & processing required by autonomous ZDM operation. Such IT/OT deployment should adhere to the QU4LITY reference architecture (RA) as described in D2.11: "Reference Architecture and Blueprints" (Marguglio (ENG), et al., 2019)

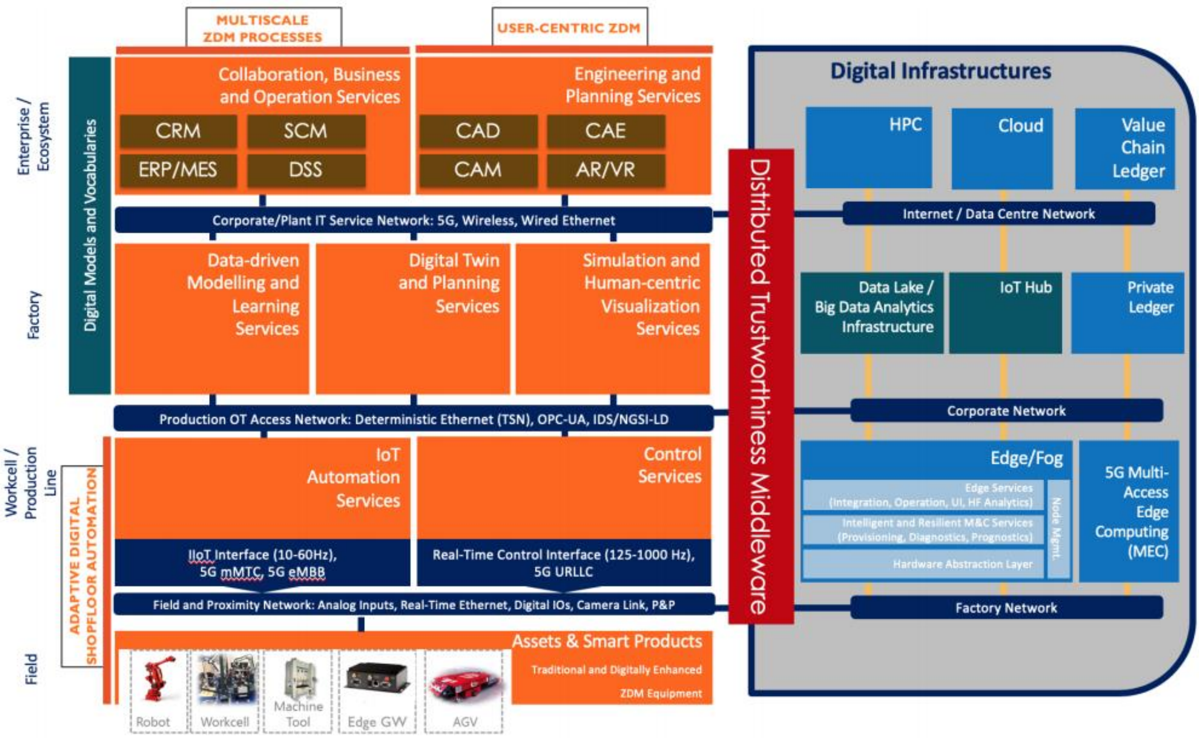

Figure 2: QU4LITY Reference Architecture

4 Relation between T2.1 and other tasks

T2.1 is part of WP2, which provides the technical requirements and specifications driving the project, as well as the detailed specification of the QU4LITY reference architecture.

In order to understand the relation of T2.1 and other tasks within the project, one needs to understand the setup of the project Work Packages (WP). The WP setup of the overall project is shown in Figure 3.

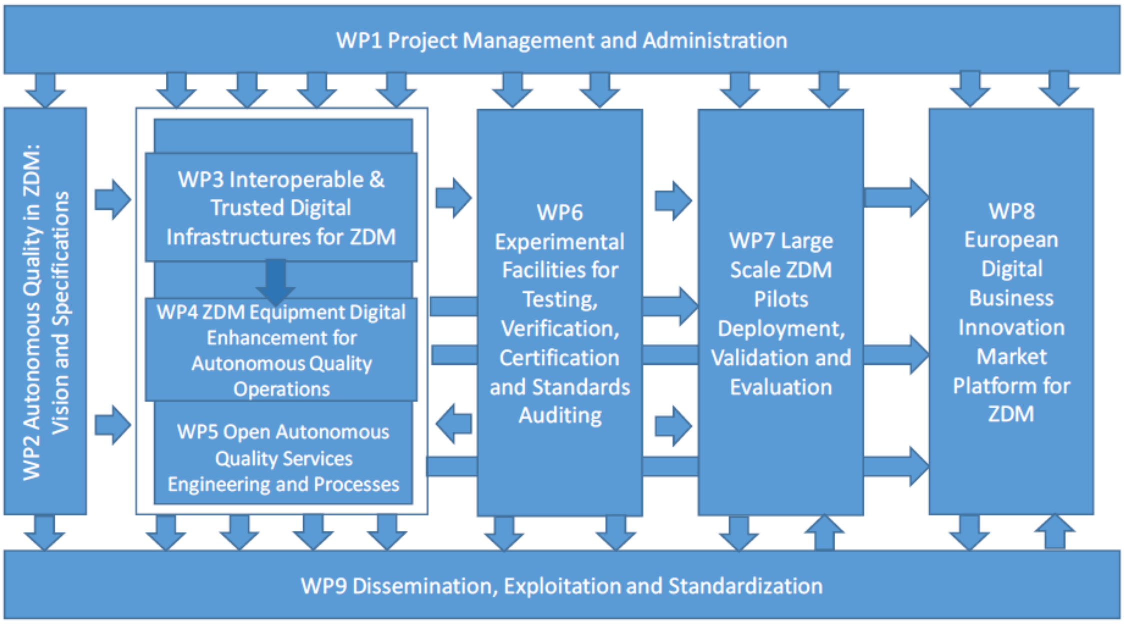

Figure 3: Work package structure of QU4LITY (Grant Agreement, Page 210)

As can be seen in this figure, WP2 is the foundation on which the output of Work Packages 3 to 5 is built. WP3, WP4 and WP5 are the basis on which the Experimental Facilities (WP6), Large Scale ZDM Pilots (WP7) and the Business Innovation Market (WP8) will rely for their starting information. WP2 consists of the tasks as described in Table 1.

Table 1: Overview of Tasks and Deliverables in WP2

Task	Description	Period	Deliverable	Milestones
2.1	User Stories and Analysis of Stakeholders' Requirements	M1-M12	D2.1	M6, M12
2.2	Autonomous Quality Paradigm Specifications	M1-M12	D2.2	M6, M12
2.3	Catalogue & Analysis of ZDM Equipment, Processes and Digital Platforms	M2-M18	D2.3	M9, M18
2.4	Standards Compliance and Interoperability Specifications	M2-M18	D2.4	M9, M18
2.5	Specification and Prototyping of Digital Models, Vocabularies and Digital Twins	M3-M27	D2.5	M9, M18, M27
2.6	Reference Architecture, Open APIs and Blueprints for Autonomous Quality Solutions	M4-M27	D2.6	M9, M18, M27

When looking at a typical system engineering V-Model (see Figure 4), the development of a project follows the V-shape. The definition of the project follows the left-hand leg of the "V" downward. At the bottom of the "V" the actual product is being fabricated. Integration and verification are performed when ascending along the right-hand leg of the "V".

The outcome of the tasks and deliverables of WP2 (Table 1) will give a complete overview of all boundary conditions, requirements and specifications for the QU4LITY solution. These tasks follow the left-hand leg of the "V" downward. WP3, WP4 and WP5 are being performed at the bottom of the "V", while WP6, WP7 and WP8 perform the required validations in the right-hand leg of the "V"

Task T2.1 and D2.2 represent the 'voice of the customer' for the project. It contains an investigation into the motivations (user stories) and requirements from the industry. The T2.1 user stories are the basis for System Demonstration and Validation at the end of the project and as such defining the required outcome of the project.

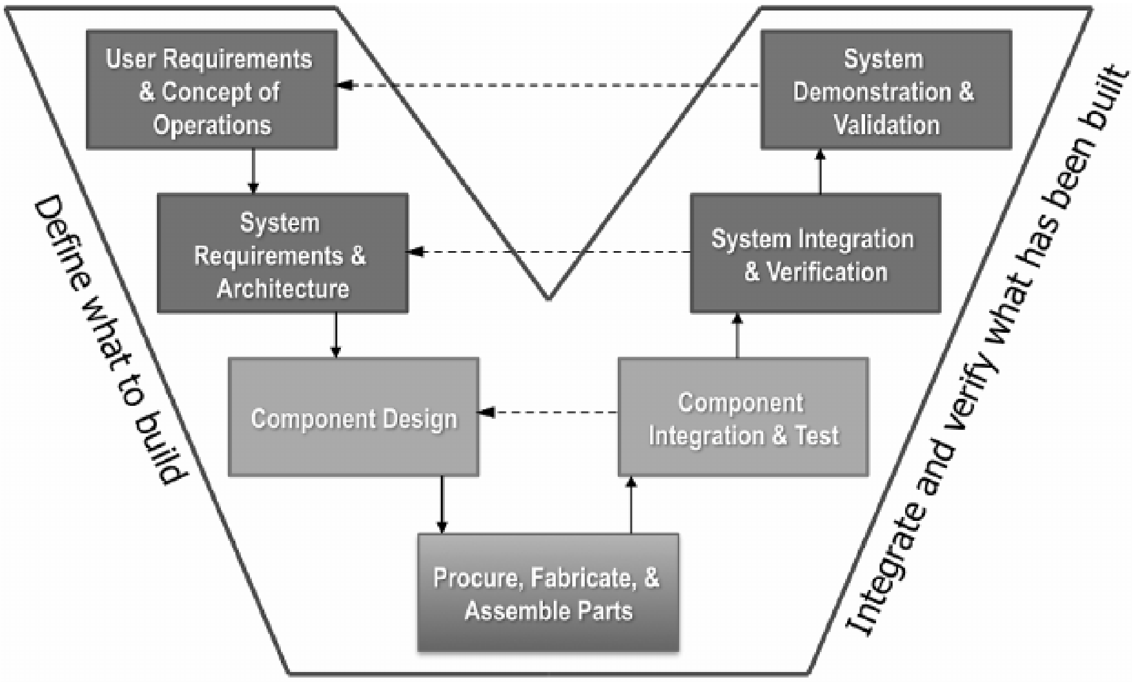

Figure 4: Typical systems engineering V-model

Relation between T2.1 and other work packages

In Table 2 is an overview of the relation T2.1 had to the other work packages. It describes what value T2.1 has for the work packages and how the information will be used.

Table 2: Relations between T2.1 and other work packages

Work package	Relation with Task T2.1
1	WP1 coordinates the whole project. Part of this work includes to ensure timely and qualitative achievement of the project results through technical and administrative coordination. In relation to the task T2.1, WP1 has participated in the definition of the methodology to infer Low Level Requirements from High-level requirements coming from the Pilots. WP1 has also set the methods for the traceability of the stakeholders' requirements and assure that they are contemplated and tested in the open calls.
2	T2.1 is a primary task of Work Package 2, aiming at identifying user stories and stakeholders' requirements. Together with T2.2, Autonomous Quality paradigm specifications, they provide inputs for other WP2 tasks through identifying industrial partners' current practice, gaps and points for improvement, vision of future practice. Based on the outcomes of T2.1, the enabling technologies that adequately meet the requirements, including ZDM equipment, processes and digital platforms, will be analysed and catalogued in T2.3. The standards compliance and interoperability specifications (T2.4), and digital models and vocabularies (T2.5) also rely on the output of T2.1 to ensure stakeholders' requirements are fully considered. Finally, the requirements and the Autonomous Quality vision will be integrated in the Reference Architecture (T2.6) supported by a set of enabling technologies, standards and models etc.
3	The main objective of Work Package 3 is the integration and seamless interworking of the digital enablers which will support the QU4LITY autonomous quality paradigm, in a way that emphasizes interoperability, flexibility of the resulting ZDM solutions. The long-term goal is to overcome the fragmentation of current digital automation platforms that support ZDM systems and processes, towards a more holistic cognitive approach of the Autonomous Quality manufacturing. To do that, a suitable customization is needed of such digital enablers for their deployment within the manufacturing equipment and platforms, in order to comply with the needs of ZDM specifications. In this direction, the activity carried out within T2.1 is essential. Indeed, this task will provide an analysis of the requirements regarding the excellence in ZDM, thanks to the involvement of interested stakeholders, such as management experts, providers of ZDM solutions, digital manufacturing solution integrators. Actually, T2.1 is one of the most important providers of inputs to the Work Package 3, which will leverage the preliminary requirements analysis in order to derive the requirements of autonomous quality ZDM applications and produce prototype deployments of the customized infrastructures for AQ/ZDM to be used by the pilot experimentations.
4	WP 4 focuses on the specification of the various types of Zero-Defect Manufacturing (ZDM) equipment that can be digitally enhanced. To do that the work focuses on collecting a list of ZDM equipment entailed in the project's pilots and experimentation

	activities along with their current capabilities and performance. T2.1. provides WP4 with the requirements and insights needed to execute this work package.
5	The overall target of Work Package 5 is to enable and foster AQ through providing the means for the engineering of entire ZDM processes, spanning multiple stages inside a factory and beyond, across adjacent supply chains. The approaches developed will target to allow the engineering open, composable, standards-based implementations of the AQ paradigm for reaching adequate ZDM processes for specific cases. The solutions and exemplary implementations will strongly build on enabling and combining existing platforms (such as simulation, augmented reality, industrial data spaces, digital twins and more) through enhancing them with Open APIs. Necessary input for adequately conceptualizing the solution approaches is a thorough understanding of the needs of the different stakeholders of the ZDM processes and supporting systems to be implemented. As this is typically retrieved from picturing the later application and use, the collection of the user stories prepared in T2.1 here provide the necessary input. The approach of investigating the later phases from different perspectives of different stakeholders also even fosters a strong cross domain perspective which is crucial especially for Quality aspects. Further, the more formalized acquisition of requirements towards AQ systems, and here, in specific, the requirements towards services will be used in WP5 to develop the solutions and enhancements to existing platforms and approaches. Finally, the detailed analysis of the outcome of several previous research projects here provides a solid base for incorporating former works to the developments in QU4LITY.
6	The main objectives of WP6 are to customize and upgrade existing testbeds, in order to make them suitable for ZDM experimentation, to validate, verify and certify the project's ZDM developments against standards and benchmarks at the equipment, platform and process levels and provide support on this. The requirements of D2.2 will specify the need and type of these services.
7	The goal of WP7 is the coordination, deployment and operation of the fourteen autonomous quality ZDM pilots. The long-term goal is to validate and demonstrate QU4LITY´s concept, getting a high cost-effective approach and ZDM performance. WP7 take charge of the preparation of the pilot sites, the pre-pilot testing and the actual deployment of the pilot system, as well as with its systematic validation and evaluation. Task T2.1 will collect the objectives of the industrial pilots within QU4LITY project, those objectives will be analysed (regarding the excellence in ZMD) based on different modalities (i.e. direct interactions with stakeholders, focus groups, providers of ZDM solutions, quality management experts, …). Having as a result of the analysis the high-level requirements for all the industrial pilots. Therefore, this task provides the floor for the development of the AQ solutions that will make possible the application and operation of the fourteen autonomous quality ZDM pilots of the WP7.
8	WP8 is in charge of creating the one-shop-stop marketplace for autonomous quality ZDM solutions, which will provide a single-entry point to the project's intellectual property (IP) and results. This will be empowered by a multi-sided market platform that consists of marketplaces for ZDM solutions that will enable the participation of both supply-side and demand-side stakeholders, as well as a virtualized Digital Innovation Hub (DIH) for AQ/ZDM that will pool the resources and expertise of the DIHs that are part of the consortium and make available the already existing services

	in these DIHs. In addition to that, innovation management services will also be offered coming from the streamlining of project developments and related requirements. T2.1 can therefore support WP8 in the definition of the requirements and needs of the stakeholders of QU4LITY that will be the participants in the multi-sided platform as well as for the solutions needed in AQ ZDM.
9	The main objective of WP9 is to communicate the QU4LITY results and to ensure maximum impact for the project through exploitation, dissemination and standardisation. QU4LITY's current activities in standardisation and relevant clusters aim to ensure appropriate development and support the development of digital manufacturing standards in general and ZDM and quality management standards in particular. Such activities generally promote the exploitation and sustainability objectives of the project and increase the awareness of all relevant stakeholders of the QU4LITY results. Therefore, the results of Task T2.1 are of great importance for WP9, as they serve as a profound contribution to the clusters, selected standardization bodies and other relevant industrial communities. To ensure this, Task 9.2 works in conjunction with Task T2.1, and prepares important documentation containing such recent results as ZDM use cases, intelligent manufacturing requirements, and others. Further details of this collaboration are described in D9.5.

5 Methodology, Tools and Approach

This chapter describes the way of working to collect the inputs for this deliverable. Because the QU4LITY project is a large project with 44 participants and 14 industrial Pilots a Task Force was created to align the approach to collect the user stories and requirements. The composition of the Task Force existed out of:

- WP Leader (EPFL)
- Task Leaders (PHILIPS)
- Project coordinator (ATOS)
- Technical Manager (ENG)
- Quality Manager (UNP)
- Pilots Manager (INNO)
- Scientific Manager (SINTEF)
- Clustering Manager (POLIMI)

The sections below will elaborate on the various aspects of this task.

5.1 Collecting requirements from Industrial Partners and Tech providers

5.1.1 Approach high-level requirements

The initial approach started with interviews at Philips as an example to get more insight in the scope, boundaries and objectives. The interviews give direction for a general questionnaire to get more insight about these items in the QU4LITY project. This questionnaire is sent out to all partners in WP2: contributing to the requirements and partners in WP7: the industrial Pilots.

The questionnaire is kept short to increase the response rate, the tool "Microsoft Forms" was used for its ease of use and user-friendly graphical interface.

Figure 5: Example of Microsoft Forms Question

The following questions are asked in the questionnaire:

- What is the best description of your activities?
- Which users have influence on the quality of your process? (multiple answers possible)

- On which level do you currently use data in your process?
- On which level do you expect to get your data use at the end of the QU4LITY project?
- Extra question: Do you already know requirements from your users?

The main source for requirement collection for the industrial pilots of the QU4LITY project are the Trial Handbooks (TH). Each pilot fills in a document covering the inputs for several work packages, these documents are called Trial Handbooks and are divided into several chapters. In the first chapter the Objectives and Benefits are described.

Describe the general objective/benefits that the implementation of the trial is expected to provide at a general level. This description should detail expected benefits in enhancement of product quality, productivity, reduction of costs, effectiveness of processes, benefit in production, improvement in company image, etc.

List at least 5 general benefits and describe its impact, justify in detail how the technology to be implemented will manage to provide these benefits.

(between 1 page and 3 pages)

Figure 6: Image of the description of Trial Handbook Chapter 1, Section 2.1

These objectives and benefits give the high-level requirements for all the Industrial Pilots. These high-level requirements are captured in Chapter 7 of this document.

The second chapter of the Trial Handbook contained a section to collect the different Stakeholders in the Industrial Pilots: The Actors. The outcomes of this exercise can be found in Appendix D.

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT (Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*

Figure 7: Template from Trial Handbook Chapter 2 to collect Actor information

5.1.2 Approach low level requirements and user stories

While processing these high-level requirements it became apparent that the work packages and the Tech providers needed lower level requirements that reflect the specific topics in the work packages. A small team of the Program, Work packages and Philips discussed an approach to decompose the high-level requirements into low-level requirements. Besides the requirements also the user stories were involved in this approach. Below a visualization of this.

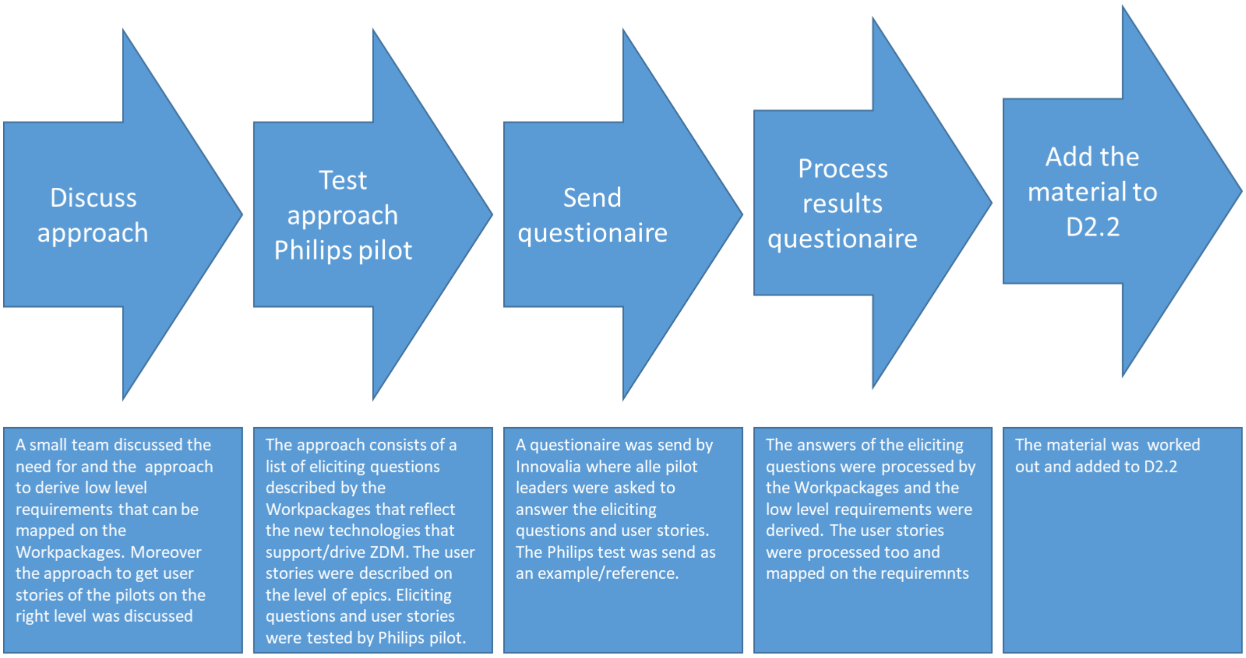

Figure 8: Visualization of requirement collection process

A set of eliciting questions were used to get the right information from the pilots. In Table 3 in an overview of the eliciting questions that were sent to the Industrial Partners. The results of this are documented in Chapter 8.

Table 3: Eliciting Questions to generate low level requirements

WP-topic	Eliciting questions	#
WP2 - Standards	Are you using specific standards (e.g. W3C DCAT, W3C ODRL, OPC-UA, OPC-UA Vision, MTconnect, UMATI, API REST, ISO/IEC 15408:2009, ISO/IEC18045:2008, RAMI 4.0, ISA 95, MIMOSA DB, IoT-A event information model, QIF and P1589-IEEE etc.)? Are you willing to start using a new standard?	1
WP2 - Digital Data Models & Vocabularies	To support the semantic interoperability, are you using any advanced knowledge management approaches (e.g. Ontology, Semantic Web, Knowledge Graph etc.)?	2
	Are you using any digital models, e.g. Digital Twins, to manage project/process data?	3
WP2 - Reference Architecture	Can you explain the main constraints on the TOBE system architecture?	4
WP3 – Connectivity & Networking	Is it required Real Time information?	5
	Are you using a cloud platform? Private or public?	6

WP-topic	Eliciting questions	#
WP3 – HPC and Cloud	Related to Cloud and HPC infrastructures do you need something more than the current solutions? How do you envisage the QU4LITY enhanced infrastructure? Are you already working to enhance your system, or do you expect support from other Partners? In case, have you already identified who?	7
WP3 – AI & Big Data	Is it required to analyse data coming from digital equipment/systems?	8
WP3 – Fog & Edge	Will you use fog/edge device in the pilot? Who will provide edge devices in your pilot? Do you need extra support? Should any sensor be connected to the edge device? Using different field bus interfaces? Are you getting data directly from PLC/SCADA/database?	9
	Does data have to be stored at the edge device locally (not at factory or cloud level)?	10
	Should data be processed locally at the edge?	11
	Do you want to deploy analytics or other application (data gathering or control) at the edge?	12
	Should data be visualized locally?	13
	Where should the data be transferred from the edge device? Do you need to enable data streams from edge to cloud or the control loop will be closed at the edge?	14
	Which virtualization approach are you using at the edge? VMs? Containers?	15
	Do you have to implement closed loop at PLC? Which activities should the edge device take over as PLC / what is being controlled? From where commands will arrive from QU4LITY-enhanced solutions? From QU4LITY enhanced edge and/or cloud?	16
WP3 – Cybersecurity	Is the information shared classified or labelled by importance, confidentiality or critical?	17
	Are there any security measures already implemented on the machine/pilot?	18
	Are there any conditions, that only specific users can perform specific activities (e.g. install programs on the edge device, view data, etc.)?	19
	Do we need to monitor asset activity in the infrastructure? What kind of assets?	20
	Do you plan to carry out a registry of system records? What type of system logs are managed?	21
	Is needed to delegate access control on the assets in this pilot? what types of access, roles, asset, privileges?	22
	Where will be the security assets deployed, on cloud or on premise? (only Siemens)	23
	Is data allowed to be stored in the cloud, or is data only allowed to be in a local storage?	24
WP3 – BlockChain	Do you need distributed execution of control program?	25
	Do you need control check on value-chain transactions?	26

WP-topic	Eliciting questions	#
	Do you need to assure confidentiality and non-repudiation across your business?	27
	Is there any trust deficit among parties in your value chain (both internal and/or external)?	28
WP3 – Interoperability	Is it required the integration with existing tools (i.e., CRM, ERP, MES, CAD, CAM, …)?	29
WP4 - Assets and Smart products	Is required enhancements in: specification of digital enhancements?	30
	Are you using improvements/digital enhancements like the following ones? - self-learning autonomous systems - self-configurable flexible cells - augmented reality - mixed reality platforms - human centred manufacturing systems - predictive maintenance	31
	Are you using other types of digital enhancement?	32
WP4 - IoT Automation Services	Is required enhancements in implementation of digital enhancements?	33
	Which degree of interoperability do you have at device level?	34
	Which degree of interoperability do you have at network level?	35
	Which degree of interoperability do you have at platform level?	36
WP4 - Control Services	Is required enhancements in distributed communication and control infrastructure?	37
	Are you using edge & cloud computing for your control & communication infrastructure?	38
	Which business requirements do you have for enhancing your pilot?	39
	Which kind of validation method do you have for your digital enhancement?	40
WP5 - Modelling and Learning Services	Which quality-related data models do/will you (constantly) use?	41
WP5 - Digital Twin and Planning Services	How are Digital Twins used in the Planning of quality-relevant services?	42
WP5 - Simulation and Human-centric visualization services	Is simulation used to adjust your product/production quality during planning/execution of production a) now b) in the future (pilot-to-be)? How would you describe the visualization required to allow a human to participate in AQ during planning and operation?	43
WP5 - Collaboration, Business and	What services do you expect to be integrated for running AQ Solutions in your Environment?	44

WP-topic	Eliciting questions	#
Operation Services		
WP5 - Engineering and Planning Services	What services do you expect to be applied for the Engineering of AQ Solutions in your Environment?	45

In T2.1 User stories are mentioned to describe the viewpoints of the users of the system. It was decided to use the general user story template: "*(as* ***<role/user>*** *I want* ***<functionality>*** *so that I can* ***<goal/business value>****)".* This template can lead to very detailed user stories usually applied in Agile development. To prevent this a short instruction and an example were added to describe them on the level of an epic according to Agile Alliance (Epic, 2020). The Epics per Industrial Pilot are documented as User Stories as part of Chapter 7.

5.2 Collecting requirements from other relevant projects and initiatives

An overview of relevant projects and initiatives can be found in the QU4LITY Grant Agreement (RODRIGUEZ EDROSO & QU4LITY Consortium, 2018) this list was the starting point to collect the requirements. For each project the QU4LITY partners who were/are involved in the project or initiative were listed, these partners received a questionnaire with the following questions:

Table 4: Questions to collect requirements from other project and initiatives

No.	Question	Explanation/Example
1	Name of the Project	E.g.: H2020 Z-BRE4K
2	Name of your organization	E.g.: Philips
3	Short Description of the project (In max. 10 lines)	E.g.: Z-BRE4K: a novel predictive maintenance platform to eliminate unexpected-breakdowns and extend the life of production systems. The Z-Break solution comprises the introduction of eight (8) scalable strategies at component, machine and system level targeting (1) the prediction occurrence of failure (Z-PREDICT), (2) the early detection of current or emerging failure (Z-DIAGNOSE), (3) the prevention of failure occurrence, building up, or even propagation in the production system (Z-PREVENT), (4) the estimation of the remaining useful life of assets (Z-ESTIMATE), (5) the management of the aforementioned strategies through event modelling, KPI monitoring and real-time decision support (Z-MANAGE), (6) the replacement, reconfiguration, re-use, retirement, and recycling of components/assets (Z-REMEDIATE), (7) synchronizing remedy actions, production planning and logistics (Z-SYNCHRONISE), (8) preserving the safety, health, and comfort of the workers (Z-SAFETY).

No.	Question	Explanation/Example
4	Which gaps are there from your project to Autonomous Quality?	E.g.: Z-Break has a focus on predictive maintenance, focusing on the wear of the equipment. To use the analytics of Z-Break Qu4ality should solve [….].
5	What are relevant requirements from your project for QU4LITY?	Please analyse the requirements document from your project and mention the requirements that are also relevant for the execution of the QU4LITY project. Kindly also add if the requirement is met in the project or not. Requirement "A": [Add relevant requirement here]. – Not met Requirement "B" [Add relevant requirement here]. – Met

The results of this survey can be found in Appendix F.

These approaches were continuously checked and adjusted in the Task Force.

6 Stakeholders

This chapter gives an overview of the stakeholders of the QU4LITY project. The official definition of a "Stakeholder" in the Cambridge dictionary (Cambridge Dictionary, 2020) is: "*a person such as an employee, customer, or citizen who is involved with an organization, society, etc. and therefore has responsibilities towards it and an interest in its success*"

In that light the number of stakeholders in the QU4LITY project can become very high with 44 participating organizations, who each have several employees involved. 14 Industrial Pilot organizations, with their own internal stakeholders. And the Stakeholders outside of the QU4LITY project as described in the Grant Agreement (RODRIGUEZ EDROSO & QU4LITY Consortium, 2018): "*…relevant project's and initiatives (e.g., projects of the 4ZDM cluster, H2020 FoF-09 projects on maintenance etc.). Interactions with stakeholders will be facilitate by the partners' business networks, including clusters, associations (e.g., EFFRA) and DIHs where the consortium partners' play a leading role.*"

In this chapter the most important stakeholders are described, these stakeholders were chosen in the Task Force mentioned in chapter 5.

6.1 Project Stakeholders

European Commission

As its client, the European Commission and all its institutions are an important stakeholder of the QU4LITY program. The requirements of the European Commission are conveyed by the agreement of the program. The government structures and administration of the program secure that the requirements of the European Commission are adopted. The input collected by the Work packages of the program will reflect the requirements of the European Commission too. Moreover, the European Commission reviews the deliverables and can designate complements.

Project Participants

As stated above there are 44 organizations participating in QU4LITY. Technology providers, Research organisations, suppliers and manufactures. Based on the information from CORDIS (Commission, 2020) 61% percent of the participants come from Private for-profit entries, 23% are Research Organisations, 9% are Higher or Secondary Education Establishments and a small portion is labelled as "Other". Also see Figure 9: Graphical representation of the QU4LITY Participants

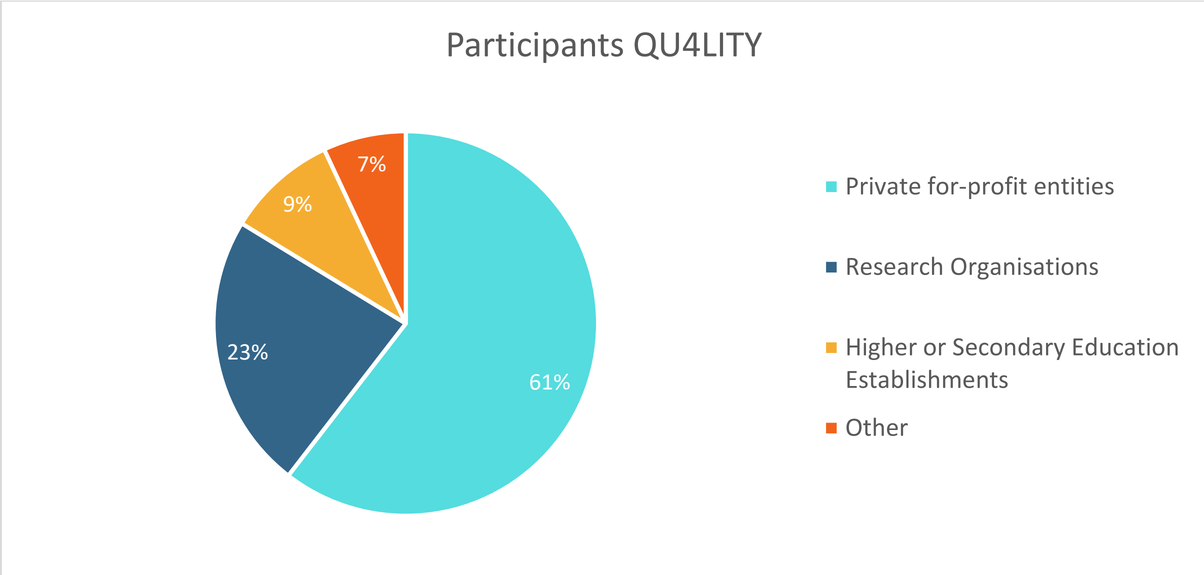

Figure 9: Graphical representation of the QU4LITY Participants

All participants are represented in one or more Work packages.

6.2 Stakeholders from the Industrial Pilots

The industrial Pilots represent a large portion of the actual end users of the solutions of QU4LITY. In the Trial Handbooks described in chapter 2 much information can be found of the stakeholders per pilot. In Appendix D all Actors per Pilot Organization are listed, including information on how they expect to be affected by the QU4LITY project. In this paragraph you can find an aggregation of this.

Table 5: Stakeholders of the Industrial Pilots

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT** **(Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Blue-collar worker	Manufacturing	Direct	Reduction of manual quality checks
Industrial Engineering	Manufacturing, Maintenance / Technical Support	Direct	Altered Systems to maintain, possibly new knowledge domains
Accounting Personnel	Accounting	Indirect	Possibly new calculation schemes to be considered
Management	Management	Indirect	New business cases and Improved business figures
Production operators	Production	Direct	Reduction manual tasks, work on higher abstraction level
Technical Assistance Service	Service	Direct	Shift to predictive maintenance
IT	Technical Support	Indirect	Real time data exchange, improved monitoring, cloud computing, analytics

As part of section 7.15 a more detailed analysis is made of the requirements from the different actors in the Pilots.

6.3 External Stakeholders

A second group of stakeholders that was chosen in the Task Force were the participants in relevant national and international research and innovation initiatives. In the Grant Agreement is described: *QU4LITY brings together the leading partners of a number of recent/on-going H2020 projects that have already produced results very closely related to QU4LITY. QU4LITY will take advantage of these projects in three main directions:*

(i) Reuse of their components (digital enablers, digital platforms) as a means of rapidly bootstrapping the project's results and maximizing value for money

(ii) Exploitation of methodological insights in quality-related aspects of production processes

(iii)Liaisons with other ecosystems as part of QU4LITY's community building efforts.

As described in section 5.2 a survey was sent out to collect inputs from these projects. The results of this survey are documented in Appendix F

7 Requirements from Industrial Partners

This chapter describes the Industrial pilots and their requirements. It gives an overview of all pilots, their objectives and the high-level requirements extracted from the Trial Handbooks. Each pilot manages its own Trial Handbook, managed by WP7. The Trial Handbook is a standardized document for each Pilot and the goal of this document is to capture all Pilot relevant information. It offers a complete overview of the details of the specific Pilot and can be used for reference. In the Trial Handbook all pilots have described the objective of their project and the expected benefits. A complete overview of all available trial handbooks is given in Table 41 in Appendix A.

Each of the following paragraphs will describe one Pilot and will list the Objective, the high-level requirements and the user stories received. In Table 6 an overview of all pilots in the QU4LITY project is given. All requirements from the pilots are combined in one table in Appendix B.

Table 6: Overview of Pilots

Pilot no.	Company	Title
I.1	Philips	Creating a competitive factory by application of autonomous quality on a OneBlade shaving unit production line
I.2	Siemens	Data analytics for ZDM efficiency increase in in electronics production
I.3	Continental	Autonomous Quality in PCB Production for Future Mobility
I.4	Whirlpool	Dryer Factory Holistic Quality Platform
I.5	Mondragon	Zero defect & Autonomous Quality in Machinery Building for Capital Goods sector
I.6	Kolektor	Autonomous detection and removal of defects in injection moulding
I.7	Thyssenkrupp	Quality Management of Steering Gear based on Acoustic control
I.8	Airbus	Trade space framework for Autonomous Quality Manufacturing Systems' Design
I.9	GHI	Real-time cognitive hot stamping furnace 4.0
I.10	RiaStone	Autonomous Quality ZDM implementation for "Ceramic tableware Single-firing"
I.11	PRIMA	Additive Manufacturing Pilot Adaptive Control Technology (AMPACT)
I.12	Danobat	High precision machining – Danobat cutting/grinding machine-tools
I.13	Fagor	Zero-Defects Manufacturing Digital Press Machine
I.14	GF	GF Digital machine and part twins for zero defect manufacturing

Besides the input from the pilots QU4LITY brings together the leading partners of several recent/on-going H2020 projects that have already produced results very closely related to QU4LITY. QU4LITY will take advantage of these projects in three main directions:

- Reuse of their components (digital enablers, digital platforms) as a means of rapidly bootstrapping the project's results and maximizing value for money.
- Exploitation of methodological insights in quality-related aspects of production processes.
- Liaisons with other ecosystems as part of QU4LITY's community building efforts.

In the appendix a list of these projects and their requirements is given.

7.1 Philips

Objective of the Pilot

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 which is under observation
- increases OEE A and P by helping the operator to take correct process adjustment decisions,
- reduces Fall Off Rate by learning from unknown data interactions.

With these elements the next step to autonomous quality/production can be made.

High-level requirements

Table 7: High-level requirements Industrial Pilot Philips

Code	Pilot	High-level requirement
Pilot_Req_PHILIPS_01	Philips	Analyse early indicators and trends from process signals and dimensional CTQs of individual components to predict quality of the finished product
Pilot_Req_PHILIPS_02	Philips	Raise early warning signals based on early indicators and trends from process signals
Pilot_Req_PHILIPS_03	Philips	Suggest feed-forward or feed-backward controls to neighbouring process stations
Pilot_Req_PHILIPS_04	Philips	Help the operator to take correct process adjustment decisions
Pilot_Req_PHILIPS_05	Philips	Learn from unknown data interactions to predict quality

User Stories

Table 8: User stories Industrial Pilot Philips

nr	User story
1	As a production manager I want prescriptive functionality on the shimmer line that automates current manual settings so that I can reduce labour and production costs
2	As a production manager I want prescriptive functionality on the shimmer line that reduces the number of errors in pad printing functionality so that I can reduce scrap and manual quality inspections and reduce costs
3	As a production manager I want prescriptive functionality on the shimmer line that optimizes the assembly of parts in the production process to avoid high torque and related errors
4	As an innovation engineer, I want insights provided by analytics that help me developing production lines that produce within tolerances
5	As a maintenance engineer I want insights provided by analytics that predict maintenance so that I can avoid any errors caused by maintenance in the production line
6	As a quality manager I want automated quality inspections on critical points in the production line resulting in all products within tolerances so that I can limit my activities to norm setting, monitoring and advice
7	As an operator I want a completely automated production line so that I can limit my activities to just feeding material, monitoring and startup/close procedures for planned interruptions.
8	As a data scientist I want a scalable platform that is fed by (near) real time data of current and new sensors of the entire shimmer production chain that describes the properties of the production process in such a detailed way that I can make prescriptive models that avoid any errors in the shimmer line

7.2 Siemens

Objective of the Pilot

With the pilot use case, the overall objective addressed is the improvement of the testing and thus the overall production efficiency. Through the collection of quality-related data on the field level in combination with data mining as well as machine learning techniques for failure classification and process simulation for logistic evaluation, the transparency for the testing and fault identification processes shall be increased. Obtaining a detailed insight into the processed shall, ultimately, lead to the development of ready-to-deploy software solutions. At the same time, the production costs are aimed to be reduced by omitting costly quality checks where they might not be necessary.

The main objectives can be briefly summarized as follows:

- Increase in added values by reducing production costs which are caused by 100% quality tests in the production line
- Identification of the potential to reduce rework on defective products through analysis of error propagation of the whole process
- Potential roll out of the developed solutions to additional lines and, later, productions sites

High-level requirements

Table 9: High-level requirements Industrial Pilot Siemens

Code	Pilot	High-level requirement
Pilot_Req_SIEMENS_01	Siemens	Reduction of operator time investment for inspection
Pilot_Req_SIEMENS_02	Siemens	Increase of transparency and track ability of errors throughout the line
Pilot_Req_SIEMENS_03	Siemens	Long-term increase of the resulting quality of the products in the long term by facilitating root cause analysis
Pilot_Req_SIEMENS_04	Siemens	Reduction of investment cost for quality tests
Pilot_Req_SIEMENS_05	Siemens	Reduction of product line disruptions through the avoidance of optional inspections

To achieve the objectives and provide the targeted benefits, the technologies that are to be implemented are first aiming to create insight into the available processes and data. Through the gradual application, the steps in the data mining process, as well as the application of corresponding methods, the desired level of transparency, shall be achieved. Once that level is reached, the applied methods are going to be refined leading to multiple specialized solutions which target at least one of the specified benefits mentioned above.

User Stories

nr	User story
1	As production manager I want a lever to reduce test effort without losing product quality.
2	As a quality manager I want an overview of quality affecting processes and components so that I can take care of root causes and indicate counter measures to ensure zero defect manufacturing with lowest failure rate.
3	As a line manager I want prescriptive functionality on failure propagation so that I can optimize the test process along production line.
4	As a line manager I want analytic functionality on test quality so that I can decide which test stations work well, which test stations cause bottlenecks, which tests should be added or which tests could be reduced.
5	As a line manager I want analytic functionality on test station quality so that I know how to improve the test process for the test station.

6	As operator I want reliable test results so that I can save unnecessary inspection time in case of false positives.
7	As operator I want interpretable test results so that I know the problem immediately and I can optimize repair time.

7.3 Continental

Objective of the Pilot

In this context it is the goal of Continental in QU4LITY to support the realization of a Zero-Defect Scenario for multi-stage production lines through capturing, communicating, secure storage and visualizing real-time holistic data on products, material, equipment, environment, human actions and quality 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.

High-level requirements

Table 10: High-level requirements Industrial Pilot Continental

Code	Pilot	High-level requirement
Pilot_Req_CONTI_01	Continental	Integrate with warehouse, Individual production lines and support production area's e.g. Planning, quality control and process settings
Pilot_Req_CONTI_02	Continental	Progress in the establishment of an advanced shop floor and machine communication
Pilot_Req_CONTI_03	Continental	Safe, secure and trustworthy data processing and storage
Pilot_Req_CONTI_04	Continental	Inclusion of the full value chain
Pilot_Req_CONTI_05	Continental	Next generation of shop floor visualization management

User Stories

Table 11: User stories Industrial Pilot Continental

nr	User story
1	As an operator I want to get aware of suspicious behaviour of a machine so that I can initiate corrective actions to avoid NOK parts production before occurrence
2	As an operator at a customer goods packing station, I want to get a risk evaluation for the shipment that I am currently working on so that I can hold the shipment in case of exceeding defined limits
3	As an operator at a customer goods packing station, I want to get an easy to understand visualisation of the different aspects of the risk, so that I can hold the shipment in case of exceeding defined limits
4	As a data scientist I want to get access to all data structured or unstructured that have a relation to the shipment that is object for a risk evaluation in order to detect abnormalities.
5	As a trainee for a workstation I want to get visual instructions from a virtual trainer via smart glasses to that I do not need a real trainer.

nr	User story
6	As a Maintenance Worker I want I want to get visual instructions from a virtual Expert via smart glasses to that I can follow maintenance and change over instructions without having to carry documents or to know them by heart.
7	As a supplier I want to get video and audio access to Equipment at customer sites in order to do problem solving without having to travel.

7.4 Whirlpool

Objective of the Pilot

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).

High-level requirements

Table 12: High-level requirements Industrial Pilot Whirlpool

Code	Pilot	High-level requirement
Pilot_Req_WHR_01	Whirlpool	A common and holistic semantic model able to represent concepts at different stages of product lifecycle;
Pilot_Req_WHR_02	Whirlpool	Standard methods and tool to gather, store and share data;
Pilot_Req_WHR_03	Whirlpool	Trustworthy digital continuity and data management
Pilot_Req_WHR_04	Whirlpool	Flexible and user-friendly analytical tools - Human-centric big data visualization
Pilot_Req_WHR_05	Whirlpool	Comprehensive way to share results among different management roles
Pilot_Req_WHR_06	Whirlpool	Equipment and process simulation and optimization solution as major leverage towards the efficient realization of complex first-time-right parts
Pilot_Req_WHR_07	Whirlpool	Implementation of a closed loop over the manufacturing process between digital and real domains

User stories

Table 13: User stories Industrial Pilot Whirlpool

nr	User story
1	As Plant Director I want to have a configurable cockpit of the KPI plant indicators, the configurability allows to have to quality issues in real time highlighted in according to the 4 main plant elements: Material, Quality, Process and Functions
2	As a Quality Plant Manager want to know and understand in real time what the most pressing problems are. In relation to the type of models that are in production, and in relation to the defect data on the market. The data must be correlated in an integrated way allowing a projection according to the seasonality and type of materials used
3	As IE Plant Manager want to have a global picture of the efficiency status of the production plants, in particular the drum production area, the heat pump area and the functional tests area. Knowing the efficiency allows me to prevent any problems by acting on a schedule of maintenance interventions on plants that are critical for production
4	As Quality Test Engineer want to know what factors are affecting the quality parameters for each product and aggregated by model. This allows me to make decisions that can concern the set-up of the production areas as well as the programming of new test plans, aimed at solving product and process quality problems effectively and quickly. The information can be aggregated so that I can

nr	User story
	know what the factor is that most influences the reduction of quality: Material, Process or Function.
5	As Group Leader Assembly have the task of checking that the production plan is carried out correctly and that all the stations have the right materials allocated in accordance with the current production plan. Having a tool that warns me if quality problems are underway on the product and / or the process allows me to re-balance production in order to have a low impact on the various KPIs, acting on the redistribution of activities and materials in the various locations of work.
6	As Group Leader Primary Process must understand how the machine that produces the drums, the core element of a dryer, is working. A whole series of dimensional and vibrational parameters are collected during production, and therefore to understand that the production trend meets the quality and productivity requirements (see Kpi) time and the aggregation of information are a fundamental factor. This allows me to act on the individual adjustments of the machine to correct size deviations in order to have harmful effects on the final configuration of the drum

7.5 Mondragon

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.

7.5.1 SCENARIO 1) Manufacturing Processes with Cutting/Grinding Machinery

Objective of the Pilot: Scenario 1

The main focus on multistage zero defect manufacturing is based on guaranteeing the optimal condition of the different process involved at railway Station to perform high processes together with precision machining.

7.5.1.1 High-level requirements for Scenario 1

Table 14: High-level requirements Industrial Pilot Mondragon; Scenario 1

Code	Pilot	High-level requirement
Pilot_Req_MON_01	Mondragon	Set up a data acquisition System
Pilot_Req_MON_02	Mondragon	Create a data management platform
Pilot_Req_MON_03	Mondragon	Perform data analysis
Pilot_Req_MON_04	Mondragon	Implement Cyber Physical Systems
Pilot_Req_MON_05	Mondragon	Use a platform for testing and simulating
Pilot_Req_MON_06	Mondragon	Standardize data models and protocols
Pilot_Req_MON_07	Mondragon	Enhance DSS System

7.5.2 SCENARIO 2) Manufacturing Processes with Hot Stamping Machinery

Objective of the Pilot: Scenario 2

The objective of this project is to reach zero defects manufacturing process collecting hot stamping critical parameters and identifying exactly the process developed in the manufacturing of parts. 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. In order to go a step further, cognitive manufacturing proposes the utilization of data across systems to derive actionable insight through the entire value chain. We envision the usage of data analysis not only at the press machine but to have a holistic view of the production.

The implementation of this process control of hot stamping facilities, would allow customers to:

- To know in more depth, the manufacturing process and the variables that are involve in it.
- Detect defective parts and the reasons why they manufactured in this way and fix the error.
- Improve and optimize the manufacturing process of boron steel components through hot stamping.

High-level requirements for Scenario 2

Table 15: High-level requirements Industrial Pilot Mondragon; Scenario 2

Code	Pilot	High-level requirement
Pilot_Req_MON_08	Mondragon	Share data (sensorized + pre-processed) with other parties of the supply chain (clients / providers) in a controlled environment where security, privacy and data trust is taken into account.
Pilot_Req_MON_09	Mondragon	Support a changing supply chain where actors and their needs changes, by allowing the elasticity of the platform. This elasticity enables the optimization of the resources and the reliability of the solution

User Stories

Table 16: User Stories Industrial Pilot Mondragon

nr	User story
1	As a maintenance manager I want to receive production line status associated with the different parts of the processes.
2	As a maintenance manager I want to introduce predictive algorithms within IIoT platform to evaluate the production line status and its components

nr	User story
3	As a machine expert I want to receive messages and data related to production lines to propose new improvements
4	As digital innovation expert I want to receive real data about the performance of the productions lines to enable new improvements associated with ZDM approach
5	As a plant manager I want to see the evolution of the variables defined as key for the performance of the production lines. Furthermore, I want to know the status of the of the machines and industrial devices to IIoT platform and Cloud environment
6	As a digitally enhanced machines manufacturer I want to connect and update the developments either local and edge easily
7	As an operator I want the production line is capable of identify an anomalous working condition and send me alarms when they occur in real-time
8	As an operator I want the production to be as automated as possible, the production line should be able to indicate recommendations for improving the performance as well as correcting them as automatically as possible.
9	As a data scientist I want collect as much data as possible from the production line devices taking into account working conditions.

7.6 Kolektor

Objective of the Pilot

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.

Based on the collected data and by applying 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. For example, we will look for correlations between the visually detected defects and the parameters of machinery involved in the production process. By collecting a sufficient amount of data, it will become possible to modify the production process parameters to remove defects of injection moulding.

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 movements required for inspection. We will 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).

High-level requirements

Table 17: High-level requirements Industrial Pilot Kolektor

Code	Pilot	High-level requirement
Pilot_Req_KOL_01	Kolektor	Have a better understanding of moulding process.

Pilot_Req_KOL_02	Kolektor	Have real-time detection and possibly prediction of failures based on advanced analytics and artificial intelligence.
Pilot_Req_KOL_03	Kolektor	Implementation of feedback loop for troubleshooting (e.g. setting process parameters, cleaning the moulding tool).

User Stories

Table 18: User stories Industrial Pilot Kolektor

nr	User story
1	As a production manager, I want prescriptive functionality on the injection moulding line that automates current manual settings so that I can reduce labour and production costs
2	As a production manager, I want prescriptive functionality on the injection moulding line that reduces the number of defects during the moulding process so that I can reduce scrap and manual quality inspections and reduce costs
3	As an innovation engineer, I want insights provided by analytics that help me improve injection moulding production lines that produce within tolerances and without defects
4	As a maintenance engineer, I want insights provided by analytics that predict maintenance so that I can avoid any errors caused by equipment breakdown in the injection moulding production line
5	As a quality manager, I want an automated quality inspection system on critical points in the injection moulding production line resulting in all products within tolerances so that I can limit my activities to norm setting, monitoring and advice
6	As an operator, I want a completely automated injection moulding production line so that I can limit my activities to just feeding material, monitoring and start-up/close procedures for planned interruptions.
7	As a data scientist, I want a scalable platform that is fed by (near) real time data of current and new sensors of the entire injection moulding production chain that describes the properties of the production process in such a detailed way that I can make prescriptive models that avoid any errors in the injection moulding line

7.7 ThyssenKrupp

Objective of the Pilot

Individual part defects are … 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.

High-level requirements

Table 19: High-level requirements Industrial Pilot ThyssenKrupp

Code	Pilot	High-level requirement
Pilot_Req_THYS_01	Thyssen	consecutively performing quality checks on a part level
Pilot_Req_THYS_02	Thyssen	Real-time adaptation of the assembly line parameters
Pilot_Req_THYS_03	Thyssen	implement a data acquisition system distributed on various points on the production line to capture: • in-process sensor data • data from the production monitoring system • operator data
Pilot_Req_THYS_04	Thyssen	Create a data model

User Stories (By CEA)

nr	User story
1	As an innovation engineer, I want to gain physical insight in process steps provided by advanced sensing technologies combined with analytics that help me to understand error sources and to avoid them in machines and productions lines

7.8 Airbus

Objective of the Pilot

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.

The idea is to build an integrated platform of process, methods and tools that are centred on these two approaches to support trade process: ZDM and autonomous quality.

High-level requirements

The general functional requirements of the integrated platform to support trade can be summarized by the system having the following capabilities:

Table 20: High-level requirements Industrial Pilot Airbus

Code	Pilot	High-level requirement
Pilot_Req_AIRBUS_01	Airbus	Define and describe objective
Pilot_Req_AIRBUS_02	Airbus	Identified candidates' technical options when known
Pilot_Req_AIRBUS_03	Airbus	Define inputs
Pilot_Req_AIRBUS_04	Airbus	Define constraints
Pilot_Req_AIRBUS_05	Airbus	Identify Stakeholders (name, role...)
Pilot_Req_AIRBUS_06	Airbus	Define scope
Pilot_Req_AIRBUS_07	Airbus	Define requirements
Pilot_Req_AIRBUS_08	Airbus	Define trade space exploration
Pilot_Req_AIRBUS_09	Airbus	Define design parameters + ranges + Design of Experiments
Pilot_Req_AIRBUS_10	Airbus	Define assessment criteria + weighting methods + associated objectives (minimize, maximize)
Pilot_Req_AIRBUS_11	Airbus	Define alternatives
Pilot_Req_AIRBUS_12	Airbus	Perform Multi-criteria assessment + Ranking
Pilot_Req_AIRBUS_13	Airbus	Select Alternatives (or areas of alternatives)
Pilot_Req_AIRBUS_14	Airbus	Trade space Exploration (pareto analysis, surface graphs, change propagation from parameters to KPIS)
Pilot_Req_AIRBUS_15	Airbus	Surrogate modelling
Pilot_Req_AIRBUS_16	Airbus	Perform sensitivity analysis
Pilot_Req_AIRBUS_17	Airbus	Design of experiments selection
Pilot_Req_AIRBUS_18	Airbus	Model integration

User stories

Table 21: User stories Industrial Pilot Airbus

nr	Epic
1	As an Industrial Architect I want to design or re-configure my industrial system in a seamless, scalable and collaborative digital environment (using MBSE methods), to define the industrial system that will produce my products with zero defects
2	As an Industrial Architect I want to manage industrial requirements, define industrial architectures and execute trade-offs to select the optimal industrial system architecture for target performances
3	As an Industrial Architect I want to visualize scenarios and have decision making engines, to select the optimal industrial system architecture for target performances
4	As an Industrial Architect I want to use referent concepts from defined ontologies, to make Industrial System architecture option and trades
5	As Manufacturing Engineer, I want to industrialize my product collaboratively for the given industrial system architecture options, to assure zero defect manufacturing
6	As Industrial System Engineer, I want to reuse Industrial System Architecture options defined by Industrial Architects, to have a first definition of my performance/behaviour model (objects)
7	As Industrial System Engineer, I want to push the results of my simulations (parameters) to feed trade-off process

8	As Industrial System Engineer, I want a scalable platform to manage configuration and lifecycle of Performance Model and data to feed architecture specification
10	As an Ontology Engineer, I want to create concepts models (ontology) and have a visual representation of the knowledge captured, to capture business objects & rules and parameters relationship and define the semantic of the concepts
11	As an Ontology Engineer, I want a scalable platform to manage ontologies configuration to have complete and formal ontology within a collaborative environment.

7.9 GHI

Objective of the Pilot

The objective of this pilot consists on the development of some enhancements that could guarantee an improved operation of the hot stamping line to reach the Zero-Defect Manufacturing target. More specifically, this objective can be divided into the following:

- To reduce defective parts manufacturing, especially crack formation. This is intended to be achieved through increased control and also thanks to the monitoring of the industrial furnace operating parameters.
- To optimize production process. The holistic approach given by this performed control platform will provide a balance between the different element's interaction. These performances will lead to a sustainable production.
- To obtain a modular solution: extensible, scalable, customizable and, replicable system that could be transferable to other process industries; e.g. steel industry.

High-level requirements

Table 22: High-level requirements Industrial Pilot GHI

Code	Pilot	High-level requirement
Pilot_Req_GHI_01	GHI	Integrate new IoT sensors
Pilot_Req_GHI_02	GHI	Improve data gathering system
Pilot_Req_GHI_03	GHI	Improve the data analysis system.
Pilot_Req_GHI_04	GHI	Improve the efficiency and control of the hot stamping process.

User stories

Table 23: User stories Industrial Pilot GHI

nr	Epic
1	As a production manager, I want an improved monitoring and data analysis platform in order to ease decision-making on the hot stamping line operation (mainly on the industrial furnace), enabling the optimization of the production process and so reduce (furnace) operational costs.
2	As a production manager, I want to analyse the correlation between quality control and furnace operation parameters for a fast detection of root cause of quality problem in order to optimize the production process but also to reduce the number of defective parts manufactured.
3	As a production manager, I want an improved monitoring and data analysis platform in order to ease decision-making on the hot stamping line operation (mainly on the industrial furnace), enabling the optimization of the production process and so reduce energy consumption.
4	As an IT provider, I want to deploy a robust data gathering solution that does not allow losses in data transmission to GHI external cloud assuring the quality of data.

nr	Epic
5	As a data Scientist, I want to obtain insights provided by the data analytics through the development of algorithms fed by the furnace operational data, in order to facilitate the optimize the furnace operation.
6	As a data scientist, I want a scalable and adaptable platform that could be fed by (near) real time data of current and new sensors integrated on the industrial furnace that allows a complete control of it and that also customized to the production process where it is integrated.
7	As a maintenance engineer, I want insights provided by trends analysis on the furnace operation for a fast detection of root cause of operational problems that requires maintenance operation, in order to reduce breakdown times.
8	As a quality manager, I want automated quality inspections to analyse crack formation on hot stamped parts, within the tolerances defined so that I can limit my activities to norm setting, monitoring and advice.
9	As a quality manager, I want insights provided by the cross-analysis between quality data and furnace operational parameters in order to find a correlation or detect trends in order to optimize the furnace operation and reduce crack formation.
10	As a Blue-Collar worker, I want a completely and improved visualization tool that ease decision-making inline operation.

7.10 RiaStone

Objective of the Pilot

Ria Stone has the objective of using the QU4LITY ZDM Systems and Processes, in order to create significant value to RiaStone by contributing for the development of a robust OPE improvement system, as well as contributing for significant energy efficiency improvements. The first level objectives for the ZDM process introduction through QU4LITY for RiaStone are:

Table 24: Objectives Industrial Pilot RiaStone

Area	Description	Measuring Unit
OPE	Increase the overall OPE KPI from 92% to 95%	% OPE Algorithm
Raw Material Reuse	Product quality improvements achieved through the new ZDM QU4LITY technologies in the production lines, will have a reuse rate of 70%	Units
Firing Oven efficiency	Through the use of ZDM QU4LITY Data technologies, 100% of the produce introduced in the firing oven will present no defects	Units

High-level requirements

Table 25: High-level requirements Industrial Pilot RiaStone

Code	Pilot	High-level requirement
Pilot_Req_RIA_01	RiaStone	Timely raise early detection warning signals of production factors that will originate product defects
Pilot_Req_RIA_02	RiaStone	Materialize feed-forward or feed-backward controls and adjustments to neighbouring process areas
Pilot_Req_RIA_03	RiaStone	Have correction capability over the future course of overall production
Pilot_Req_RIA_04	RiaStone	Effectively increase OPE by helping the factory operator to take correct process adjustment decisions
Pilot_Req_RIA_05	RiaStone	Increase FPY overall in the complete production lines of Riastone

User stories

Table 26: User stories Industrial Pilot RiaStone

nr	User story
1	As a production manager I want automated dimensional conformity checks so that I can have defective products automatically removed early from the production Lines
2	As a production manager I want that the dimensional conformity data automatically reconfigures through edge node computing the isostatic Press settings data, so that I can have early elimination of defect production
3	As a production manager I want automated glazing uniformity control checks so that I can have defective products automatically removed early from the production Lines
4	As a production manager I want that the glazing uniformity control data automatically reconfigures through edge node computing the Glazing viscosity control settings data, so that I can have early elimination of defective production
5	As a production manager I want the automation QC verifications from the current operator-based verifications so that I can reduce labour and production costs
6	As a Maintenance manager I want evident and timely detected machine performance variations to be reported early, so that I can reduce the downtime of Manufacturing line components keeping the complete manufacturing system at 99% availability status
7	As a Maintenance manager, I want insights provided by analytics that help me to maintain production lines that produce within assigned conformity tolerances
8	As a Maintenance manager I want insights provided by analytics that predict needed maintenance so that I can avoid any errors caused by lack of timely maintenance in the production line

9	As a quality manager I want automated quality inspections on critical points in the production line resulting in all products within tolerances so that I can achieve and report 99% OPE efficiency
10	As an operator I want a completely automated production line so that I can limit my activities to just manufacturing line monitoring, and start-up/close procedures for planned interruptions.
11	As a data scientist I want a scalable platform that is fed by real time sensor data of the entire Greenware/Tableware production chain that controls the conformity and the quality production process in such a detailed way that I can assure the lowest possible defects rate, and the best possible FPY indicator in the RiaStone Factory
12	As a production manager I want automated dimensional conformity checks so that I can have defective products automatically removed early from the production Lines

7.11 PRIMA

Objective of the Pilot

Main activities in Prima Pilot case will focus on Additive Manufacturing for collecting, tracking and analysis of data to enhance process robustness.

Additive Manufacturing has proven its benefits across a number of industries and use cases, while research has widely invested in consolidating the opportunities envisaged years ago, also opening the door to new cutting-edge solutions. Nevertheless, the high operative costs of the process and the high cost of additive-manufactured products make this technology still uncompetitive. The main reason is the low productivity of the technology and process variability and its low robustness is one of the factors that impact on this reason.

The ambition is to create a modular monitoring and control system that can be used with many different sensors and process models, in order to increase process robustness and reach the ZDM target. 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.

Thanks to this new approach with modular adaptable signal processing system that can operate to RAMI standards on the edge (connectivity to MES and control systems) and a strong interaction with data space and simulation tools trough the Prima’s fleet management platform, will be possible to detect anomaly and have an equipment condition reporting, reduce reject rate by application of data-driven process model that has been derived by AI algorithms, increase OEE by recommending process adjustments to the operator or directly change the parameters in real time, so to reduce also the operator costs.

High-level requirements

Table 27: High-level requirements Industrial Pilot PRIMA

Code	Pilot	High-level requirement
Pilot_Req_PRIMA_01	PRIMA	Create a modular monitoring and control system that can be used with many different sensors and process models
Pilot_Req_PRIMA_02	PRIMA	Analyse real-time process and machine signals with machine-learning algorithms to find structures and pattern related to the required key quality indicators (critical defects per track, distortion, keeping of dimensions).
Pilot_Req_PRIMA_03	PRIMA	Connect the system to a higher-level factory data interface
Pilot_Req_PRIMA_04	PRIMA	Exchange process information and reassign the production strategy based on additional factory conditions
Pilot_Req_PRIMA_05	PRIMA	operate to RAMI standards on the edge (connectivity to MES and control systems)
Pilot_Req_PRIMA_06	PRIMA	interaction with data space and simulation tools trough the Prima's fleet management platform
Pilot_Req_PRIMA_07	PRIMA	recommend process adjustments to the operator or directly change the parameters in real time

User Stories

Table 28: User stories Industrial Pilot PRIMA

nr	User story
1	As an application engineer I want time estimation and first check verification to avoid failure and so reduce time and cost
2	As an R&D engineer I want insights provided by analytics that help me understanding components that need to be improved
3	As an innovation engineer I want insights provided by analytics that help me understanding key features on the market for competitiveness
4	As a service engineer I want insights provided by analytics that predict maintenance so that I can avoid any errors caused by maintenance on the machines and provide always a best services for customers
5	As a quality manager I want automated quality inspections on critical points in the part production so that I can easily check the results
6	As an operator I want new digital devices (for instance AR/VR Tools) that help me avoid any mistake and set-up the machine in the proper way

nr	User story
7	As a trainer operator I want new digital devices (for instance AR/VR Tools) that help me to teach better and faster the new operators.
8	As a data scientist I want a scalable platform that is fed by (near) real time data of current and new sensors of the systems that describes the properties of the production process in such a detailed way that I can make smart algorithms for prediction processes

7.12 Danobat

Objective of the Pilot

The DANOBAT machine level trial has the goal to build enhanced DANOBAT AQ Precision Grinding machines by means of incorporating hardware (CPS) and software (AI fingerprints) to the machine taking advantage and integrating QU4LITY technology modules.

High-level requirements

Table 29: High-level requirements Industrial Pilot Danobat

Code	Pilot	High-level requirement
Pilot_Req_DAN_01	Danobat	Gather data through sensors
Pilot_Req_DAN_02	Danobat	Connect to an edge and cloud infrastructure
Pilot_Req_DAN_03	Danobat	Extract/download data for analysis
Pilot_Req_DAN_04	Danobat	Develop machine learning models
Pilot_Req_DAN_05	Danobat	Automate communication of information with users
Pilot_Req_DAN_06	Danobat	Auto correct processes

User stories

Table 30: User stories Industrial Pilot Danobat

nr	User story
1	As a maintenance manager I want to receive warnings about the condition of the machine and its components
2	As a machine expert I want to receive real working condition data of the machines to be able to design improvement for new machine models
3	As a machine and digital innovation expert I want to receive real data about the performance of the machines to be able to develop new digitally enhanced functionalities to improve the value added to the client and help to achieve a zero-defect manufacturing
4	As a plant manager I want to control de connection of the machines to the internet and I feel more comfortable if the digitally enhanced machines can provide their

nr	User story
	functionalities with restrictions of the connection to the cloud (for example I want to actively give the connection periodically and by a limited amount of time)
5	As a digitally enhanced machines manufacturer I want to be able to embed intelligent functions at the edge in the machine. So the developments done with the data collected from the cloud can be easily installed at plant level.
6	As an operator I want the machine to be able to identify an anomalous working condition and send me alarms when they occur
7	As an operator I want the production to be as automated as possible, the machine should be able to identify problems and correct them as automatically as possible.
8	As a data scientist I want collect as much data as possible from the machine working conditions, I need data to be easily analysed

7.13 Fagor

Objective of the Pilot

This pilot, 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.

High-level requirements

Table 31: High-level requirements Industrial Pilot Fagor

Code	Pilot	High-level requirement
Pilot_Req_FAGOR_01	Fagor	Implement prescriptive analytics
Pilot_Req_FAGOR_02	Fagor	Identify optimum press machine control parameters
Pilot_Req_FAGOR_03	Fagor	Gather data from machine sensors
Pilot_Req_FAGOR_04	Fagor	Gather data of the part under manufacturing
Pilot_Req_FAGOR_05	Fagor	Implement an autonomous control loop
Pilot_Req_FAGOR_06	Fagor	Provide information about the future part quality

User stories

Table 32: User stories Industrial Pilot Fagor

nr	User story
1	As a maintenance manager I want to receive warnings about the condition of the machine and its components
2	As a machine expert I want to receive real working condition data of the machines to be able to design improvement for new machine models
3	As a machine and digital innovation expert I want to receive real data about the performance of the machines to be able to develop new digitally enhanced functionalities to improve the value added to the client and help to achieve a zero-defect manufacturing
4	As a plant manager I want to see the evolution of the variables defined as key for the performance of the machine. Furthermore, I want to know the status of the of the machines and industrial devices to IIoT platform and Cloud environment
5	As a digitally enhanced machines manufacturer I want to connect and update the developments either local and edge easily
6	As an operator I want the machine to be able to identify an anomalous working condition and send me alarms when they occur
7	As an operator I want the production to be as automated as possible, the production line should be able to indicate recommendations for improving the performance as well as correcting them as automatically as possible.
8	As a data scientist I want collect as much data as possible from the machine working conditions, I need data to be easily analysed. I also want to access the data with easy tools and deploy the algorithms in production easily.

7.14 GF

Objective of the Pilot

The GF pilot will set up a first digital system for detecting, diagnosing, and fully compensating deviations on accuracy, productivity and sustainability of a robotized machining cell based on the aggregation of information from Milling and Electro erosion (EDM) machinery health, process performance and geometrical part characterization. This will be achieved by implementing a common data space for making possible a realistic information integration of such multistage processes, from different types of hardware & software coexisting at different end-users' factories, and targeting fully automated, zero defect manufacturing across the full chain."

In the particular domain of High Speed Milling, the pilot will develop an advanced, high precision data-driven system for the manufacturing of aerospace components by closing the loop with the machining strategy design stage after data collection from on-machine geometrical measurements, machine component stage and critical process parameter data. A similar objective will target EDM machines, using measurement systems integrated in automated cells and setting up a multi-process adaptive - deviation compensation process with focus on mould and die applications.

High-level requirements:

Table 33: High-level requirements Industrial Pilot GF

Code	Pilot	High-level requirement
Pilot_Req_GF_01	GF	Create Data storage space
Pilot_Req_GF_02	GF	Implement Cloud infrastructure
Pilot_Req_GF_03	GF	Perform Data analytics in different authorized environments
Pilot_Req_GF_04	GF	Set up a Digital Twin for error compensation, KPI prediction and control
Pilot_Req_GF_05	GF	Create a simulation-based framework to update NC codes and maintenance plans
Pilot_Req_GF_06	GF	Create Semantic data models and acquisition systems
Pilot_Req_GF_07	GF	Data collection campaign for pre-defined use cases and digital model and KPIs optimization

User stories

Table 34: User stories Industrial Pilot GF

nr	User story
1	As a production manager I want predictive functionality on the automated line that estimates time and costs for part production and allows for selecting the best machining strategies for a mould or production part following the factory KPIs
2	As a production manager I want prescriptive functionality on the automated line that provides an automated adjustment of offsets and machining strategies so to attain the required accuracy in the mould of part
3	As a production manager I want a prescriptive functionality on the automated line which anticipates equipment failures and part defects and maximises OEE
4	As a design engineer I want a predictive functionality that provide guidance for designing the tools so that manufacturing quality and costs are optimised
5	As a maintenance engineer I want a prescriptive functionality provided by analytics which indicates sufficiently in advance the time and component to be replaced so that maximum efficiency of the equipment is maintained and defects are avoided on production parts
6	As a quality manager I want an automated quality control that exploits data from CMM machines and machine reports in order to check potential defects and allow automated correction or updates in case they arise during the production process

nr	User story
7	As an operator I want a completely automated production line so that I can limit my activities to just feeding material, monitoring and start up/close procedures for planned interruptions.
8	As a data scientist I want a scalable platform that is fed by real time data from machine sensors of the entire automated line, including the CMM, containing all needed parameters for the deployment of efficient predictive and prescriptive algorithms, to be used for supporting the design, manufacturing and quality control phases of the production process according to the factory KPIs.

7.15 Analysis & Conclusions

As discussed in Chapter 5 the high-level requirements were refined using eliciting questions and processing by the work packages. The outcomes of this exercise are documented in chapter 8.

7.15.1 Analysis of High-level requirements

In Table 35**Error! Not a valid bookmark self-reference.** the high-level requirements from the industrial partners are categorized and summed per category. This table shows that most pilot requirements are related to data management in general and some specific phases e.g. data collection, data visualization and data mining. It reflects the fact that most pilots realized the importance of their data and wish to exploit the value contained. However, they are facing difficulties in handling their data. Some more advanced requirements are also proposed such as autonomous control, decision support, quality monitoring and prediction, as well as production system optimization etc. These requirements demonstrate that at least some pilots require more than just digitalization. Instead, they hope to reach a higher level of intelligence which aligns with the vision of Industry 4.0 and the aim of QU4LITY project. In Figure 10 the data is visualized in a graph which gives a better overview of the distribution of the requirements across the categories.

Table 35: High-level requirements categorized

HL Requirement	Sum
Autonomous control	6
Cyber Physical Systems	2
Data collection	7
Data management	12
Data mining	8
Data visualization	2
Decision support	6
Digital Twins	3
Model based systems engineering	1
Predictive maintenance	1
Production system optimization	9

Quality monitoring	5
Quality prediction	8
Root cause analysis	2
Semantic modelling	3

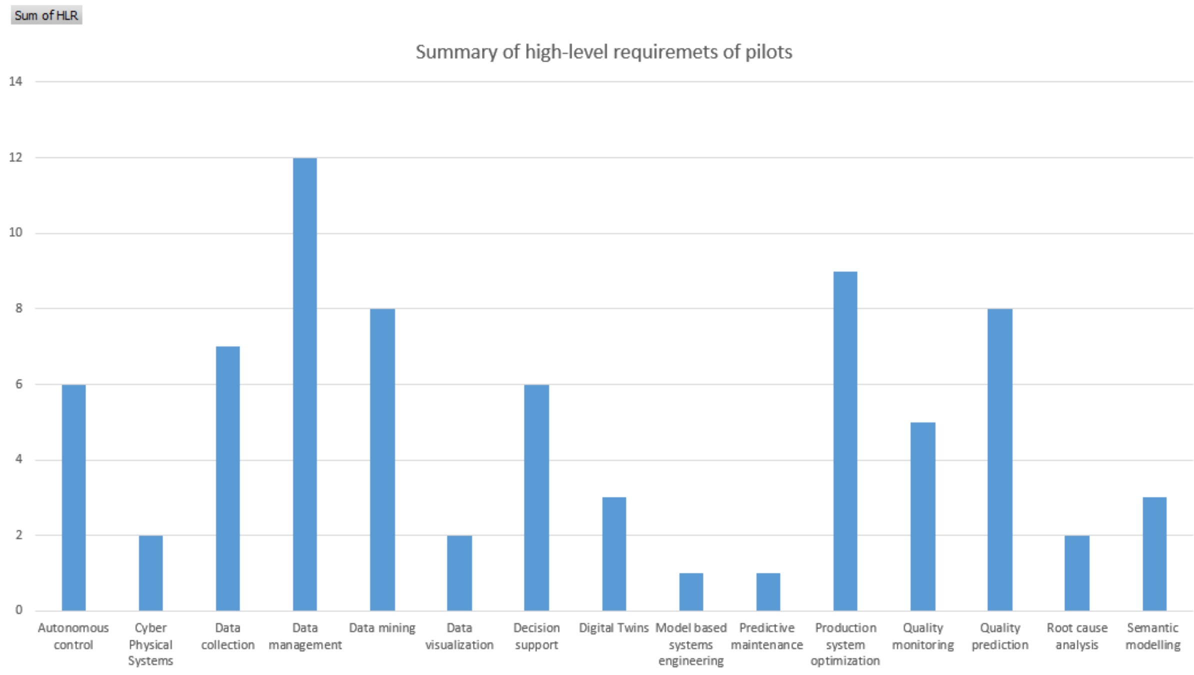

Figure 10: Graphical overview of high-level requirements

7.15.2 Analysis of User stories

Across the different Pilots there are various names for roles, for the analysis a general role was chosen for further analysis. For example, "Maintenance manager" and "Maintenance Engineer" are both categorized as Maintenance manager.

The analysis of the user stories shows that the Actor groups that contributed the most in the industrial pilots are the Production/Plant managers, the innovation Engineers and the Operators. A visual overview of all Actor Groups and the number of User stories is shown in Figure 11

This top 3 of Actors have been analysed further in the sections below. An overview of all User stories per actor group is added in Appendix C.

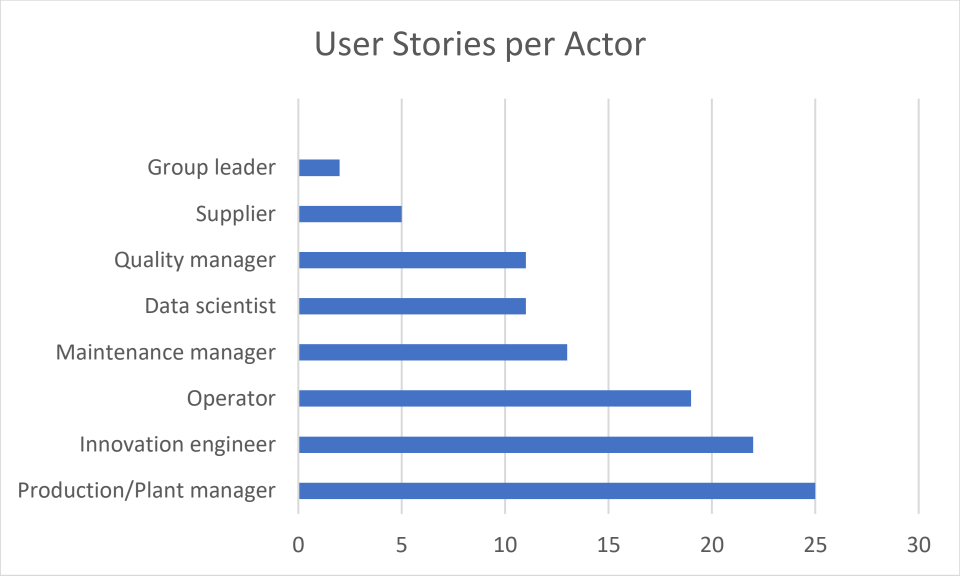

Figure 11: Graphical overview of User Stories by Actor

Production or plant manager

The user stories of the production or plant manager are mostly focused on prescriptive functionality, automated quality checks and performance information of machines/equipment (Figure 12). Their main interest is in reducing scrap or excluding the defective products/parts. Of course, also reduction of cost is an important outcome generally, specifically in the area of labour, more details can be found in Figure 13. In general, the core of these user stories from production or plant managers is zero-defect manufacturing which is the ultimate goal of QU4LITY project despite the differences of their specific focuses. For example, the aforementioned prescriptive functionality corresponds to the QU4LITY objective of predictive maintenance and defect prediction, automated quality checking corresponds to the cognitive and autonomous control, performance information of machines/equipment reflects the digital twin objective etc. These stories also align with the high-level requirements presented in the previous section. Most of these stories and requirements are fully covered in the QU4LITY vision and will be divided into more detailed lower-level requirements, making them achievable through the reference architecture and related enabling technologies.

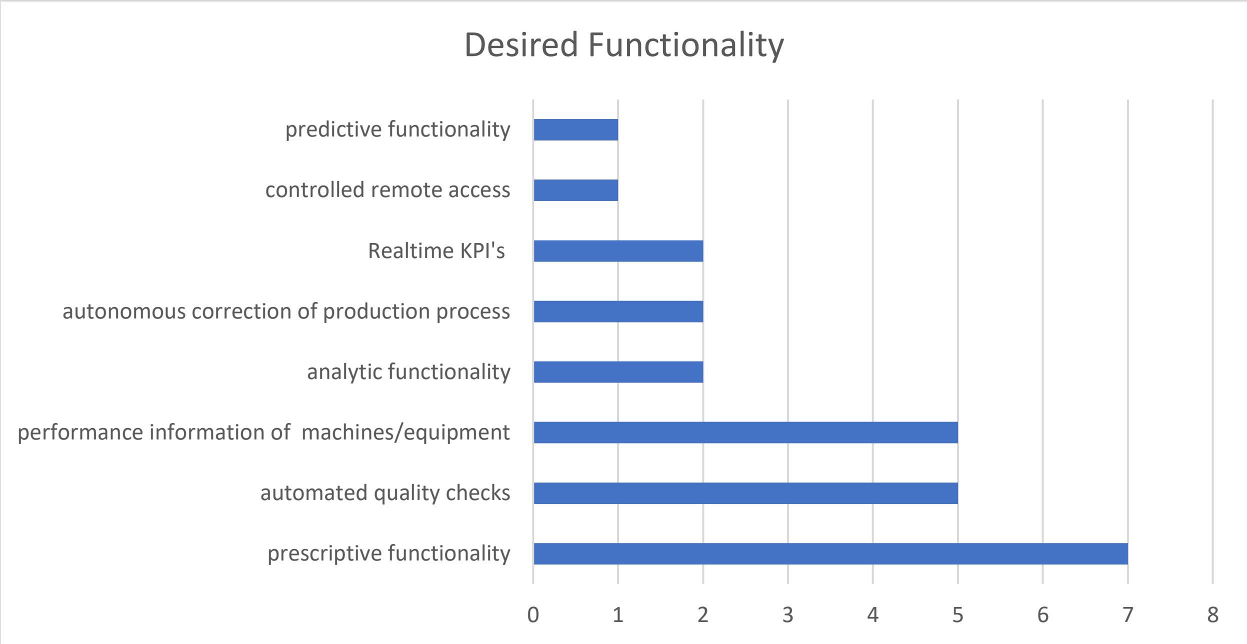

Figure 12: Graphical overview of desired functions from Production managers

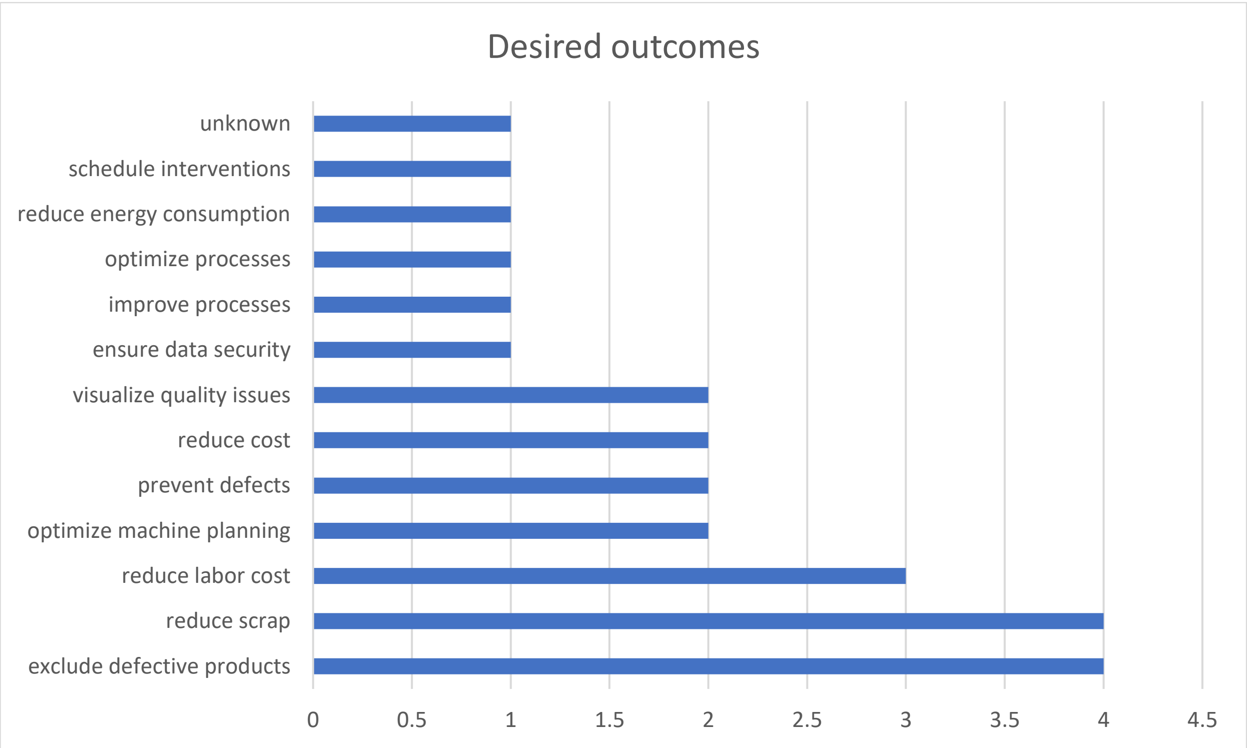

Figure 13: Graphical overview of desired outcomes of Production Managers

Innovation Engineer

The Innovation Engineer function includes functions that were described by the Industrial pilots as:

- Design engineer
- Digital innovation expert
- Industrial System Engineer
- Industrial Architect
- Innovation engineer
- Machine and digital innovation expert
- Machine expert
- Manufacturing Engineer
- Ontology Engineer
- R&D engineer

These are all functions that work on the implementation and improvement of industrial processes and machines. To be able to create a general analysis these functions were combined in the Actor Group "Innovation Engineer".

The Functions the innovation engineers desire are more varied than those of the Production managers, but there are some functions that are joined across the different Industrial Pilots: Receive real data about the performance of the process and Gain insights provided by analytics. See Figure 14 below. This result emphasizes the importance of industrial data the potential value contained. It also aligns with the high-level requirements, i.e. data management, data collection and data mining. To meet these requirements, advanced data management solutions are necessary covering different levels of a production system, i.e. product, machine, control devices, stations, workshops, intra-/inter- enterprise etc. All necessary technologies will be further analysed in WP3 and WP4.

The most important outcome for the Innovation Engineers is to improve the design of the processes. Many other outcomes are related to that by gaining more insights in the processes they work on. See Figure 15: Graphical overview of desired outcomes from Innovation Engineers.

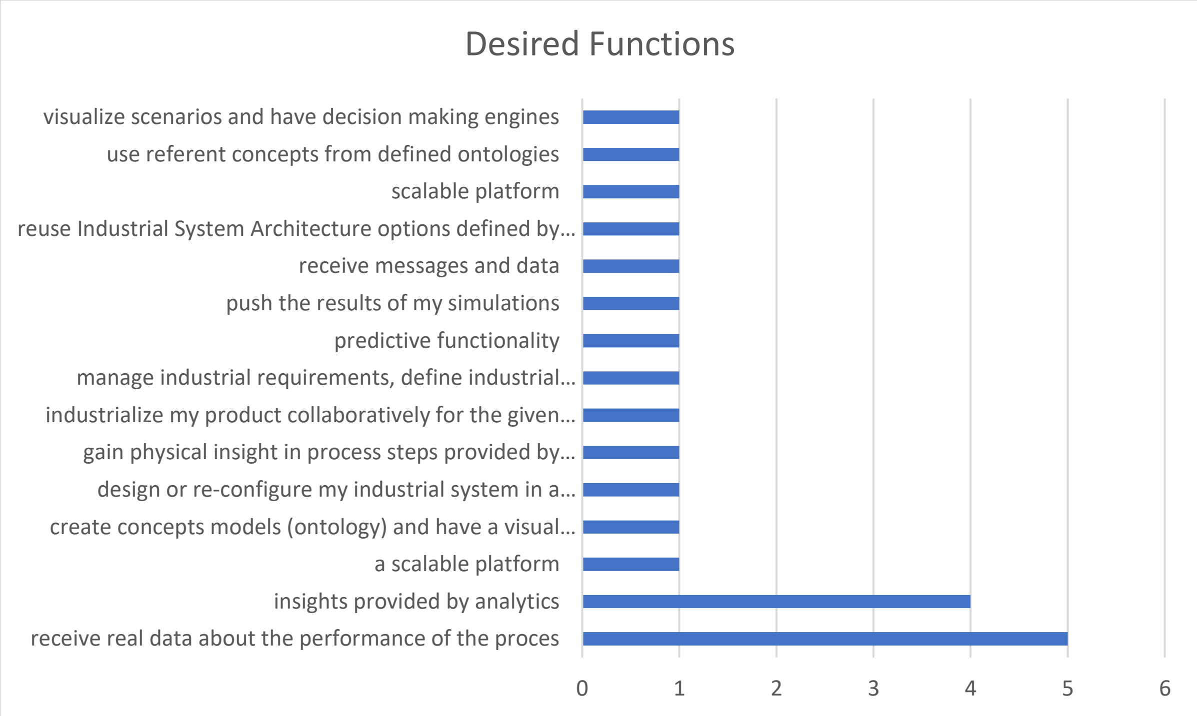

Figure 14: Graphical overview of desired functions from Innovation Engineers

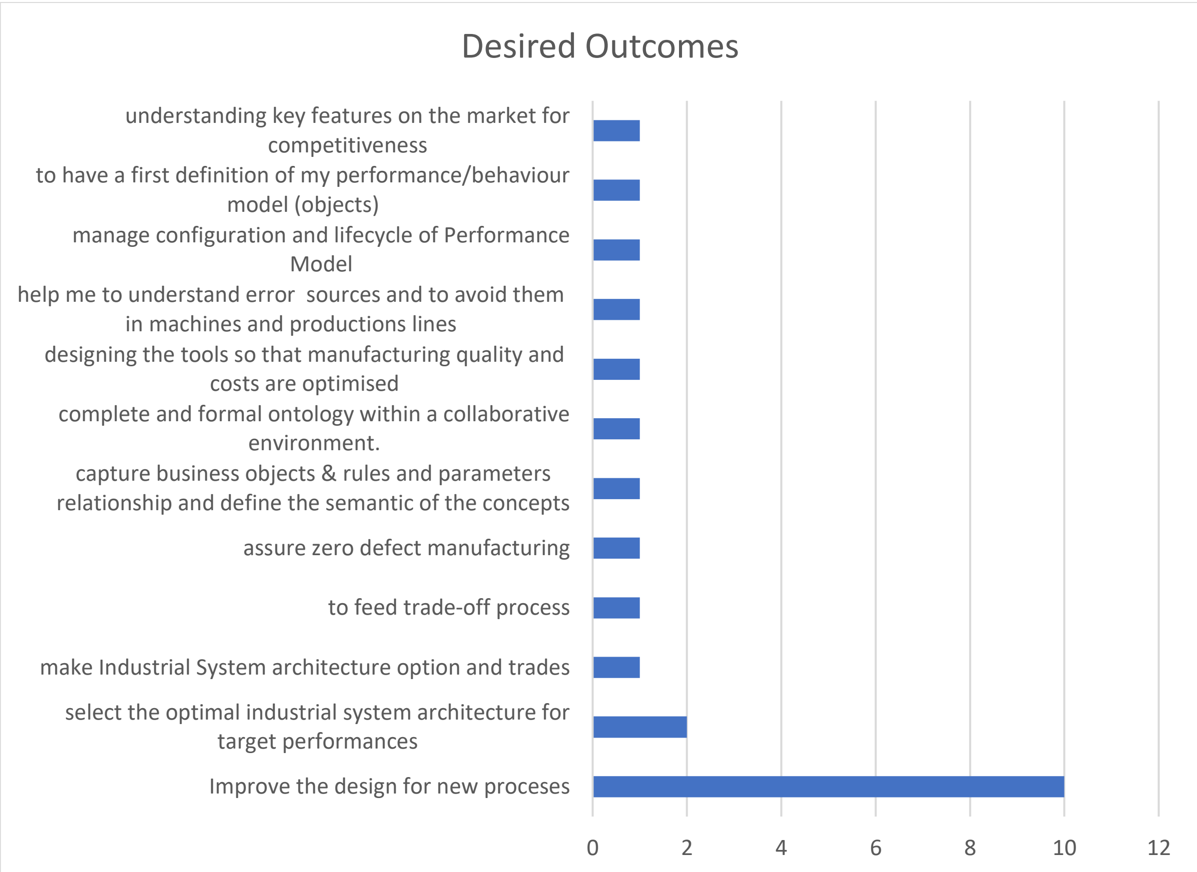

Figure 15: Graphical overview of desired outcomes from Innovation Engineers

Operator

The Operator Actor Group are the people working in the production lines, also referred to as "Blue-Collar Worker". These people have more similar desired Functions with at the top: "A Completely automated production line" which of course matches the goal of the QU4LITY project and can be linked to Autonomy Level 4 (explained in Figure 1 in Chapter 2). The most named Outcome of this function is that they can focus on manufacturing line monitoring, and startup/close procedures for planned interruptions. They also see benefits when they can receive a signal when the process is showing deviations that might lead to errors, this function matches Autonomy Level 3. Another joint function is the use of Virtual Support, e.g. AV/VR, for training or instructions.

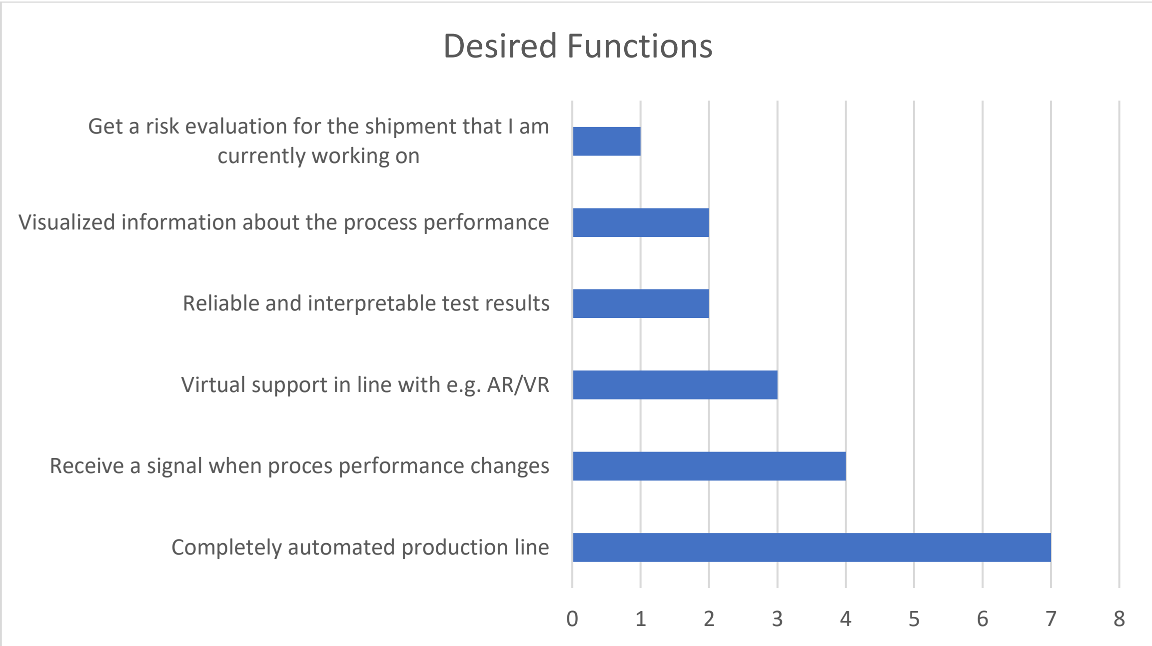

Figure 16: Graphical overview of desired functions from Operators

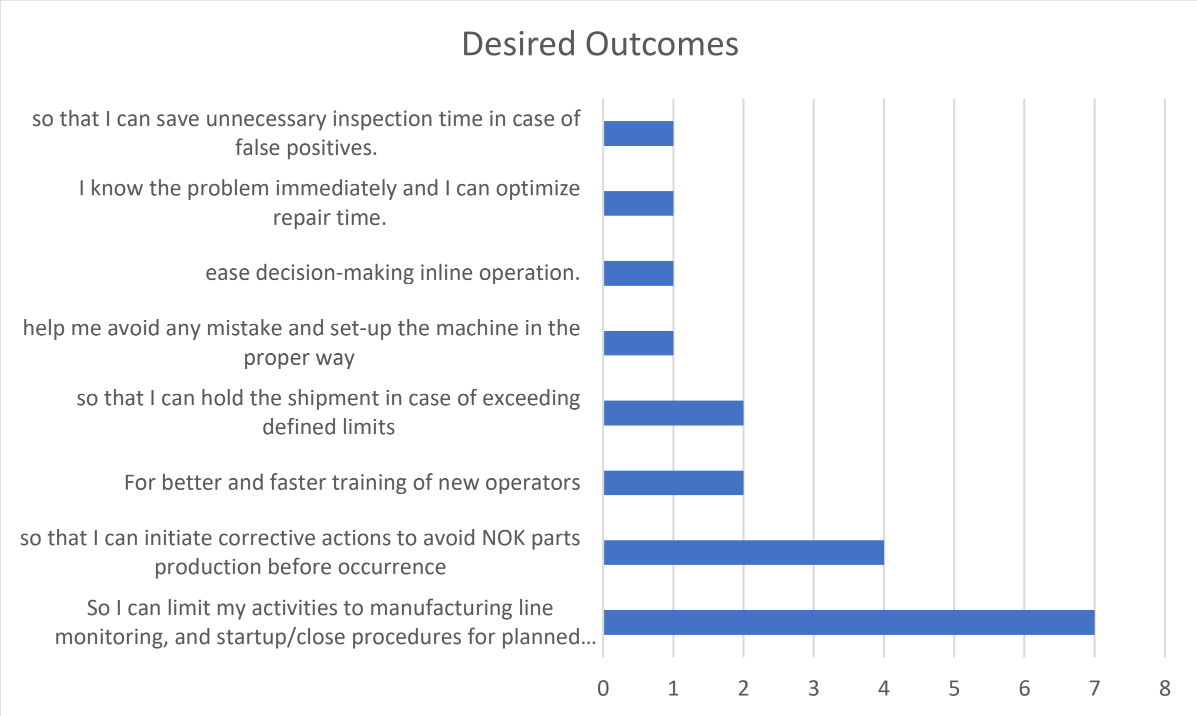

Figure 17: Graphical overview of the desired outcomes from Operators

8 Low level requirements

As described in Chapter 5 the high-level requirements in Chapter 7 should be refined to low level requirements that can be used by the work packages and technology partners. For this purpose, a questionnaire with a list of eliciting questions (Table 3) was used. The answers to these questions, provided by the pilot owners, give an impression of the current state of the Industrial Pilots and the need for new technologies that will be used to realize the high-level requirements.

Using the answers on the eliciting questions the work packages processed a set of low-level requirements.

8.1 Requirements for Vision and Specifications (WP2)

Work package 2 will:

- collect and document requirements and user stories
- refine the AQ vision of the project
- analyse the background platforms and technologies that will support the implementation of AQ platforms and processes, including relevant standards and interoperability needs
- specify the digital models that will drive data exchanges and integration across the different systems and stages of the AQ ZDM deployments
- provide detailed specifications for the QU4LITY-Rerence architecture

Table 36: Low level requirements for work package 2

Task	Summary of input from industrial Pilots	Requirement
T2.4 Standards	"All Pilot understand the need of communication and integration of Industry 4.0 components, which relies heavily on the communication standards. Although most pilots do not need to use all of the standards that have been anticipated, they are open to new standards if necessary. Especially, attention should be given to currently lacking or immature standards focusing Digital Data Models, i.e. ontology standards and standard regarding data models. The work done in pilots ensures positive steps towards the compliance to the QUALITY reference architecture, which is one of the essential requirements in the project.	"QU4LITY should extend/update the current list of standards to include the latest standards regarding interoperability for IIoT and digital twin applications, AAS discussions and integration of ontology, data models, and vocabulary. The compliance of the QU4LITY reference architecture must be verified against the latest standards, e.g. RAMI 4.0. "

Task	Summary of input from industrial Pilots	Requirement
T2.5 Digital Data Models & Vocabularies	All Pilot understand the need of communication and integration of Industry 4.0 components, which relies heavily on the communication standards. Although most pilots do not need to use all of the standards that have been anticipated, they are open to new standards if necessary. Especially, attention should be given to currently lacking or immature standards focusing Digital Data Models, i.e. ontology standards and standards regarding data models. The work done in pilots ensures positive steps towards the compliance to the QUALITY reference architecture, which is one of the essential requirements in the project.	QU4LITY should extend/update the current list of standards to include the latest standards regarding interoperability for IIoT and digital twin applications, AAS discussions and integration of ontology, data models, and vocabulary. The compliance of the QU4LITY reference architecture must be verified against the latest standards, e.g. RAMI 4.0.
	Most pilots are not using any knowledge management approaches like Ontology, Semantic Web. Only four pilots are using or developing Ontologies, which mainly focus on quality management and defect prediction.	QU4LITY should provide an upper-level Ontology and at least one domain Ontology with detailed specifications to showcase how such semantic modes can be developed and applied for knowledge management. The vocabulary for QU4LITY should be defined including the latest publications regarding terms and definitions, especially ZDM and quality aspects.
T2.6 Reference Architecture	Two pilots are already using Digital Twin and four pilots are planning to develop DT models during QU4LITY project.	The digital models of QU4LITY should support the integration and improvement of existing Digital Twins covering both product and process perspectives, possibly supported by semantic engineering or knowledge graph.

8.2 Requirements for Digital Enablers (WP3)

Work package 3 will develop and integrate a range of digital enablers, which will support the QU4LITY autonomous quality paradigm. In Table 37 the requirements, derived from the answers on the eliciting questions per task of WP3 are documented.

Table 37: Low level requirements for work package 3

Task	Summary of input from industrial Pilots	Requirement
T3.1 Connectivity & Networking	FAGOR, MON, KOL, RIA, PRIMA(?) require real time, others are fine with near-real time processing	To provide active monitoring of production lines, QU4LITY networking-related digital enablers should provide real-time communication capability otherwise ZDM processing may be impacted.
T3.2 HPC &Cloud	Both private and public cloud platforms are used in most cases, GFMS and PRIMA only rely on Azure Cloud, CON and KOL only on private cloud (Amazon private cloud and Sinapro.IIoT), SAG is moving towards Mindsphere and RIA, due to low latencies required, doesn't use it at all	(1) QU4LITY Cloud Infrastructure should be CSP (Cloud Service Provider) independent. (2) QU4LITY Cloud Infrastructure should be able to support both private and public cloud. (3) QU4LITY Cloud Infrastructure should provide interoperability across Cloud solutions and on-premise storage solutions.
	SAG, PHI, CON, FAGOR, MON and GFMS require new equipment connectors with other data platforms. MON suggests a "Message Broker" as an interoperability layer together with data converter from different industrial devices.	Digital enhancements are already planned and ongoing in the pilots, but QU4LITY should support in developing/integrating new connectors and interfaces toward more-exploited data platforms.
T3.3 AI & Big Data	YES	(1) To improve machining process and manufacturing process planning, QU4LITY enablers should provide processing and sensor data analysis at both edge and cloud level; (2) Need for Machine Learning Techniques for Data Driven Calculation of Asset Lifecycle Parameters (Remaining Useful Life, End of Life); (3) Need for Machine Learning Techniques for Optimizing Sensor Placement and Deployment for Capturing Quality Parameters; (4) Management and Analytics of Streaming Data (Sensors, IoT Devices); (5) Visualization of Data For Presenting Abnormalities (Quality Issues, Defects)
T3.4 Fog & Edge	Fog/edge devices are needed to gather data, process models and return decisions/settings to equipment. PRIMA Won't use them. KOL reports some data will be acquired from PLC and database by means of fieldbus connectivity and intranet.	QU4LITY edge enablers must provide local data processing, visualization, storage capabilities, (deterministic) communication and data synchronization mechanisms with central data warehouse.
	YES in most cases, KOL doesn't want them to be stored, GFMS want them stored also in Azure Cloud and quality cognitive database, RIA want them	

Task	Summary of input from industrial Pilots	Requirement
	stored also in their DataWarehouse for bulk data analysis	
	YES	
	YES, GFMS already owns a digital hub to deploy apps at the edge	QU4LITY edge enablers should be open to provide the capability to deploy analytics and/or other applications on edge nodes.
	YES except KOL, PRIMA and DANOBAT	QU4LITY edge enablers should support both Docker and Virtual Machines as virtualization strategy
	to local db storage, SAG to Cloud db storage, DANOBAT to Danobat Cloud	QU4LITY edge enablers should potentially support low cycle times to support control applications (nice to have)
T3.5 Cybersecurity	Docker, RIA is using VM	(1) QU4LITY PST framework must provide authorization/authentication policies with the goal of assuring data confidentiality, data integrity and non-repudiation. (2) QU4LITY PST framework should support encryption and point-to-point connection. (3) QU4LITY PST framework should be able to interact with company IT security policies.
	Closed control loop on top of current PLS functionalities	
	YES, only for RIA and CON no	
	Closed loop systems	
	YES	
	N/A, Prima: Failure detection, tolerance bands, feedback from the shop floor via the Notification subsystem	
	NO, Prima TBD	
	Authorization/Authentication required	
	N/A	
	Mostly local, PRIMA: pilot policy, GFMS: no machining strategies. DANOBAT and WHR both locally and on cloud	
T3.6 BlockChain	NO, PRIMA interested	N/A
T3.7 Interoperability	Yes, to SAP, MES, FMS and CAD/CAM	(1) QU4LITY interoperability enablers should support the integration with existing tools such as SAP, MES, FMS and CAD/CAM; (2) Syntactic Interoperability Across Different Components and Their Platforms; (3) Semantic Interoperability for Quality in Supply Chain Scenarios; (4) Modular Deployment and Integration (Containerization)

8.3 Requirements for ZDM Equipment Digital Enhancement for Autonomous Quality Operations (WP4)

Table 38: Low level requirements for work package 4

Task	Summary of input from industrial Pilots	Requirement
WP4 - Assets and Smart products	Further information about the Requirements for the digital enhancements collected for D4.2. Self-learning, self-configurable system for every pilot except WHR and GHI. Predictive Maintenance in scope for PHI, SAG, FAG, GFMS, PRIMA, CONTI, DANO and THK. Human-centred manufacturing systems in scope for PHI, SAG, FAG, GFMS, MON, WHR and DANO. AR for PRIMA. AR/MR for CONTI. AR/MR solutions are not discarded for GFMS.	These are the relevant digital enhancements to be developed, implemented and used at pilot premises: - Adaptive hot stamping machines (x2) - Self-learning and autonomous systems (x11) - High-precision machining (x3) - Augmented Reality and Mixed Reality platforms (x2) - Human-centered manufacturing systems (x7) - Predictive maintenance and autonomous field service engineering (x8) - Quality-controlled Additive Manufacturing to self-configurable flexible cells (x1)
WP4 - IoT Automation Services	Most of the pilots don't need any improvement for of the digital enhancements for its implementation. PRIMA would need a DSS, CONTI is developing a managerial tool for its AGVs	The different pilots require different degrees of interoperability in terms of device, network and platform levels. The most common case are the ones that require protocol & syntactic interoperability degree at device level and dynamic interoperability degree at platform level. Network level does not constitute any specific requirement for most of the pilots.
WP4 - Control Services	Some pilots (example: CONTI) require improvements in the distributed C&C in terms of response times. Edge & Cloud computing to be used for communication and control in the case of all the pilots except GFMS, RIA and WHR.	Edge & Cloud computing to be used at 11 of the 14 pilots (further description at the THs). Business requirements to be mainly focused on scrap reduction -even to zero or the technical minimum- in the path to a true ZDM strategy, OEE improvement, data spaces for correlating process and quality and fast root cause detection. Validation procedures consisting on KPIs assessment. Sometimes, if applicable, integration and testing of the DSS mobile apps. Normally run on standard internal procedures.

8.4 Requirements for Open Autonomous Quality Services Engineering and Processes (WP5)

Table 39: Low level requirements for work package 5

Task	Summary of input from industrial Pilots	Requirement
WP5 - Modelling and Learning Services	Data Models not yet defined for majority of cases, partially proprietary models in use. No referencing of Services required for modelling and learning.	Human-in-the-loop processes need to address different layers from individual production processes to factory levels and have to cover humans in Supervision, Investigation, Prescriptive guidance, Predictive support and Collaborative processes. Interfaces for user interaction shall address the specific role a user has.
WP5 - Digital Twin and Planning Services	Most users indicate no use of DTs or refer to the general response in WP2.	The simulation framework shall enable the use of simulation during both, planning and execution phases of production. It shall cover the use of different simulation types (e.g. material flow, bottleneck identification, process simulation, parts handling) and tools (e.g. Plant Simulation, Anylogic, Python-based simulators) and operating systems those are executed on.
WP5 - Simulation and Human-centric visualization services	Majority sees simulation as a possible enhancement later on. If mentioned, simulation is intended to be used in the conventional way for process planning and optimization, with no specific addressing of quality. Majority does not mention visualization requirements, if mentioned these address individual visualizations to be possible, purpose-wise a quick identification of quality-related issues shall be possible.	ZDM processes have to be able to (semi-) automatically adapt themselves to changing conditions of the shop floor. For allowing this, depending on the use case (pilot), a modular integration of adapted and customized tools, as defined by the pilots, has to be possible. Communication Standards and Interface covering (e.g. MQTT, OPC-UA, TCP/IP, UDP, ROS, Database Connections), depending on the use case, shall be applied to allow communications of the respective modules.

Task	Summary of input from industrial Pilots	Requirement
WP5 - Collaboration, Business and Operation Services	Majority does not consider specific AQ processes to be used. Mentioned usages are to indicate Quality Deviations and support decision making upon.	OpenAPI developments need to take into account the different developments of the solutions developed in QU4LITY. Key characteristics to be considered need to cover service-oriented or REST architectural styles and adopted most relevant communication protocols in ZDM processes (e.g. MQTT, AMQP, OPC UA, etc.). For securely exchanging data via the IDS, respective components shall implement the IDS Connector. The Connector is a dedicated software component, which allows sharing, processing and exchanging data in a secure and sovereign manner. The IDS-Connector must therefore implement a number of services (e.g. encryption, usage policy enforcement, logging of data operations). It has to be adaptable to be used on edge/fog as well as cloud level.
WP5 - Engineering and Planning Services	Engineering Services are not requested by the pilots, except WHR. No specific requirements given, though.	Service Planning and Engineering needs to cover definition and implementation phases. Engineering services shall support engineering a quality system according to the MPFQ Model (Material, Processes, Features/Functions, Quality). Modelling services shall allow the use of proprietary data models.

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List of Abbreviations

Table 40: List of abbreviations

Abbreviation	Explanation
AGV	Automatic Guided Vehicle
AI	Artificial Intelligence
AIC	Akaike information criterion
AM	Additive Manufacturing
AmI	Ambient Intelligence
API	Application Programming Interface
AQ	Autonomous Quality
AR	Augmented Reality
CAD	Computer-aided drafting
CPN	Connected Product Networks
CPS	Cyber Physical System
CTQ	Critical to Quality
DEI	Digitizing European Industry
DIH	Digital Innovation Hub
DSS	Decision Support System
EDM	Electrical Discharge Machining
EFFRA	European Factories of the Future Research Association
FMEA	Failure Modes and Effect Analysis
FPY	First Pass Yield
FTA	Free To Air
HA	Health Assessment
HMI	Human Machine Interface
HPC	High Performance Computing
ICT	information and communication technology
IDS	Industrial Data Space
IIMS	Integrated Information Management Systems
IoT	Internet of Things
IoT	Internet of Things
IoTA	Open source crypto currencies
IT	Information technology
JIT	Just In Time
KPI	Key Performance Indicator
LL	Low Level
LTE	Long Term Evolution (4G)
MES	manufacturing execution system
MGEP	Mondragón Goi Eskola Politeknikoa
mMTC	Massive Machine Type Communications
MPEQ	Multiclass Priority Fair Queuing
MTBF	Mean Time Between Failures
MTTR	Mean time to repair
NC	numerical control
OEE	Overall Equipment Effectiveness
OPE	From trial handbook Riastone, no explanation found

OPIL	Open Platform for Innovations in logistics
PA	Prognostic Assessment
PDM	Product data management
PES	Product Extension Services
PLM	PLM
PnP	Plug 'n Produce
PPM	Parts per million
PSS	Product Service System
SD	State detection
SDK	software development kit
SME	Small Medium Enterprise
SoPS	Systems of Production Systems
THM	Trial Handbook Machines
THM-<#>	Enumerated Trial Handbook Machines. Reference number <#>
TSN	Time-Sensitive Networking
URLLC	Ultra-Reliable Low-Latency Communication
US	User Story
US-<#>	Enumerated User Story. User Story number <#>
WP	Work Package
ZDM	Zero defect manufacturing

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Partners

Appendix A. Reference Table Trial Handbooks

Table 41: Reference Table of Trial Handbooks

Code	Explanation	Pilot	Document Name	Chapter	Paragraph
THM-01	Trial handbook Machines 1	Danobat	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user)
THM-02	Trial handbook Machines 2	Fagor	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user)
THM-03	Trial handbook Machines 3	GHI	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user
THM-04	Trial handbook Machines 4	PREMIUM	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user
THM-05	Trial handbook Machines 5	GF	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user)
THP-01	Trial handbook Process 1	Mondragon	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user)
THP-02	Trial handbook Process 2	Airbus	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user)
THP-03	Trial handbook Process 3	Continental	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user)
THP-04	Trial handbook Process 4	KOLEKTOR	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user)
THP-05	Trial handbook Process 5	Thyssen	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user)
THP-06	Trial handbook Process 6	PHILIPS	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user
THP-07	Trial handbook Process 7	RiaStone	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user
THP-08	Trial handbook Process 8	SIEMENS AG	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user
THP-09	Trial handbook Process 9	Whirlpool	QU4LITY_TH_Chapter1	2: Section 1 Data: Trial Overview	2.2General Description: (End user

Appendix B. High-level Pilot Requirements

Table 42: Overview of all pilot requirements

Code	Pilot	High-level requirement
Pilot_Req_PHILIPS_01	Philips	Analyse early indicators and trends from process signals and dimensional CTQs of individual components to predict quality of the finished product
Pilot_Req_PHILIPS_02	Philips	Raise early warning signals based on early indicators and trends from process signals
Pilot_Req_PHILIPS_03	Philips	Suggest feed-forward or feed-backward controls to neighbouring process stations
Pilot_Req_PHILIPS_04	Philips	Help the operator to take correct process adjustment decisions
Pilot_Req_PHILIPS_05	Philips	Learn from unknown data interactions to predict quality
Pilot_Req_SIEMENS_01	Siemens	Reduction of operator time investment for inspection
Pilot_Req_SIEMENS_02	Siemens	Increase of transparency and track ability of errors throughout the line
Pilot_Req_SIEMENS_03	Siemens	Long-term increase of the resulting quality of the products in the long term by facilitating root cause analysis
Pilot_Req_SIEMENS_04	Siemens	Reduction of investment cost for quality tests
Pilot_Req_SIEMENS_05	Siemens	Reduction of product line disruptions through the avoidance of optional inspections
Pilot_Req_CONTI_01	Continental	Integrate with warehouse, Individual production lines and support production area's e.g. Planning, quality control and process settings
Pilot_Req_CONTI_02	Continental	Progress in the establishment of an advanced shop floor and machine communication
Pilot_Req_CONTI_03	Continental	Safe, secure and trustworthy data processing and storage
Pilot_Req_CONTI_04	Continental	Inclusion of the full value chain
Pilot_Req_CONTI_05	Continental	Next generation of shop floor visualization management
Pilot_Req_WHR_01	Whirlpool	A common and holistic semantic model able to represent concepts at different stages of product lifecycle;
Pilot_Req_WHR_02	Whirlpool	Standard methods and tool to gather, store and share data;
Pilot_Req_WHR_03	Whirlpool	Trustworthy digital continuity and data management
Pilot_Req_WHR_04	Whirlpool	Flexible and user-friendly analytical tools - Human-centric big data visualization
Pilot_Req_WHR_05	Whirlpool	Comprehensive way to share results among different management roles
Pilot_Req_WHR_06	Whirlpool	Equipment and process simulation and optimization solution as major leverage towards the efficient realization of complex first-time-right parts
Pilot_Req_WHR_07	Whirlpool	Implementation of a closed loop over the manufacturing process between digital and real domains
Pilot_Req_MON_01	Mondragon	Set up a data acquisition System
Pilot_Req_MON_02	Mondragon	Create a data management platform
Pilot_Req_MON_03	Mondragon	Perform data analysis
Pilot_Req_MON_04	Mondragon	Implement Cyber Physical Systems
Pilot_Req_MON_05	Mondragon	Use a big data platform for testing and simulating
Pilot_Req_MON_06	Mondragon	Standardize data models and protocols
Pilot_Req_MON_07	Mondragon	Enhance DSS System

Code	Pilot	High-level requirement
Pilot_Req_MON_08	Mondragon	Share data (sensorized + pre-processed) with other parties of the supply chain (clients / providers) in a controlled environment where security, privacy and data trust is taken into account.
Pilot_Req_MON_09	Mondragon	Support a changing supply chain where actors and their needs changes, by allowing the elasticity of the platform. This elasticity enables the optimization of the resources and the reliability of the solution
Pilot_Req_KOL_01	Kolektor	Have a better understanding of moulding process.
Pilot_Req_KOL_02	Kolektor	Have real-time detection and possibly prediction of failures based on advanced analytics and artificial intelligence.
Pilot_Req_KOL_03	Kolektor	Implementation of feedback loop for troubleshooting (e.g. setting process parameters, cleaning the moulding tool).
Pilot_Req_THYS_01	Thyssen	consecutively performing quality checks on a part level
Pilot_Req_THYS_02	Thyssen	Real-time adaptation of the assembly line parameters
Pilot_Req_THYS_03	Thyssen	implement a data acquisition system distributed on various points on the production line to capture: • in-process sensor data • data from the production monitoring system • operator data
Pilot_Req_THYS_04	Thyssen	Create a data model
Pilot_Req_AIRBUS_01	Airbus	Define and describe objective
Pilot_Req_AIRBUS_02	Airbus	Identified candidates' technical options when known
Pilot_Req_AIRBUS_03	Airbus	Define inputs
Pilot_Req_AIRBUS_04	Airbus	Define constraints
Pilot_Req_AIRBUS_05	Airbus	Identify Stakeholders (name, role...)
Pilot_Req_AIRBUS_06	Airbus	Define scope
Pilot_Req_AIRBUS_07	Airbus	Define requirements
Pilot_Req_AIRBUS_08	Airbus	Define trade space exploration
Pilot_Req_AIRBUS_09	Airbus	Define design parameters + ranges + Design of Experiments
Pilot_Req_AIRBUS_10	Airbus	Define assessment criteria + weighting methods + associated objectives (minimize, maximize)
Pilot_Req_AIRBUS_11	Airbus	Define alternatives
Pilot_Req_AIRBUS_12	Airbus	Perform Multi-criteria assessment + Ranking
Pilot_Req_AIRBUS_13	Airbus	Select Alternatives (or areas of alternatives)
Pilot_Req_AIRBUS_14	Airbus	Trade space Exploration (pareto analysis, surface graphs, change propagation from parameters to KPIS)
Pilot_Req_AIRBUS_15	Airbus	Surrogate modelling
Pilot_Req_AIRBUS_16	Airbus	Perform sensitivity analysis
Pilot_Req_AIRBUS_17	Airbus	Design of experiments selection
Pilot_Req_AIRBUS_18	Airbus	Model integration
Pilot_Req_GHI_01	GHI	Integrate new IoT sensors
Pilot_Req_GHI_02	GHI	Improve data gathering system
Pilot_Req_GHI_03	GHI	Improve the data analysis system.
Pilot_Req_GHI_04	GHI	Improve the efficiency and control of the hot stamping process.
Pilot_Req_RIA_01	RiaStone	Timely raise early detection warning signals of production factors that will originate product defects

Code	Pilot	High-level requirement
Pilot_Req_RIA_02	RiaStone	Materialize feed-forward or feed-backward controls and adjustments to neighbouring process areas
Pilot_Req_RIA_03	RiaStone	Have correction capability over the future course of overall production
Pilot_Req_RIA_04	RiaStone	Effectively increase OPE by helping the factory operator to take correct process adjustment decisions
Pilot_Req_RIA_05	RiaStone	Increase FPY overall in the complete production lines of Riastone
Pilot_Req_PRIMA_01	PRIMA	Create a modular monitoring and control system that can be used with many different sensors and process models
Pilot_Req_PRIMA_02	PRIMA	Analyse real-time process and machine signals with machine-learning algorithms to find structures and pattern related to the required key quality indicators (critical defects per track, distortion, keeping of dimensions).
Pilot_Req_PRIMA_03	PRIMA	Connect the system to a higher-level factory data interface
Pilot_Req_PRIMA_04	PRIMA	Exchange process information and reassign the production strategy based on additional factory conditions
Pilot_Req_PRIMA_05	PRIMA	operate to RAMI standards on the edge (connectivity to MES and control systems)
Pilot_Req_PRIMA_06	PRIMA	interaction with data space and simulation tools trough the Prima’s fleet management platform
Pilot_Req_PRIMA_07	PRIMA	recommend process adjustments to the operator or directly change the parameters in real time
Pilot_Req_DAN_01	Danobat	Gather data through sensors
Pilot_Req_DAN_02	Danobat	Connect to an edge and cloud infrastructure
Pilot_Req_DAN_03	Danobat	Extract/download data for analysis
Pilot_Req_DAN_04	Danobat	Develop machine learning models
Pilot_Req_DAN_05	Danobat	Automate communication of information with users
Pilot_Req_DAN_06	Danobat	Auto correct processes
Pilot_Req_FAGOR_01	Fagor	Implement prescriptive analytics
Pilot_Req_FAGOR_02	Fagor	Identify optimum press machine control parameters
Pilot_Req_FAGOR_03	Fagor	Gather data from machine sensors
Pilot_Req_FAGOR_04	Fagor	Gather data of the part under manufacturing
Pilot_Req_FAGOR_05	Fagor	Implement an autonomous control loop
Pilot_Req_FAGOR_06	Fagor	Provide information about the future part quality
Pilot_Req_GF_01	GF	Create Data storage space
Pilot_Req_GF_02	GF	Implement Cloud infrastructure
Pilot_Req_GF_03	GF	Perform Data analytics in different authorized environments
Pilot_Req_GF_04	GF	Set up a Digital Twin for error compensation, KPI prediction and control
Pilot_Req_GF_05	GF	Create a simulation-based framework to update NC codes and maintenance plans
Pilot_Req_GF_06	GF	Create Semantic data models and acquisition systems
Pilot_Req_GF_07	GF	Data collection campaign for pre-defined use cases and digital model and KPIs optimization

Appendix C. Overview of User stories Industrial Pilots

User stories Data scientists

User story	ID code
As a data scientist I want a scalable platform that is fed by (near) real time data of current and new sensors of the entire shimmer production chain that describes the properties of the production process in such a detailed way that I can make prescriptive models that avoid any errors in the shimmer line	US_Phi8
As a data scientist I want to get access to all data structured or unstructured that have a relation to the shipment that is object for a risk evaluation in order to detect abnormalities.	US_Con4
As a data scientist I want collect as much data as possible from the production line devices taking into account working conditions.	US_Mon9
As a data scientist, I want a scalable platform that is fed by (near) real time data of current and new sensors of the entire injection moulding production chain that describes the properties of the production process in such a detailed way that I can make prescriptive models that avoid any errors in the injection moulding line	US_Kol8
As a data Scientist, I want to obtain insights provided by the data analytics through the development of algorithms fed by the furnace operational data, in order to facilitate the optimize the furnace operation.	US_GHI5
As a data scientist, I want a scalable and adaptable platform that could be fed by (near) real time data of current and new sensors integrated on the industrial furnace that allows a complete control of it and that also customized to the production process where it is integrated.	US_GHI6
As a data scientist I want a scalable platform that is fed by real time sensor data of the entire Greenware/Tableware production chain that controls the conformity and the quality production process in such a detailed way that I can assure the lowest possible defects rate, and the best possible FPY indicator in the RiaStone Factory	US_Ria11
As a data scientist I want a scalable platform that is fed by (near) real time data of current and new sensors of the systems that describes the properties of the production process in such a detailed way that I can make smart algorithms for prediction processes	US_Pri8
As a data scientist I want collect as much data as possible from the machine working conditions, I need data to be easily analysed	US_Dan8
As a data scientist I want collect as much data as possible from the machine working conditions, I need data to be easily analysed. I also want to access the data with easy tools and deploy the algorithms in production easily.	US_Fag8
As a data scientist I want a scalable platform that is fed by real time data from machine sensors of the entire automated line, including the CMM, containing all needed parameters for the deployment of efficient predictive and prescriptive algorithms, to be used for supporting the design, manufacturing and quality control phases of the production process according to the factory KPIs.	US_GF8

User Stories Innovation Engineers

User story	code
As an innovation engineer, I want insights provided by analytics that help me developing production lines that produce within tolerances	US_Phi4
As a machine expert I want to receive messages and data related to production lines to propose new improvements	US_Mon3
As digital innovation expert I want to receive real data about the performance of the productions lines to enable new improvements associated with ZDM approach	US_Mon4
As an innovation engineer, I want insights provided by analytics that help me improve injection moulding production lines that produce within tolerances and without defects	US_Kol4
As an innovation engineer, I want to gain physical insight in process steps provided by advanced sensing technologies combined with analytics that help me to understand error sources and to avoid them in machines and productions lines	US_Thy1
As an R&D engineer I want insights provided by analytics that help me understanding components that need to be improved	US_Pri2
As an innovation engineer, I want insights provided by analytics that help me understanding key features on the market for competitiveness	US_Pri3
As a machine expert I want to receive real working condition data of the machines to be able to design improvement for new machine models	US_Dan2
As a machine and digital innovation expert I want to receive real data about the performance of the machines to be able to develop new digitally enhanced functionalities to improve the value added to the client and help to achieve a zero-defect manufacturing	US_Dan3
As a machine expert I want to receive real working condition data of the machines to be able to design improvement for new machine models	US_Fag2
As a machine and digital innovation expert I want to receive real data about the performance of the machines to be able to develop new digitally enhanced functionalities to improve the value added to the client and help to achieve a zero-defect manufacturing	US_Fag3
As a design engineer I want a predictive functionality that provide guidance for designing the tools so that manufacturing quality and costs are optimised	US_GF4

User stories Maintenance managers/engineers

user story	code
As a maintenance engineer I want insights provided by analytics that predict maintenance so that I can avoid any errors caused by maintenance in the production line	US_Phi5
As a Maintenance Worker I want I want to get visual instructions from a virtual Expert via smart glasses to that I can follow maintenance and change over instructions without having to carry documents or to know them by heart.	US_Con6
As a maintenance engineer, I want insights provided by analytics that predict maintenance so that I can avoid any errors caused by equipment breakdown in the injection moulding production line	US_Kol5
As a maintenance engineer, I want insights provided by trends analysis on the furnace operation for a fast detection of root cause of operational problems that requires maintenance operation, in order to reduce breakdown times.	US_GHI7

user story	code
As a service engineer, I want insights provided by analytics that predict maintenance so that I can avoid any errors caused by maintenance on the machines and provide always a best service for customers	US_Pri4
As a maintenance engineer I want a prescriptive functionality provided by analytics which indicates sufficiently in advance the time and component to be replaced so that maximum efficiency of the equipment is maintained, and defects are avoided on production parts	US_GF5
As a maintenance manager I want to receive production line status associated with the different parts of the processes.	US_Mon1
As a maintenance manager I want to introduce predictive algorithms within IIoT platform to evaluate the production line status and its components	US_Mon2
As a Maintenance manager I want evident and timely detected machine performance variations to be reported early, so that I can reduce the downtime of Manufacturing line components keeping the complete manufacturing system at 99% availability status	US_Ria6
As a Maintenance manager, I want insights provided by analytics that help me to maintain production lines that produce within assigned conformity tolerances	US_Ria7
As a Maintenance manager I want insights provided by analytics that predict needed maintenance so that I can avoid any errors caused by lack of timely maintenance in the production line	US_Ria8
As a maintenance manager I want to receive warnings about the condition of the machine and its components	US_Dan1
As a maintenance manager I want to receive warnings about the condition of the machine and its components	US_Fag1

User stories Operators

User story	ID code
As an operator I want a completely automated production line so that I can limit my activities to just feeding material, monitoring and startup/close procedures for planned interruptions.	US_Phi7
As an operator I want to get aware of suspicious behaviour of a machine so that I can initiate corrective actions to avoid NOK parts production before occurrence	US_Con1
As an operator at a customer goods packing station, I want to get a risk evaluation for the shipment that I am currently working on so that I can hold the shipment in case of exceeding defined limits	US_Con2
As an operator at a customer goods packing station, I want to get a easy to understand visualisation of the different aspects of the risk, so that I can hold the shipment in case of exceeding defined limits	US_Con3
As a trainee for a workstation I want to get visual instructions from a virtual trainer via smart glasses to that I do not need a real trainer.	US_Con5
As an operator I want the production line is capable of identify an anomalous working condition and send me alarms when they occur in real-time	US_Mon7

User story	ID code
As an operator I want the production to be as automated as possible, the production line should be able to indicate recommendations for improving the performance as well as correcting them as automatically as possible.	US_Mon8
As an operator, I want a completely automated injection moulding production line so that I can limit my activities to just feeding material, monitoring and startup/close procedures for planned interruptions.	US_Kol7
As a Blue-Collar worker, I want a completely and improved visualization tool that ease decision-making inline operation.	US_GHI10
As an operator I want a completely automated production line so that I can limit my activities to just manufacturing line monitoring, and startup/close procedures for planned interruptions.	US_Ria10
As an operator I want new digital devices (for instance AR/VR Tools) that help me avoid any mistake and set-up the machine in the proper way	US_Pri6
As a trainer operator I want new digital devices (for instance AR/VR Tools) that help me to teach better and faster the new operators.	US_Pri7
As an operator I want the machine to be able to identify an anomalous working condition and send me alarms when they occur	US_Dan6
As an operator I want the production to be as automated as possible, the machine should be able to identify problems and correct them as automatically as possible..	US_Dan7
As an operator I want the machine to be able to identify an anomalous working condition and send me alarms when they occur	US_Fag6
As an operator I want the production to be as automated as possible, the production line should be able to indicate recommendations for improving the performance as well as correcting them as automatically as possible..	US_Fag7
As an operator I want a completely automated production line so that I can limit my activities to just feeding material, monitoring and start up/close procedures for planned interruptions.	US_GF7

User stories Production/Plant manager

User story	code
As a production manager I want prescriptive functionality on the shimmer line that automates current manual settings so that I can reduce labour and production costs	US_Phi1
As a production manager I want prescriptive functionality on the shimmer line that reduces the number of errors in pad printing functionality so that I can reduce scrap and manual quality inspections and reduce costs	US_Phi2
As a production manager I want prescriptive functionality on the shimmer line that optimizes the assembly of parts in the production process to avoid high torque and related errors	US_Phi3
As Plant Director I want to have a configurable cockpit of the KPI plant indicators, the configurability allows to have to quality issues in real time highlighted in according to the 4 main plant elements: Material, Quality, Process and Functions	US_Whi1
As IE Plant Manager want to have a global picture of the efficiency status of the production plants, in particular the drum production area, the heat pump area and the functional tests area. Knowing the efficiency allows me to prevent any problems	US_Whi3

User story	code
by acting on a schedule of maintenance interventions on plants that are critical for production	
As a plant manager I want to see the evolution of the variables defined as key for the performance of the production lines. Furthermore, I want to know the status of the machines and industrial devices to IIoT platform and Cloud environment	US_Mon5
As a production manager, I want prescriptive functionality on the injection moulding line that automates current manual settings so that I can reduce labour and production costs	US_Kol1
As a production manager, I want prescriptive functionality on the injection moulding line that reduces the number of defects during the moulding process so that I can reduce scrap and manual quality inspections and reduce costs	US_Kol2
As a production manager, I want an improved monitoring and data analysis platform in order to ease decision-making on the hot stamping line operation (mainly on the industrial furnace), enabling the optimization of the production process and so reduce (furnace) operational costs.	US_GHI1
As a production manager, I want to analyse the correlation between quality control and furnace operation parameters for a fast detection of root cause of quality problem in order to optimize the production process but also to reduce the number of defective parts manufactured.	US_GHI2
As a production manager, I want an improved monitoring and data analysis platform in order to ease decision-making on the hot stamping line operation (mainly on the industrial furnace), enabling the optimization of the production process and so reduce energy consumption.	US_GHI3
As a production manager I want automated dimensional conformity checks so that I can have defective products automatically removed early from the production Lines	US_Ria1
As a production manager I want that the dimensional conformity data automatically reconfigures through edge node computing the isostatic Press settings data, so that I can have early elimination of defect production	US_Ria2
As a production manager I want automated glazing uniformity control checks so that I can have defective products automatically removed early from the production Lines	US_Ria3
As a production manager I want that the glazing uniformity control data automatically reconfigures through edge node computing the Glazing viscosity control settings data, so that I can have early elimination of defective production	US_Ria4
As a production manager I want the automation QC verifications from the current operator-based verifications so that I can reduce labour and production costs	US_Ria5
As a production manager I want automated dimensional conformity checks so that I can have defective products automatically removed early from the production Lines	US_Ria12
As a plant manager I want to control de connection of the machines to the internet and I feel more comfortable if the digitally enhanced machines can provide their functionalities with restrictions of the connection to the cloud (for example I want to actively give the connection periodically and by a limited amount of time)	US_Dan4

User story	code
As a plant manager I want to see the evolution of the variables defined as key for the performance of the machine. Furthermore, I want to know the status of the of the machines and industrial devices to IIoT platform and Cloud environment	US_Fag4
As a production manager I want predictive functionality on the automated line that estimates time and costs for part production and allows for selecting the best machining strategies for a mould or production part following the factory KPIs	US_GF1
As a production manager I want prescriptive functionality on the automated line that provides an automated adjustment of offsets and machining strategies so to attain the required accuracy in the mould of part	US_GF2
As a production manager I want a prescriptive functionality on the automated line which anticipates equipment failures and part defects and maximises OEE	US_GF3

User stories Quality manager

User story	ID code
As a quality manager I want automated quality inspections on critical points in the production line resulting in all products within tolerances so that I can limit my activities to norm setting, monitoring and advice	US_Phi6
As a Quality Plant Manager want to know and understand in real time what the most pressing problems are. In relation to the type of models that are in production, and in relation to the defect data on the market. The data must be correlated in an integrated way allowing a projection according to the seasonality and type of materials used	US_Whi2
As Quality Test Engineer want to know what factors are affecting the quality parameters for each product and aggregated by model. This allows me to make decisions that can concern the set-up of the production areas as well as the programming of new test plans, aimed at solving product and process quality problems effectively and quickly. The information can be aggregated so that I can know what the factor is that most influences the reduction of quality: Material, Process or Function.	US_Whi4
As a quality manager, I want an automated quality inspection system on critical points in the injection moulding production line resulting in all products within tolerances so that I can limit my activities to norm setting, monitoring and advice	US_Kol6
As a quality manager, I want automated quality inspections to analyse crack formation on hot stamped parts, within the tolerances defined so that I can limit my activities to norm setting, monitoring and advice.	US_GHI8
As a quality manager, I want insights provided by the cross-analysis between quality data and furnace operational parameters in order to find a correlation or detect trends in order to optimize the furnace operation and reduce crack formation.	US_GHI9
As a quality manager I want automated quality inspections on critical points in the production line resulting in all products within tolerances so that I can achieve and report 99% OPE efficiency	US_Ria9
As an application engineer, I want time estimation and first check verification to avoid failure and so reduce time and cost	US_Pri1

User story	ID code
As a quality manager I want automated quality inspections on critical points in the part production so that I can easily check the results	US_Pri5
As a quality manager I want an automated quality control that exploits data from CMM machines and machine reports in order to check potential defects and allow automated correction or updates in case they arise during the production process	US_GF6

User stories Supplier

User story	ID code
As a supplier I want to get video and audio access to Equipment at customer sites in order to do problem solving without having to travel.	US_Con7
As a digitally enhanced machines manufacturer I want to connect and update the developments either local and edge easily	US_Mon6
As an IT provider, I want to deploy a robust data gathering solution that does not allow losses in data transmission to GHI external cloud assuring the quality of data.	US_GHI4
As a digitally enhanced machines manufacturer I want to be able to embed intelligent functions at the edge in the machine. So the developments done with the data collected from the cloud can be easily installed at plant level.	US_Dan5
As a digitally enhanced machines manufacturer I want to connect and update the developments either local and edge easily	US_Fag5

User stories Group leaders

User story	ID code
As Group Leader Assembly have the task of checking that the production plan is carried out correctly and that all the stations have the right materials allocated in accordance with the current production plan. Having a tool that warns me if quality problems are underway on the product and / or the process allows me to re-balance production in order to have a low impact on the various KPIs, acting on the redistribution of activities and materials in the various locations of work.	US_Whi5
As Group Leader Primary Process must understand how the machine that produces the drums, the core element of a dryer, is working. A whole series of dimensional and vibrational parameters are collected during production, and therefore to understand that the production trend meets the quality and productivity requirements (see Kpi) time and the aggregation of information are a fundamental factor. This allows me to act on the individual adjustments of the machine to correct size deviations in order to have harmful effects on the final configuration of the drum	US_Whi6

Appendix D. Overview of affected users Industrial Pilots

In this section you can find the overview of the affected users per Pilot, in which business area they are active within the Pilot Organization, how they are impacted and what the expected impact per user(group) is. This information is collected via the Trial Handbooks: Chapter 2.

Philips

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT** **(Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
- Administration - Data Analyst - Line Operator - Logistics Engineer - Quality Engineer - Maintenance Engineer - Maintenance Operator - Manager - Researchers - Service Engineers - Supplier	- Administration - Engineering - Manufacturing - Manufacturing - Manufacturing - Manufacturing - Manufacturing - Manufacturing - Innovation/Engineering - Manufacturing - Supplier	- Indirect - Indirect - Direct - Indirect - Quality Engineer - Indirect - Direct - Indirect - Indirect - Indirect - Indirect	- No change - Less improvements can be found - Less load, more in control - Less load, more in control - Less load, less "blocked" batches - More planned - Less escalations, more planned - Less load - Input for next gen - Less load - Smarter requirements set

Siemens

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)[1]*	**TYPE OF IMPACT** **(Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Blue-collar worker	Manufacturing	Direct	Reduction of manual quality checks after solder paste inspection
Industrial Engineering	Manufacturing, Maintenance / Technical Support	Direct	Altered Systems to maintain, possibly new knowledge domains
Accounting Personnel	Accounting	Indirect	Possibly new calculation schemes to be considered
Management	Management	Indirect	Improved business figures

Continental

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)[1]*	**TYPE OF IMPACT** **(Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Blue Collar Workers	Manufacturing	Direct	Workplace design will enable faster processing of shipments.
Setter	Manufacturing	Direct	AR guidance of Change overs will enable faster and error free process
Production Manager	Manufacturing	Direct	Higer transparency of the risk level in current production process and due shipments

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT (Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Customers	Production	Indirect	Faster resolution of issues

Whirlpool

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT (Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Quality Manager	Manufacturing	Direct	Enriched access to data will improve decision making on Production Filtering, Quarantine, investment and people organization.
Industrial Engineer	Manufacturing	Direct	More accurate maintenance plan and process improvement thanks to a better correlation of process performances to product Quality
Product Development Engineer	Product Development	Direct	Better and faster product or component redesign thank to a direct correlation of quality data to functions chain in the product
Test Engineer	Manufacturing	Direct	More accurate and customized testing programs driven by a more detailed access to product and process quality data.

Mondragon

ACTOR	BUSINESS AREA	TYPE OF IMPACT	DESCRIPTION OF THE IMPACT
Production operators	Production	Direct	Ensure the correct state of the production line
Technical Assistance Service	Service	Direct	Monitoring and anticipation of the ZDM production
Tech provider	Other: ICT	Indirect	Development and maintenance of the cloud infrastructure

Kolektor

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	BUSINESS AREA *(marketing, administration, manufacturing, etc.)*[1]	TYPE OF IMPACT **(Direct or Indirect)**	DESCRIPTION OF THE IMPACT *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Worker, moulding machine specialist	Manufacturing	Direct	Worker role will less important since It will mostly deal with mechanical issues on the production line.
Manager	Manufacturing	Direct	Will have much better insights in the production process.
Manager	Customer Relationships	Indirect	Data, data processing, tracking, smart agents will provide better information about production.
Technician	Technical support	Direct	New paradigms will change the interaction human-machine. It will become more digital,

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT (Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
			data oriented compared to today physical.

ThyssenKrup

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT (Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Quality Technician	- Manufacturing	- Direct	A user-friendly and non-intrusive diagnostic system wi ll help to quickly and easily identify the root causes of Quality issues of th e production without interfering machine performa nce. An AI correlation between pr ocess operations and Quality measurement will better help to better adjust process target values than with classical exp erimental plan.
Production Line Responsible	- Management	- Indirect	A live process adjustment r elated to Quality deviations within the production line will maximize OEE, PPM, FPY.
Innovation Engineer	- Technical Support	- Indirect	Non-intrusive system which is al so interoperable between all company machines and PLC

ACTOR (Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)	BUSINESS AREA (marketing, administration, manufacturing, etc.)[1]	TYPE OF IMPACT (Direct or Indirect)	DESCRIPTION OF THE IMPACT Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area
			will allow to mutualize it faster within the overall manufacturing system .

Airbus

ACTOR (Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)	BUSINESS AREA (marketing, administration, manufacturing, etc.)[1]	TYPE OF IMPACT (Direct or Indirect)	DESCRIPTION OF THE IMPACT Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area
Industrial architects Aircraft Architects Industrial Engineers	Manufacturing	Direct	Industrial architects will be able to manage trade off studies, explore interesting areas and make decision based on data analysis which makes their decision more efficient
Blue collar	Manufacturing	Indirect	The choice of the best scenarios makes the production process more efficient and tends towards a better quality, which will make the performance of the blue collar more interesting.

GHI

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT** **(Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Blue Collar Workers	Manufacturing	Direct	Increase on the number of manufactured parts. Reduce the number of defective parts manufactured. Improved decision-making efficiency thanks to the analysis & visualization tool.
Production area Coordinator	Manufacturing	Direct	Fast detection of root cause of quality problem. Improved decision-making efficiency thanks to the analysis & visualization tool.
IT provider (real-time device)	Technical Support	Direct	Fast detection of root cause of quality problem. Improved decision-making efficiency thanks to the analysis & visualization tool.
IT provider (Data ingestion platform)	Engineering 4.0	Indirect	Reduce furnace operational costs. Fast detection of root cause of quality problem. Reduce energy consumption of the plant.
Data Scientist	Engineering 4.0	Direct	Reduce furnace operational costs.

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT** **(Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
			Fast detection of root cause of quality problem. Reduce energy consumption of the plant. Improved decision-making efficiency thanks to the analysis & visualization tool.
IT support	Technical Support	Indirect	Improved decision-making efficiency thanks to the analysis & visualization tool. Fast detection of root cause of quality problem.

RiaStone

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT** **(Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Shift Managers	Manufacturing	Direct	Lower number of events that will trigger human operator interventions, while increasing the quality of produce.
Production Line Operators	Manufacturing	Direct	The implementation of ZDM technologies in the production lines increases

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT (Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
			efficiency and will eliminate constant needs to react to emergency situations

PRIMA

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT (Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Operators	Manufacturing	Direct	Operators will work in a safer condition
Customer Care	Service	Indirect	Easy intervention with AR support

Danobat

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT (Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Production operators	Production	Direct	Ensure the correct state of the production line
Maintenance department	Maintenance	Direct	Maintenance advising and recommendations

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)*[1]	**TYPE OF IMPACT** **(Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Technical Assistance Service	Service	Direct	Monitoring and anticipation of the ZDM production
Tech provider	Other: ICT	Indirect	Development and maintenance of the cloud infrastructure

Fagor

ACTOR	**BUSINESS AREA**	**TYPE OF IMPACT**	**DESCRIPTION OF THE IMPACT**
Production operators	Production	Direct	Ensure the correct state of the production line
Maintenance department	Maintenance	Direct	Maintenance advising and recommendations
Technical Assistance Service	Service	Direct	Monitoring and anticipation of the ZDM production
Tech provider	Other: ICT	Indirect	Development and maintenance of the cloud infrastructure

GF – Business Process 1

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	BUSINESS AREA *(marketing, administration, manufacturing, etc.)[1]*	TYPE OF IMPACT (Direct or Indirect)	DESCRIPTION OF THE IMPACT *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Machine operators	Manufacturing	Direct	Improvement of visibility of equipment performance and additional means for improving it in less time
Production managers	Management	Direct	Better allocation of resources and reduction of overall costs
Assembly operators	Manufacturing	Direct	Reduction of errors due to assistance of digital system and better self-assessment of performance
Marketing and Sales Managers	Marketing and Sales	Direct	Lead time advantage with superior quality offer for machine products

GF – Business Process 2

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	BUSINESS AREA *(marketing, administration, manufacturing, etc.)[1]*	TYPE OF IMPACT (Direct or Indirect)	DESCRIPTION OF THE IMPACT *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Machine operators	Manufacturing	Direct	Improvement of visibility of equipment performance and additional means for improving it in less time

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	**BUSINESS AREA** *(marketing, administration, manufacturing, etc.)[1]*	**TYPE OF IMPACT** **(Direct or Indirect)**	**DESCRIPTION OF THE IMPACT** *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Production managers	Management	Direct	Better allocation of resources and reduction of overall costs
Assembly operators	Manufacturing	Direct	Reduction of errors due to assistance of digital system and better self-assessment of performance
Marketing and Sales Managers	Marketing and Sales	Direct	Lead time advantage with superior quality offer for machine products
Technical Support	Manufacturing	Direct	Improvement of technical support due to regular and comprehensive monitoring of the machine tool state
Customer Relationships	Marketing and Sales	Direct	Increase satisfaction of customers by providing personalized reports on requested quality parameters

Appendix E. Relevant project requirements

Table 43: Overview of all relevant project requirements

Code	Project	Requirement	Met
PR_req_CLF_01	CloudiFacturing	None	N/A
PR_req_MAN_01	ECSEL Mantis	Our concern (MGEP) is with interoperability among platforms and systems. In the previous project we provide interoperability between IoTA events and Mimosa databases. The interoperability challenges are many more. The number of commercial and proprietary platforms to interconnect is extended. Need to identify those platforms and the protocols and data formats they use.	Unknown
PR_req_FE_01	FAR-EDGE (H2020-FOF-2016)	"FAR-EDGE shall execute and control production (semi-) automatically and manually". A production control system must facilitate the automatic, semi-automatic and manual execution and control of production processes for (parts of) a product	Met
PR_req_FE_02	FAR-EDGE (H2020-FOF-2016)	"FAR-EDGE shall be able to adjust with respect to the production needs". The system shall be able to perform its functionalities and to reconfigure itself depending on production needs (e.g. product fluctuation, change in the production equipment due to breakdowns). Complete customization can be seen as a limit case where all the products are different from each other.	Met
PR_req_Ifa_01	FP07 IFaCOM, Intelligent Fault Correction and self-Optimizing Manufacturing systems	Censoring and cognitive signal analysis,	Unknown
PR_req_Ifa_02	FP07 IFaCOM, Intelligent Fault Correction and self-Optimizing Manufacturing systems	Real-time corrections and adaptive control (self-optimizing)	Unknown
PR_req_Ifa_03	FP07 IFaCOM, Intelligent Fault Correction and self-Optimizing Manufacturing systems	AI Techniques (Neural Networks and Fuzzy logic) for machine system self-adaption,	Unknown
PR_req_Ifa_04	FP07 IFaCOM, Intelligent Fault Correction and self-Optimizing Manufacturing systems	Data communication	Unknown
PR_req_Ifa_05	FP07 IFaCOM, Intelligent	Integration and storage	Unknown

Code	Project	Requirement	Met
	Fault Correction and self-Optimizing Manufacturing systems		
PR_req_PRO_01	FP7 ProSEco (GA 609143)	Not applicable due to the focus of the project being on the product services and production process design phase.	N/A
PR_req_BO_01	H2020 BOOST4.0	Overall Big Data Analytics Framework Architecture Specification including data and information flow. Overall Framework architecture will be specified, including the detailed formalization of modules interaction including communication and data-flow.	Not met
PR_req_BO_02	H2020 BOOST4.0	BOOST 4.0 Industrial Data Space (IDS) will be designed and developed.	Not met
PR_req_BO_03	H2020 BOOST4.0	The IDS will support the sharing of data and analytics within the industrial sector.	Not met
PR_req_BO_04	H2020 BOOST4.0	Big Data Analytics Platform focuses on the customization and extension of existing digital manufacturing platforms with analytics methods, in order to apply them in the field of manufacturing.	Not met
PR_req_BO_05	H2020 BOOST4.0	Extension of the capabilities of ATLANTIS tools to be able to exploit the BOOST 4.0 big data and analytics framework.	Not met
PR_req_BO_06	H2020 BOOST4.0	Analysis of the data perspective of the end-to-end production meta-process in Whirlpool and Benteler. All phases of the Digital Thread (whole life cycle) will be considered, including design, supply, manufacturing, delivery and post-sale intelligence. The outcome of this analysis will be a detailed specification of the relevant data sources, from both the business and the technical viewpoints.	Not met
PR_req_BO_07	H2020 BOOST4.0	On top of the previous specification there will be the design of the conceptual information model: an integrated logical view on the relevant information available, each element linked to its physical source.	Not met
PR_req_BO_08	H2020 BOOST4.0	Perform early experimentation on available data sets, which include inspection, selection and fusion of available machine, maintenance and manufacturing data.	Not met
PR_req_BO_09	H2020 BOOST4.0	Domain-knowledge is elicited and consolidated in form of generic plant description model using modelling techniques for later roll-out and prescriptive applications.	Not met
PR_req_BO_10	H2020 BOOST4.0	Further domain knowledge includes fault patterns and their relevance is documented using established tool such as FMEA and FTA.	Not met
PR_req_BO_11	H2020 BOOST4.0	Based on the BOOST 4.0 framework, a generic blueprint for predictive maintenance applications, comprising a process model as well as a software architecture, is designed that serves for and is validated by the subsequent experimentation.	Not met

Code	Project	Requirement	Met
PR_req_BO_12	H2020 BOOST4.0	Establishment of the main components for predictive maintenance of the plants. Faults identified with the help of domain-experts are considered.	Not met
PR_req_BO_13	H2020 BOOST4.0	Evaluation entails model accuracy, sensitivity/specificity, as well as to devise KPIs w.r.t. expected economic impact of early fault detection e.g. on overall equipment efficiency. In a second step, the data is leveraged for fault diagnostics and prescriptive analytics. The latter entails fusion and deeper analysis of unstructured maintenance reports, machine data, as well as utilization of the FMEA and FTA results.	Not met
PR_req_BO_14	H2020 BOOST4.0	Deployment of the previously mentioned models for (close to) real-time analytics to the plants at Benteler factory, based on the BOOST architecture blueprint and the adopted process models.	Not met
PR_req_BO_15	H2020 BOOST4.0	Development and process integration of interactive data visualization and analysis dashboard applications for mobile of stationary devices on the shop-floor.	Not met
PR_req_BO_16	H2020 BOOST4.0	The installed on-site trials serve as basis for evaluation by means of in-process model performance (e.g. false positives and false negatives) as well as the devised KPIs.	Not met
PR_req_BO_17	H2020 BOOST4.0	Model transfer is established by a dedicated teach-in/model adoption phase, which significantly reduces development time and demand for training data.	Not met
PR_req_BO_18	H2020 BOOST4.0	Pilot Area KPI Collection and Benchmarking Data involves the actual preparation of the pilot demonstration and deployment of the BOOST 4.0 big data processing infrastructure and applications (digital thread, data space apps, predictive analytics and data visualizations).	Not met
PR_req_CO_01	H2020 COMPOSITION	Development of the Decision Support System (DSS) within COMPOSITION. The data from different stakeholders, sensors, IoT, MES and CMMS will be combined, so that the interested party will be able to make an informed decision.	Not met
PR_req_CO_02	H2020 COMPOSITION	Supported by machine learning algorithms, the end users will receive notifications on events that require their attention accompanied with the respective recommendation as to how to handle them.	Not met
PR_req_CO_03	H2020 COMPOSITION	Analysis of the business workflow and breakdown of the sub-processes in order to accommodate for business priorities and plans of each stakeholder involved in the supply chain (raw material/products/services, suppliers, production, recycling and delivery).	Not met
PR_req_CO_04	H2020 COMPOSITION	Data analytics required to describe and assess factory profiles and reference profiles of related external service providers, that will	Not met

Code	Project	Requirement	Met
		be included in the DFM model using rstudio, vstudio and Hadoop among others.	
PR_req_CO_05	H2020 COMPOSITION	Lead the Communication, Dissemination and Exploitation activities.	Not met
PR_req_DA_01	H2020 DAEDALUS	Interoperability between CPS under the scope of a standardized approach to develop real-time automation.	Unknown
PR_req_DI_01	H2020 DIVERSITY (GA 636692)	Not applicable due to the focus of the project being on the PSS design phase.	N/A
PR_req_F2F_01	H2020 Factory2Fit	The project’s requirements included technical, business, user, safety and ethical related requirements. However, the requirements were not listed one by one but instead described in general level.	Unknown
PR_req_AM_01	H2020 I4MS AMable	Ensuring zero defect in each value creation (functional issue)	Partly met
PR_req_AM_02	H2020 I4MS AMable	Persisting quality data (in a Block chain)	Met
PR_req_L4_01	H2020 L4MS	none	Unknown
PR_req_PER_01	H2020 PERFORM	Requirement “Increased adaptability”	Met
PR_req_PER_02	H2020 PERFORM	Requirement “Reduced complexity”	Not met
PR_req_PER_03	H2020 PERFORM	Requirement “Enhanced productivity”	Met
PR_req_PER_04	H2020 PERFORM	Requirement “Advanced product quality”	Met
PR_req_PRO_01	H2020 PROPHESY	Architecture	Met
PR_req_PRO_02	H2020 PROPHESY	B. Cyber Physical System Platform integration - Met	Met
PR_req_PRO_03	H2020 PROPHESY	C. Data collection and Analytics - Running	Running
PR_req_PRO_04	H2020 PROPHESY	D. Visualization - Running	Running
PR_req_PRO_05	H2020 PROPHESY	E. Integration and Validation in Industrial demonstrators - Running	Running
PR_req_IDS_01	The Industrial Data Space (IDS)	[Secure data exchange]	Met
PR_req_IDS_02	The Industrial Data Space (IDS)	[Decentral infrastructure]	Met
PR_req_IDS_03	The Industrial Data Space (IDS)	[Data Sovereignty]	Met
PR_req_IDS_04	The Industrial Data Space (IDS)	[Data Security]	Met
PR_req_IDS_05	The Industrial Data Space (IDS)	[Governance]	Met

Code	Project	Requirement	Met
PR_req_IDS_06	The Industrial Data Space (IDS)	[Openness]	Met
PR_req_IDS_07	The Industrial Data Space (IDS)	[Scalability]	Met
PR_req_IDS_08	The Industrial Data Space (IDS)	[Network Effects]	Met
PR_req_Rec_01	H2020 ReconCell	Requirement robot work cell reconfiguration	Met
PR_req_Rec_02	H2020 ReconCell	Requirement programming by demonstration	Met
PR_req_Rec_03	H2020 ReconCell	Requirement visual quality control	Partly met
PR_req_Rec_04	H2020 ReconCell	4. Requirement force-based quality control	Partly met
PR_req_SAF_01	H2020 SAFIRE	Able to monitor machine current status data to identify situations	Met
PR_req_SAF_02	H2020 SAFIRE	Able to monitor machine health status to identify current situations	Met
PR_req_SAF_03	H2020 SAFIRE	Able to monitor overall equipment effectiveness (OEE) to identify situations	Not met
PR_req_SAF_04	H2020 SAFIRE	Able to monitor production status to identify current situation	Met
PR_req_SAF_05	H2020 SAFIRE	Able to provide situational information based on raw and monitored data	Met
PR_req_SAF_06	H2020 SAFIRE	Able to extract situational information from monitored machines	Met
PR_req_SAF_07	H2020 SAFIRE	Able to dynamically extract situational information from sensor data	Met
PR_req_SAF_08	H2020 SAFIRE	Ensures data integrity	Met
PR_req_SAF_09	H2020 SAFIRE	Prevents unauthorized access	Met
PR_req_SAF_10	H2020 SAFIRE	Does not negatively affect the usual production processes	Met
PR_req_SAF_11	H2020 SAFIRE	Support for scalability in the size of cloud and computing resources	Partly met
PR_req_SAF_12	H2020 SAFIRE	Capable of real time data ingestion (registering data) Partly Met	Partly met
PR_req_SAF_13	H2020 SAFIRE	Capable of real time data processing	Partly met
PR_req_ZB_01	H2020 Z-BRE4K	Strategies to improve maintainability and increase operating life of production. Update of existing and development of new strategies based on real data to improve maintainability and operating life of production systems	Not met
PR_req_ZB_02	H2020 Z-BRE4K	Decision support for Predictive & JIT maintenance towards operational optimisation. The ultimate aim is to introduce and apply a holistic approach to increase maintainability, accurately predict the condition and the remaining useful life of networked machines and adapt the performance to increase the operating life span of production systems.	Not met

Code	Project	Requirement	Met
PR_req_ZB_03	H2020 Z-BRE4K	Predictive Maintenance DSS will also include dedicated modules for recommendations provision for improving maintainability and operational efficiency at shop floor. It uses previous recommendations and their result as training data to assess the effectiveness of provided recommendations. Machine-learning algorithms will be used for improved recommendations.	Not met
PR_req_ZB_04	H2020 Z-BRE4K	Technical indicators for performance and reliability assessment (KPIs).	Not met
PR_req_ZB_05	H2020 Z-BRE4K	Decide on possible alarms and activation of remedy strategies.	Not met
PR_req_ZB_06	H2020 Z-BRE4K	Condition Monitoring models will be enriched to detect deterioration rate and raise alarms for further actions at MES level.	Not met
PR_req_ZB_07	H2020 Z-BRE4K	Condition Monitoring Suite (CM) for predicting machinery system failures based on trends forecasting and deterioration rate.	Not met
PR_req_ZF_01	H2020 Z-Fact0r	Interfacing with the specific defect prediction/detection sources of the pilots and filtering out false alarms	Not met
PR_req_ZF_02	H2020 Z-Fact0r	Customizing the semantic rules to address the pilots' specificities and the AQ requirements.	Not met
PR_req_ZF_03	H2020 Z-Fact0r	Automated Decision-support using rule-based engines, including i) KPIs for performance auditing; ii) Modeling and Deployment of Strategies for ZDM (including Reverse-Supply-Chain). Adapting the DSS Strategies, recommendations and KPIs to project requirements	Not met
PR_req_ZF_04	H2020 Z-Fact0r	Reverse Supply Chain processes for defected items. RSC contextualises defects and decides process flows (e.g. return to supplier, return to previous stage for repair, dispose/recycle) of defected items in multi-stage production environments.	Not met
PR_req_ZF_05	H2020 Z-Fact0r	Rule-based engine for decision support in ZDM. Incorporating semantic rules and a rule-based engine to cope with detected/predicted defects identified from corroborating sources (e.g. different sourced of defect detection);	Not met
PR_req_ZF_06	H2020 Z-Fact0r	Deciding the mitigation actions to cope with defects and triggering the activation of the appropriate ZDM Strategy(ies)	Not met
PR_req_ZF_07	H2020 Z-Fact0r	Providing recommendations for performance improvements, based on KPIs assessment and dashboards (e.g. scrap level, rework level, throughput, FAR, Precision in warning signals, defects per stage, etc.).	Not met
PR_req_FOC_01	H2020, FOCUS Creating FoF project clusters to enhance their impact	Cyber-Physical systems able to adapt process plans, parameters and production routings based on the detected quality of the parts under processing, thus smoothing the propagation of defects at the end of the production line.	Unknown

Code	Project	Requirement	Met
PR_req_FOC_02	H2020, FOCUS Creating FoF project clusters to enhance their impact	Profile monitoring tools for functional data and geometrical product features, supporting zero-defect manufacturing in small batch productions	Unknown
PR_req_FOC_03	H2020, FOCUS Creating FoF project clusters to enhance their impact	Effect propagation in complex manufacturing system architectures and non-linear material flows, e.g. under autonomous, decentralized part flow control mechanisms.	Unknown
PR_req_FOC_04	H2020, FOCUS Creating FoF project clusters to enhance their impact	Dynamic control of production quality target performance during the system life-cycle for reduced ramp-up times among system reconfigurations	Unknown
PR_req_SER_01	H2020-FOF-2017 SERENA	Requirement "Health Assessment (HA) block": is an information block which utilizes expertise from a human or automated agent to determine the current health of the equipment and to diagnose existing fault conditions	Met
PR_req_SER_02	H2020-FOF-2017 SERENA	Requirement "State Detection (SD) block". The primary function of the SD block (sometimes referred to as "state awareness") is to compare Data Manipulation and/or Data Acquisition outputs against expected baseline profile values or operational limits, in order to generate enumerated state indicators with respective boundary exceedances. The SD block generates indicators which may be utilized by the Health Assessment block to generate alerts and alarms. When appropriate data are available, the SD block should generate assessments based on operational context, sensitive to the current operational state or operational environment	Partly met
PR_req_SER_03	H2020-FOF-2017 SERENA	Requirement "Prognostic Assessment (PA) block" The primary function of the PA block is to project the future state of the monitored equipment using a combination of prognostic models and their algorithms, including future operational usage model(s). This block determines the future state of health and failure modes by combining the relevant outputs of the other blocks and applying a prognostic algorithm or model based on supplied projected operational utilization.	Met
PR_req_MAY_01	MAYA	Digital continuity	Met
PR_req_MAY_02	MAYA	Synchronization of the digital and real factory	Met
PR_req_MAY_03	MAYA	Multidisciplinary integrated simulation and modelling	Met
PR_req_MEG_01	MEGaFiT	To be able to identify the main 5-10 important process parameters and interactions upfront	Met
PR_req_MEG_02	MEGaFiT	Capture the main process interactions in a quantitative model that can be evaluated in real-time by the adaptive process control.	Met

Code	Project	Requirement	Met
PR_req_MEG_03	MEGaFiT	Realise in-line measurement equipment and strategies to be able to measure process and product parameters in real-time (>100 parts/minute)	Met
PR_req_MEG_04	MEGaFiT	Realise process actuation and control system to adjust the process in real-time	Met
PR_req_MEG_05	MEGaFiT	To validate the reduction of defects from 5-15% to <1% in pilot production lines	Met

Appendix F. National and International Research & Innovation Activities

QU4LITY brings together the leading partners of a number of recent/on-going H2020 projects that have already produced results very closely related to QU4LITY. QU4LITY will take advantage of these projects in three main directions:

- Reuse of their components (digital enablers, digital platforms) as a means of rapidly bootstrapping the project's results and maximizing value for money.
- Exploitation of methodological insights in quality-related aspects of production processes.
- Liaisons with other ecosystems as part of QU4LITY's community building efforts.

The structure of this section is based on the like-named section in the Grant Agreement (RODRIGUEZ EDROSO & QU4LITY Consortium, 2018) The projects described in paragraph 1.3.1.8 of the proposal are listed in Table 44. For each project one of the QU4LITY partners was asked to fill in a short questionnaire, together with the input from the proposal that led to the input for this chapter, which resulted in a short description of each project, a description of the link with QU4LITY, the gap between the project and QU4LITY a number of relevant requirements from that project for QU4LITY.

Table 44: Overview of related projects and initiatives

Project No.	Project name
P1	H2020 DAEDALUS
P2	H2020 AUTOWARE
P3	H2020 FAR-EDGE
P4	H2020 PERFORM
P5	H2020 SAFIRE
P6	H2020 COMPOSITION
P7	H2020 Connected Factories (CSA)
P8	H2020 Z-Fact0r
P0	H2020 ZAERO
P10	FP7 MIDEMMA
P11	FP7 IFACOM
P12	FP7 MEGAFIT
P13	FP7 MUPROD
P14	H2020 Factory2Fit
P15	H2020 MAYA
P16	H2020 DIVERSITY
P17	H2020 FOCUS (CSA)
P18	H2020 I4MS MIDIH
P19	H2020 I4MS CloudiFacturing
P20	H2020 I4MS ReconCell
P21	H2020 I4MS L4MS
P22	H2020 I4MS AMable
P23	H2020 Z-BRE4K
P24	H2020 PROPHESY
P25	H2020 SERENA
P26	H2020 I4MS BeInCPPS

Project No.	Project name
P27	I4MS ProSEco
P28	Industrial Data Space (IDS)
P29	H2020 BOOST4.0
P30	H2020 Productive4.0
P31	ECSEL MANTIS

The inputs from the projects AUTOWARE, Connected Factories, ZAERO, MUPROD and BeInCPPS could not be collected and are therefor not in this Appendix.

Appendix F.1 H2020 Project DAEDALUS

Short description of DAEDALUS

Daedalus is conceived to enable the full exploitation of the CPS concept of virtualized intelligence, through the adoption of a completely distributed automation platform based on IEC-61499 standard, fostering the creation of a Digital Ecosystem that could go beyond the current limits of manufacturing control systems and propose an ever-growing market of innovative solutions for the design, engineering, production and maintenance of plants' automation. The following objectives will be reached:

- Ease the conception, development and distribution of intelligence into CPS for real-time execution of orchestrated manufacturing tasks;
- Foster interoperability of CPS from different vendors at orchestration-level (= "between CPS");
- Simplify the design, implementation and integration of optimal coordinating control intelligence of CPS;
- Enable near-real-time co-simulation of manufacturing systems as a fully integrated "service" of a CPS;
- Create a Digital Marketplace to simplify the matchmaking between offer and demand within the Ecosystem;
- Conceive a multi-sided business model for the Automation Ecosystem and the corresponding business plans for its Complementors
- Foster the widespread acceptance of the Ecosystem platform to guarantee success and impact of Daedalus multi-sided market.

The project approach is based on 3 technological pillars, one platform pillar and a final ecosystem pillar:

1. IEC61499-based reconfigurable automation platform for distributed orchestration of interoperable CPS;
2. "Simulation-as-a-service" for integrated near-real-time co-simulation of CPS behavioural models;
3. Advanced SDKs for simplified design of hierarchically distributed optimal control applications;
4. Digital Marketplace for the creation of an interdependent ecosystem of automation solutions providers;
5. Proof-of-concept showcases to accelerate the involvement of "complementors" and the maturation of the Ecosystem.

Relevance and linking to QU4LITY

The project provides an IEC-61499 platform for distributed real-time automation and control, which will be among the digital enablers of QU4LITY

Gaps between DAEDALUS and QU4LITY

Adopting IEC-61499 to support real-time quality evaluation in industrial automation requires its integration with specific predictive maintenance runtime environment.

Requirements from DAEDALUS

Table 45: Requirements from DAEDALUS

Code	Project	Requirement	Met
PR_req_DA_01	H2020 DAEDALUS	Interoperability between CPS under the scope of a standardized approach to develop real-time automation.	Unknown

Appendix F.2 H2020 Project FAR-EDGE

Short description of FAR-EDGE

FAR-EDGE is a joint effort of leading experts in manufacturing, industrial automation and FI technologies towards the smooth and wider adoption of virtualized factory automation solutions based on FI technologies. It will research a novel factory automation platform based on edge computing architectures and IoT/CPS technologies. FAR-EDGE will provide a reference implementation of emerging standards-based solutions for industrial automation (RAMI 4.0, Industrial Internet Consortium reference architecture), along with simulation services for validating automation architectures and production scheduling scenarios. FAR-EDGE will lower the barriers for manufacturers to move towards Industry 4.0, as a means of facilitating mass-customization and reshoring. Emphasis will be paid in the study of migration options from legacy centralized architectures, to emerging FAR-EDGE based ones

Relevance and linking to QU4LITY

Provides edge computing and block chain-based digital enablers for simulation, analytics and automation, which will be exploited in the project's solutions and pilots.

Gaps between FAR-EDGE and QU4LITY

FAR-EDGE has a main focus on novel decentralized automation solutions for the factories of the future. QU4LITY could leverage the architectural approach adopted in FAR-EDGE, particularly for what concerns the data analytics. But an effort should be made to ensure real-time quality control, self-learning processes and predictive maintenance, in order to reach the maximum level of system autonomy.

Requirements from FAR-EDGE

Table 46: Requirements from FAR-EDGE

Code	Project	Requirement	Met
PR_req_FE_01	FAR-EDGE (H2020-FOF-2016)	"FAR-EDGE shall execute and control production (semi-) automatically and manually". A production control system must facilitate the automatic, semi-automatic and manual execution and control of production processes for (parts of) a product	Met
PR_req_FE_02	FAR-EDGE (H2020-FOF-2016)	"FAR-EDGE shall be able to adjust with respect to the production needs". The system shall be able to perform its functionalities and to reconfigure itself depending on production needs (e.g. product fluctuation, change in the production equipment due to breakdowns). Complete customization can be seen as a limit case where all the products are different from each other.	Met

Appendix F.3 H2020 Project PERFORM

Short description of PERFORM

PERFORM provides Plug n´ Produce (PnP) solutions in various areas (e.g. maintenance) that increase production flexibility, which reducing cost and improving quality. Within the data analytics module (1), for example, a failure data base is used in combination with machine process data to interpret and predict machine health status. Which was visualized on a web service (2). Additionally, shop floor process data in combination with MES are used for model generation and logistic simulation to evaluate best schedule for maintenance tasks (3). This scheduling module supports maintenance planning and execution. With these PnP framework solutions machine down times are reduced and machine health KPIs support in predictive maintenance.

Relevance and linking to QU4LITY

Provides Plug n' Produce (PnP) solutions in various areas (e.g., maintenance) that increase production flexibility, which reducing cost and improving quality. The PnP framework will be used in QU4LITY

Gaps between PERFORM and QU4LITY

The PnP solutions in PERFORM are used for diagnosis and first prediction. But the human manual part is still very high. The user can get KPIs regarding machine health status, but he must interpret and decide on its own, which will be the necessary maintenance tasks. The user will get suggestions for optimal scheduling of maintenance task, but the decision of best alternative is done also manually. Towards autonomous quality the control feedback loop from diagnostic, prediction and suggestion must be done automatically.

Requirements from PERFORM

Table 47: Requirements from PERFORM

Code	Project	Requirement	Met
PR_req_PER_01	H2020 PERFORM	Requirement "Increased adaptability"	Met
PR_req_PER_02	H2020 PERFORM	Requirement "Reduced complexity"	Not met
PR_req_PER_03	H2020 PERFORM	Requirement "Enhanced productivity"	Met
PR_req_PER_04	H2020 PERFORM	Requirement "Advanced product quality"	Met

Appendix F.4 H2020 Project SAFIRE

Short description of SAFIRE

"The SAFIRE project targets two related technology challenges for smart factories that present new opportunities for improving production, products and services:

1. Interconnected Systems of Production Systems (SoPS) within smart manufacturing environments where individual production systems and the SoPS as a whole have hardware and software requirements to be addressed to achieve specific business objectives such as scheduling, power consumption, throughput, and maintenance.
2. Connected Product Networks (CPNs) where networked smart products collect data, can be adapted in the field, and can deliver extended services to customers through optimization of smart product performance parameters and customization of products to environments, usage patterns and other dynamic factors. The advanced analytics and reconfiguration capabilities to be developed in SAFIRE will be based on mastering the big data challenges associated with manufacturing (sensor and process data), enterprise data and smart product data to provide advanced analytics that allow manufacturers to address production system behaviour forecasting and to establish optimization methods that are integrated in the design and product chain. The project will deliver big data analytic capabilities that meet real-time requirements so that dynamic run-time reconfiguration decisions are made during production time rather than pre-planned at production planning time."

Relevance and linking to QU4LITY

Focuses on reconfigurable automation solutions that optimize performance with respect to KPIs like throughput, power consumption, utilization, maintenance and other factors. They will be used in QU4LITY pilots

Gaps between SAFIRE and QU4LITY

SAFIRE provides a cloud-based analytics and reconfiguration platform. Using SAFIRE, it could be possible to deploy ZDM algorithms that monitor production systems in real-time.

Requirements from SAFIRE

Table 48: Requirements from SAFIRE

Code	Project	Requirement	Met
PR_req_SAF_01	H2020 SAFIRE	Able to monitor machine current status data to identify situations	Met
PR_req_SAF_02	H2020 SAFIRE	Able to monitor machine health status to identify current situations	Met
PR_req_SAF_03	H2020 SAFIRE	Able to monitor overall equipment effectiveness (OEE) to identify situations	Not met
PR_req_SAF_04	H2020 SAFIRE	Able to monitor production status to identify current situation	Met
PR_req_SAF_05	H2020 SAFIRE	Able to provide situational information based on raw and monitored data	Met

Code	Project	Requirement	Met
PR_req_SAF_06	H2020 SAFIRE	Able to extract situational information from monitored machines	Met
PR_req_SAF_07	H2020 SAFIRE	Able to dynamically extract situational information from sensor data	Met
PR_req_SAF_08	H2020 SAFIRE	Ensures data integrity	Met
PR_req_SAF_09	H2020 SAFIRE	Prevents unauthorized access	Met
PR_req_SAF_10	H2020 SAFIRE	Does not negatively affect the usual production processes	Met
PR_req_SAF_11	H2020 SAFIRE	Support for scalability in the size of cloud and computing resources	Partly met
PR_req_SAF_12	H2020 SAFIRE	Capable of real time data ingestion (registering data) Partly Met	Partly met
PR_req_SAF_13	H2020 SAFIRE	Capable of real time data processing	Partly met

Appendix F.5 H2020 Project COMPOSITION

Short description of COMPOSITION

COMPOSITION will create a digital automation framework (the COMPOSITION IIMS) that optimizes the manufacturing process by exploiting existing data, knowledge and tools to increase productivity and dynamically adapt to changing market requirements. This technology acts as the technical operating system for business connections between factories and their suppliers. Furthermore, it opens a new space for third party entities to actively interact in the supply chain, e.g. by providing services to improve cycle time, cost, flexibility or resource usage. In addition to the supply chain improvements, also the processes inside the company will be addressed and optimized. Data across the multi-sided company internal value chain is integrated by an Integrated Information Management System (IIMS) with optimization and modelling tools for resource management, including innovative, multi-level, real-time, cross-domain analytics, including a Decision Support System. COMPOSITION will implement, demonstrate and validate the system in two multi-sided pilots that show the modularity, scalability and re-configurability of the platform across multiple application domains.

Relevance and linking to QU4LITY

Provides an ecosystem that connects (securely) data and services between factories and their suppliers, in order to increase the flexibility of the supply chain and meet changing market requirements. It will be used as part of the QU4LITY supply chain solutions for the pilots

Gaps between COMPOSITION and QU4LITY

In QU4LITY we could adapt and reuse: DSS for managing defects. Regarding prediction of defects based on asset's deterioration rate (through data analytics and machine learning) there will be enhancements of the algorithm design to address the autonomous quality requirements of the project, introducing the concept of autonomous quality signatures at the level of each monitored asset. As far as DSS is concerned there will be enhancements of DSS semantic rules to address the autonomous quality requirements (i.e. prediction of quality, flexibility, rapid adaptivity) of the project. Furthermore, the subsystem will be partially redesigned to incorporate ZDM process requirements and topology of the project pilots to be facilitated.

Requirements from COMPOSITION

Table 49: Requirements from COMPOSITION

Code	Project	Requirement	Met
PR_req_CO_01	H2020 COMPOSITION	Development of the Decision Support System (DSS) within COMPOSITION. The data from different stakeholders, sensors, IoT, MES and CMMS will be combined, so that the interested party will be able to make an informed decision.	Not met
PR_req_CO_02	H2020 COMPOSITION	Supported by machine learning algorithms, the end users will receive notifications on	Not met

Code	Project	Requirement	Met
		events that require their attention accompanied with the respective recommendation as to how to handle them.	
PR_req_CO_03	H2020 COMPOSITION	Analysis of the business workflow and breakdown of the sub-processes in order to accommodate for business priorities and plans of each stakeholder involved in the supply chain (raw material/products/services, suppliers, production, recycling and delivery).	Not met
PR_req_CO_04	H2020 COMPOSITION	Data analytics required to describe and assess factory profiles and reference profiles of related external service providers, that will be included in the DFM model using rstudio, vstudio and Hadoop among others.	Not met
PR_req_CO_05	H2020 COMPOSITION	Lead the Communication, Dissemination and Exploitation activities.	Not met

Appendix F.6 H2020 Project Z-Fact0r

Short description of Z-Fact0r

Zero-defect manufacturing (ZDM) strategies towards multi-stage production management; Development of Reverse-Supply-Chain Strategy; Development of defects' prognosis model based on trend-analysis of assets' condition; Development of DSS to support ZDM;

Relevance and linking to QU4LITY

Develops ZDM strategies for multi-stage production processes. QU4LITY will build on some of its results (e.g., reverse Supply Chain package to manage reverse process on defected items, DSS for managing defects, ZDM Strategies for multi-stage production)

Gaps between Z-Fact0r and QU4LITY

In QU4LITY we could adapt and reuse: i) Reverse Supply Chain package to manage reverse process (e.g. return to supplier, return to previous stage for repair, dispose/recycle) on defected items; ii) DSS for managing defects; iii) ZDM Strategies for multi-stage production: Predict, Prevent, Repair, Manage. Regarding prediction of defects based on asset's deterioration rate (through data analytics and machine learning) there will be enhancements of the algorithm design to address the autonomous quality requirements of the project, introducing the concept of autonomous quality signatures at the level of each monitored asset: (i) Identification of deterioration for asset's condition parameters. (ii) Correlation of identified deteriorations; rising of alarms for detected/predicted asset failures. As far as DSS and ZDM Strategies are concerned there will be enhancements of all strategies and DSS semantic rules to address the autonomous quality requirements (i.e. prediction of quality, flexibility, rapid adaptivity) of the project. Furthermore, the subsystem will be partially redesigned to incorporate ZDM process requirements and topology of the project pilots to be facilitated.

Requirements from Z-Fact0r

Table 50: Requirements from Z-Fact0r

Code	Project	Requirement	Met
PR_req_ZF_01	H2020 Z-Fact0r	Interfacing with the specific defect prediction/detection sources of the pilots and filtering out false alarms	Not met
PR_req_ZF_02	H2020 Z-Fact0r	Customizing the semantic rules to address the pilots' specificities and the AQ requirements.	Not met
PR_req_ZF_03	H2020 Z-Fact0r	Automated Decision-support using rule-based engines, including i) KPIs for performance auditing; ii) Modeling and Deployment of Strategies for ZDM (including Reverse-Supply-Chain). Adapting the DSS Strategies, recommendations and KPIs to project requirements	Not met
PR_req_ZF_04	H2020 Z-Fact0r	Reverse Supply Chain processes for defected items. RSC contextualises defects and decides	Not met

Code	Project	Requirement	Met
		process flows (e.g. return to supplier, return to previous stage for repair, dispose/recycle) of defected items in multi-stage production environments.	
PR_req_ZF_05	H2020 Z-Fact0r	Rule-based engine for decision support in ZDM. Incorporating semantic rules and a rule-based engine to cope with detected/predicted defects identified from corroborating sources (e.g. different sourced of defect detection);	Not met
PR_req_ZF_06	H2020 Z-Fact0r	Deciding the mitigation actions to cope with defects and triggering the activation of the appropriate ZDM Strategy(ies)	Not met
PR_req_ZF_07	H2020 Z-Fact0r	Providing recommendations for performance improvements, based on KPIs assessment and dashboards (e.g. scrap level, rework level, throughput, FAR, Precision in warning signals, defects per stage, etc.).	Not met

Appendix F.7 Project MIDEMMA

Short description of MIDEMMA

The quality controls used in the environment of micro-manufacturing are mainly taken from macro-manufacturing, based on geometric controls after obtaining the components. This entails that a lot of time passes between error generation and detection, possibly causing a large number of defective parts or an unnecessary long processing time. Furthermore, this method does not provide direct information about the error generation, preventing rapid action on the cause. Micro-manufacturing processes require "zero defect" approaches, both in mass-manufacturing and in single-unit production environments. For this reason, it is necessary to extend the validation of the end product to focussing on process monitoring. This focus should apply to the monitoring of all process parameters and to aspects of raw material control or final handling of the manufactured parts. The information obtained should be processed in real time and be used as fresh input to predict the possible errors and to, thus, take action to prevent this error. With this approach, the MIDEMMA project aims to provide a comprehensive solution for the implementation of "zero defects" methodologies in micro-manufacturing processes on a European level.

Relevance and linking to QU4LITY

Develops ZDM multi-stage production monitoring processes. QU4LITY will build on some of its results (e.g. inline process monitoring, machine signal processing)

Gaps between MIDEMMA and QU4LITY

MIDEMMA was focused on micromanufaturing. Due to the needs related to measuring/monitoring these processes (very small sizes and very low signal-to-noise ratios), lot of effort was applied to the development of measuring/monitoring equipment. Also, the parts, tools and machines in micro scale do not behave as in macro scale so much effort was dedicated too to the defect generation analysis and defect avoidance strategies. With this, the possibility to integrate the developed data gathering systems and strategies into a generic ZDM platform would be very interesting.

Requirements from MIDEMMA

Table 51: Requirements from MIDEMMA

Code	Project	Requirement	Met
PR_req_MIDEM_1	MIDEMMA	Shop floor digitalization that enables the data capture for learning purposes that facilitate the generalization of results	Not met
PR_req_MIDEM_2	MIDEMMA	Software and hardware infrastructure for the implementation of autonomous control loops	Partly met

Appendix F.8 Project IFACOM

Short description of IFACOM

Zero defect level of manufacturing for all kinds of manufacturing, with emphasis on production of high value parts, on large variety custom design manufacturing and on high performance products

Relevance and linking to QU4LITY

Develops ZDM strategies for multi-stage production processes. QU4LITY will build on some of its results (e.g., reverse Supply Chain package to manage reverse process on defected items, DSS for managing defects, ZDM Strategies for multi-stage production)

Gaps between IFACOM and QU4LITY

The real time vital parameter control loop, The process optimization loop, The machine system optimization loop: Machine learning.

Requirements from IFACOM

Table 52: Requirements from IFACOM

Code	Project	Requirement	Met
PR_req_Ifa_01	FP07 IFaCOM, Intelligent Fault Correction and self-Optimizing Manufacturing systems	Censoring and cognitive signal analysis,	Unknown
PR_req_Ifa_02	FP07 IFaCOM, Intelligent Fault Correction and self-Optimizing Manufacturing systems	Real-time corrections and adaptive control (self-optimizing)	Unknown
PR_req_Ifa_03	FP07 IFaCOM, Intelligent Fault Correction and self-Optimizing Manufacturing systems	AI Techniques (Neural Networks and Fuzzy logic) for machine system self-adaption,	Unknown
PR_req_Ifa_04	FP07 IFaCOM, Intelligent Fault Correction and self-Optimizing Manufacturing systems	Data communication	Unknown
PR_req_Ifa_05	FP07 IFaCOM, Intelligent Fault Correction and self-Optimizing Manufacturing systems	Integration and storage	Unknown

Appendix F.9 Project MEGAFIT

Short description of MEGAFIT

Today, Europe's leading position in manufacturing of high-precision metal parts is being threatened by developed non-EU countries that catch up quickly on product quality at low cost. If no further action is taken, loss of jobs and GDP are at risk. To face global competition, a breakthrough is needed in tackling the following 4 challenges: 1) High number of defects 2) Many costly, energy consuming finishing operations are needed. 3) Continuous trend for higher quality, smaller features, lower costs, at simultaneous demand for customized products. 4) Six-Sigma methodology reaches its limits for these complex processes (multi step / customised). MEGaFiT will realize this essential breakthrough. The primary goal of MEGaFiT is to develop and integrate all necessary technologies which create the basis to reduce the number of defects in manufacturing of complex high-precision metal parts. This will be achieved by developing and integrating in-depth process knowledge, in-line measurement and real-time adaptive process control. Proof will be given on pilot production lines in industrial settings. MEGaFiT will do this with a consortium of partners best-in-class in these fields. The methodology that will be used to come to efficient realization is the following: (1) Define and describe the process (2) Measure actual process performance (3) Identify potential adaptive control solutions (4) Design adaptive control solutions and (5) Verify the adaptive control solution. This methodology will result in reduction of: defects from 5-15% to <1%; cost by >20%; material and energy consumption by >20%; and number of finishing operations by >35%. The knowledge-based MEGaFiT results are also applicable in different sectors, leading to low defects, despite customization trends. MEGaFiT will therefore help in assuring a competitive and sustainable European manufacturing industry.

Relevance and linking to QU4LITY

Develops ZDM multi-stage production monitoring processes. QU4LITY will build on some of its results (e.g. inline process monitoring, machine signal processing)

Gaps between MEGAFIT and QU4LITY

This MEGaFiT methodology will result in the following expected benefits as defined in the FoF roadmap 2: Reduction of rejected components (from 5-15% to <1%); Reduction of cost (>20%); Reduction of raw material needed, waste, energy consumption (>20%); Reduction of number of finishing operations (>35%);

MEGaFiT will do this by solving the problem in an integral way by the strong combination of the following objectives:

1. To be able to identify the main 5-10 important process parameters and interactions upfront.
2. Capture the main process interactions in a quantitative model that can be evaluated in real-time by the adaptive process control.
3. Realise in-line measurement equipment and strategies to be able to measure process and product parameters in real-time (>100 parts/minute).
4. Realise process actuation and control system to adjust the process in real-time.

5. To validate the reduction of defects from 5-15% to <1% in pilot production lines. - All met!

Requirements from MEGAFIT

Table 53: Requirements from MEGAFIT

Code	Project	Requirement	Met
PR_req_MEG_01	MEGaFiT	To be able to identify the main 5-10 important process parameters and interactions upfront	Met
PR_req_MEG_02	MEGaFiT	Capture the main process interactions in a quantitative model that can be evaluated in real-time by the adaptive process control.	Met
PR_req_MEG_03	MEGaFiT	Realise in-line measurement equipment and strategies to be able to measure process and product parameters in real-time (>100 parts/minute)	Met
PR_req_MEG_04	MEGaFiT	Realise process actuation and control system to adjust the process in real-time	Met
PR_req_MEG_05	MEGaFiT	To validate the reduction of defects from 5-15% to <1% in pilot production lines	Met

Appendix F.10 H2020 Project Factory2Fit

Short description of Factory2Fit

Smart factories mean more automation and more customization. Flexible and adaptive environments are crucial – both for productivity and for work satisfaction. The Factory2Fit project will develop adaption solutions to engage and motivate manufacturing workers with different skills, capabilities and preferences. Essentially, it will help current and future workers to become knowledge workers in smart factories with fulfilling careers.

Relevance and linking to QU4LITY

QU4LITY will leverage the project's results in terms of participatory adaptation of factory automation to fit for workers, as well as quality-enhancing tools for knowledge workers

Gaps between Factory2Fit and QU4LITY

Factory2Fit has engaged and empowered workers in smart factories. However, knowledge sharing between production and operators should be make more automatic (and use e.g., AI). For example, augmented reality tools are good in visualizing assembly order but creating content can be laborious. Another example is that if an operator knows a good way of solving a problem situation in production line, machines could learn how it was done and next time when the same error occurs the machine could suggest the solution operators used before (instead of the normal error information).

Requirements from Factory2Fit

Table 54: Requirements from Factory2Fit

Code	Project	Requirement	Met
PR_req_F2F_01	H2020 Factory2Fit	The project's requirements included technical, business, user, safety and ethical related requirements. However, the requirements were not listed one by one but instead described in general level.	Unknown

Appendix F.11 H2020 Project MAYA

Short description of MAYA

MAYA aims at developing simulation methodologies and multidisciplinary tools for the design, engineering and management of CPS-based (Cyber Physical Systems) Factories, in order to strategically support production-related activities during all the phases of the factory life-cycle, from the integrated design of the product-process-production system, through the optimization of the running factory, till the dismissal/reconfiguration phase. The concurrence and the cross-combination of the Cyber and the Physical dimensions with the Simulation domain is considered as cornerstone in MAYA innovations, to successfully address a new generation of smart factories for future industry responsiveness. MAYA finds complete validation in one of the most competitive, advanced and complex industrial sector in Europe, the automotive, where it will accomplish reduced time to production & reduced time to optimization

Relevance and linking to QU4LITY

QU4LITY will leverage MAYA's simulation framework, including semantic models for describing the capabilities of CPS systems in simulation applications

Gaps between MAYA and QU4LITY

The main outcome of MAYA was a simulation framework based on a semantic data model to support simulation and optimization related activities during all the phases of the factory life-cycle. This project was focused on the integration of simulation tools with CPS and therefore autonomous decision system was out of its goal: Qu4lity can fill this gap

Requirements from MAYA

Table 55: Requirements from MAYA

Code	Project	Requirement	Met
PR_req_MAY_01	MAYA	Digital continuity	Met
PR_req_MAY_02	MAYA	Synchronization of the digital and real factory	Met
PR_req_MAY_03	MAYA	Multidisciplinary integrated simulation and modelling	Met

Appendix F.12 H2020 project DIVERSITY

Short description of DIVERSITY

DIVERSITY relies on a combination of classical product engineering tools, cloud technologies and social software solutions to meet the requirements of distributed manufacturing enterprises to allow for effective Product Service System (PSS) engineering utilising manufacturing intelligence and experience of all actors in the value chain, including both business customers and consumers. On top of that, enormous amount of knowledge to be gathered and shared under dynamic conditions, and diffused to a wide spectrum of actors involved, having different expertise and working conditions/cultures, asks for effective context sensitive solutions for knowledge capturing, analysis and diffusion. DIVERSITY proposes an engineering environment following a service-oriented approach, combining services to extend PDM/PLM/CAD tools, knowledge provision, key performance indicators assessment, social networking, context-sensitive provision, security, setup, administration and ontologies.

Relevance and linking to QU4LITY

QU4LITY will take into account DIVERSITY's product-service design aspects.

Gaps between DIVERSITY and QU4LITY

DIVERSITY had the focus on support of the PSS design phase, approaching products and services in a holistic way not taking Product and Service design separately. DIVERSITY focus on PSS design phase, not the improvement of the manufacturing process itself. Context sensitive solution of knowledge in association with the PSS ontology developed within the DIVERSITY project could be further developed to support ZDM process.

Requirements from DIVERSITY

Not applicable due to the focus of the project being on the PSS design phase.

Appendix F.13 H2020 project FOCUS (CSA)

Short description of the project

Creating clusters of FoF project activities, according to their objectives and addressed themes, is an effective way to enhance the impact of FoF projects. Focus will support methods for improved exploitation of FoF project results from our five participating FoF clusters

Relevance and linking to QU4LITY

FOCUS brings together 5 clusters and 36 projects dealing with topics and solutions closely related to QU4LITY. Hence, QU4LITY will collaborate with FOCUS on ecosystem building efforts

Gaps between FOCUS and QU4LITY

Mass customization and one-of-a-kind production, Zero Defect Manufacturing solutions for Complex, dynamic and changeable manufacturing contexts.

- Quality assurance in presence of alternative process plans

Requirements from FOCUS

Table 56: Requirements from FOCUS

Code	Project	Requirement	Met
PR_req_FOC_01	H2020, FOCUS Creating FoF project clusters to enhance their impact	Cyber-Physical systems able to adapt process plans, parameters and production routings based on the detected quality of the parts under processing, thus smoothing the propagation of defects at the end of the production line.	Unknown
PR_req_FOC_02	H2020, FOCUS Creating FoF project clusters to enhance their impact	Profile monitoring tools for functional data and geometrical product features, supporting zero-defect manufacturing in small batch productions	Unknown
PR_req_FOC_03	H2020, FOCUS Creating FoF project clusters to enhance their impact	Effect propagation in complex manufacturing system architectures and non-linear material flows, e.g. under autonomous, decentralized part flow control mechanisms.	Unknown
PR_req_FOC_04	H2020, FOCUS Creating FoF project clusters to enhance their impact	Dynamic control of production quality target performance during the system life-cycle for reduced ramp-up times among system reconfigurations	Unknown

Appendix F.14 H2020 I4MS project MIDIH

Short description of MIDIH

MIDIH is a one-stop-shop marketplace of services, providing industry with access to advanced digital solutions, pools of human and industrial competencies and access to "ICT for Manufacturing" market and financial opportunities. MIDIH connects Digital Innovation Hubs, Competence Centres and Pan-European Digital Innovation Hubs to enable cross-DIH exchange of competencies and services with the aim to create an interconnected ecosystem to support the digitalization of the Manufacturing SMEs in Europe. MIDIH aims at improving the adoption of Industry 4.0 solutions (IloT and CPPS) in the Manufacturing Industry, especially SMEs upon four main pillars: "Open Platform architecture, development, integration and testing Open Platform" , "Network of Competence Centres and pan-EU DIHs in CPS/IOT , "DIH Innovation Management and Sustainability Model" , "Cross-Border Industrial Experiments".

Relevance and linking to QU4LITY

QU4LITY will collaborate with MIDIH in the establishment of the project's virtualized innovation hub for AQ solutions.

Gaps between MIDIH and QU4LITY

MIDIH has structured the portfolio of services a DIH should offer to guarantee the spread of knowledge and the adoption of technological solutions for the digitalization of manufacturing SMEs. Services related to data management, technology provision and up/re-skilling are of relevance in supporting the development and realization of the concept of autonomous quality, despite MIDIH is not specifically oriented to zero-defect-manufacturing, it is focused on the adoption of CPS/IoT technologies in the manufacturing field (especially SMEs). The role of a DIH in supporting SMEs in achieving their business goals by exploiting the power of technological solutions is something that is of interest of the QU4LITY project as well, if translated in to ZDM objectives. MIDIH has structured a portfolio of services a DIH should offer to support SMEs in digitalize, and this could be of relevance also for the QU4LITY project. Access to business development, community building, technological solutions, data management services and education and training for new skills may support the provision of services to achieve the ZDM paradigm in an autonomous (supported by technology) way.

Requirements from MIDIH

Table 57: Requirements from MIDIH

Code	Project	Requirement	Met
PR_req_MIDI_1	MIDIH	Ecosystem to cross-exchange services in the ZDM Definition of how the collaboration among entities (inside or outside the consortium) can work to provide the final customer with the right service Definition of the business innovation and sustainability model for collaboration	

Code	Project	Requirement	Met
PR_req_MIDI_2	MIDIH	Ways to adopt the Industrial Dataspace model to manage data for ZDM purposes	

Appendix F.15 H2020 I4MS project CloudiFacturing

Short description of CloudiFacturing

The mission of CloudiFacturing is to optimize production processes and producibility using Cloud/HPC-based modelling and simulation, leveraging online factory data and advanced data analytics, thus contributing to the competitiveness and resource efficiency of manufacturing SMEs, ultimately fostering the vision of Factories 4.0 and the circular economy. To pursue this mission, computationally demanding production engineering and simulation, as well as data analytics tools, are to be provided as Cloud services to ease accessibility and make their use more affordable. In CloudiFacturing, the consolidated platform between CloudFlow and CloudSME will be extended with capabilities to process factory data and enriched by additional manufacturing process simulation tools. It is going to be accessed through a central interface, enabling the stakeholders to interact, and collaborate. The protection of stakeholder's data is going to be safeguarded with a proven security and privacy framework.

Relevance and linking to QU4LITY

QU4LITY will liaise with CloudiFacturing in order to boost the HPC & Cloud resources segment of its market platform, with particular emphasis on resources for modelling and simulation.

Gaps between CloudiFacturing and QU4LITY

CloudiFacturing focuses on providing engineering and manufacturing services in a Cloud environment, making HPC resources available for SMEs. The integration of this cloud platform into the QU4LITY multi-sided marketplace would lay the foundation to use services like data analysis tools or simulation frameworks as cloud services in the context of ZDM. The application of these services to sensors data relevant for the product quality results in a further step towards AQ.

Requirements from CloudiFacturing

None

Appendix F.16 H2020 I4MS project ReconCell

Short description of ReconCell

ReconCell aims at designing and implementing a new kind of an autonomous robot workcell, which will be attractive not only for large production lines but also for few-of-a-kind production, which often takes place in SMEs. The proposed workcell is based on novel ICT technologies for programming, monitoring and executing assembly operations in an autonomous way. It can be nearly automatically reconfigured to execute new assembly tasks efficiently, precisely, and economically with a minimum amount of human intervention. This approach is backed up by a rigorous business-case analysis, which shows that the ReconCell system is economically viable also for SMEs.

Relevance and linking to QU4LITY

QU4LITY will liaise with ReconCell in order to boost the robotics HPC & Cloud resource segment of its market platform.

Gaps between ReconCell and QU4LITY

ReconCell focused on automated robot assembly for small batch size production. It developed various new technologies for quick reconfiguration of robot workcells to quickly switch production from one assembly process to another. However, the programming of new visual and robustness of force-based quality control processes remain an issue.

Requirements from ReconCell

Table 58: Requirements from ReconCell

Code	Project	Requirement	Met
PR_req_Rec_01	H2020 ReconCell	Requirement robot work cell reconfiguration	Met
PR_req_Rec_02	H2020 ReconCell	Requirement programming by demonstration	Met
PR_req_Rec_03	H2020 ReconCell	Requirement visual quality control	Partly met
PR_req_Rec_04	H2020 ReconCell	4. Requirement force-based quality control	Partly met

Appendix F.17 H2020 I4MS project L4MS

Short description of L4MS

L4MS (Logistics for Manufacturing SMEs) will spark incremental (productivity increase of new users by a factor of 4 and system setup time reduction by a factor of 10) and disruptive innovation (batch size one & consumerization) for over 100,000 European Manufacturing SMEs & Mid-Caps, building on their intra-factory logistics challenge (50% of the production cost of an item) unleashing their digitalization potential by powering new robot systems that are more cost effective at lower lot sizes. L4MS relies upon: - An open industrial IoT platform with enablers for rapid and efficient deployment of customized logistics solutions.

- A suite of "Smartization services" including business modelling, technical support, mentoring, access to skills and to finance.
- The L4MS Marketplace, a one-stop-shop, where European Manufacturing SMEs & Mid-Caps will access the L4MS services.
- A portfolio of 23 cross-border Application Experiments by 50 SMEs selected through 2 competitive Open Calls, that will test more than 40 services & apps leveraging 10M€ of public funding across 12 established and emerging Digital Innovation Hubs.
- A growing ecosystem that will foster Smart Specialization in each single region linked to L4MS.

L4MS will transform a Pan-European ecosystem into a self-sustainable start-up operating an Open Platform for Innovations in Logistics (OPIL) and L4MS marketplace consisting of 21 members. Comprising 6 Competence Centres, 5 technology providers, 4 industry associations, 3 end-users and 3 business developers -currently engaged in I4MS (XS2I4MS, HORSE and BEinCPPS) and FIWARE- plus 6 Satellites Nodes. L4MS covers 14 EU countries, 15 regions with 8 of them from East Europe. L4MS will help demonstrate that public funded research with a "Smartization" approach (accelerating Industry 4.0) can help manufacturing SMEs & Mid-Caps achieve digital excellence and global competitiveness through logistics automation become "entrepreneurial states and digital industries".

Relevance and linking to QU4LITY

QU4LITY will collaborate with L4MS as part of the support of the logistics and supply chain management solutions of its market platform.

Gaps between L4MS and QU4LITY

Logistics automation for factories.

Requirements from L4MS

None

Appendix F.18 H2020 I4MS project AMable

Short description of AMable

EU SMEs/mid-caps face clear barriers in the uptake of Additive Manufacturing (AM) related to lack of skilled human resources, and lack of access to know-how, equipment, infrastructure and markets. The principal objective of this project is to overcome those barriers and enable the uptake of AM technologies by SMEs/mid-caps leading to the development of innovative business and service models and new value-chain models in a fully digital environment – thus bringing their ideas and business cases to life and making their innovations Additively Manufacturable (AMable). To achieve this objective, partners with expertise right across the AM value chain have been brought together from the four corners of the EU.

Relevance and linking to QU4LITY

QU4LITY will collaborate with L4MS as part of the support of the logistics and supply chain management solutions of its market platform.

Gaps between AMable and QU4LITY

AMable enables an autonomous data-driven cross-company value chain. E.g. a constructor creates a construction model, hands it to a designer; the designed model is transmitted to the 3D printing service and the physical good finally delivery by a logistics service provider. Transactions are persisted in a Block chain. Hence, QU4ALITY should solve the issue how the quality in each value creation step can be monitored.

Requirements from AMable

Table 59: Requirements from AMable

Code	Project	Requirement	Met
PR_req_AM_01	H2020 I4MS AMable	Ensuring zero defect in each value creation (functional issue)	Partly met
PR_req_AM_02	H2020 I4MS AMable	Persisting quality data (in a Block chain)	Met

Appendix F.19 H2020 project Z-BRE4K

Short description of Z-BRE4K

H2020 Z-BRE4K: A novel predictive maintenance platform to eliminate unexpected breakdowns and extend the operating life of production systems. The Z-BRE4K solution comprises the introduction of eight scalable strategies at component, machine and system level targeting

1. the prediction occurrence of failure (Z-PREDICT);
2. the early detection of current or emerging failure (Z-DIAGNOSE);
3. the prevention of failure occurrence, building up, or even propagation in the production system (Z-PREVENT);
4. the estimation of the remaining useful life of assets (Z-ESTIMATE);
5. the management of the aforementioned strategies through event modelling, KPI monitoring and real-time decision support (Z-MANAGE);
6. replacement, reconfiguration, re-use, retirement, and recycling of components/assets (Z-REMEDIATE);
7. synchronizing remedy actions, production planning and logistics (Z-SYNCHRONISE); and,
8. preserving the safety, health and comfort of the workers (Z-SAFETY).

Relevance and linking to QU4LITY

QU4LITY will leverage predictive analytics methods and components from all these three projects, which are approaching predictive maintenance through different, complementary approaches.

Gaps between Z-BRE4K and QU4LITY

Z-Break has a focus on predictive maintenance, focusing on the wear of the equipment. In the use case AIC is involved (Gestamp use case) quality is not tackled directly, but in an indirect way by checking the quality of the manufactured parts after the press station. In this project this information is used to analyse the health of the dimensional measurement equipment. The information gathered is not currently used to act on the quality of the parts.

QU4LITY will leverage predictive analytics methods and components, which are approaching predictive maintenance through different complementary approaches. In QU4LITY we could adapt and reuse:

- DSS for managing defects
- ZDM Strategies for multi-stage production: Predict, Prevent, Repair, Manage.

Regarding prediction of defects based on asset's deterioration rate (through data analytics and machine learning) there will be enhancements of the algorithm design to address the autonomous quality requirements of the project, introducing the concept of autonomous quality signatures at the level of each monitored asset:

- Identification of deterioration for asset's condition parameters.

- Correlation of identified deteriorations; rising of alarms for detected/predicted asset failures.

Requirements from Z-BRE4K

Table 60: Requirements from Z-BRE4K

Code	Project	Requirement	Met
PR_req_ZB_01	H2020 Z-BRE4K	Strategies to improve maintainability and increase operating life of production. Update of existing and development of new strategies based on real data to improve maintainability and operating life of production systems	Not met
PR_req_ZB_02	H2020 Z-BRE4K	Decision support for Predictive & JIT maintenance towards operational optimisation. The ultimate aim is to introduce and apply a holistic approach to increase maintainability, accurately predict the condition and the remaining useful life of networked machines and adapt the performance to increase the operating life span of production systems.	Not met
PR_req_ZB_03	H2020 Z-BRE4K	Predictive Maintenance DSS will also include dedicated modules for recommendations provision for improving maintainability and operational efficiency at shop floor. It uses previous recommendations and their result as training data to assess the effectiveness of provided recommendations. Machine-learning algorithms will be used for improved recommendations.	Not met
PR_req_ZB_04	H2020 Z-BRE4K	Technical indicators for performance and reliability assessment (KPIs).	Not met
PR_req_ZB_05	H2020 Z-BRE4K	Decide on possible alarms and activation of remedy strategies.	Not met
PR_req_ZB_06	H2020 Z-BRE4K	Condition Monitoring models will be enriched to detect deterioration rate and raise alarms for further actions at MES level.	Not met
PR_req_ZB_07	H2020 Z-BRE4K	Condition Monitoring Suite (CM) for predicting machinery system failures based on trends forecasting and deterioration rate.	Not met

Appendix F.20 H2020 project PROPHESY

Short description of PROPHESY

PROPHESY's vision is to act as a catalyst for the wider deployment and uptake of next generation, optimal, adaptive and self-configurable PdM services. The main goal of the project is to provide, validate and develop a viable route to market for a novel PdM platform, which will enable end-to-end development, deployment and operationalization of adaptive self-configurable PdM services, based on the combination of leading edge CPS components (i.e. CPS architectures, data analytics algorithms for PdM, augmented reality) and novel business models. PROPHESY will enable the development of PdM services considering both the technical excellence and the business relevance of the solution, towards optimizing technical characteristics (e.g., latency, scalability, response time, adaptivity level) and business parameters (e.g., OEE (Overall Equipment Effectiveness), product quality, delivery times, inventory costs) at the same time. Likewise, PROPHESY will also facilitate the deployment of new maintenance concepts, such as the expanded use of remote support and AR as part of predictive maintenance solutions.

Relevance and linking to QU4LITY

QU4LITY will leverage predictive analytics methods and components from all these three projects, which are approaching predictive maintenance through different, complementary approaches.

Gaps between PROPHESY and QU4LITY

Data fragmentation and lack of interoperability across different datasets. / Inability to combine multiple maintenance modalities based on advanced analytics. / Lack of integrated solutions and holistic approach to PdM. / Lack of flexibility in reconfiguring production processes (i.e. closing the loop to production). / Limited exploitation of remote service opportunities.

Requirements from PROPHESY

Table 61: Requirements from PROPHESY

Code	Project	Requirement	Met
PR_req_PRO_01	H2020 PROPHESY	Architecture	Met
PR_req_PRO_02	H2020 PROPHESY	B. Cyber Physical System Platform integration - Met	Met
PR_req_PRO_03	H2020 PROPHESY	C. Data collection and Analytics - Running	Running
PR_req_PRO_04	H2020 PROPHESY	D. Visualization - Running	Running
PR_req_PRO_05	H2020 PROPHESY	E. Integration and Validation in Industrial demonstrators - Running	Running

Appendix F.21 H2020 project SERENA

Short description of SERENA

The SERENA project will build upon the need of truly connected production processes where all machinery data are accessible allowing easier maintenance of them in case of unexpected events, minimizing the costly production downtimes, for saving time and money. The proposed solutions are covering the requirements for versatility, transferability, remote monitoring and control by

- a plug-and-play cloud based communication platform for managing the data and data processing remotely,
- advanced IoT system and smart devices for data collection and monitoring of machinery conditions,
- artificial intelligence methods for predictive maintenance (data analytics, machine learning) and planning of maintenance and production activities,
- AR based technologies for supporting the human operator for maintenance activities and monitoring of the production machinery status.

SERENA represents a powerful platform to aid manufacturers in easing their maintenance burdens and for this purpose will be applied in different applications.

Relevance and linking to QU4LITY

QU4LITY will leverage predictive analytics methods and components from SERENA.

Gaps between SERENA and QU4LITY

SERENA has strong focus on predictive maintenance, enabling prevention of failures. QU4LITY should enhance this concept towards the Autonomous Quality, through the adoption of cognitive manufacturing solutions and other digital enhancements into the current ZDM equipment and processes.

Requirements from SERENA

Table 62: Requirements from SERENA

Code	Project	Requirement	Met
PR_req_SER_01	H2020-FOF-2017 SERENA	Requirement "Health Assessment (HA) block": is an information block which utilizes expertise from a human or automated agent to determine the current health of the equipment and to diagnose existing fault conditions	Met
PR_req_SER_02	H2020-FOF-2017 SERENA	Requirement "State Detection (SD) block". The primary function of the SD block (sometimes referred to as "state awareness") is to compare Data Manipulation and/or Data Acquisition outputs against expected baseline profile values or operational limits, in order to generate enumerated state indicators with respective boundary exceedances. The SD	Partly met

Code	Project	Requirement	Met
		block generates indicators which may be utilized by the Health Assessment block to generate alerts and alarms. When appropriate data are available, the SD block should generate assessments based on operational context, sensitive to the current operational state or operational environment	
PR_req_SER_03	H2020-FOF-2017 SERENA	Requirement "Prognostic Assessment (PA) block" The primary function of the PA block is to project the future state of the monitored equipment using a combination of prognostic models and their algorithms, including future operational usage model(s). This block determines the future state of health and failure modes by combining the relevant outputs of the other blocks and applying a prognostic algorithm or model based on supplied projected operational utilization.	Met

Appendix F.22 H2020 I4MS project ProSEco

Short description of ProSEco

The proliferation of new emerging technologies and paradigms together with a wider dissemination of information technology (IT) can significantly improve the capability of manufacturing companies to infuse services in their own products. This can be enabled by making use of sensors and actuators already within existing physical goods; by adding them to existing physical goods; and/or by selling new physical goods. Technological developments from the EU ProSEco project enable the fulfilment of the huge marketing potential of meta-products by extending their scope and improving their technical performance. The effective extension of products with new services in different sectors (automotive, home appliances, automation equipment, etc.) has been achieved by means of Ambient Intelligence (AmI) technology, Lean and Eco-design principles and applying Life Cycle Assessment techniques. The objective of the ProSEco project was to provide a novel methodology and a comprehensive ICT solution for collaborative design of product-services (Meta Products) and their production processes. ProSEco focuses on the capture and exploitation of customer side relevant information related to the use of the product or machine and its environment (by means of Ambient Intelligence (AmI) technology, context awareness, eco-impact assessment, etc.) to create better and new services in combination with the product (so-called servitization).This enables the creation of new business model providing more value to the customer, to rapidly response to the competitive economic climate and respecting the environment at the same time. The Integrated ProSEco Prototype supports industries in collaborative design, development and management of new Product Extension Services (PES). It provides two working environments, the development and the deployment platform that requires different type of knowledge expertise and IT capabilities.

Relevance and linking to QU4LITY

QU4LITY will leverage ProSEco's results in terms of collaborative products' design and their production processes, but also in terms of Lifecycle Assessment methods

Gaps between ProSEco and QU4LITY

ProSEco main focus is in the support of Product-Services as well as the production processes collaborative design not on the manufacturing processes themselves.

Requirements from ProSEco

Not applicable due to the focus of the project being on the product services and production process design phase.

Appendix F.23 Industrial Data Space (IDS)

Short description of IDS

The Industrial Data Space (IDS) is one of several initiatives of the Industrial Data Spaces Association and provides a reference architecture for supporting data exchanges in an industrial context. The reference architecture highlights technical and organisational security as well as the integrity and authenticity of data transactions in order to enable the sovereign data exchange among organizations.

Relevance and linking to QU4LITY

IDS is one of the main technological pillars of QU4LITY in terms of interoperable data exchange and management

Gaps between IDS and QU4LITY

The IDS provides a reference architecture for sovereign data exchange but lacks the realization of autonomous data management in cross company data transfers. This gap should be addressed by extending the IDS framework with data profiling and data quality services.

Requirements from IDS

Table 63: Requirements from IDS

Code	Project	Requirement	Met
PR_req_IDS_01	The Industrial Data Space (IDS)	[Secure data exchange]	Met
PR_req_IDS_02	The Industrial Data Space (IDS)	[Decentral infrastructure]	Met
PR_req_IDS_03	The Industrial Data Space (IDS)	[Data Sovereignty]	Met
PR_req_IDS_04	The Industrial Data Space (IDS)	[Data Security]	Met
PR_req_IDS_05	The Industrial Data Space (IDS)	[Governance]	Met
PR_req_IDS_06	The Industrial Data Space (IDS)	[Openness]	Met
PR_req_IDS_07	The Industrial Data Space (IDS)	[Scalability]	Met
PR_req_IDS_08	The Industrial Data Space (IDS)	[Network Effects]	Met

Appendix F.24 H2020 project BOOST4.0

Short description of the project

BOOST 4.0 "Big Data Value Spaces for Competitiveness of European Connected Smart Factories 4.0" will demonstrate, in a realistic, measurable, and replicable way an open, certifiable and high standardized and transformative shared data-driven Factory 4.0 model through 10 lighthouse factories. BOOST 4.0 will also demonstrate how European industry can build unique strategies and competitive advantages (significantly increase operational efficiency, E2E manufacturing planning and deliver improved smart product customer experience, and foster new digital business models; e.g. outcome-based and product servitisation) through big data across all phases of product and process lifecycle (engineering, planning, operation, production and after-market services) building upon the BOOST 4.0 connected smart Factory 4.0 model to meet the Industry 4.0 challenges (lot size one distributed manufacturing, operation of zero defect processes and products, zero break down sustainable operations, agile customer-driven manufacturing value network management and human centered manufacturing).) Relevance and linking to QU4LITY

Relevance and linking to QU4LITY

The European data space lighthouse project is of the main technological pillars of QU4LITY in terms of interoperable data exchange and big data platforms and ecosystem.

Gaps between this project and QU4LITY

The European data space lighthouse project is of the main technological pillars of QU4LITY in terms of interoperable data exchange and big data platforms and ecosystem. QU4LITY will leverage predictive analytics methods and components, which are approaching predictive maintenance through different complementary approaches.

Requirements from the project

Table 64: Requirements from BOOST4.0

Code	Project	Requirement	Met
PR_req_BO_01	H2020 BOOST4.0	Overall Big Data Analytics Framework Architecture Specification including data and information flow. Overall Framework architecture will be specified, including the detailed formalization of modules interaction including communication and data-flow.	Not met
PR_req_BO_02	H2020 BOOST4.0	BOOST 4.0 Industrial Data Space (IDS) will be designed and developed.	Not met
PR_req_BO_03	H2020 BOOST4.0	The IDS will support the sharing of data and analytics within the industrial sector.	Not met
PR_req_BO_04	H2020 BOOST4.0	Big Data Analytics Platform focuses on the customization and extension of existing digital manufacturing platforms with analytics	Not met

Code	Project	Requirement	Met
		methods, in order to apply them in the field of manufacturing.	
PR_req_BO_05	H2020 BOOST4.0	Extension of the capabilities of ATLANTIS tools to be able to exploit the BOOST 4.0 big data and analytics framework.	Not met
PR_req_BO_06	H2020 BOOST4.0	Analysis of the data perspective of the end-to-end production meta-process in Whirlpool and Benteler. All phases of the Digital Thread (whole life cycle) will be considered, including design, supply, manufacturing, delivery and post-sale intelligence. The outcome of this analysis will be a detailed specification of the relevant data sources, from both the business and the technical viewpoints.	Not met
PR_req_BO_07	H2020 BOOST4.0	On top of the previous specification there will be the design of the conceptual information model: an integrated logical view on the relevant information available, each element linked to its physical source.	Not met
PR_req_BO_08	H2020 BOOST4.0	Perform early experimentation on available data sets, which include inspection, selection and fusion of available machine, maintenance and manufacturing data.	Not met
PR_req_BO_09	H2020 BOOST4.0	Domain-knowledge is elicited and consolidated in form of generic plant description model using modelling techniques for later roll-out and prescriptive applications.	Not met
PR_req_BO_10	H2020 BOOST4.0	Further domain knowledge includes fault patterns and their relevance is documented using established tool such as FMEA and FTA.	Not met
PR_req_BO_11	H2020 BOOST4.0	Based on the BOOST 4.0 framework, a generic blueprint for predictive maintenance applications, comprising a process model as well as a software architecture, is designed that serves for and is validated by the subsequent experimentation.	Not met
PR_req_BO_12	H2020 BOOST4.0	Establishment of the main components for predictive maintenance of the plants. Faults identified with the help of domain-experts are considered.	Not met
PR_req_BO_13	H2020 BOOST4.0	Evaluation entails model accuracy, sensitivity/specificity, as well as to devise KPIs w.r.t. expected economic impact of early fault detection e.g. on overall equipment efficiency. In a second step, the data is leveraged for fault diagnostics and prescriptive analytics. The latter entails fusion and deeper analysis of unstructured maintenance reports, machine data, as well as utilization of the FMEA and FTA results.	Not met

Code	Project	Requirement	Met
PR_req_BO_14	H2020 BOOST4.0	Deployment of the previously mentioned models for (close to) real-time analytics to the plants at Benteler factory, based on the BOOST architecture blueprint and the adopted process models.	Not met
PR_req_BO_15	H2020 BOOST4.0	Development and process integration of interactive data visualization and analysis dashboard applications for mobile of stationary devices on the shop-floor.	Not met
PR_req_BO_16	H2020 BOOST4.0	The installed on-site trials serve as basis for evaluation by means of in-process model performance (e.g. false positives and false negatives) as well as the devised KPIs.	Not met
PR_req_BO_17	H2020 BOOST4.0	Model transfer is established by a dedicated teach-in/model adoption phase, which significantly reduces development time and demand for training data.	Not met
PR_req_BO_18	H2020 BOOST4.0	Pilot Area KPI Collection and Benchmarking Data involves the actual preparation of the pilot demonstration and deployment of the BOOST 4.0 big data processing infrastructure and applications (digital thread, data space apps, predictive analytics and data visualizations).	Not met

Appendix F.25 ECSEL project MANTIS

Short description of MANTIS

MANTIS' proactive service maintenance platform and its associated architecture draw inspiration from the Cyber Physical System approach. Physical systems (e.g. industrial machines, vehicles, renewable energy assets) and the environment they operate in are monitored continuously by a broad and diverse range of intelligent sensors, resulting in massive amounts of data that characterise the usage history, operational condition, location, movement and other physical properties of those systems. These systems form part of a larger network of heterogeneous and collaborative systems (e.g. vehicle fleets or photovoltaic and windmill parks) connected via robust communication mechanisms able to operate in challenging environments.

Relevance and linking to QU4LITY

QU4LITY will leverage results from "flagship" ECSEL and ARTEMISIA projects, notably the ones with the larger scale implementation and the highest impact in the European manufacturing community: Validated solution blueprints from MANTIS

Gaps between MANTIS and QU4LITY

Within the Pilot use-case, a focus was made on identifying the relation between the actual status of machine tooling (wear) and the quality of produced parts. The Critical-To-Quality inputs are used to create a prediction towards tool life, but this model could also be inversed. Another output of the project is multivariate statistical analysis to estimate actual product quality based on process sensor parameters.

Requirements from MANTIS

Table 65: Requirements from MANTIS

Code	Project	Requirement	Met
PR_req_MAN_01	ECSEL Mantis	Our concern (MGEP) is with interoperability among platforms and systems. In the previous project we provide interoperability between IoTA events and Mimosa databases. The interoperability challenges are many more. The number of commercial and proprietary platforms to interconnect is extended. Need to identify those platforms and the protocols and data formats they use.	Unknown