D1.1 – Project Vision Guide Document

WP1 – NEED: Industrial Scenarios and Requirements Analysis

European Commission

i4Q has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958205.

Document Information

GRANT AGREEMENT NUMBER	958205	ACRONYM	i4Q
FULL TITLE	Industrial Data Services for Quality Control in Smart Manufacturing		
START DATE	01-01-2021	DURATION	36 months
PROJECT URL	https://www.i4q-project.eu/		
DELIVERABLE	D1.1 – Project Vision Guide Document		
WORK PACKAGE	WP1 – NEED: Industrial Scenarios and Requirements Analysis		
DATE OF DELIVERY	CONTRACTUAL: Mar. 2020	ACTUAL	Mar. 2020
NATURE	Report	DISSEMINATION LEVEL	Public
LEAD BENEFICIARY	CERTH		
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CONTRIBUTIONS FROM	1-CERTH, 2-ENG, 3-IBM, 4-ITI, 5-KBZ, 6-EXOS, 7-IKER, 8-BIBA, 9-UPV, 10-TUB, 11-UNI, 12-TIAG, 13-CESI, 14-AIMP, 15-FBA, 16-IVLAB, 17-DIN, 18-LIF, 19-WHI, 20-BIES, 21-FACT, 22-RIAS, 23-FARP, 24-FIDIA		
TARGET AUDIENCE	1) i4Q Project partners; 2) industrial community; 3) other H2020 funded projects; 4) scientific community		
DELIVERABLE CONTEXT/ DEPENDENCIES	This document has no preceding documents or further iterations. This document is one of the cornerstones for establishing the research, development, and exploitation baseline for the project and provide inputs for all other project deliverables.		
EXTERNAL ANNEXES/ SUPPORTING DOCUMENTS	None		
READING NOTES	None		
ABSTRACT	This document aims to define a consensual project vision, establish the state of art in terms of technologies for quality in manufacturing, as well as regulation and trustworthy system for data management and set the specifications driving the creation of the i4Q Solutions and Key Performance Indicators (KPIs). Deliverable D1.1 is a balanced guide document, the 'Project Vision Guide', which will act as a reference for the project and will be used by all partners to stay focused on the main ideas and goals of the project.		

Document History

VERSION	ISSUE DATE	STAGE	DESCRIPTION	CONTRIBUTOR
0.1	25-Jan-2021	Draft	Table of contents and sections allocation to partners	CERTH, UPV
0.2	1-Feb-2021	Draft	Section 1 first draft	CERTH, UPV
0.3	8-Feb-2021	Draft	Sections 2.1 and 2.2 first draft	CERTH, UPV
0.4	15-Feb-2021	Draft	i4Q Solutions first draft	BIBA, CERTH, ENG, EXOS, IBM, IKER, ITI, KBZ, TIAG, TUB, UNI, UPV
0.5	22-Feb-2021	Draft	Pilots 1, 2, 3, 4 and 6 first draft	FIDIA, ITI, CESI, BIES, ENG, TIAG, WHI, ENG, FACT, EXOS, UPV, FARP, ITI, AIMP
0.6	1-Mar-2021	Draft	Sections 3 and 4.2 first draft	FBA, KBZ, DIN
0.7	8-Mar-2021	Draft	All sections final draft	ALL
0.8	9-Mar-2021	Draft	Deliverable ready for internal review	ALL
0.9	15-Mar-2021	Draft reviewed	Deliverable reviewed	UPV, TUB
1.0	29-Mar-2021	Draft	Final version sent to CERTH for the final quality check	ALL
2.0	31-Mar-2021	Final doc	Final quality check and issue of final document	CERTH

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ABBREVIATIONS/ACRONYMS

AI	Artificial Intelligence
API	Application Programming Interface
AS	Aerospace Standard
AWS	Amazon Web Services
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CLI	Command Line Interface
CNC	Computer Numerical Control
CWA	CEN Workshop Agreement
DB	Database
EC	European Commission
EU	European Union
FMS	Flexible Manufacturing System
FMU	Functional Mock up Units
FTO	Freedom to Operate
GA	Grant Agreement
GPU	Graphics Processing Unit
gRPC	gRPC Remote Procedure Calls
GUI	Graphical User Interface
HDL	High-Definition LiDAR
HSM	Hardware Security Module
HTML	Hypertext Markup Language
IACS	Industrial Automation and Control Systems
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IIoT	Industrial Internet of Things
IMC	Innovation Management Committee
IP	Intellectual Property
IPR	Intellectual Property Rights
ISO	International Organization for Standardization

IT	Information Technology
LM	Legal Manager
MES	Manufacture Execution System
MES	Manufacturing Execution System
ML	Model Life
MQTT	Message Queuing Telemetry Transport
MS	Milestone
NA	Not applicable
NOK	Not Okay
NPI	New Product Introduction
OEE	Overall Equipment Effectiveness
OEM	Original Equipment Manufacturer
OPE	Overall Production Effectiveness
OS	Operating System
PC	Project Coordinator
PCB	Printed Circuit Board
PCI	Peripheral Component Interconnect
PEDR	Plan for Exploitation and Dissemination of Results
PKI	Public Key Infrastructure
PLC	Programmable Logic Controllers
QC	Quality Control
QCM	Quality Control Manager
RBAC	Role-based access control
REST API	RESTful API
RIDS	Reliable Industrial Data Services
RoT	Root of Trust
SDN	Software defined networks
SME	Small Medium Enterprise
SQL	Structured Query Language
SWOT	Strengths, Weaknesses, Opportunities, Threats
TCP	Fieldbus communication

TM	Technical Manager
TPM	Trusted Platform Module
TRL	Technical Rediness Level
TSN	Time Sensitive Networks
UA	Unified Architecture
UI	User Interface
UK	United Kingdom
VRM	Value Roadmapping Method
WP	Workpackage
WPL	Workpackage leader
WSN	Wireless Sensors Technologies
ZDMP	Zero Defects Manufacturing Platform

Executive summary

The i4Q Project aims to provide a complete solution consisting of an IoT-based Reliable Industrial Data Services (RIDS), a complete suite composed of 22 i4Q Solutions, able to manage the huge amount of industrial data coming from cheap cost-effective, smart, and small size interconnected factory devices for supporting manufacturing online monitoring and control. The i4Q Framework will guarantee data reliability with functions grouped into five basic capabilities around the data cycle: sensing, communication, computing infrastructure, storage, and analysis and optimization. The i4Q RIDS will include simulation and optimization tools for manufacturing line continuous process qualification, quality diagnosis, reconfiguration and certification for ensuring high manufacturing efficiency, leading to an integrated approach to Zero Defect Manufacturing.

Work package WP1, and more specifically the deliverable D1.1 aims at defining a consensual project vision, establishing the state of art in terms of technologies for quality in manufacturing, as well as regulation and trustworthy system for data management and setting the specifications driving the creation of the i4Q Solutions and Key Performance Indicators (KPIs). Task T1.1 will provide a balanced guide document as a deliverable (D1.1), the 'Project Vision Guide', which will act as a reference for the project and will be used by all partners to stay focused on the main ideas and goals of the project. The document will also be used internally to keep the performed tasks in synchronisation with the overall idea of the project. It may also be used by the partners as a source for documents, deliverables and presentations to third parties to get an early overview of the project. In addition, this document will include an initial risk table, upgraded from the DoA, which itemises general inherent risks of innovation activities.

More specifically, deliverable D1.1 starts with Section 1, where the i4Q Solutions, software tools and guidelines are presented. Next, Section 2 includes information regarding the overall concept and positioning of the project (Subsection 2.1) in terms of business, research and technological objectives. Section 2 continues with Subsection 2.2, where information regarding the project's realisation and, more specifically, how the project will achieve its objectives are provided and, finally, with Subsection 2.3, where use case scenarios and pilots are addressed.

Six Use Cases will be used for the demonstration of the i4Q RIDS. These use case scenarios come from relevant industrial sectors and represent two different levels of the manufacturing process: machine tool providers and production companies. The i4Q pan-European consortium entails Industrial partners: WHIRLPOOL (White goods manufacturer), BIESSE (Wood industrial equipment), FACTOR (Metal machining), RIASTONE (Ceramic pressing), FARPLAS (Plastic injection) and FIDIA (Metal industrial equipment); Implementers: TIAG (Industrial Communication Protocols and Standards), CESI (Machine tools, Advanced Materials, Micro-technology) and AIMPLAS (Thermoplastic and thermosetting plastic materials); Technology Providers: IBM (Information Technologies Company), ENGINEERING (Software and Services Company), ITI (Information Technologies Institute), KNOWLEDGEBIZ (Information Systems Company), EXOS (Operations Consulting Company); R&D partners: CERTH (Research Institute), IKERLAN (Technological Centre), BIBA (Research Institute), UPV (University), TUBERLIN (University), UNINOVA (Research Institute); Specialist partners: FUNDINGBOX (Exploitation), INTEROP-VLAB (Dissemination), DIN (Standardisation), LIF (Legal).

The document continues with Section 3, where project's positioning is addressed, including project's context (Subsection 3.1), business opportunities, SWOT analysis, stakeholders and post-project commercialisation of the i4Q project results and, finally, with customer needs in the areas of manufacturing data quality, manufacturing data analytics for manufacturing quality assurance, rapid manufacturing line qualification and reconfiguration (Subsection 3.2). Section 4 summarises the project results; the i4Q Reliable Industrial Data Services and the 22 i4Q Solutions.

Last but not least, Section 5 addresses the milestones and deliverables of the project and Section 6 the risks. Finally, the deliverable ends with the presentation of conclusions in Section 7 and the summary of the entire document.

Document structure

Section 1 Elevator Pitch: Executive description of the i4Q Project and its results that explains the concept in a way such that any reader or listener can understand it in a short period of time.

Section 2 High Level Vision: Positions the project in terms of business, research and technological objectives, and use case scenarios.

Section 3 Positioning: Characterises the project in terms of context (business opportunities, SWOT analysis, stakeholders, post-project commercialisation) and customer needs in the areas of manufacturing data quality, manufacturing data analytics for manufacturing quality assurance, rapid manufacturing line qualification and reconfiguration.

Section 4 Project Results: Summarises the i4Q Reliable Industrial Data Services and the 22 i4Q Solutions by providing an explanation addressed to end-users (industrial companies) and another explanation addressed to technologists (software developers, system integrators, ICT implementers, etc.).

Section 5 Milestones and deliverables: Provides both tables with the project milestones and the project deliverables.

Section 6 Risks: Presents the critical implementation risks and mitigation actions of the i4Q project.

Section 7 Conclusions: Summarises the Project Vision Document.

1. Elevator Pitch

The i4Q Project proposes the creation of sustainable an IoT-based Reliable Industrial Data Services (RIDS) with the aim of assuring data quality, traceability and proper use, in order to achieve manufacturing lines' continuous process qualification, quality diagnosis, reconfiguration and certification.

Figure 1. i4Q RIDS

The i4Q RIDS is a complete package consisting of 22 i4Q Solutions, 17 software tools and 5 guidelines, which are described below:

i4Q^{QE} QualiExplore for Data Quality Factor Knowledge: is a web-based software tool for the visualisation of information quality characteristics and quality factors using the Evolutional Data Quality Concept and a Data Life Cycle: data collection, data storage, data analysis, data distribution, data use and data deletion.

i4Q^{DQG} Data Quality Guidelines: is a complete guide for planning and performing an information flow analysis to identify the relevant data sources, data storages, communication channels and data users, and model relevant factors that influence data quality, including technical (hardware), organisational (human activities), and programmatic factors (in software).

i4Q^{BC} Blockchain Traceability of Data: provides tools to ensure data trustiness and full traceability, enhancing the level of trust by employing a blockchain based data service, improving trust and acceptability by providing security and trust in the data that flows directly to the blockchain, serving as a single point of truth, preserving provenance and supporting non-repudiation.

i4Q^{TN} Trusted Networks with Wireless & Wired Industrial Interfaces: is a software-defined wireless industrial interfaces for data communication, characterized by predictability and determinism, high reliability and trustability and low consumption, while reducing the installation cost of new-wired infrastructure. **i4Q^{TN}** ensures reliable data collection, providing connectivity to industrial data sources through Trusted Networks able to assess and ensure precision, accuracy, and reliability.

i4Q^{SH} IIoT Security Handler: is a cloud service that distributes trust across the architecture using a hardware secure module as trust anchor point. Once the trust is distributed, the software enables the mechanisms to expose cryptography operations that other i4Q Solutions can consume, adjusting security and safety policies at different levels to ensure trustability and privacy of data.

i4Q^{CSG} Cybersecurity Guidelines: is a document that includes a set of recommendations to enable multilayer cyber security features in Industrial Internet of Things (IIoT), enabling IIoT devices to interact with industrial platforms securely in all stages in a manufacturing scenario. i4Q^{CSG}

includes an architecture and methodology to provision signed certificates with Hardware Security Module (HSM) and trusted material to devices' Trusted Platform Module (TPM).

i4Q^{DR} Data Repository: is a distributed storage system for supporting a high degree of digitisation in companies with most manufacturing devices acting as sensors or actuators and generating vast amounts of data. i4Q^{DR} is able to absorb large volumes of data coming into the system at high speeds. i4Q^{DR} is elastic to adapt the required computing resources to the existing demand and ready to use additional resources, either local to the factory or from remote systems like public or private clouds.

i4Q^{DRG} Guidelines for building Data Repositories for Industry 4.0: is a guide for building Data Repositories for Industry 4.0, for estimating the storage capabilities and for building systems providing easy ways to access industry data and to communicate with industrial platform components and microservice applications.

i4Q^{DIT} Data Integration and Transformation Services: is a distributed server-based platform with analytic and decision-making services, able to prepare manufacturing data for being efficiently processed by microservice applications. **i4Q^{DIT}** includes all the elements required for manufacturing data stream management: reading, cleaning, storing, indexing, enriching, searching & retrieving, maintaining, and correspondence of open APIs.

i4Q^{DA} Services for Data Analytics: provides a set of specialised analytic functions and incremental algorithms, operating on data streams with fast incremental updates, suitable for analytic processing of high-speed data streams.

i4Q^{BDA} Big Data Analytics Suite: provides core functions related to clustering, regression, classification, anomaly detection and temporal correlation of data generated by sensors and other Cyber Physical Systems mounted on industrial facilities. The key property of i4Q^{BDA} is speed and ability to support intensive data streams.

i4Q^{AD} Analytics Dashboard: is a reporting interface that allows to monitor industrial data with fully flexible visualization drill down charts and flexible dashboard to provide meaningful analytics to users in real time basis using incremental algorithms.

i4Q^{AI} AI Models Distribution to the Edge: is a multi-tier infrastructure to address the management of AI-based workloads in a hybrid cloud edge manufacturing environment. i4Q^{AI} integrates a policy-based distribution mechanism for smart manufacturing environments scalability. The i4Q^{AI} AI model distribution isd coordinated with the workload distribution mechanism to ensure that the right set of AI models is made available.

i4Q^{EW} Edge Workloads Placement and Deployment: is a toolkit for deploying and running AI workloads on edge computing environment, prevalent in manufacturing facilities, using a Cloud/Edge architecture. i4Q^{EW} provides interfaces and capabilities for running different workloads on different industrial devices, efficiently on the edge, including placement and deployment services.

i4Q^{IM} Infrastructure Monitoring: provides an ensemble of monitoring tools for smart manufacturing workload orchestration and predictive failure alerting, including monitoring the health of workloads and productively alerting and taking corrective actions when a predicted problem is detected. i4Q^{IM} supports industrial companies to reach autonomous operation in manufacturing environments.

i4Q^{DT} Digital Twin simulation services: allows industrial companies to achieve a connected 3D production simulation, with a digital twin for manufacturing enabling virtual validation/visualisation and productivity optimisation using pre-existing and data from different factory levels (small cell to entire factory).

i4Q^{PQ} Data-driven Continuous Process Qualification: is an intelligent and automated Continuous Process Qualification (CPQ) micro-service for rapid monitoring of stability, capability, and performance of manufacturing processes. i4Q^{PQ} is based on real-time data with improved smart data analytics and algorithms, for achieving faster process approval and in-line continuous process validation after process reconfiguration.

i4Q^{QD} Rapid Quality Diagnosis: is a micro-service for providing rapid diagnosis of manufacturing line on the possible cause of failures, evaluating data fidelity, product-quality and process condition, and providing action recommendations for sensor/data processing recalibrations, process line/machine reconfiguration or maintenance actions.

i4Q^{PA} Prescriptive Analysis Tools: is a micro-service consisting of simulation models as a service, taking as input the manufacturing resources, current production planning and process condition, and proposing process configuration parameters, ensuring that non-simulation experts may also exploit the prescriptive analyses.

i4Q^{LRT} Manufacturing Line Reconfiguration Toolkit: is a collection of optimisation micro-services that use simulation to evaluate different possible scenarios and propose changes in the configuration parameters of the manufacturing line to achieve improved quality targets. i4Q^{LRT} AI learning algorithms develop strategies for machine parameters calibration, line setup and line reconfiguration.

i4Q^{LRG} Manufacturing Line Reconfiguration Guidelines: is a multi-media user guide for adapting the optimisation reasoning rules according to the achieved results for machine parameters calibration, line setup and line reconfiguration. i4Q^{LRG} allows to increase productivity and reduce the efforts for manufacturing line reconfiguration through AI, considering both automated approaches and collaboration with humans.

i4Q^{LCP} Manufacturing Line Data Certification Procedure: provides an audit procedure applied to the manufacturing resources (machine, cell or manufacturing line) for ensuring that the data resulting from the manufacturing processes are accurate and reliable, providing recommendations for process reconfiguration, audit strategies, certificates and regulations. i4Q^{LCP} addresses definition and vocabulary, frame and application areas, prerequisites, planning, implementation, controlling, improvement and documentation of data-driven qualification, reconfiguration, and quality control.

2. High Level Vision

Smart factories with high levels of digitalisation will be a key element for the new form of industrial production based on Industry 4.0 initiatives. Here, a key challenge is to transform cost-based competitive advantages into those that rely on sustainable, high-value-added production. An important lever to address this challenge is to enable manufacturing companies to achieve superior product quality with highly efficient, smart production processes. A successful smart factory needs to manage data-related processes along the entire data life cycle, including data collection, storage, distribution, analysis, use, and deletion, to ensure high data quality at all times.

The i4Q RIDS (Reliable Industrial Data Services) is a complete solution, founded on a modular Framework, rooted in a Reference Architecture which incorporates the business, usage, functional and implementation viewpoints involved in the process.

The i4Q RIDS aims to support the complete flow of industrial data, starting from data collection to data analysis, simulation and prediction. It provides solutions to ensure data quality, security and trustworthiness, such as blockchain-based data services and distributed storage.

The i4Q RIDS also includes a set of services for data integration and fusion, data analytics and data distribution. Execution of AI workloads is enabled and managed through dedicated services based on a cloud/edge architecture. Monitoring at various levels is provided in i4Q through scalable monitoring tools.

Digital twins are used to enable full digitisation of the manufacturing process and providing simulation and modelling capabilities. Digital twins are also used for process qualification to obtain virtual sensors, explore potential upgrade actions and extend existing process data. Additionally, digital twins support quality diagnosis of the manufacturing line.

The i4Q RIDS adopts a modular microservices-based approach to be adapted and integrated in different manufacturing scenarios, for diverse companies and at varying maturity levels.

2.1 Overall Concept and Positioning of i4Q

The i4Q Project will develop a set of Solutions to improve the quality of manufactured products aiming at zero-defect manufacturing, therefore pushing forward the concept of a smart, fully digitised factory.

The i4Q objectives to create the project results and outcomes are:

O1: To develop and share among the different consortium partners and other stakeholders the i4Q Project Vision, establish the state of the art in terms of technologies for quality in manufacturing, and to set the requirements driving the creation of i4Q Solutions. (WP1)

O2: To design the i4Q Framework and deliver the Reference Architecture built on key digital models and ontologies for smart manufacturing and devised using multiple perspectives, related to business, usage, functional and implementation viewpoints. (WP2)

O3: To build the i4Q Manufacturing Data Quality, providing methodologies, tools and infrastructure to ensure the necessary data quality to enable operational intelligence and improve data analysis results effectiveness. (WP3)

O4: To build the i4Q Manufacturing Data Analytics, a set of management tools for cloud/edge lifecycle of manufacturing related AI models. (WP4)

O5: To build the i4Q Rapid Manufacturing Line Qualification and Reconfiguration, a set of new and improved strategies and methods for process qualification as well as process reconfiguration and optimisation using existing manufacturing data and machine learning (ML) algorithms. (WP5)

O6: To test and validate the i4Q Solutions in 6 use cases, covering different manufacturing perspectives (industrial equipment manufacturers, parts and components manufacturers and final products manufacturers) and industrial sectors (metal, plastic, wood and ceramics). (WP6)

O7: To disseminate the i4Q Solutions, providing outreach of the project activity and results, paving the way for a broad adoption of i4Q Solutions in the industry, offering benefits for final users, and to create the i4Q standards, compliant with existent and evolving ICT and CE standards, facilitating regulation and certification. (WP7)

O8: To facilitate technology uptake by the i4Q start-up company that is being created and long-term adoption of the i4Q Solutions by the industry. (WP8)

O9: To properly manage the project for guaranteeing that the project objectives are met by ensuring the successful completion of the project on-resource, on-quality and on time. (WP9)

2.2 Realising the i4Q Concept

In order to achieve the previous objectives, i4Q adopts a straightforward approach which includes a need capturing part, a design phase to produce a reference architecture and framework, a build phase which delivers the actual tools and technologies used in the framework, an evaluation phase to ensure real-world applicability of the results and an impact generation activities centred around disseminate and exploit actions and tasks (**Figure 2**).

Figure 2. i4Q implementation approach

Figure 3 shows the i4Q Conceptual Architecture mapped on the work packages. The design process in i4Q takes an approach which is at the same time holistic and modular. A Framework, based on a Reference Architecture (RA) will be delivered (WP2). The i4Q Framework will include the required digital models and ontologies employed in the manufacturing process including supply chain and all of the tools and processes involved.

Figure 3. i4Q Conceptual Architecture

The RA will then incorporate the following viewpoints involved in the smart manufacturing, high quality production process and related to address the data reliability challenges.

1. The business viewpoint will not only capture business, regulatory and stakeholders-view aspects but will also analyse the business requirements and (potentially new) business models to be supported by the RA.
2. The usage viewpoint aims to analyse and achieve optimal usage of the framework and will guide the implementation of the i4Q RIDS by identifying its key elements: tasks, roles, activities and parties. It will also define roles and responsibilities as well as workflows and organisation of activities.

3. The functional viewpoint will provide a description of the control, operations, information, application and business domains composing the i4Q Framework and all of the related flows (data, decision, commands/requests), as well as the orchestration between these domains.
4. Finally, the implementation viewpoint will provide a technical description (through the delivery of a technical specification) of all the technical components and architecture of the i4Q RIDS.

Thus, the key aspects of how i4Q Project will achieve its objectives are the following:

NEEDS (WP1): To synchronise the project vision and provide an overview to the target audience, perform a multidimensional assessment of current technologies for quality in manufacturing and establish benchmarks and to capture the needs from industry to be satisfied by the project outputs.

DESIGN (WP2): To provide the i4Q Framework, based on a Reference Architecture, and to describe it using multiple perspectives: business, usage, functional and implementation.

BUILD Data Reliability (WP3): To achieve data reliability and quality, from i4Q ecosystem to the discovery useful insights in manufacturing, guaranteeing security and privacy aspects:

- Integrity, reliability and privacy of data: by providing a secure and safe oriented communication infrastructure and security mechanisms, such as PKI infrastructure and project level certificates. But also, to analyse the suitability of adopting a distributed ledger approach for data traceability.
- Data storage: by implementing a distributed storage architecture and infrastructure capable of handling an exponential increase of data volumes, integrating with services for data integration and fusion.

BUILD Data Analytics (WP4): To turning data into information and actionable insights:

- Big data analytics: by implementing big data technologies for offline and online streaming data processing enabling, categorisation and classifications of manufacturing data and derive actionable insights.
- Real-time monitoring and predictive alerting mechanisms: by implementing a distributed AI-based approach (from cloud to edge).
- Virtual visualization/validation: by integrating pre-existing and real-time data from different factory levels, with digital twins.

BUILD Optimization, Qualification and Reconfiguration of Manufacturing Lines (WP5): To provide next-generation of Quality Control in Smart Manufacturing seeking:

- Development of strategies and methods: by transforming manufacturing data into quality-sensitive features and support rapid and continuous manufacturing line qualification.
- Simulation and optimisation: using existing data and smart algorithms to support the development of new strategies and methods for manufacturing line digital twins.
- Address data quality in smart manufacturing: by providing recommendations for certification and audit guidelines.

VALIDATE Demonstration (WP6): To demonstrate and validate the i4Q Solutions:

- 1 Product Manufacturer Pilot: To demonstrate the impact of i4Q Solutions throughout a full production line, from the arrival of raw materials to the final approval of the finished product.
- 3 Part Manufacturers Pilots: To demonstrate the impact of the i4Q Solutions in different industrial sectors (metal, ceramics, wood) manufacturing parts for downstream companies in the supply chain.
- 2 Industrial Equipment Manufacturers Pilots: To demonstrate the impact of the i4Q Solutions through its integration into industrial equipment and its offer as a service with high added value.
- 1 Solutions Demonstrator: To demonstrate the i4Q Solutions in an experimentation facility beyond the more restricted and definite environments of the pilots.

DISSEMINATE Dissemination and Standardisation (WP7): To ensure that the project results will have a significant impact putting the project on the reference map of quality control in smart manufacturing:

- Clear message: To make knowledge available in a suitable format to enterprises in the entire supply chain and final consumers in order to increase the adoption of the i4Q Solutions.
- Events: To strengthen the outreach of i4Q Solutions in the target market (parts/products manufacturers and industrial equipment manufacturers), organisation of workshops and active participation in industrial events and conferences will be a priority to present and increase the adoption of the project outcomes.
- Strong Collaboration: To create awareness with EU clusters, e.g., EFFRA, I4MS, DIHs, and related associations to improve the framework conditions for the adoption of i4Q outcomes
- Regional interactions: To ensure the engagement with Regional entities and leveraging structural funds for the empowerment of the i4Q results.
- Standards: To ensure compliance of the project results in existing standards (e.g., ISO/IEC 21778, ISO/IEC 20922, IEC 62541 series, ISO/IEC 19464) by connecting to standardisation bodies and forums and actively contributing to standardisation working groups.

EXPLOIT Exploitation (WP8): To ensure that the project results will be effectively exploited in the market:

- Market Approach: A thorough and ongoing market analysis and tracking will be carried out to position and differentiate the i4Q Solutions, and to project the potential market evolution over time.
- Business Opportunities and Models: By applying standard methodologies, business opportunities around i4Q Solutions will be identified, business models defined and then contrasted with the market in a feasibility analysis.
- Exploitation Plans: By establishing the joint and individual exploitation plans around the i4QSolutions.
- Start-up Company: Provide exploitation plans and a sustainability model for the continuance of the project results including the establishment of a start-up company to exploit the i4Q Solutions.

- IPRs: By establishing the background and IPR baselines as well as the foreground IPRs agreements among i4Q partners.

MANAGE Management (WP9): To guarantee successful project management activities and ensure on-time and on-definition project delivery.

The i4Q consortium is made up of 24 stakeholders covering all the areas of expertise and demonstration necessary for a correct execution of the project. The following is the list of all stakeholders grouped by their role in the project:

- Industrial partners (USER): WHI (White goods manufacturer), BIES (Wood industrial equipment), FACT (Metal machining), RIAS (Ceramic pressing), FARP (Plastic injection), FIDIA (Metal industrial equipment)
- Implementers (IMP): TIAG (Industrial Communication Protocols and Standards), CESI (Machine tools, Advanced Materials, Micro-technology), AIMP (Thermoplastic and thermosetting plastic materials)
- Technology providers (TECH): IBM (Information Technologies Company), ENG (Software and Services Company), ITI (Information Technologies Institute), KBZ (Information Systems Company), EXOS (Operations Consulting Company)
- Research & development (R&D): IKER (Technological Centre), BIBA (Research Institute), UPV (Technical University), TUB (Technical University), UNI (Research Institute), CERTH (Research Institute)
- Specialist Companies: FBA (Dissemination and Exploitation), IVLAB (Dissemination and Exploitation), DIN (Standardisation), LIF (Legal)

2.3 Scenarios

They are identified 6 industrial scenarios for the i4Q RIDS testing and validation coupled with a high-level user expectation of impact across different industrial activities, sectors and domains.

Pilot cases are defined to guarantee the success of the i4Q Solutions exploitation with secure and trustworthy data management policies and the applicability of the i4Q Solutions to other industrial sectors beyond the i4Q pilots.

2.3.1 Use Case Scenarios

The concrete industrial use cases will be implemented as part of the i4Q Project to demonstrate the applicability and the impact of the project and its results in the market environment under real-world conditions. It should be noted that the i4Q Solutions will be designed for any industrial sector in highly complex inter- or intra-organisation scenarios, and not limited to the challenges of the pilot cases of the project.

The i4Q Project will deploy/validate the i4Q Solutions in pre-defined use cases which have been chosen for their complementary nature yet building upon some common themes.

A total of 6 Pilots are envisioned, representing different Industrial Sectors and activities:

- White Goods
- Wood Equipment
- Metal Machining
- Ceramics Pressing
- Plastic Injection
- Metal Equipment

All of them are representative of high-tech manufacturing sectors characterised by an increasing demand for high quality products and a need for factories digitisation and data reliability.

The 6 pilots belong to 2 different levels of the manufacturing process where the exploitation of data is instrumental to optimise the production's quality: i) machine tool providers, and ii) production companies. Players in these two levels need to interact to tackle specific challenges related to quality monitoring, and process qualification.

To gain a general vision of the i4Q Pilots and see their complementarity, they have been characterised by 3 main criteria:

i) if the use case addresses the challenges in data reliability, data fusion and simulation tackled in DT- FOF-11-2020,

ii) the set of generic technologies to be worked on

iii) the industrial and technical partners of the consortium that will be involved.

2.3.1.1 Pilot 1: Smart Quality in CNC Machining

Context

FIDIA develops and produces a wide range of numerical controls and milling machines. Fidia expanded its manufacturing capacity in this sector of activity through the acquisition of Meccanica

Cortini, Sitra Automazione and Simav. Nowadays, Fidia is listed among the world's leading manufacturers of high-speed milling systems. With high-speed technology, that allows to perform both the roughing and the finishing processes on metal parts, manual finishing at the end of the milling process is virtually eliminated. More complex forms can be produced with improved quality, while machining times are significantly reduced. This complex task can be achieved only with a strict control of all the processing parameters and conditions and can be disrupted by unexpected problems. The i4Q solutions will be devoted to the collection and exploitation of workshop data (coming both from the range of FIDIA numerical controls as well as available and retrofitted sensors systems) to perform a monitoring of the processing conditions, the prediction of the final surface quality and, eventually, the adaption of processing parameters to prevent quality loss and potential failures.

Figure 4. FIDIA milling centre.

Current situation

Vibrations are well-known issues in the machining and metal cutting sector, where the spindle vibration is the primary responsible for poor surface quality in workpieces. The consequences range from the need to finish manually the metal surfaces, resulting in time consuming and costly operations, to the scrap of high value parts, with the corresponding loss both in terms of time and profit. At present it is not possible to predict the final surface quality, due to the high number of factors on which such performance indicator depends. Thus, it is the operator responsibility to decide (based on his experience and on the available controller signals) whether the final quality will be in line with customers' requirements and if the current processing condition should be altered to achieve the sought objective. In particular the detection of chatter (a highly disruptive vibrations linked to the equipment natural resonant frequencies) can be achieved only through on online analysis of the vibration Fast Fourier Transform (FFT), that requires an HW and SW toolkit not integrated with the machine tool controller.

Finally, machine tool conditions are prevalently assessed by implementation of ad-hoc preventive maintenance tasks (that of course cannot always prevent some failures). Predictive strategies, e.g., based on condition monitoring and data-driven approach, are not yet adopted.

Figure 5. Chatter marks both on the vertical and horizontal surfaces of a workpiece.

Future situation

FIDIA high speed milling CNC machine will exploit the i4Q RIDS for the off-line and on-line monitoring of processing conditions, based on signals coming from the available sources (mainly the numerical control, with its integrated drive boards and temperature converters) as well as new ones (3-axial accelerometers) installed on purpose. In particular, the following functionalities will be added:

1. An **estimation of the final surface quality**: depending on the processing conditions (axial and radial depths of cut, axes feed, spindle rotation speed, workpiece material, tool geometry) different level of energies are transmitted by the machine tool end effector to the workpiece and, as a consequence, different level of vibration may arise. The i4Q Solutions, thanks to an AI based clustering of the processing parameters, will allow to create a correlation between the process conditions and the final surface roughness, thus allowing to predict the final surface quality. The AI algorithms will be trained by a wide campaign of milling tests performed on FIDIA test machine tools.
2. A special type of machining vibration, the Chatter occurs when the tool, toolholder, and spindle vibrate at the resonant frequency of the assembly. The vibrations result in waves on the machined surface and a regular but otherwise unacceptable mark is left by the tool due to machining vibrations. The i4Q Solutions will allow to compute and analyse the FFT, compare it with forced vibrations (and related harmonics) for the **online detection of the chatter insurgence** and report back this information to the machine tool controller**,** where the CNC GUI will inform the operator of this condition and allow him to take

appropriate countermeasures. Furthermore, AI algorithms will allow to suggest the best action to adapt current processing conditions and remove the vibration.

3. A **trend-based evaluation of machine tool conditions**: over time problems may arise in the kinematic chain of the machine tool, e.g., in the spindle bearings, axis joints, belts and gearboxes, etc. These problems (such as clearances or wear) may lead to an unacceptable loss of precision and the consequent loss of surface quality. i4Q Big Data solutions will analyse the trends of the processing signals (positions, speeds, currents and torques) during the periodical execution of dedicated reference tests. The variation of such parameters during otherwise identical tests will allow to identify degradation patterns (compared to nominal conditions) by an unsupervised machine-learning approach and identify possible faulty components (failure modes).

2.3.1.2 Pilot 2: Diagnostics and IoT Services

Context

Biesse is the Biessegroup's business unit specialising in the woodworking segment. Since 1969 Biesse has been designing, producing and marketing a complete range of technologies and solutions for the carpenter and the large furniture, window and wooden building components industry. In the last years, Biesse is present in plastic processing machines with solutions designed, specifically, for a growing market. The project scope is to improve data quality, consistency and integrity in its CNC machines to allow the use of available information and add-on sensors in diagnostic analytic tools. Opening the way to new diagnostic tools is a crucial step towards reducing machine break-down and detecting early degradation, increasing productivity and quality.

The i4Q Solutions will be adopted for the top CNC woodworking. The machine will be installed at an important Italian customer, where optimised manufacturing operations and high-quality are needed. Biesse aims at increasing data quality by using additive and virtual sensors and adopting an edge architecture to increase computational processing capacity on the machine's PC. Additive sensors, actuators and instruments will provide data to the machine's PC, where analysis and prediction will be done online. Besides, the proposal solution ensures automated data collection using open protocols, standardised activities and efficient storage. Machine integration to smart factory will be done thanks to OPCUA communication protocol supported by the machine. At the end, aggregated data and results will be sent to the Biesse Digital Platform for remote control and deep storage. KPIs will be checked day by day, so that production data can lead to an integrated approach to zero-defect manufacturing.

Figure 6. CNC woodworking machine, used by Biesse.

Current situation

In manufacturing processes, production and maintenance data is increasingly important, as it could be related to the machine's degradation or the job's quality, providing a way to increase product quality and machine useful life. However, often readily available data in machine tools (e.g., currents, accelerations, vibrations, temperature) has poor quality due to its limited sampling rate and resolution. Furthermore, the sensors needed to monitor certain subsystems may not be available, due to limited accessibility, cost feasibility or because the required sensor is too intrusive. Available data may be sent to Biesse Digital Platform, that ensures data storage and integrity on cloud. However, data integrity on machine must be improved to exploit all platform features, which calls for innovative techniques to collect and manage data. Furthermore, Biesse already show data for statistics, diagnostics and preventive maintenance, using OPC UA as standard protocol. However, new OPC UA deep data to feed predictive analysis algorithms is needed.

Future situation

Biesse's top CNC woodworking machine will exploit i4Q RIDS to continuously monitor working conditions and process parameters. The i4Q Solutions will use readily available sensors, such as vibration or temperature, and will leverage the available PLCs, that are able to adapt the process to the recorded working conditions providing a way to correct process drifts (e.g., reducing the working speed in case of unjustified increase in the current absorbed by the inverter).

In addition, further sensors and fieldbus data will be included on Biesse CNC woodworking machine to support advanced continuous monitoring algorithms (edge computing), and IoT functionalities will be added to communicate machine data with Biesse Digital Platform. This data will feed a DSS (Decision Support System) and predictive maintenance algorithms, for example to detect electro-spindle degradation before faults, or to find in advance critical jobs or inappropriate use, increasing thus the useful life of the machine. The performance of these algorithms is highly dependent on the reliability of data: test cycles aimed to acquire quality data will be developed for each meaningful device wired on Biesse CNC woodworking. Precision and accuracy are ensured by each device that generates data at various levels of integration in the manufacturing process.Finally, the machine will incorporate simulation capabilities, which together with additive sensors will allow to test the programs in advance in a scenario very similar to the real one, thus minimizing the rejects due to incorrect planning or configuration and setting of the processes.

The project scope for this Pilot could be extended considering:

- an additional installation of the machine at another important customer;
- the opportunity to monitor additional parameters;
- the possibility to test i4Q solutions on further machine models;
- the opportunity to considering systems based on additional standards with respect to OPC UA.

2.3.1.3 Pilot 3: White Goods Product Quality [WHI, ENG]

Context

Whirlpool Corporation is the biggest white goods business player in the world, with approximately 21B$ revenues and 60M products sold in 170 countries in 2018. Whirlpool EMEA is a relevant part of this business addressing 4,5B$ of sales and producing and distributing around 20M appliances in a challenging business, with a strong competition that can be dealt with only through cost and quality. In this context, it is crucial to provide the best features, the widest functionalities range, lower price, and the best quality.

Within quality management, the product conformity verification is one of those which may have the higher benefit from a structural data integration, envisioning the possibility to create a dynamic framework for the products test.

Currently, the product conformity test is based on a statistical verification in laboratory applied to pre-series products in case of new products introduction or of meaningful product changes. The products are selected, randomly, according to specific and fixed percentages, and moved to dedicated labs, which test the marketing key features (e.g., Energy consumption, capacity, product dimension, water consumption, performances, etc.). This phase is mandatory to proceed to mass production but it is, generally, not replicated during normal product lifecycle: due to test duration, these characteristics are, generally, not fit to be evaluated during the EoL (end of line) functional test and may be, partially, addressed only through the so called zero-hour test, that is still on statistical base but focused only on some of these features.

It this way is sometimes very difficult to capture eventual drifts of manufacturing process that, even if within the single process control charts tolerances, may move one or more of these characteristics out of control levels, impacting directly on the final customer. This calls for new methods for increased product quality.

The possibility to cover the whole production lifecycle with the product conformity verification process will then ensure a higher and more stable quality level for the final customers, granting the respect of the main product features that customers expect from white good appliances. This calls for new methods for data consistency and data integrity.

Current situation

The main issue to be faced in the extension of product conformity testing is the feasibility of a massive test execution on the whole production scope. The high duration of the test is not compliant with production pace and with the order to delivery timing of a just in time production, like is the current production planning model in Whirlpool factories. Besides, the need to massively address all products implies the need to create advanced laboratory, like the ones existing in product development department, with a relevant cost impact.

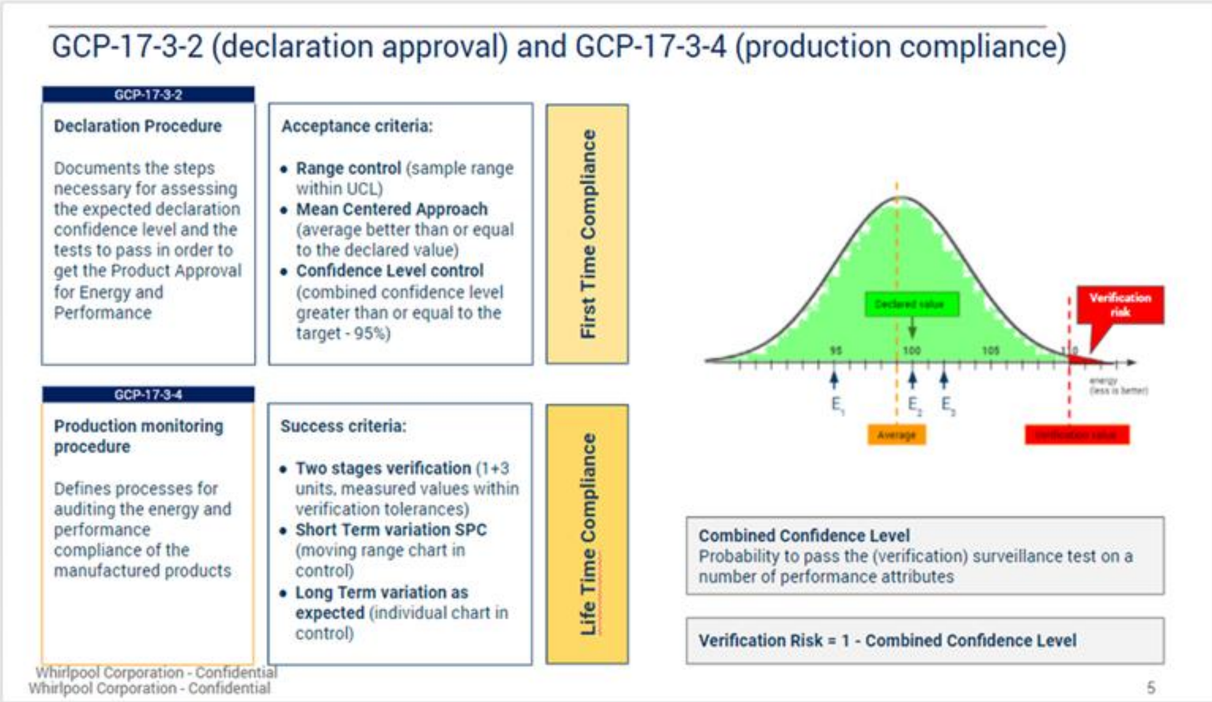

Figure 7. GCP-17-3-2 (declaration approval) and GCP-17-3-4 (production compliance).

The possibility to identify through a systematic approach to data analysis some critical correlations, between the non-conformity and some specific sets of data, may address a more focused actions on testing campaign. These correlations, once identified and confirmed, may be used as alerts which may arise the level of warning on a specific product, addressing a dynamic increase of the percentage of selected production to be verified and in this way, being able to identify epidemic problems without applying conformity test to the whole production.

This possibility will lead, surely, to a higher efficiency in problem detection, granting an early warning management, and minimizing the costs related to laboratory empowerment in the factories' environment.

This correlation between processes of which we may be able to gather process capability data, and the different elements to be verified in the conformity test, may sometimes be simple and immediate. In other cases, these relationships are hidden and unknown and they have to be identified before setting up the alerting system which may ensure the focused testing.

Future situation

The pilot will be conducted in Dishwasher factory of Radomsko Poland.

Figure 8. Whirlpool Dishwasher factory of Radomsko Poland.

Through the i4Q RIDS all data from relevant sources will be used in a systematic and integrated way to infer conformity or non-conformity of each single product item produced, versus current situation which is checking it before NPI start of production or, in better case, along all the production lifetime but based on statistical samples.

During the pilot, i4Q services will be trained to learn how to correlate on-going production data to proven conformity characteristics already known through previous internal methods.

Various i4Q Solutions, in particular i4Q Data Integration and Transformation Services, i4Q Services for Data Analytics, i4Q Distributed AI services and i4Q Analytics Dashboard will use this rich and deep dataset mapped to the i4Q Ontology and a specific business requirement in order to be trained to correlate on-going production data to proven conformity characteristics already known through previous internal methods so to infer conformities and non-conformities in real time without an expensive and slow massive execution of tests.

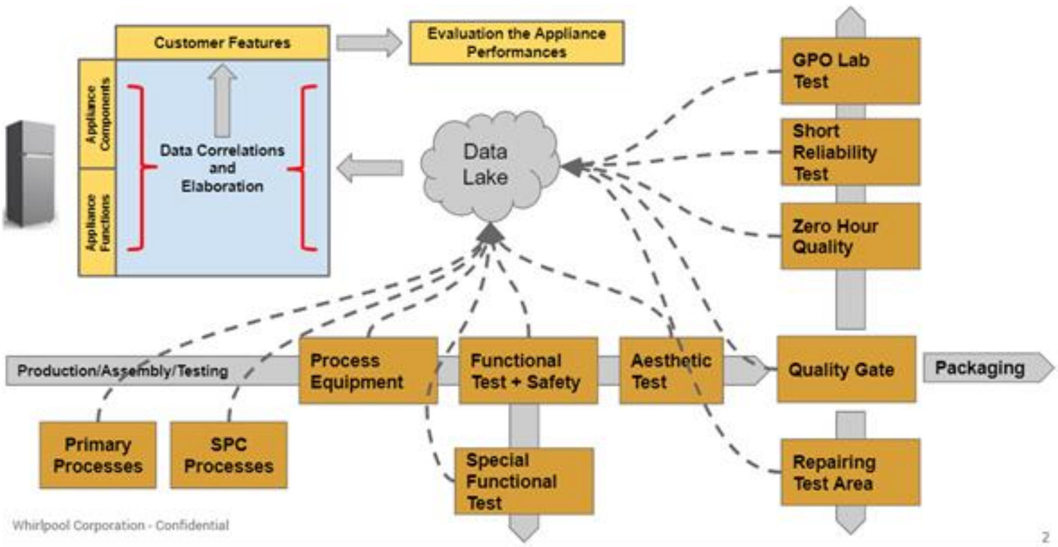

Figure 9. AI Conformity system for Whirlpool.

The AI Conformity system delivered by i4Q will be able to be trained on every new product introduction and as a consequence will let Whirlpool to:

1. Certify product conformity at serial number level;
2. Early identify dangerous conformity drift which may be premonition of quality issues;
3. Help to adjust the Quality plan embedding new correlation knowledge.

2.3.1.4 Pilot 4: Aeronautics and Aerospace Metal Parts Quality

Context

Factor is a Spanish SME, located in Puzol, Valencia, specialized in metal machining and precision turning, offering a comprehensive solution for the outsourcing of metal mechanical components to customers in the most demanding and leading industrial sectors (Aeronautics, Agriculture, Automotive, Electronics, Lifting and Handling, Energy, Hydraulics, Medical, Naval). Factor has no own product, therefore everything it manufactures is on request from customers. Manufactures may or may not be repeated and are, usually, short or medium series, therefore there are many changes of parts in the machines weekly.

Factor manufacturing process consists of a main process and the rest are less value-added processes (cleaning and packaging) that do not require special equipment. Factor machines can process different types of raw materials (stainless steel, aluminum, titanium, hardened steel, brass, technical plastics etc.) with wide ranges (parts from 1 mm to 130 mm) using different equipment.

Once the parts come out of the machine, they are considered finished and only in cases where they are required, that is some heat or surface treatment that is outsourced.

The Factor machine park currently consists of 21 CNC lathes that can manufacture parts between 1 mm and 130 in diameter and lengths ranging from 2 to 300 mm.

Figure 10. FACTOR´s production and transformation plant.

Factor quality control resources include vision control system, coordinate measuring machine, optical measuring machine, microscopes, roughness meters, coating layer measuring instruments, profilometers, gauge blocks and a range of other features to perform incoming and end systematic inspection, batch checking, certificates and non-quality costs. Factor wants to become a supplier to the aerospace industry and needs to improve its manufacturing quality assurance system to follow the strict data quality management requirements of the aerospace industry, including the requirement to be AS 9100 certified. AS 9100 combines and harmonizes Europe's AS 9000, ISO 9001 and prEN 9000-1 quality systems and defines specialized areas within an aerospace quality management system such as procurement traceability, configuration management, product documentation and control of work performed outside the supplier's premises.

The use case will be developed at the Factor factory located in Puzol on at least one machine of each of the following types: Swiss-type Automatic CNC Lathes, Multitasking Machines, Ultrasonic Cleaning Machine. The i4Q Solutions tested and validated in Pilot Factor, and the expected TRL achieved.

Current situation

The implementation of Industry 4.0 in Factor currently consists of a machine data collection system that provides information for the control of the Overall Equipment Effectiveness (OEE). Machines connected to a MES capture uptime and online cycle times, but the reasons for machine stops and non-compliant unit data must be entered manually by operators. Machines are able to detect the vast majority of stop reasons, but this functionality is not implemented yet. The data that the machines generate daily is not preserved and, of course, their analysis is not being exploited to prevent future problems related to tool breakage, such as minimizing the breakage of cutting tools due to the lack of cutting lubricant or due to the obstruction of the cooling channels of the tools, facilitate the diagnosis and evaluation of break incidents, ensure that the tools operate within their optimal range, predict damage to the equipment.

With regard to part quality control, there is currently no capacity with the current means of automating the control and recording of the quantity and reasons for NOK. Quality control over manufactured parts is done manually or semi-automatically with CNC measuring machines that perform part measurement, but unitarily. All data generated by operators or measuring machines is recorded in digital format, but is processed exclusively for ongoing manufacturing, is not then analyzed, for example, to anticipate potential problems in future manufactures. All this data is lost for future analysis.

Currently, Factor does not have a manufacturing line qualification system based on continuous validation of the process to certify its level of manufacturing quality and cannot guarantee the unalter ability of product and process data to its customers, this being a requirement of some aerospace customers and a competitive factor in other sectors.

Future situation

Factor wants to evolve into zero-defect manufacturing by eliminating efficiency failures caused by cutting lubricant status, minimizing breakage of cutting tools due to lack of cutting lubricant or due to locking tool cooling channels, facilitating diagnosis and evaluation of breakage incidents, ensuring tools operate within their optimal range, predict equipment damage and implement efficient inspection of all manufactured parts, particularly complex parts (Rapid Quality Diagnosis-i4Q^{QD}).

Factor will use the i4Q Digital Twin (Digital Twin Simulation Services-i4Q^{DT}) and i4Q data repository (Data Repository-i4Q^{DR}) to digitize its entire factory, using sensors, cameras, and other data collection techniques, so they can evaluate production decisions based on data analysis and simulation, visualize products that work in they environments in real time, and connect separate processes to improve tracking and monitoring, and gain control over they complex processes. i4Q services for data analysis (Services for Data Analytics-i4Q^{DA}) will be applied to data collected, in real time, to alert you to product and process deviations, and AI algorithms will recommend parameter reconfiguration (Manufacturing Line Reconfiguration Toolkit-i4Q^{LRT} and Manufacturing Line Reconfiguration Guidelines-i4Q^{LRG}).

Factor will use sensors to measure the properties of the cutting lubricant (pH, salt concentration, bacterial level, metal particle size, etc.) to facilitate the diagnosis and evaluation of incidents in tool breaks. Real-time measurement of the temperature of the cutting area will ensure that the equipment functions within the optimal range, raising system efficiency, reducing setup times and the number of incidents, and preventing premature wear or tear of cutting tools. Measuring the oil/water concentration will ensure that the equipment is working properly, preventing wear or premature breakage of cutting tools due to lack of lubrication or coolant.

Real-time analysis of temperature and vibration from different machine sites (head, cannon, motors, etc.) will predict future failures. The use of vibration sensors in the cutting tools and supports they are working on, and real-time analysis will prevent premature wear or breakage of cutting tools, defective parts and machine stops.

The use of laser sensors and artificial vision will allow us to check the optimal condition of the cutting tool by detecting whether it has deteriorated or broken, in this way we will avoid defective parts and most importantly massive collisions and breaks of tools derived from the breakage or deterioration of tools that should have worked with correction previously.

Capturing data will offer us the sensorization of the different elements of the machine such as motors, spindles, refrigerant, etc. and cutting elements such as tool holders and cutting tools involved in the process of manufacturing the parts, we will be able to analyze this data online (Infrastructure Monitoring-i4Q^{IM}) or later to anticipate situations that lead us to machine stops, not quality or breakdowns, this being an aspect that would make us greatly evolve the control of the process.

Likewise, with the capture of the data obtained from the measurements made online through the independent measurement system of the people, automatic and online manufacturing, and with the interaction of these with the machine, correcting the deviations that occur during the process by wear of tools, or mismatches of the machine (Analytics Dashboard-i4Q^{AD}), we will anticipate and eliminate the causes that produce us non-conformities in the parts and with the subsequent treatment of all this data once the manufacture is finished we will be able to anticipate situations and correct these for future manufactures of these or other parts to be manufactured, with the aim of obtaining 100% quality.

In terms of quality control, the use of laser sensors and artificial vision will allow metrological inspection of 100% of the parts in real time of manufacture. This aspect is essential to ensure the continuous operation of the machine avoiding machine stops caused by defects in manufacturing. The objective would be to get the sensors to automatically correct the machine when they detect deviations from the measures over the face value, without operator intervention, which will be a great advance in increasing the availability, performance and quality of the OEE plant.

Virtual and augmented reality will allow the measurement of complex parts, reducing measurement time in complex parts and eliminating human error and minimizing inspection training time for operators and verifiers. The data collected by i4Q systems will allow to build a knowledge base (Guidelines for building Data Repositories for Industry 4.0-i4Q^{DRG}) to estimate the working ranges H2020-DT-FOF-11-2020 - Quality Control in Intelligent Manufacturing (IA) i4Q optimal working ranges of machines and tools, anticipate maintenance, increase the efficiency of the entire production system by reducing setup times and drastically reducing incidents (Big Data Analytics Suite-i4Q^{BDA}). Finally, Factor will use i4Q data integration and transformation services (Data Integration and Transformation Services-i4Q^{DIT}) to ensure the quality of their manufacturing data (accuracy, accuracy, integrity, consistency, and reliability) and to ensure the reliability of all raw industrial data to their customers, especially in the aerospace and aeronautical sectors.

2.3.1.5 *Pilot 5: Advanced In-line Inspection for incoming Prime Matter Quality Control*

Context

RiaStone is part of "Visabeira Industria" a sub-holding of the "Visabeira Group" conglomerate, RiaStone was created in 2014, after being awarded a contract by IKEA Sweden for the manufacturing of 486 million tableware products in the timeframe 2014-2026. RiaStone manufactures the IKEA worldwide supply of "Dinera", "Fargrik" and "Flitighet" IKEA tableware families, being products fabricated through an innovative Industrial ceramics production process: tableware automated single firing.

RiaStone has the urgent need to improve its Overall Production Effectiveness (OPE) Key performance Indicator, presently RiaStone has an OPE of ~92%, having as a main improvement Goal, reaching an OPE of 99%. This improvement ambition requires new approaches to production, promoting innovative defect management and production control methods, namely in-line inspection technologies, and integration of ICT tools for autonomous, automatic, smart system decision taking. There are several difficulties and inefficiencies in the processes being used today, impacting overall production efficiency, and causing significant levels of product rejection (waste to be scrapped) as a result of poor quality of incoming matters which today are not detected by the quality control inspection, namely: Isostatic Pressing Process: Density and composition variations of incoming prime matters, produce volumetric mass density differences is post-pressing raw greenware, directly affecting the quality levels in finished stoneware products.

The i4Q use case will be implemented at the RiaStone Factory located in Ilhavo/Aveiro/Portugal in one of the Prime Matter Storage Silo Units, and at one of the Iso-static presses for stoneware ceramics. The RiaStone use case will guarantee data accuracy, and data veracity for prime matter quality diagnosis through a real time certification system, for ensuring high manufacturing efficiency and optimal manufacturing quality of finished goods. The i4Q Solutions tested and validated in RiaStone pilot, and the expected TRL achieved, are shown in **Figure *11***.

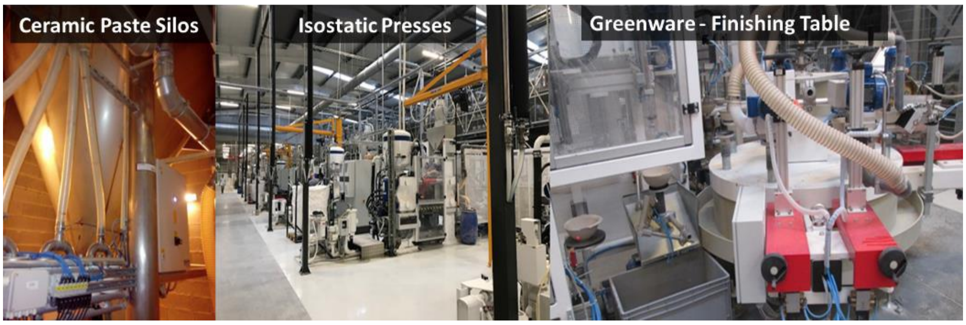

Figure 11. Prime Matter storing, dosing, and first usage.

Current situation

Presently, QC techniques applied by RiaStone to incoming prime matters from 3rd party providers, namely ceramic pastes, are performed almost exclusively through standard lot sampling, the QC Techniques under use are traditional methods of sample testing, made by collecting two working paste sample amounts and performing to them two separate QC operations, a) A regular chemical laboratory analyses (Chemometrics), and b) A functional QC test, performed by using the paste sample to produce one or several greenware test plate(s) in one of the isostatic press.

Both QC methods currently under use rely on non-timely, practical hands-on approaches, that effectively do not allow for an immediate timely and accurate confirmation that incoming ceramic pastes from 3rd parties, comply with the exact formulations that will allow for trouble free production of greenware products in the automated production line.

Further, before final quality control, random intermediate quality checkouts are performed over limited production samples, the product final QC process is only really carried out at the very end of the production line, when produced greenware enter the final selection, product grouping, and packing stage.

The final QC verification is performed by selected and specifically trained operators, by using human visual inspection coupled with a defect classification matrix. In this process the human QC operator visually inspects each finished piece and categorizes it into three quality standards: A (best quality), B (sufficient quality) and C (rejected as scrap). The operator also describes the defects encountered, which can, in the future, be correlated with the quality of the raw matters and with other variations on each stage of the production process.

Moreover, in the ceramics industry as a whole there is no general or specific track-and-trace method traditionally implemented in the industry for traceability implementation of any individual pieces during the traditional ceramics production process. Hence, there is a need to find innovative technologies and strategies that enable the forementioned correlations between the data quality.

Future situation

RiaStone has the ambition of improving the Production Efficiency of its Production Processes, through new and advanced processes that can measure the quality of the incoming Raw Matters inline, going from the current status of statistical offline sampling quality control methods, towards the implementation of a continuous and complete data driven incoming raw matter quality control at RiaStone.

This will be achieved through the implementation of a new and innovative, in-line QC spectrometry analysis system, that will add to Riastone the capability of inline, realtime analyses of all incoming ceramic pastes, the spectrometric analyses will focus in the detection and quantification of two elements in the incoming raw matters, namely a) Water, and b) PVA-Polyvinylic Alcohol, that are the two major chemical markers of incoming Raw matter quality.

The inline analysis system will also use a laser inspection system to analyse the raw matter granularity dimension, which in ideal condition will vary between 400microns, and 800microns. The variations of these three factors, namely: water, PVA, and granularity, are the key markers for the assessment of raw matter quality.

Apart from the previous objective of analysing the raw matter's composition and characteristics, the main goal of the RiaStone pilot is to leverage the value created in both i4Q and previous EC-funded projects to enable efficient quality control throughout the entire production line. In order to achieve full line quality control, several piloting activities were developed, namely within the scope of BOOST 4.0 and QU4LITY EC-funded projects.

In QU4LITY, an image processing-based approach was developed to detect defects in the pressing process, as well as after the glazing process. In BOOST4.0, a first root-cause analysis was performed, linking possible defect types to the glazing material specification parameters (e.g., temperature, density, etc.). Data collected by these proofs-of-concept will be integrated with data collected during raw matter's analyses, in order to be used by the necessary i4Q Solutions, so as to achieve full line quality control and root-cause detection.

2.3.1.6 Pilot 6: Automatic Advanced Inspection of Automotive Plastic Parts

Context

Farplas, flagship of "Fark Holding" established in 1968 as an automotive supplier, designs, develops and manufactures vehicle plastic systems, such as interior/exterior parts, instrument panels and electronic based ceiling and lighting systems. With 1800+ employees, 3 manufacturing sites (80 injection machines distributed in these 3 production sites) and 2 R&D Centres, Farplas has consolidated as a full system automotive Tier1 company.

The technique used to produce these high-quality solid parts is injection moulding. Injection moulding is an established production process in which a molten plastic material is injected into a mould cavity. The melted plastic then cools and hardens and the finished part is removed. Though the mould design process is critical and challenging, injection moulding itself is a reliable method for producing solid plastic parts with a high-quality finish.

This technique is one of the most commonly used production processes for components in the automotive industry where repeatability, scalability and cost are all of great importance, since it is ideal for producing plastic parts with relatively simple geometries and results in parts with high surface finish quality. At the same time, consistency, safety, and quality of manufactured pieces is of the utmost importance in the automotive sector. Farplas aims to increase manufacturing process productivity through rapid error identification, which has the potential to reduce the production cycle in 18% and increase the performance in the detection of defective pieces up to a 99%.

Current situation

The inspection and quality assurance in the production of plastic injected parts for the automotive industry relies on the following techniques:

1. Visual inspection of the injection process in the manufacturing plant by the operator or technician close to the machine, using as reference standard parts or negative models for comparison and to measure critical dimensions.
2. Technical measurement of some reference samples taken from the lot and performed by qualified technicians.

Up to now, neither of those approaches achieve the ideal of 100% control and inspection, and it depends, in most cases, on the specialisation and qualification of the assigned technician, introducing "human variables" in this validation process that has a strong influence on the final validation results. For the original equipment manufacturer (OEM) in the automotive industry, the 0% defects are a basic requirement to introduce these plastic parts in the final assembling of the car structure in their facilities. If there is any defective part detected by the OEM, all the production sent by the TIER 1 provider is rejected until the problem is solved, causing delays on the whole process assembly, influencing also in other parallel process of the car assembly

Figure 12 shows one of the main plastic injection defects (white mark) which is hard to detect using computer vision systems.

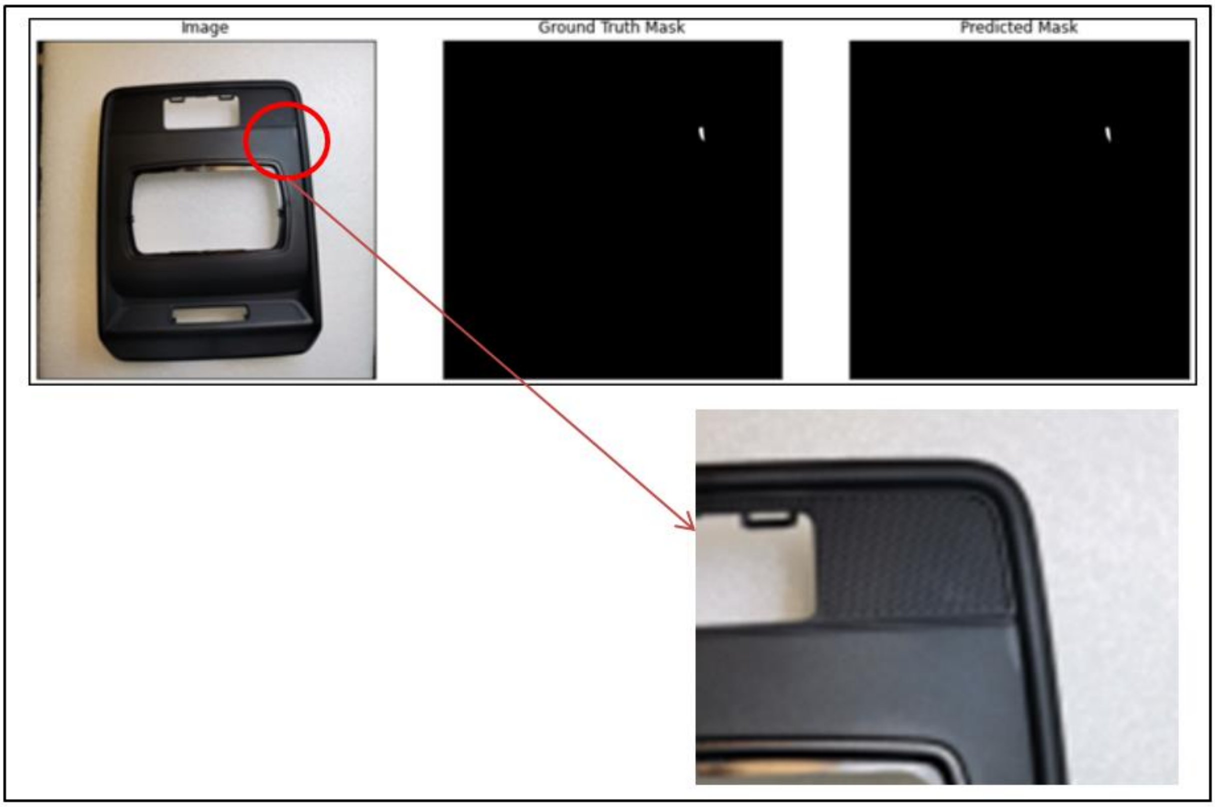

Figure 12. Vehicle plastic parts.

Current detection accuracy is 83%, therefore we still require additional human dependent control mechanisms which causes additional cost and inefficient process flow.

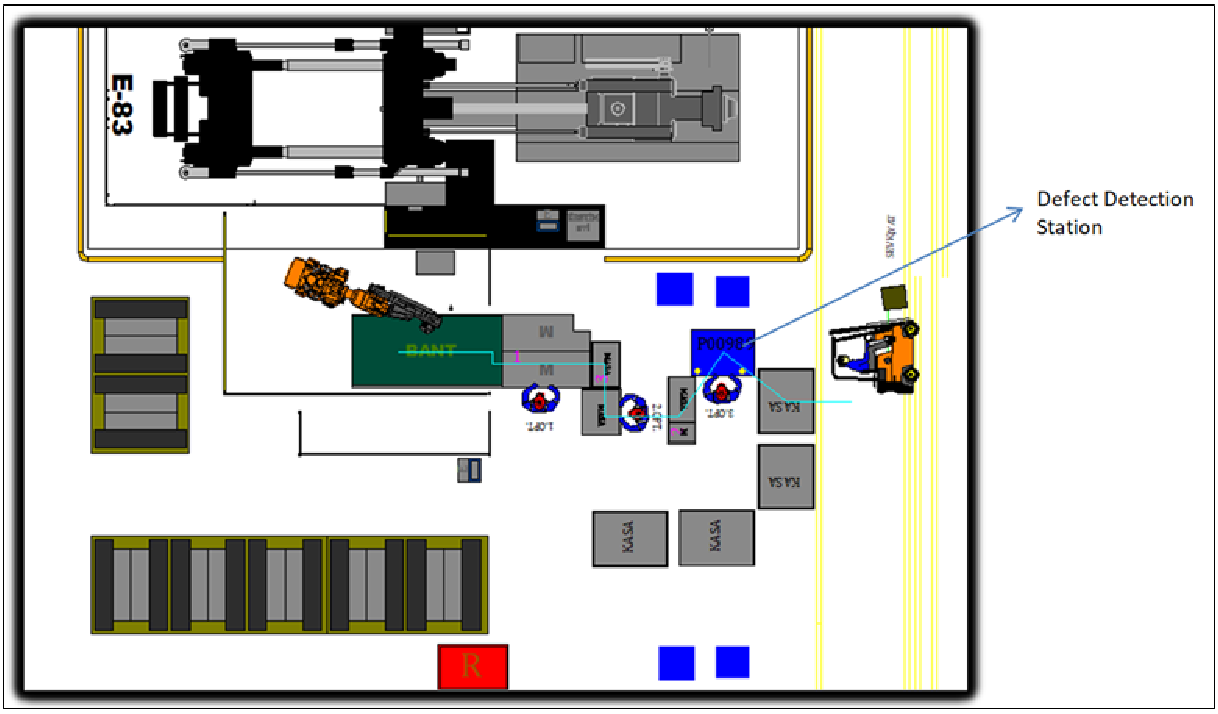

Figure 13. Example of current process flow and defect detection station.

Figure 13 shows one of the examples of current process flow and defect detection station.

The use case-6 will be developed in one of the plastic injection machines that Farplas has in its factory in Kocaeli (each machine produces approximately 10 different pieces). The most appropriate machine will be chosen according to the pilot specifications. Currently, detection of defective pieces is performed by visual control equipment (achieving an 83% of performance). The objective of the pilot is to incorporate automatic industrial inspection and AI-based detection algorithms (providing 100% performance), reduce workforce in the process, and move the visual defect control to the conveyor belt. The i4Q Solutions are tested and validated in the Farplas pilot.

Future situation

This use case complements the plastic injection manufacturing process with an automatic advanced inspection phase based on artificial intelligence and applies the i4Q Solutions developed in the project to collect data from all phases, perform the corresponding data analytics, and actuate over the different devices in order to optimize several processes. For instance, the so-called ZG3D artificial vision-based inspection system will be implemented. The application of the ZG3D advanced industrial inspection system overcomes the problems encountered in previous approaches (discretional inspection and human factor in the visual inspection), since it is able to automatically discard all defective pieces and achieve a real zero-defect scenario. On the other hand, information related to the injection process will be collected by the i4Q middleware and analysed and correlated with that coming from the inspection at ZG3D system, in order to find hidden patterns that will allow to "learn and improve" the injection process, thus increasing the efficiency of the process and reducing the number of final defective pieces. Finally, notice that the coupling of the ZG3D inspection system to the plastic injection process is possible due to the value of injection cycles (about 20-30 seconds).

2.3.2 Generic Scenario

The Generic Scenario will be an experimentation facility for i4Q Solutions beyond the more restricted and definite environments of the pilots.

The facility will be a physical environment in which all the i4Q Solutions can be tested and experimented since the pilots themselves will be restricted in terms of both scope and willingness of the users to experiment in their factories on scenarios which have less relevance to them and will remain as i4Q Solutions Demonstrator beyond the i4Q Project. The experimentation facility will be provided by UPV a flexible smart factory system for teaching and research purposes.

The system simulates a mobile phone manufacturing process and it consists of a cell assembled. On one hand, a cell responsible for assembling the different parts of the phone (Front and Back cover, PCB and fuses).

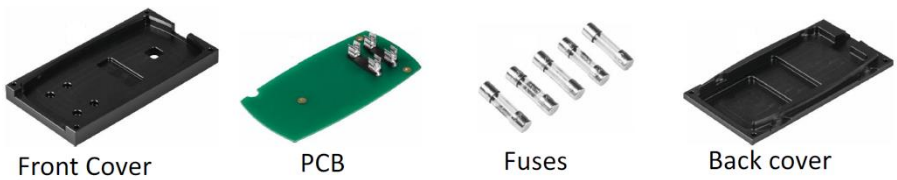

Figure 14. Parts of the phone.

On the other hand, it has a cell palletized where the system can load and unload to pallet.

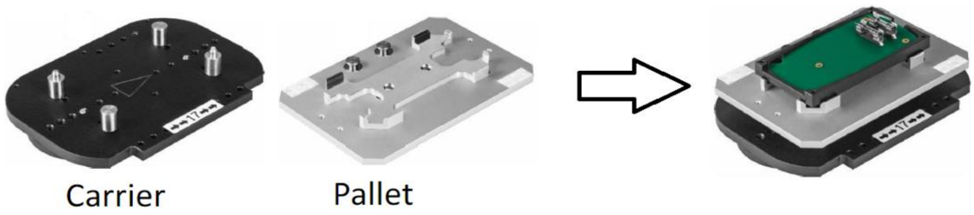

Figure 15. Cell assembled.

This system is compound by individual stations. Every station consists of a conveyor and an application module. There modules are independent and can be easily switched.

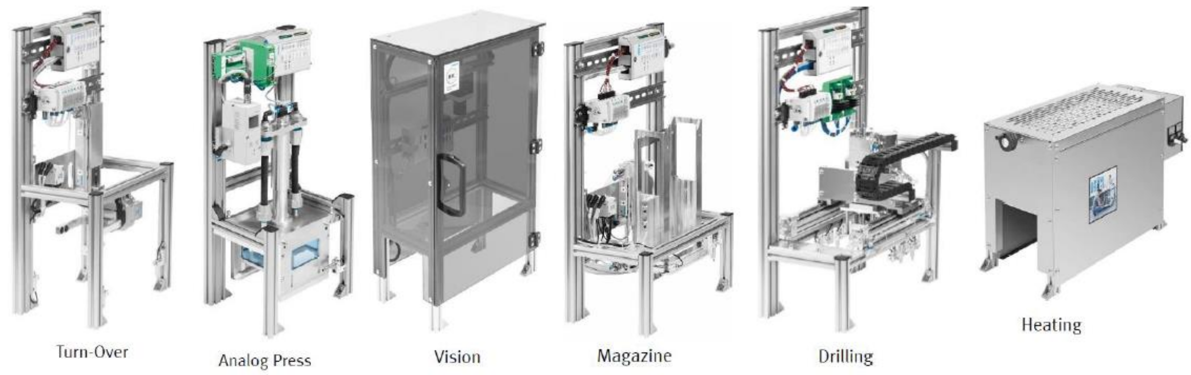

Figure 16. Module station.

This supply chain is composed of connected application modules (e.g., including artificial vision, drilling, heating, collaborative robots, automatic warehouse). Each module is equipped with Programmable Logic Controllers (PLC) with TCP (Fieldbus communication) and OPC UA connectivity. The modules are integrated with a Manufacturing Execution System to control operation and interconnected with a conveyor belt close loop that transports carriers and pallets with products.

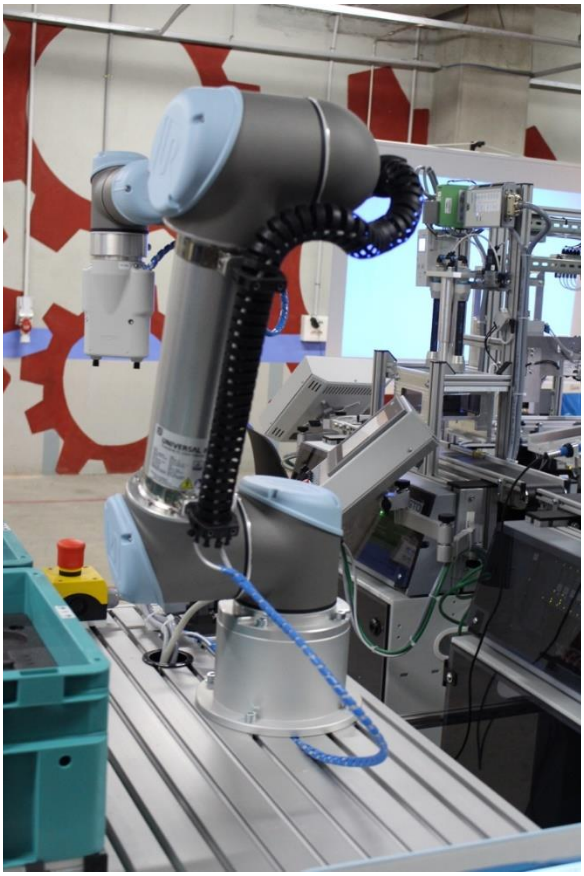

Figure 17. Robotic Arm.

This cell would be used to continuously generate data that we can explore. Thanks to it, data would be validated and we would have a basis to demonstrate its proper functioning. On the other hand, they could deploy the solutions on the UPV's servers, thanks to continuous integration pipelines, would perform tests that include connection to this cell.

Figure 18. Experimentation facility.

3. Positioning

The general objective of the i4Q exploitation activities is to facilitate technology uptake by the i4Q start-up company and long-term adoption of the i4Q Solutions by the industry. The positioning will be done collaboratively between FBA and KBZ teams in order to assure the smooth exploitation strategy. Also, LIF will be involved assuring the proper alignment of Business Plan with IPR issues that will be necessary to tackle.

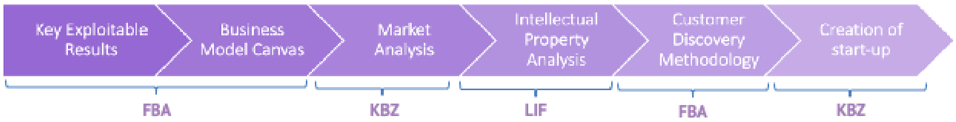

Figure 19. Actions that will re-force the commercial roll-out of the i4Q final products.

3.1 Context

The main objectives of the exploitation activities are showing the general scope of the actions that will re-force the commercial roll-out of the i4Q final products.

O8.1 To define Key Exploitable Results and a Business Model Canvas of i4Q.

O8.2 To perform Market Analysis for the selected target segments and develop a PEDR.

O8.3 To perform IP evaluation of the KERs and understand the FTO situation; also get acquainted with the national and EU law and regulatory frameworks.

O8.4 To apply Customer Discovery Loop practically and receive unbiased end-user feedback directly from manufacturing SMEs in Europe to improve the functionalities of the i4Q end-product.

O8.5 To ensure that the created i4Q start-up that uptakes the innovation, is equipped with a clear roadmap and IP Protection Strategy and practical connections with public and private investors to successfully take the innovation to the market.

3.1.1 Business Opportunities

The initial Business Model Canvas of the project is showing the starting point of business-driven logic of the project (**Figure 20**):

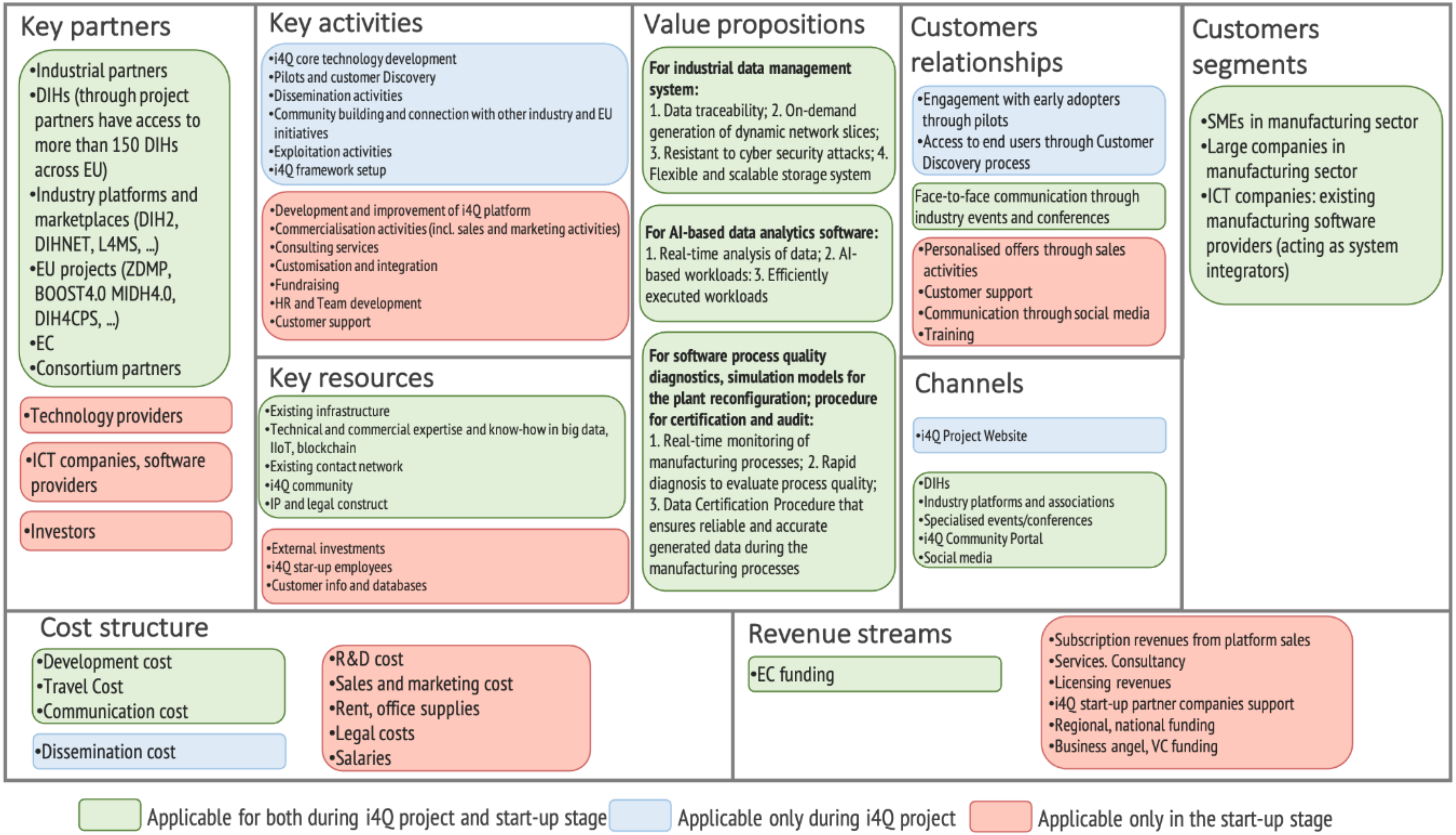

Figure 20. Business Model Canvas of the i4Q Project.

The Canvas will be used as the general tool to absorb different expansions and actualizations that will emerge from the i4Q exploitation work package activities.

The most relevant for business opportunities mapping will be the KBZ PEDR Deliverable, which will incorporate the market analysis for different customers segments. This task will include:

- Market qualitative and quantitative assessment around i4Q Solutions.
- Categorization of target groups to create value propositions and achieve impact objectives.
- Setup workshops for sketching offers and solutions using Value Roadmapping Method (VRM).
- Create realistic and achievable PEDR.

Figure 21. Market assessment around i4Q Solutions.

Also, in the second half of the project the Customer Delivery methodology will be applied by FBA workshops in order to polish the possible touchpoints with the market for each of the KERs of the project:

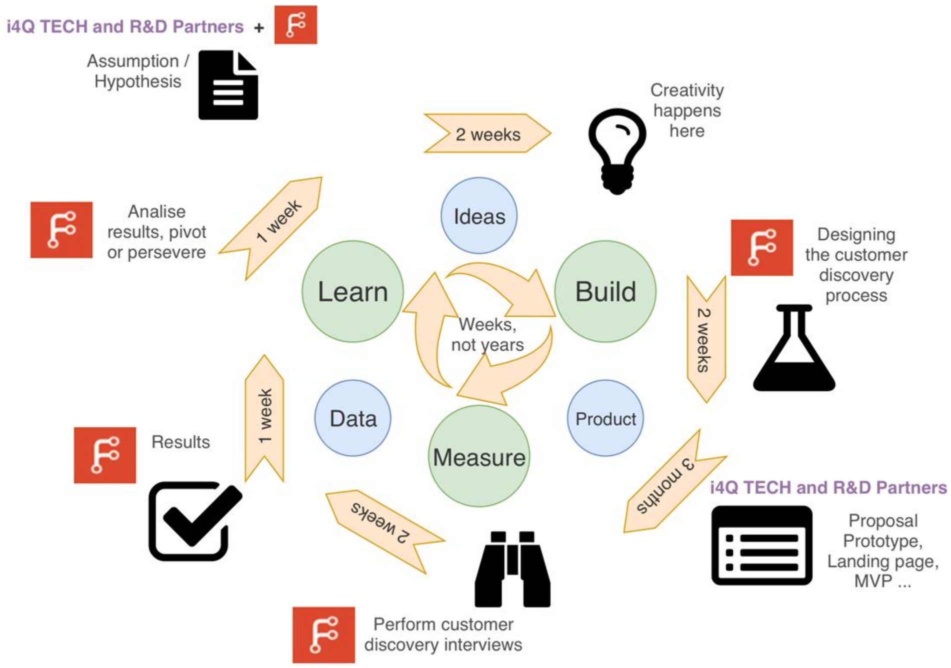

Figure 22. Customer Discovery Loop.

3.1.2 SWOT Analysis

A closer look at the market dynamics will be undertaken by assessing the market regarding technologies, market barriers, key players and drivers. The market analysis will comprise an analysis focused on i4Q's target markets. The preliminary SWOT analysis below touches several different aspects in order to evaluate strengths, weakness, opportunities and threats to the exploitation of i4Q.

STRENGHTS	WEAKNESSES
· IIoT based Reliable Industrial Data Management System (RIDS) able to manage large amounts of industrial data · Data consistency spread throughout different branches and factories locations · AI based for real-time data analytics and transformation services · Blockchain traceability of data · Rapid reconfiguration guidelines for manufacturing lines · Excellence partners working together within a EC framework initiative leveraging on long-term experience in the industry	· Key players in the market might create barriers to the collaboration when managing data · Difficulty of integration regarding legacy systems · Constant change in ICT technologies and methodologies · Difficulty to modify data in blockchain · Newcomer to the market
OPPORTUNITIES	**THREATS**
· Strategic alliances and partnerships with relevant clusters · Competitors solutions covers large-scale activities being not SME oriented · Create new business opportunities for companies · Increased processing capabilities of sensor devices	· Secure data transmission · Deep data heterogeneity · Unknown topologies · Unexpected developments of the market requirements

3.1.3 Stakeholders

There are different groups of stakeholders who will benefit from i4Q's project results. They belong to the industrial sectors of i4Q Pilots as well as to other industrial sectors or other interested stakeholder groups such as technology providers, integrators, standardisation and certification bodies, etc.

- **Industrial Equipment Manufacturers:** i4Q is expected to define a "de facto" standard, so the Industrial Equipment Manufacturers can benefit from this project in two ways: i) through value-added, offering its machinery integrated with i4Q Solutions, embedded using an OEM license or as an external service; and ii) improving its own products with the results of i4Q, so they can achieve excellent quality level.
- **Final Products and Parts Manufacturers (specially in Metal, Plastic, Ceramics and Wood sectors):** The main beneficiaries from i4Q are the manufacturers of final products, which will get huge efficiency gains on its processes through quality control. The main impact will be: i) Detection of quality deviation at the moment it happens - no more "complete lot" waste; ii) Implementation of Quality Assurance Processes for more manufacturers, as the main work is done by the system; iii) Increment of quality level. Due to the nature of

the Pilots, the manufacturers of Metal, Plastic, Ceramics and Wood goods will have immediate benefits. These sectors lack in Quality Assurance Processes, as they work with high volume of goods but are very traditional sectors.

- **Technology Providers:** Providers of industrial devices such as smart sensors, industrial network components or industrial data gateways will benefit from a wider range of applications for their products, including sectors and market niches where security and reliability are important entry barriers for their products.
- **IT Integrators:** i4Q Solutions need to be integrated with existing information systems at different levels (from industrial control systems to enterprise systems). IT integrators will benefit indirectly from this increased demand for integration services.
- **Software Developers:** The availability of industrial datasets with enhanced quality and reliable industrial data services specifically designed to process and reason with these data will boost the development of new AI applications to support production planning and execution. i4Q will thus open up new opportunities for software developers in the manufacturing sector.
- **Specialist Companies:** These parties will benefit indirectly from the i4Q results by strengthening their services portfolio thus the main benefit for such specialists is future ongoing business. Such parties range from those that could help engage with technologies and standards, those with knowledge of regulation and policy, through to marketing and lead generation organisations.
- **Consulting Companies:** Whether to help companies rethink their strategies to seize the potential benefits of i4Q Solutions, to support the acquisition of needed talent, or promote the development of new applications, consulting companies will find new opportunities around i4Q.
- **Research Institutions:** i4Q offers research institutions the opportunity to develop industrial partnerships to help industry grow, develop, and be more efficient. This represents an excellent way to leverage research lines focused on the technologies to be used in the project. The knowledge acquired as a result of the methodologies, software tools and technologies developed in i4Q will be applied both to train students (e.g., Universities) and to carry out technology transfer projects with companies (e.g., Research Centres). Moreover, it will contribute to increase their technological product offer and service portfolio.
- **Standardisation and Certification Bodies:** i4Q will connect with standardisation bodies and assess project results to provide input to standardisation, if suitable. Standardisation bodies will benefit from the connection to i4Q experts and from the i4Q input, if provided. Certification bodies value standards as a basis and will therefore possibly use results from i4Q.
- **Other European actions**: EU funded projects interested in collaborating with i4Q (e.g., BOOST4.0, MUSKETEER, ZDMP, etc.), FoF and I4MS initiatives as well as initiatives beyond them of relevance to i4Q purposes (e.g., euRobotics, BDVA, AIOTI, etc.), Digital Innovation Hubs and networks of DIHs (e.g., MIDIH, DIH4CPS, etc.).
- **General audience**: including a wide range of stakeholders interested in project activities and results, from individuals to organisations, public and society.

The project's dissemination activities targeted at these stakeholders will focus on:

- the promotion of i4Q project, objectives and results to the different identified target audiences,
- raising awareness of i4Q activities and solutions among different stakeholders, and
- establishing potential collaborations and engagement with other European initiatives, especially other FoF/I4MS projects.

3.1.4 Post-project Commercialisation of i4Q

The important aspect to mention here is the final commercialisation vehicle the i4Q start-up. Although there is the option of creating a new company, the option of using a newly created start-up will be considered. Such a company is **i4FS**, a UK based Start-Up (https://i4fs.com). **i4FS Managing Director Tony Velin** is considered to become a member of the i4Q Advisory Board in order to follow up the project results from the beginning of the project.

To ensure a successful market entry for the i4Q start-up, FBA will develop a comprehensive Go-to market plan, providing practical steps for the start-up and guiding them in future activities in commercializing the i4Q system. The plan will be, partly, based on the outcomes from the Market Analysis and PEDR and the Application of Customer Discovery Methodology, outlining the most potential target segments and potential customers identified. The plan will give a detailed overview of the timeline, including additional development needs and financial needs associated to exploiting the i4Q system. Furthermore, an IPR Protection Strategy for the start-up will be developed by LIF, which will suggest the most appropriate IP protection means (patenting, trademark protection, trade secrets, copyrights, etc) that helps to protect the key IP of the i4Q start-up. This strategy will ensure long term strategic protection and a competitive advantage on the market. The input for this task comes from the Business Model Canvas, the Market Analysis, the IPR evaluation and EU and national law and regulation and the Customer Discovery interviews.

3.2 Customer Needs

i4Q Value Propositions are a marketable set of modular software products, methodologies, models and consulting services that can be applied to many industries, by fulfilling manufacturers needs in terms of improving their quality control capabilities to support better product-services designs and better manufacturing processes and operations.

The tool set, methodologies and models include:

- **Industrial data management system**: The direct exploitable results will be: i) i4Q Data Quality Guidelines which describe how manufacturers can setup and maintain a data quality management for their production, ii) i4Q Blockchain Traceability of Data which will store collected data and ensure the data reliability and traceability, iii) i4Q Trusted Network Industrial Interface which will enable the on-demand generation of dynamic network slices, iv) i4Q IIoT Cybersecurity Handler which handles the security aspects of IIoT devices and how they interact with each other and among other modules (resistant to cyber security attacks), v) i4Q Data Repository which implements a distributed, flexible and scalable storage system.
- **AI-based data analytics software**: The exploitable results will be: i) i4Q Data Integration and Transformation Services to handle the extraction, load and transformation processes as

necessary for analysis, ii) i4Q Big Data Analytics Suite which can perform real-time analysis of data as soon as that data becomes available even in intensive data streams to allow the business to react without delay, iii) i4Q AI Models Distribution to the Edge which will manage AI-based workloads, iv) i4Q Edge Workloads placement and Deployment Services which enables workloads to execute efficiently on the edge, v) i4Q Infrastructure Monitoring tool to monitor the manufacturing edge environment including applications, resources and AI models.

- **Software process quality diagnostics**: The exploitable results will be: i) i4Q Data-driven Continuous Process Qualification for real-time monitoring the stability, capability and performance of manufacturing processes, ii) i4Q Rapid Quality Diagnosis to evaluate the process' quality.
- **Simulation models for the plant reconfiguration**: The direct exploitable results will be: i) i4Q Prescriptive Analysis Tools to simulate potential manufacturing line upgrade solutions, ii) i4Q Manufacturing Line Reconfiguration Toolkit which are based on strategies and methods for manufacturing operations supported by AI reasoning techniques.
- **Procedure for certification and audit**: The exploitable results will be the i4Q Manufacturing Line Data Certification Procedure which aims to define an audit procedure applied to the manufacturing resources to ensure reliable and accurate generated data during the manufacturing processes.

The main end-user customer segments for i4Q are European manufacturing companies - both SMEs and large companies. More specific break-down and analysis of the sectors that have the highest potential and should be the focus of the i4Q exploitation efforts, will be done during the execution of the project. Additionally, i4Q will also focus on the customer segment consisting of ICT companies that provide software for manufacturing companies and could act as system integrators, aggregating i4Q Solutions into their existing product portfolio. This segment can also be seen as a reseller of i4Q Solutions and provides scalability in the long run.

The main channels that i4Q will use to access customers, both during the project stage and start-up stage, are Digital Innovation Hubs (DIHs) -it is estimated that through i4Q project partners there is access to 150 DIHs in Europe-, Industry platforms and associations (such as vf-OS, L4MS, BOOST 4.0, MIDH 4.0), specialised events and conferences, i4Q community portal and social media channels such as Twitter and LinkedIn. During the project, another channel that is used is the i4Q project website. During the project, the consortium will deploy a dual strategy to build and maintain customer relationships. Namely, an engagement of early adopters is made through the execution of 6 pilots. Furthermore, in order to strengthen the connection with the market actors, additional access to 20 end-users will be gained through a customer discovery process. In addition, during the project and beyond, customer relationships are built and maintained also through face-to-face interaction in industry events and conferences. Beyond the project, some additional customer relationship building and maintenance methods will be added such as customer support, communication through social media, providing training for the customers and personalised pitches and offers.

3.2.1 Manufacturing Data Quality

This part of the project will provide the necessary strategies, methods, and key technologies to ensure data quality, which is influenced by many factors including human error, communication issues or inaccuracies.

Monitoring systems are expected to be reliable enough for decision-making, but sensors are susceptible to provide unreliable information. Trusted networks allow ensuring the reliability, integrity and privacy of the data exchanged. The heterogeneity in technologies leads to a complex ecosystem of data models that is difficult to contextualize, leading to misinterpretations and incomplete data analysis.Setting the guidelines for information models, needed metadata for traceability and interoperability is crucial for ensuring data quality.

Finally, the increasing amount of collected data requires flexible data storage and data analysis infrastructure able to process information without affecting data quality. Distributed systems can help improve the performance of data storage and data processing, opening the door to the use of Distributed Ledger Technologies (DLTs).

The working methodology will be as follows:

- **Manufacturing Data Quality Strategy**: Use case partners will provide the relevant information about relevant data infrastructures and procedures. Relevant factors influencing data quality, such as technical, organizational or programmatic factors, will be identified and modelled (QualiExplore will be used to find those relations among factors). Strategies and procedures, and the available resources to categorize data quality factors will be identified among the due partners. Results obtained will be adjusted based on evaluation, e.g., adding or changing factors, and changing the strategies and procedures. The results of this task will be the Data Quality Guidelines and the QualiExplore for Data Quality Factor Knowledge.
- **Manufacturing Data Trustiness and Traceability**: It is necessary here to analyse and model incoming data, in order to standardize the information models and metadata required. The idea is, at the end, to enhance the level of trust by employing a blockchain based data service. This way, data cannot be changed or erased, and it is proved authentic. Trustable data access with traceability and verifiable provenance will be established. Leverage blockchain to encode data access policies rules into smart contract layer. Gateway API for another platform component to interact with blockchain network will be defined and setup. Setup and configure consortium to bootstrap permissioned blockchain network which will encompass consensus mechanism and define application trust model. Architecture of the network governance models and policies. Prevent leakage of private and sensitive information. As a result, Blockchain Traceability of Data will be granted.
- **Manufacturing Data Trusted Communication and Distribution**: Achieving reliable data collection, which is a basic first step to ensure data quality, requires providing connectivity to industrial data sources through Trusted Networks, capable of evaluating and guaranteeing precision, accuracy, and reliability. Technologies such as TSN (Time Sensitive Networks) for cable communications, and wireless access networks (Industrial WSN, LPWAN, ad-hoc connections, etc.) can enhance the reliability and integrity of data exchanged by integrating with other solutions such as Software Defined Network, Network Function Virtualization, o Network Slicing. These solutions include the

development of software-defined wireless industrial interfaces for data communication, focusing on requirements such as predictability and determinism, high reliability and trustability. Other aspects addressed are achieving low power consumption, that reflects in longer networks lifetimes and therefore less chances to lose relevant data, while reducing the cost of installing the new wired infrastructure in applications that may be fulfilled with wireless networks. Otherwise, Time-sensitive data transmission over deterministic Ethernet networks are the solution proposed for applications that require very low transmission latency and high availability and can utilize the wired network infrastructure present in the floor plant. As a result, Trusted Networks with Wireless & Wired Industrial Interfaces will be settled.

- **Manufacturing Data Security**: Data will be delivered by many different devices and transmitted and processed in different ways. Therefore, some recommendations, guidelines and tools will be proposed following standards such as IEC 62443, in order to enable the Industrial IoT to interact with the platforms created in the project. The data life cycle will be revisited to identify where to address the cybersecurity guidelines. The boundaries between the security and non-security processes will be set. The security handler will be designed based on the requirements, and implemented to distribute the trust in the architecture using x509 certificates and PKI infrastructure using secure hardware. Security and safety policies will be adjusted and audited at different levels to ensure the trustability and privacy of data. The results of this task will be the Cybersecurity Guidelines and the IIoT Security Handler.
- **Manufacturing Data Storage and Use**: A suitable storage system for the collected data will be created. This system or repository will be in charge of receiving, storing and serving the data in a proper way to the other components in the architecture. The most important aspects to consider on the development of this task are its volume, performance and data policies. Volume: the type of repository to be implemented may vary greatly depending on the amount of data to store. Having an accurate estimation can help greatly to determine the kind of structure to use. Performance: receiving and supplying the data to the different components of the architecture can be a costly task. Resources are limited and they should be used as efficiently as possible. Solution: a scalable system, ready to use both local and remote computing resources, following the hybrid cloud paradigm. Data policies: Such as the level of privacy, the type of encryption or the expiration period. The result of this task will be an efficient repository, ready to provide its service to the rest of the components present in the system.

3.2.2 Manufacturing Data Analytics for Manufacturing Quality Assurance

The main objective of data analytics is to turn data into information and actionable insights. Ways to achieve this are to move analysis workloads close to the data sources, thus contributing to the reduction of the Big Data challenge, in addition to helping with security/privacy aspects, while maintaining a low latency response time which may be crucial for example in production facilities, as well as feeding such insights to the end consumer, via smart monitoring and alerting mechanisms or through the integration with digital twins and other simulation models.

The following specific objectives are described as follows:

- To develop services for data integration and fusion, so that higher level services can process it in an efficient way.
- To implement data analytics services for categorisation and classifications of manufacturing data and derive actionable insights.
- To design and deploy a scalable policy-based Model Distribution from cloud to edge.
- To develop modules for AI workload placement and deployment on the edge.
- To develop an efficient monitoring and predictive alerting platform in manufacturing.
- To develop Manufacturing Digital Simulation Models, such as Digital Twins, enabling virtual validation /visualisation and productivity optimisation using pre-existing and real time data from different factory levels.

Data analytics for quality assurance, aims to tackle the analysis of manufacturing data by combining simulation and real data, while employing data fusion techniques to help with the final analysis task. In addition, it will handle AI Model Life-Cycle Management, from a central cloud to an edge-based environment, in order to support the distribution, deployment, and monitoring of AI models. This way, Microservice applications will be able to use manufacturing data processing services, data streams and AI models in an efficient way, scaling up resources in a transparent way. One of the goals, is to design and build a set of management tools for cloud/edge lifecycle of manufacturing related AI models. Currently the manufacturing environment is heterogeneous and dynamic, including nodes with different characteristics.

3.2.3 Rapid Manufacturing Line Qualification and Reconfiguration

The Rapid Manufacturing Line Qualification and Reconfiguration aims at developing new and improved strategies and methods for process qualification as well as process reconfiguration and optimisation using existing manufacturing data and smart algorithms. It builds upon the methods and tools developed in Manufacturing Data Quality and Manufacturing Data Analytics for Manufacturing Quality Assurance, bringing the realisations closer to the final process. To this end, it considers the particularities of the final process, adapting the available algorithms when needed. Furthermore, it considers the format in which the data may be obtained from the system, such as, newly added sensors, readily available legacy data, or virtual sensors. A breakthrough of this work package lies in the use of the Digital Twin with three different objectives:

- Analyse the effect of process parameters on the final product quality.
- Obtain virtual sensors that extend available process data.
- Explore potential upgrade actions on the system.

The Rapid Manufacturing Line Qualification and Reconfiguration addresses the following topics:

- Continuous process qualification to determine that outputs are within limits.
- Diagnosis strategies to detect cause of defect and recommend rapid corrective actions.
- Simulation to guide preventive actions.
- Optimisation to reconfigure the production line.
- Process and data certification based on reliable collected data.

4. Project Results

The **i4Q RIDS** is an IoT-based **Reliable Industrial Data Services** toolset for assuring data quality, traceability and proper use, to achieve manufacturing lines' continuous process qualification, quality diagnosis, reconfiguration and certification. The **i4Q RIDS** consist of 22 i4Q Solutions: 17 software tools and 5 guidelines.

4.1 i4Q Solutions

i4Q Project is an Innovation Action that will contribute to the development and transfer of knowledge and innovation across its stakeholders. As such, it will not perform pure research, but will primarily consist of applied R&D activities directly aimed at enabling business by deploying the i4Q RIDS (Reliable Industrial Data Services) composed by the i4Q Solutions on Manufacturing Data Quality (WP3), Manufacturing Data Analytics for Manufacturing Quality Assurance (WP4), and Rapid Manufacturing Line Qualification and Reconfiguration (WP5).

The i4Q RIDS is a complete package consisting on 22 i4Q Solutions, 17 software tools and 5 guidelines: i4Q^{DQG} Data Quality Guidelines, i4Q^{QE} QualiExplore for Data Quality Factor Knowledge, i4Q^{BC} Blockchain Traceability of Data, i4Q^{TN} Trusted Networks with Wireless & Wired Industrial Interfaces, i4Q^{CSG} Cybersecurity Guidelines, i4Q^{SH} IIoT Security Handler, i4Q^{DRG}Guidelines for building Data Repositories for Industry 4.0, i4Q^{DR} Data Repository, i4Q^{DIT} Data Integration and Transformation Services, i4Q^{DA} Services for Data Analytics, i4Q^{BDA} Big Data Analytics Suite, i4Q^{AD} Analytics Dashboard, i4Q^{AI} AI Models Distribution to the Edge, i4Q^{EW}Edge Workloads Placement and Deployment, i4Q^{IM} Infrastructure Monitoring, i4Q^{DT} Digital Twin simulation services, i4Q^{PQ} Data-driven Continuous Process Qualification, i4Q^{QD} Rapid Quality Diagnosis, i4Q^{PA} Prescriptive Analysis Tools, i4Q^{LRG} Manufacturing Line Reconfiguration Guidelines, i4Q^{LRT} Manufacturing Line Reconfiguration Toolkit, i4Q^{LCP} Manufacturing Line Data Certification Procedure.

With regard to the Technology Readiness Levels (TRL) formulated for the H2020 Work Programme, it is expected that the technology beneficiaries will be able to fine-tune and enhance their own or existing products and services. The activities expected in the call are at TRL 7 but, since the partners are reusing and repurposing at least some solid background, and preferably commercial grade-product, it is felt by the partners they could be in advancement of that. In other words, they will be able to show at least "system prototype demonstration in operational environment" (TRL 7) for the full i4Q RIDS and between TRL 7 and TRL 9 in thei4Q Pilots for each i4Q Solution (**Error! Reference source not found.** and ***Table 2***).

Project Results: i4Q Solutions integrated in the i4Q RIDS	Code	WP	Partners	Current Technologies	Start TRL	Final TRL
i4Q Data Quality Guidelines	**i4Q^{DQG}**	3	BIBA	QualiExplore (NIMBLE)	5	7-8
i4Q QualiExplore for Data Quality Factor Knowledge	**i4Q^{QE}**	3	BIBA	QualiExplore (NIMBLE)	5	7-8
i4Q Blockchain Traceability of Data	**i4Q^{BC}**	3	IBM	Hyperledger Fabric	7	7-8
i4Q Trusted Networks with Wireless & Wired Industrial Interfaces	**i4Q^{TN}**	3	ITI	WSN, SDN, LoRaWAN, TSN, Network Slicing	5	7

Project Results: i4Q Solutions integrated in the i4Q RIDS	Code	WP	Partners	Current Technologies	Start TRL	Final TRL
i4Q Cybersecurity Guidelines	i4Q^{CSG}	3	IKER	Secure Elements, Trusted Zone: PKI, HSM	5	7-8
i4Q IIoT Security Handler	i4Q^{SH}	3	IKER	Secure Elements, Trusted Zone: PKI, HSM	5	7-8
i4Q Guidelines for building Data Repositories for Industry 4.0	i4Q^{DRG}	3	ITI	Cassandra, Elastic Search, Kafka, CockroachDB	5	7-8
i4Q Data Repository	i4Q^{DR}	3	ITI	Hadoop, Hive, HBase, InfluxDB	5	7-8
i4Q Data Integration and Transformation Services	i4Q^{DIT}	4	CERTH	Talend, Pentaho, Dask, Spark	5	7-8
i4Q Services for Data Analytics	i4Q^{DA}	4	UNI	Spring, Spark MLLib, Scikit-learn, Koalas, Knowage	5	7-8-9
i4Q Big Data Analytics Suite	i4Q^{BDA}	4	UNI	Radiatus, Spark, Flink, Storm	5	7-8-9
i4Q Analytics Dashboard	i4Q^{AD}	4	UNI	Grafana, Zeppelin	5	7-8-9
i4Q AI Models Distribution to the Edge	i4Q^{AI}	4	IBM	Cloud - Edge synchronization service	5	7-8
i4Q Edge Workloads Placement and Deployment	i4Q^{EW}	4	IBM	Open-Horizon	5	7-8-9
i4Q Infrastructure Monitoring	i4Q^{IM}	4	CERTH	Prometheus / Nagios	5	7-8
i4Q Digital Twin simulation services	i4Q^{DT}	4	IKER	Functional Mock-up Interface, System Structure and Parameterization: Keras, Statsmodels, TensorFlow, Sklearn	5	7-8
i4Q Data-driven Continuous Process Qualification	i4Q^{PQ}	5	TUB	Data-drive predictive models, data-driven multivariate SPC models: PIA, ProVo	5	7-8
i4Q Rapid Quality Diagnosis	i4Q^{QD}	5	CERTH	OpenCV, PCL, MEMO-HQ	5	7-8
i4Q Prescriptive Analysis Tools	i4Q^{PA}	5	IKER	Simulation tools: pyFMI, LambdaSim, FMI, SSP. Model updating, verification and validation (ASME)	5	7
i4Q Manufacturing Line Reconfiguration Guidelines	i4Q^{LRG}	5	UPV	Jena, Fuseki, Pellet, Milo	5	7-8-9
i4Q Manufacturing Line Reconfiguration Toolkit	i4Q^{LRT}	5	UPV	Jena, Fuseki, Pellet, Milo	5	7-8-9
i4Q Manufacturing Line Data Certification Procedure	i4Q^{LCP}	5	TUB	First concepts for data certificates	5	7-9

Table 1. i4Q Project results start and end TRL

		Machine tool manufacturers		Production companies			
Task	**i4Q Solution**	**P1 FIDIA**	**P2 BIESSE**	**P3 WHIRPOOL**	**P4 FACTOR**	**P5 RIASTONE**	**P6 FARPLAS**
T3.1	i4Q Data Quality Guidelines / QualiExplore	TRL 7	TRL 8	TRL 7	TRL 7	TRL 7	TRL 7
T3.2	i4Q Blockchain Traceability of Data			TRL 8	TRL 8	TRL 7	TRL 7
T3.3	i4Q Trusted Networks with Wireless & Wired Industrial Interfaces	TRL 7	TRL 7		TRL 7	TRL 7	TRL 7
T3.4	i4Q Cybersecurity Guidelines / IIoT Security Handler	TRL 8	TRL 8	TRL 7	TRL 7	TRL 7	TRL 8
T3.5	i4Q Guidelines for Building Data Repositories for Industry 4.0 / i4Q Data Repository	TRL 7	TRL 8	TRL 8	TRL 8	TRL 8	TRL 8
T4.1	i4Q Data Integration and Transformation Services		TRL 8	TRL 8	TRL 7	TRL 8	TRL 7
T4.2	i4Q Services for Data Analytics / i4Q Big Data Analytics Suite /i4Q Analytics Dashboard	TRL 7	TRL 7	TRL 9	TRL 8	TRL 9	TRL 8
T4.3	i4Q AI Models Distribution to the Edge		TRL 7	TRL 8		TRL 8	TRL 8
T4.4	i4Q Edge Workloads Placement and Deployment		TRL 9	TRL 7		TRL 7	TRL 8
T4.5	i4Q Infrastructure Monitoring		TRL 7	TRL 7		TRL 8	TRL 8
T4.6	i4Q Digital Twin	TRL 8	TRL 7	TRL 7	TRL 8	TRL 8	TRL 7
T5.1	i4Q Data-Driven Continuous Process Qualification			TRL 8	TRL 7	TRL 8	
T5.2	i4Q Rapid Quality Diagnosis	TRL 8	TRL 8	TRL 8	TRL 7	TRL 7	
T5.3	i4Q Prescriptive Analysis Tools	TRL 7	TRL 7	TRL 7	TRL 7		TRL 7
T5.4	i4Q Manufacturing Line Reconfiguration Guidelines / i4Q Manufacturing Line Reconfiguration Toolkit	TRL 8	TRL 8		TRL 7		TRL 7
T5.5	i4Q Manufacturing Line Data Certification Procedure			TRL 7	TRL 9	TRL 7	TRL 7

Table 2. i4Q Project results TRL in Pilots

TRL 7: **i4Q** Solution validated in test production
TRL 8: **i4Q** Solution running in test production and expected to be used beyond the project
TRL 9: **i4Q** Solution running in production and guaranteed to be used beyond the project

4.1.1 i4Q QualiExplore for Data Quality Factor Knowledge

Explanation for end-users

- **WHAT:** i4Q QualiExplore is a web-based software tool to identify factors that influence data quality in manufacturing. It contains an editor to add new or modify factors and a conversational interface for fast and intuitive use.
- **WHO:** Employees that need to know how they can improve/maintain data quality + data quality managers.
- **HOW:** Users can access a deployed i4Q QualiExplore via the browser or via conversational interface (e.g. chatbot).
- **WITH:** The solution is standalone but could interface other i4Q Solutions provided they offer useful information about data quality factors (e.g. KPIs).
- **INPUT:** Manual input of data quality characteristics and quality-related factors via editor.
- **OUTPUT**: A tree-structure containing data quality characteristics and related factors (web interface). A text description of factors (conversational interface).

Explanation for technologists

- **WHAT:** i4Q QualiExplore contains a knowledge base and two interfaces to access it (website and chatbot/voicebot).
- **HOW:** The solution comes as a Docker stack with all required components. The chatbot part uses the Open Source framework Rasa.
- **INTERFACES:** Likely, there are no data exchange interfaces. It has a web interface for users (website) and a conversational interface (chatbot/voicebot).
- **DEPENDENCIES:** Various Python libraries.
- **WITH:** Chatbot part realized with Rasa.

4.1.2 i4Q Data Quality Guidelines

Explanation for end-users

- **WHAT:** A document with a guide for planning and performing an information flow analysis to identify the relevant data sources, data storages, communication channels and data users, and model relevant factors that influence data quality, including hardware, human activities, and software.
- **WHO:** Data quality managers.
- **HOW:** A text document.
- **WITH:** Standalone.
- **INPUT:** No data inputs.
- **OUTPUT**: Instructions for data quality management in manufacturing.

Explanation for technologists

- **WHAT:** A document with a guide for planning and performing an information flow analysis to identify the relevant data sources, data storages, communication channels and data users, and model relevant factors that influence data quality, including technical (hardware), organisational (human activities), and programmatic factors (in software).

- **HOW:** No technical solution. The guideline implementation requires that clients assign a data quality manager or similar responsible for data quality.
- **INTERFACES:** No interfaces.
- **DEPENDENCIES:** No dependencies.
- **WITH:** User can use i4Q QualiExplore in combination to address specific aspects of the guideline, e.g., when identifying data quality characteristics, data-related risks, etc.

4.1.3 i4Q Blockchain Traceability of Data

Explanation for end-users

- **WHAT:** This i4Q service provides tools to ensure trust in data and full traceability; enhancing the level of trust by employing a blockchain based data service, improving acceptability by providing security and trust in the data that flows directly to the blockchain, serving as a single point of truth, preserving provenance and supporting non-repudiation. The service provides an audit trail for all inserted data, guaranteeing immutability and finality.
- **WHO:** This component provides services to higher layer services, such as analysis components, that need trust and traceability of data for their smooth operations.
- **HOW:** This is an infrastructure component, providing services to higher layer components. Connectivity shall take place via GRPC interfaces. Installation on a Linux based server in a docker environment.
- **WITH:** This solution provides value to additional i4Q Solutions (such as analysis), by ensuring traceability and a full audit trail of assets and data.
- **INPUT:** Mainly data coming from sensors or other system components.
- **OUTPUT**: Responds to queries on stored data; execution of smart contracts.

Explanation for technologists

- **WHAT:** This component relies on a blockchain based infrastructure, adding required smart contracts and interfaces. The infrastructure provides an immutable append-only log of ordered transactions, where all parties involved agree on transactions order via a distributed consensus algorithm, securing all transactions, preventing their content from being tempered after being added. Respectively, network participants hold their copy of the ledger since no one is trusted, making it nearly impossible for a single individual to forge recorded transactions or decline the agreement. The ledger captures the entire history of transactions, while a world state database reflects the system's updated state for a given point in time. Providing guarantees of the authenticity of data is essential to enhance trust in incoming data and subsequent actions. This component shall be at the infrastructure level, exposing gRPC interfaces for communication with other components.
- **HOW:** This component is a software solution that can be containerised and run over a group of VMs. Smart contracts can be written to govern the system behaviour. Different channels can be established on the same infrastructure to enable interactions between different sets of components. Governance rules and components need to be agreed among the core members of a running network.

- **INTERFACES:** This component exposes gRPC interfaces for other software components to make use of. Main interfaces are for invoking transactions on the blockchain network (for adding data to the blockchain) and for querying data residing within the network.
- **DEPENDENCIES:** Linux, Docker
- **WITH:** Hyperledger Fabric as a possible basis for a permissioned blockchain implementation.

4.1.4 i4Q Trusted Networks with Wireless & Wired Industrial Interfaces

Explanation for end-users

- **WHAT:** software-defined wireless industrial interfaces for data communication and wired deterministic networks for very low transmission latency and high availability requirements.
- **WHO:** IT administrator and network infrastructure manager. These networks and interfaces can be used by different elements (devices, machines, software clients and servers) to exchange information reliably.
- **HOW:** Depending on use case requirements, a wireless or wired network for sensors and actuators can be deployed. The wired option allows achieving better performance in case of hard time requirements, but its deployment is more costly. Hardware includes specific gateways and network interfaces for connected machines, while network optimization software may run on local or cloud servers.
- **WITH:** This solution is intended to connect data sources with other i4Q components.
- **INPUT:** All relevant floor plant data and control traffic.
- **OUTPUT**: Data delivery guarantee.

Explanation for technologists

- **WHAT:** Hybrid wireless-wired networks with high Quality of Service assurance. This solution includes Software defined networks (SDN, slicing) applied to wireless sensors technologies (WSN, LPWAN) with state-of-the-art mechanisms to ensure robustness in these types of noise and interference prone networks. Also, Deterministic Ethernet (e.g., Time Sensitive Networks (TSN) can be used to provide an even further strict time response for applications with hard real time requirements.
- **HOW:** This solution is hardware dependent, requiring specific network interfaces and gateways to relay data. Network optimization can be customized to adapt to different use cases, and scalability can be addressed by adding more gateways and router in case of need. Security can be covered with the encryption of data and channels.
- **INTERFACES:** Depending on protocol and type of network chosen, devices integrate the corresponding interfaces (PCI or embedded network cards, antennas). These network interfaces may contain e.g., IEEE802.15.4, LoRaWAN, IEEE 802.1Qbv among others.
- **DEPENDENCIES:** It may depend on embedded OS such as Contiki OS, Chirpstack OS, and RTOS compliant systems for Deterministic Ethernet drivers.
- **WITH:** OPC UA, MQTT as possible application protocols over the described networks.

4.1.5 i4Q IIoT Security Handler

Explanation for end-users

- **WHAT:** i4Q^{SH} is a cloud service that distributes trust across the different components of the architecture using a hardware secure module as trust anchor point. Once the trust is distributed, the software enables the mechanisms to expose cryptography operations that other components can consume, adjusting security and safety policies at different levels to ensure trustability and privacy of data.
- **WHO:** The devops team to configure the security in the platform components and data software developers to include the IIoT security handler API, managing the whole life cycle, and cryptography operations. Also, system operators to configure the system, maintaining the trustiness of deployed processes and services.
- **HOW:** The solution is a cloud service deployed as a container which needs communication with a hardware secure module.
- **WITH:** The solution can be used stand-alone to offer digital identity management and cryptography services.
- **INPUT:** Digital identity and cryptography requests of other components.
- **OUTPUT**: Digital identity and cryptography operations processed requests.

Explanation for technologists

- **WHAT:** i4Q^{SH} is a docker container running software to manage the life cycle of certificates of different data analysis components and a trustiness endpoint where other data analysis components can delegate cryptography operations that are backed up by a hardware security module (HSM).
- **HOW:** The docker container runs a Certification Authority, Registration Authority and Validation Authority exposing properly the interfaces to manage the life cycle of certificates. The docker container runs a REST API that connects the HSM through a PKCS11 interface leveraging security and safety policies for the clients that use them.
- **INTERFACES:** API SOAP and CMP to manage certificate life cycle. API REST to consume cryptography services through PKCS11 HSM interface.
- **DEPENDENCIES:** Non-functional requirements, such as concurrent sessions, throughput of operations, etc.
- **WITH:** i4Q^{SH} can be used in combination with other i4Q Solutions for assuring the security across the data life cycle management.

4.1.6 i4Q Cybersecurity Guidelines

Explanation for end-users

- **WHAT:** i4Q^{CSG} is a set of recommendations to enable multilayer cyber security features in Industrial Internet of Things (IIoT), enabling IIoT devices to interact with industrial platforms securely in all stages in a manufacturing scenario. i4Q^{CSG} includes an architecture and methodology to provision signed certificates with Hardware Security Module (HSM) and trusted material to devices' Trusted Platform Module (TPM).
- **WHO:** System operators and managers, as well as the developers of other data analysis components.

- **HOW:** Guidelines to provide cybersecurity based on the security standard 62443 and an architectural proposal to distribute the digital identity using security hardware.
- **WITH:** Can be utilized to enforce the security in other i4Q solutions.
- **INPUT:** The input is a light risk analysis of the i4Q solutions.
- **OUTPUT**: A document with guidelines and a reference architecture.

Explanation for technologists i4QLRG

- **WHAT:** i4Q^{CSG} is a document that contains a guideline that follows 62443 standard on how to provide security in a IACS environment and during the product development of an industrial equipment. It also is a set of rules to distribute a digital identity using x509 certificates and how to manage the life cycle of the digital identity using a hardware root of trust (RoT). It also covers the usage of the digital identity as RoT to provide security when communicating different entitites.
- **HOW:** The solution are guidelines to provide cybersecurity based on the security standard 62443 and an architectural proposal to distribute the digital identity using security hardware.
- **INTERFACES**: NA.
- **DEPENDENCIES**: NA.
- **WITH**: NA.

4.1.7 i4Q Data Repository

Explanation for end-users

- **WHAT:** A distributed data repository storage system for supporting a high degree of digitisation in companies with most manufacturing devices acting as sensors or actuators and generating vast amounts of data. i4Q^{DR} is able to absorb large volumes of data coming into the system at high speeds. i4Q^{DR} is elastic to adapt the required computing resources to the existing demand and ready to use additional resources, either local to the factory or from remote systems like public or private clouds.
- **WHO:** System operators or IT administrators. The data in this repository can be consumed by other components to perform data analytics. It may also be offered to data scientists as a dataset for experimentation.
- **HOW:** The repository can be seen as a local database. However, behind the scenes, it may be deployed as a local solution, although ready to scale out to the cloud and act as a hybrid-cloud repository if required by the volume of data. The repository is distributed, with multiple replicable instances. These instances are deployable both on local or remote (private or public cloud) infrastructures.
- **WITH:** The solution is connected to two types of components. First, data origins delivering data. Second, data consumers, requesting these data for analysis or other purposes.
- **INPUT:** Data from the installed sensors and the associated metadata.
- **OUTPUT**: Structured data consumable through DB interfaces.

Explanation for technologists

- **WHAT:** A distributed data repository that can be deployed locally and extend to a public cloud if required, acting as a hybrid cloud solution. This repository is ready to ingest data from the installed sensors, store it in a structured way and provide the required APIs or drivers so the data can be consumed by third parties. It must also include a management interface, either via user (UI) or command line (CLI) interface.

- **HOW:** The repository and its different components can be deployed using container technology. To allow for scalability and elasticity, a container orchestration tool (e.g., K8s, Docker swarm) is used in the local infrastructure. The solution may be heterogeneous in the technology used (e.g., containers, VMs) if required when extending to a public cloud.
- **INTERFACES:** The repository offers the required drivers or APIs that are required to ease the ingestion or reception of data from sensors as well as to ease the consumption of data by third parties. If any sensor or agent requires special APIs or drivers that will be studied.
- **DEPENDENCIES:** The main dependencies are with container technologies (e.g., Docker) and orchestration tools (e.g., Kubernetes or Docker Swarm). Other dependencies may arise depending on the selected DB technology.
- **WITH:** In principle, considering the distributed nature of the repository, technologies like Docker and a container orchestrator can be required. For the data repository itself, technologies like CockroachDB are considered.

4.1.8 i4Q Guidelines for building Data Repositories for Industry 4.0

Explanation for end-users

- **WHAT:** A document with practical guidelines for the deployment and configuration of a data repository on the industries 4.0 context.
- **WHO:** System operators or IT administrators who deploy and use the repository.
- **HOW:** Describe the most relevant processes and steps on the deployment and use of the repository.
- **WITH:** Provided as a document.
- **INPUT:** In order to create the document, the experience from the design and development team will be used, jointly with the feedback collected from the use cases. All the knowledge earned from the process will be put into the document.
- **OUTPUT**: A detailed guidelines document aimed at helping both advanced and basic users.

Explanation for technologists

- **WHAT:** A document with practical guidelines for the deployment and configuration of a data repository on the industries 4.0 context.
- **HOW:** The guidelines describe the most relevant processes and steps on the deployment and use of the repository. Some relevant topics in the document are the configuration of the database instances, the orchestrator, depending on whether it is to deployed from scratch or there is already an orchestrator in place, and describing how to extend to a public cloud.
- **INTERFACES:** NA.
- **DEPENDENCIES:** NA.
- **WITH:** The guidelines are provided as a text document. Other approaches, like a wiki or video tutorial may be considered but are not the main target at the moment.

4.1.9 i4Q Data Integration and Transformation Services

Explanation for end-users

- **WHAT:** i4Q^{DIT} is a software tool, incorporating analytic and decision-making services. This solution performs various processes on manufacturing data, so that they will be ready to be used by higher level services. i4QDIT includes all the elements required for manufacturing data stream management: reading, cleaning, storing, indexing, enriching, searching & retrieving, maintaining, and correspondence of open APIs.
- **WHO:** This solution is considered one of the basic ones and can interact with many other i4Q Solutions that provide or require datasets. Inside a company, this solution could be useful for the following departments: data analysis, engineering, quality control, etc.
- **HOW:** The solution is server-based. It draws data from the data repository (i4Q^{DR}) process and then store it in a database. The large amount of heterogeneous data is also fused and stored as an integrated database.
- **WITH:** This solution is utilised in combination with other i4Q Solutions.
- **INPUT:** The inputs of this solution are sensor and other types of manufacturing data that need to be integrated.
- **OUTPUT**: The output are databases with clean and integrated data that will later be fed to other components for further processing and analysis.

Explanation for technologists

- **WHAT:** i4Q^{DIT} is a distributed, sever-based platform, incorporating analytic and decision-making services. It performs functions required for manufacturing data stream management.
- **HOW:** i4Q^{DIT} draws data from corresponding open APIs. Preparation, processing and fusion of the large amounts of heterogeneous data are conducted on a server. Big data analytic databases are used and parameterized to support the complex high-level services.
- **INTERFACES:** The interface of the solution provides access to databases of aggregated and processed data.
- **DEPENDENCIES:** Libraries of statistical software like R, Python.
- **WITH:** Open software as R/Python libraries, e.g. Pandas, NumPy for data preparation.

4.1.10 i4Q Services for Data Analytics

Explanation for end-users

- **WHAT:** i4Q^{DA} builds a set of specialised analytic functions on top of the data infrastructure with several incremental algorithms (i.e. operating on data streams with fast incremental updates) suitable for analytic processing of high-speed data streams.
- **WHO:** IT Managers, Data Analysts of manufacturing companies of any industrial sector.
- **HOW:** i4Q^{DA} can be deployed on premise or use in Cloud. You can deploy it on premise in a High-Performance Cluster environment.
- **WITH:** The tools can be used standalone. Furthermore, they are interoperable and can be connected to i4Q data services and digital twins as well as third party solutions.
- **INPUT:** Cleaned and modelled data from shop-floor.
- **OUTPUT**: Contextualized and aggregated data.

Explanation for technologists

- **WHAT:** is responsible for the heavy, demanding, intensive tasks, fundamentally working on data already stored. In this layer normally two steps happen: transformation of the data followed by analysis of the data.
- **HOW:** Data Analytics are implemented using the following technologies: (i) Apache Spark, a fast and general-purpose cluster computing engine; it provides high-level APIs in Java, Scala, Python and R, offering a complete framework for Big Data processing and mining; and (ii) Apache Flink Framework and processing engine that works with unbounded (have a start but no defined end) and bounded (have a defined start and end) data streams.
- **INTERFACES**: provided through open API.
- **DEPENDENCIES:** No strict dependencies. It is interoperable with i4Q Digital Twin, i4Q Services for Data Analytics, i4Q Edge Workloads Placement and Deployment.
- **WITH:** Open software such as Python libraries, e.g., Pandas, Tensor Flow for data analytics.

4.1.11 i4Q Big Data Analytics Suite

Explanation for end-users

- **WHAT:** The Big Data Analytics Suite, are a set of technologies grouped together efficiently gather, harmonize, store and apply analytic technics to data generated by sensors and other Cyber Physical Systems mounted on facilities. The objective is to manage raw data, and from it, generate information to improve the supervision of all supply chain and production stages, from the shop floor to the office floor.
- **WHO:** IT Managers, Data analysts of manufacturing companies of any industrial sector.
- **HOW:** i4Q^{BDAS} can be deployed on premise or use in Cloud. You can deploy it on premise in a High-Performance Cluster environment.
- **WITH:** The tools can be used standalone. Furthermore, they are interoperable and can be connected to i4Q data services and digital twins as well as third party solutions.
- **INPUT:** Raw data from shop-floor.
- **OUTPUT**: Contextualized and aggregated data.

Explanation for technologists

- **WHAT:** The Suite is mainly split into four layers, being most of the technologies supported by the Apache Foundation. It can be split in the following logic layers: Data ingestion layer, Data Storage layer, Data Processing layer, and Data Querying/ Analytics/Visualization layer Technologies showed in the general architecture are deployed in Docker containers.
- **HOW:** Docker Swarm tool is used to scale processing/storage capabilities and better benefit from distributed technologies such as Hadoop, Apache Spark, Apache Flink, MongoDB, and others included in the general architecture. Docker Swarm is a clustering and scheduling tool for Docker containers, integrating orchestration capabilities with decentralized design, multi-host networking.
- **INTERFACES:** ORION is used as a Context Broker, part of the FIWARE platform and compliant with FIWARE standards. ORION is responsible for managing the hole context information, such as updates and queries. It supports also triggers, so that when some

conditions are achieved (e.g. some value as been reached, some variable as change) the user receives warnings. Kafka is used as a distributed streaming platform to publish and subscribe (send/receive) streams of data, similar to a message queue or enterprise messaging system. It can store streams of records in a fault-tolerant durable way and process streams of records as they occur.

- **DEPENDENCIES:** No strict dependencies. It is interoperable with i4Q Digital Twin, i4Q Services for Data Analytics, i4Q Edge Workloads Placement and Deployment.
- **WITH:** Open-source tools such as Hadoop, Apache Spark, Apache Flink.

4.1.12 i4Q Analytics Dashboard

Explanation for end-users

- **WHAT:** i4Q^{AD} works together with processing engines, having the key function of creating value from the stored data, by showing useful information. On the other hand, it can contribute for a better overall knowledge of the performance and weaknesses of the entire manufacturing production line, either in for real-time assessment or later analysis.
- **WHO:** Decision makers, Production Managers, IT Managers, Data analysts of manufacturing companies of any industrial sector.
- **HOW:** i4Q^{AD} can be deployed on premise or use in Cloud. You can deploy it on premise in a High-Performance Cluster environment.
- **WITH:** The tools can be used standalone. Furthermore, they are interoperable and can be connected to i4Q data services and digital twins as well as third party solutions.
- **INPUT:** Contextualized and aggregated data.
- **OUTPUT**: Data visualizations and reports.

Explanation for technologists

- **WHAT:** i4Q^{AD} are a set of one or more web-based panels organized and arranged into one or more rows. It provides easy to construct queries, and customize the display properties so that each dashboard is configured for different needs. Each panel can interact with data from any configured Data Source, such as Prometheus, Elasticsearch, InfluxDB, OpenTSDB, MySQL, PostgreSQL, Microsoft SQL Server and AWS Cloudwatch.
- **HOW:** It is supported by Grafana, a big data analytics and visualization platform with integration with other distributed processing technologies like Apache Spark or Flink and allow the build of interactive, data-driven documents using SQL, Scala, R, or Python directly in a web interface. Grafana concept is based on interpreters that allow the framework to query databases and data-processing-backends. Other technologies (Hadoop HDFS, Hbase, Mongodb) are supported by Grafana.
- **INTERFACES**: Via web-browser.
- **DEPENDENCIES:** No strict dependencies. It is interoperable with i4Q Digital Twin, i4Q Services for Data Analytics, i4Q Big Data Analytics Suite, i4Q Edge Workloads Placement and Deployment.
- **WITH**: Open-source software such as Grafana and Apache Superset.

4.1.13 i4Q AI Models Distribution to the Edge

Explanation for end-users

- **WHAT:** This component provides a scalable, easy to use, policy-based distribution mechanism to ease the task of distributing AI/ML models and other metadata to the edge. The component addresses the challenge of providing AI based edge workloads the models they need in order to perform their tasks. Unlike workloads which have well established image distribution mechanisms that are utilized by platforms such as Docker, Kubernetes, OpenStack and others, consistent and efficient distribution of metadata in general and AI models in particular remains a challenge. This component addresses this challenge with particular focus on the unique requirements of various edge computing use cases including industrial and manufacturing use cases.
- **WHO:** This component is used by the system operator and/or the workload developer. It is part of the overall AI/ML model lifecycle management. The operator/developer uses the component to distribute newly developed AI models to a set of edge nodes.
- **HOW:** This component is composed of a management unit which runs in the cloud or some other control hub and an edge unit that runs in each edge node. The cloud unit is responsible for processing users requests for distribution of AI models (and metadata in general) to edge nodes, storing the models and communicating with edge nodes to deliver them the data they need. The edge unit is a small footprint component that is responsible for obtaining the data from the cloud unit and providing it to the appropriate edge workload.
- **WITH:** The model distribution is a stand-alone component. Typically, this component operates hand in hand with the AI Workload Placement and Deployment and Smart Manufacturing Monitoring and Alerting components
- **INPUT:** Input includes the model to be distributed to the edge and the rules/policy that determines to which edge nodes this model needs to be distributed to.
- **OUTPUT**: Information about the delivery status of each model and each edge node. For example, a model can be in a state of pending initial transfer, transfer ongoing, consumed, deleted on edge node, error while deploying, etc

Explanation for technologists

- **WHAT:** This component provides infrastructure for managing AI-based workloads in a hybrid cloud edge manufacturing environment, addressing scalability requirements. A policy-based distribution mechanism is envisioned to ease the distribution task by enabling the specification of rules for eligible targets in a simplified manner. Policy distribution may include, for example, a single target, all targets of a certain Type, all targets with certain characteristics, or all targets. The edge environment presents several challenges for model lifecycle management, such as scale, constrained resources, and disconnected mode. This component shall provide a model distribution component designed for edge computing, targeting manufacturing as primary use cases, integrated with an overall AI model lifecycle management. Support policy-based distribution for simple and flexible definition of where models should be deployed. Integration and coordination with workload distribution to ensure workloads and their AI models meet at the edge.

- **HOW:** This is a software component. It is deployed as a set of containers in the cloud (or a central server) and can run on platforms such as Kubernetes or Docker. The edge component can run either as a container or an embedded middleware. Required authentication / authorization mechanisms via keys and secrets. Exposes a set of RESTful APIs.
- **INTERFACES:** Exposes a set of RESTful APIs for companion components, such as deployment. The edge component also exposes a set of direct APIs allowing it to run in embedded mode.
- **DEPENDENCIES:** The AI model distribution shall be coordinated with the workload distribution mechanism to ensure that the right set of AI models is made available for the workload that uses them.
- **WITH:** The main open-source software considered for this component is the edge-sync-service (https://github.com/open-horizon/edge-sync-service).

4.1.14 i4Q Edge Workloads Placement and Deployment

Explanation for end-users

- **WHAT:** This component allows deploying and running AI workloads on the edge enable efficient analysis. It shall enable workloads to execute efficiently on the edge, including placement and deployment services. The placement service ensures that workloads are deployed on edge nodes that can provide them the resources they need and allow the workload to run in an efficient manner. Target deployment environments may be very heterogeneous and dynamic; thus, deployment needs to take a variety of criteria into consideration.
- **WHO:** This component is used by the system operator and/or the workload developer. It is part of the overall workload lifecycle management. The operator/developer uses the component to deploy workloads on edge nodes. Workload could be applications, or services such as AI/ML based services used to analyse data on the edge and act based on it.
- **HOW:** This component is composed of a management unit which runs in the cloud or some other control hub communicating with edge node services. The cloud unit is responsible for deploying workloads on edge nodes based on a set of consideration such as availability of resources, policies, and cost. The cloud unit runs as a containerized service that can run on a Kubernetes cluster. The edge component is a process running on the edge node. It communicates with the cloud unit and coordinates workload deployments. The OS for both the cloud and edge components is Linux.
- **WITH:** The AI workload placement and deployment is a stand-alone component, typically collaborating with the model distribution and Smart Manufacturing Monitoring and Alerting components.
- **INPUT:** Input includes the characteristics of an AI workload to be deployed at the edge, and potentially monitoring related information from the edge nodes.
- **OUTPUT**: Information about the workloads that have been deployed to the edge including the edge nodes on which the workload has been deployed along with its associated state.

Explanation for technologists

- **WHAT:** Analysis components make use of AI workloads being deployed and run on the edge. This component shall enable workloads to execute efficiently on the edge, including placement and deployment services. Target deployment environments may be very heterogeneous and dynamic; thus, deployment needs to take a variety of criteria into consideration. Re-deployment of the entire workload or the adaptation of the underlying model may be required while the workload is running. Interfaces and capabilities to run different workloads on different devices shall be pursued. A Cloud/edge architecture provides efficient and flexible management of edge workloads.
- **HOW:** This is a software component. It is deployed as a set of containers in the cloud (or a central server) and can run on platforms such as Kubernetes or OpenShift. The edge component runs as an agent on the edge node and would typically run as a stand-alone process. Required authentication / authorization mechanisms via keys and secrets. Exposes a set of RESTful APIs.
- **INTERFACES:** Exposes a set of RESTful APIs for companion components, such as distribution. Provides a CLI interface for local management.
- **DEPENDENCIES:** The AI workload deployment shall be coordinated with the AI model distribution mechanism and the monitoring service.
- **WITH:** The main open-source software considered for this component is the open horizon (https://github.com/open-horizon).

4.1.15 i4Q Infrastructure Monitoring

Explanation for end-users

- **WHAT:** i4Q[IM] assists in monitoring the health of workloads, predict problems and take corrective actions, predict failures and provide alerts. provides an ensemble of monitoring tools for smart manufacturing workload orchestration and predictive failure alerting, including monitoring the health of workloads and productively alerting and taking corrective actions when a predicted problem is detected. i4QIM supports industrial companies to reach autonomous operation in manufacturing environments.
- **WHO:** Infrastructure companies, managers of manufacturing companies of any industrial sector.
- **HOW:** i4Q[IM] monitors the manufacturing processes by combining advanced monitoring methods, with AI-driven prediction of Quality indicators. This solution is a cloud service.
- **WITH:** i4Q[IM] can be utilised in combination with other i4Q Solutions.
- **INPUT**: Input data from various stages of manufacturing processes, e.g. sensor data from sensors attached to machines in order to measure vibration.
- **OUTPUT**: Alerts regarding failures in the manufacturing procedures, predictions about harmful events, indicators about the health of manufacturing workloads.

Explanation for technologists

- **WHAT:** i4Q[IM] is a monitoring and alerting toolkit. This is a reliable solution which allows a fast problem/error diagnosis. It could serve both in machine-centric monitoring, and in monitoring of highly dynamic service-oriented architectures, as well. This solution could run in cloud.

- **HOW:** i4Q^IM is a software solution that can be containerised and managed using platforms like the Cloud Native Computing Foundation or Kubernetes.
- **INTERFACES:** the interface provides visualizations on the health of workloads, monitoring tools with alert and prediction add-ons. The initial planning for the interfaces includes the following:
    - industrial devices
    - humans
    - Manufacturing Workloads
- **DEPENDENCIES:** No strict dependencies.
- **WITH:** Existing solution that could be used as a baseline and parameterized is Prometheus monitoring system (https://prometheus.io/).

4.1.16 i4Q Digital Twin Simulation Services

Explanation for end-users

- **WHAT:** i4Q^DT is a micro-service that allows industrial companies to achieve a connected 3D production simulation, with a digital twin for manufacturing enabling virtual validation/visualisation and productivity optimisation using pre-existing and/or simulated data and data from different factory levels (small cell to entire factory). Thus, the user of i4Q^DT will be able to launch simulations of the manufacturing asset/plant based on production/machine data and the digital twin, and obtain results that are visualized in a 3D environment and other data visualization formats (graphs/tables).
- **WHO:** i4Q^DT can be used in general by the machine owner or manufacturer, a system operator or by another data analysis component.
- **HOW:** i4Q^DT is a cloud service deployed as a container.
- **WITH:** i4Q^DT can be used as stand-alone, but all its functionalities can be deployed when used together with other i4Q Solutions.
- **INPUT:** the input data are dependent on the specific Digital Twin under use, but in general, it can be said that input data can come from different sensors and production or resources information.
- **OUTPUT**: The output is the visualization of the data in different forms (3D visualization, virtual sensors' graphs, time series graphs, tables with KPIs, etc.). When connected with other components, i4Q^DT provides the simulation results in terms of time series, parameters, etc.

Explanation for technologists

- **WHAT:** i4Q^DT is a docker container allowing to create a connected 3D production simulation, with a digital twin for manufacturing enabling virtual validation/visualisation and productivity optimisation using pre-existing and/or simulated data and data from different factory levels (small cell to entire factory). Thus, the user of i4Q^DT will be able to launch simulations of the manufacturing asset/plant based on production/machine data and the digital twin, and obtain results that are visualized in a 3D environment and other data visualization formats (graphs/tables).
- **HOW:** The software solution can be containerised.

- **INTERFACES:** Each Digital Twin developed allows calls to perform simulations that can be managed through REST APIs.
- **DEPENDENCIES:** It may depend on some of the basic solutions (security, data traceability, etc.) it may also depend on the data integration and fusion micro-service and the i4Q Data Repository. It gives inputs to the i4Q Prescriptive Analytics solution.
- **WITH:** The Digital Twin models inside the REST APIs can make use of, for example, Functional Mock-up Units FMU for physics-based models, for data-based models libraries like TensorFlow, Keras, Sklearn. For the 3D visualization of the results, tools such as Godot or Unity can be used. In general, for the visual representation of the results of i4Q^{DT} tools like Shiny, Tkinter, Plotly can be used.

4.1.17 i4Q Data-driven Continuous Process Qualification

Explanation for end-users

- **WHAT:** i4Q^{PQ} is a microservice which monitors all quality influencing process parameters and predicts product quality. According to the parameter settings during manufacturing an algorithm predicts how the quality features of the produced products will develop throughout the process and the quality of final product. Based on the monitored features process performance and capability is predicted.
- **WHO:** Process owners, shop floor workers (Machine operators) and personnel responsible for manufacturing processes.
- **HOW:** The i4Q^{PQ} tool uses different information sources, e.g., real, or simulated machine sensors, as input to predict the flow process output. Based on historical data taken from the manufacturing lines a model is derived. Therefore, a server needs to be installed which accesses all relevant data and calculates the model for prediction. This server additionally hosts the dashboard visualisation tool. Depending on the complexity of the process the needed hardware is recommended to use available cloud computing resources (easy adaption of hardware for specific use cases). The specific hardware resources will be clearer when the needed data and use cases are available.
- **WITH:** The company specific final solution can be implemented as standalone solution in the company's information system and provides interoperability with other i4Q Solutions, e.g. i4Q Digital Twin of manufacturing lines.
- **INPUT:** Real and simulated sensors' data.
- **OUTPUT**: The output is visualized on a dashboard solution containing information about the actual state of the process in form of data and diagrams.

Explanation for technologists

- **WHAT:** The i4Q^{PQ} software uses an applicable framework for calculating statistical models for prediction purposes. ABBs: 1. Data acquisition unit (APIs, data bases, data pipelines) 2. Data pre-processing unit, 3. Model building unit, 4. Dashboard.
- **HOW:** To be determined when basic Technologies from Pilot- and Development-Side are defined.
- **INTERFACES:** Existing APIs, data bases, data pipelines, Dashboard with UI.
- **DEPENDENCIES:** To be determined when basic Technologies from Pilot- and Development-Side are defined.

- **WITH:** All software components are open source. Data acquisition: SQL, Programming languages: R, Python, HTML, Potential frameworks for models: Keras, Tensorflow, Scikit, Potential dashboard solution: Shiny, Python, Plotly.

4.1.18 i4Q Rapid Quality Diagnosis

Explanation for end-users

- **WHAT:** i4Q^{QD} solution is a micro-service that provides smart alerting and quality diagnosis. It aims to evaluate the process' quality during manufacturing. It is a micro-service for providing rapid diagnosis of manufacturing line on the possible cause of failures, evaluating data fidelity, product-quality and process condition, and providing action recommendations for sensor/data processing recalibrations, process line/machine reconfiguration or maintenance actions.
- **WHO:** i4Q^{QD} can be used by the machine/system operator, manager owner or the manufacturer.
- **HOW:** i4Q^{QD} is a software solution, which handles real-time data and allows operations during the manufacturing process. It detects failures in the quality of the products during manufacturing and send notifications/alerts to the system operator. It also include 2D and 3D feature toolkits in order to be user-friendly to the end-users and to allow fast and efficient handling.
- **WITH:** i4Q^{QD} can be utilised in combination with other i4Q Solutions, such as i4Q^{IM}.
- **INPUT:** The input data is real-time sensor's data, stored in a library.
- **OUTPUT**: The output is the data visualization in different forms (2D, 3D visualization, virtual sensors' graphs, timeseries graphs).

Explanation for technologists

- **WHAT:** i4Q^{QD} is a micro-service for providing rapid diagnosis of failures in manufacturing line, evaluate data fidelity, product quality and process condition and provides actions recommendations for various actions.
- **HOW:** The software solution can be containerised.
- **INTERFACES:** The interface helps the user to monitor the manufacturing line, track the process condition and receive recommendations regarding sensor recalibrations and maintenance actions.
- **DEPENDENCIES:** i4Q^{QD} uses algorithm's programming in C++, Python, Java, and/or MATLAB/OCTAVE. It is possible to run on both desktop (Windows, Linux, Android, MacOS, FreeBSD, OpenBSD) and mobile devices (Android, Maemo, iOS). This solution can run in cloud service.
- **WITH:** i4Q^{QD} could use cameras for data collection, such as the OpenNI, Velodyne High-Definition LiDAR (HDL) system, HDL-64e, HDL-32e, Dinast Cameras, IDS-Imaging Ensenso cameras, DepthSense cameras (e.g., Creative Senz3D, DepthSense DS325), and/or davidSDK scanners.

4.1.19 i4Q Prescriptive Analysis Tools

Explanation for end-users

- **WHAT:** i4Q^{PA} is a micro-service consuming simulation models, taking as input the manufacturing resources, current production planning and process condition, and proposing process configuration parameters, based on different possible scenarios, ensuring that non-simulation experts may also exploit the prescriptive analyses.
- **WHO:** i4Q^{PA} can be used in general by the machine owner or manufacturer or by a system operator.
- **HOW:** i4Q^{DT}is a cloud service deployed as a container.
- **WITH:** i4Q^{PA} requires i4Q^{DT}.
- **INPUT:** Besides the model to be simulated i4Q^{PA} receives as input different sensors and production or resources information, depending on the specific Digital Model under use. Moreover, the definition of the scenarios requires the introduction of process/machine parameters or range parameters.
- **OUTPUT**: The output is a prescriptive analysis based on the different simulation options tested.

Explanation for technologists

- **WHAT:** i4Q^{PA} is a micro-service consisting of simulation models as a service, taking as input the manufacturing resources, current production planning and process condition, it makes use of the i4Q^{DT} in order to test different possibilities and proposing process configuration parameters. First a set of possible scenarios needs to be defined, they can then be simulated through the Digital Twin and the results evaluated and compared in order to provide a prescriptive analysis.
- **HOW:** The software solution can be containerized.
- **INTERFACES:** i4Q^{PA} allows to define different simulations to be performed (the scenarios) and its performance tested.
- **DEPENDENCIES:** i4Q^{PA} depends on i4Q^{DT}, as it supplies the simulation models. It may depend on some of the basic solutions (security, data traceability…), it may also depend on the data integration and fusion micro-service, as well as the Data Repository. It may also give inputs to the i4Q Line Reconfiguration Toolkit.
- **WITH:** For Digital Twins of the FMU type, the use of the pyFMI package will be evaluated. In general, the communication with the Digital Twins can be managed through REST APIs provided by the i4Q^{DT} solution. This analysis can be visualized using a GUI generated using tools such as Shiny, Tkinter, Plotly.

4.1.20 i4Q Manufacturing Line Reconfiguration Toolkit

Explanation for end-users

- **WHAT:** The Manufacturing Line Reconfiguration Toolkit (i4Q^{LRT}) is a set of tools for optimising manufacturing processes. These tools can be easily used to deal with known optimisation use cases in the manufacturing line reconfiguration problem domain. Fine tune the configuration parameters of machines along the line to improve quality standards, or improve the manufacturing line set-up time are some examples of the problems that the i4Q^{LRT} solves for manufacturing companies.
- **WHO:** Production Managers of manufacturing companies of any industrial sector.

- **HOW:** i4Q^{LRT} can be deployed on premise or use in Cloud. You can deploy it on premise easily in any corporate server (Linux or Windows) using the provided installer.
- **WITH:** The tools can be used standalone. Furthermore, they are interoperable and can be connected to i4Q data services and digital twins as well as third party solutions.
- **INPUT:** Operational (sensor) data and production needs.
- **OUTPUT**: Operational data (configuration parameters and actuation commands) and optimised production schedules.

Explanation for technologists

- **WHAT:** The AI services in the i4Q^{LRT} are primarily optimisation algorithms developed in Python and deployed as services using a containerised (Docker) wrapper that exposes its main functions (metadata description and input/output configuration) as REST interfaces and provides access to data services (messaging, storage). It delivers optimisation features ready to be used in business processes, data pipelines, or applications. In this sense, the main Architecture Building Blocks (ABBs) identified are the set of algorithms implemented in Python and the REST wrapper that facilitates the deployment and integration into data pipelines and workflows. The wrapper should implement clients' libraries to connect to the i4Q data services and digital twin APIs, and should be deployable in the edge and managed as an AI workload.
- **HOW:** AI services are software solutions that are containerised and deployed using Docker and Kubernetes. They do not have any strict hardware requirements although may benefit from GPU acceleration. They come in two flavours, pre-trained models ready to use in specific sectors and abstract models ready to be customised for a specific use case. Security, governance, and manageability are delegated to external services through integrations using standard technologies (e.g., OAuth, certificates, RBAC).
- **INTERFACES:** Software interfaces to integrate into data pipelines (e.g., messaging, REST APIs, gRPC).
- **DEPENDENCIES:** No strict dependencies. It is interoperable with i4Q Digital Twin, i4Q Services for Data Analytics, i4Q Big Data Analytics Suite, i4Q Edge Workloads Placement and Deployment.
- **WITH:** ZDMP PO Runtime, ZDMP AI and Analytics runtime, ZDMP PO Layers, C2NET Optimisation Algorithms.

4.1.21 i4Q Manufacturing Line Reconfiguration Guidelines

Explanation for end-users

- **WHAT:** **i4Q**^{LRG} is a multi-media user guide to adapt the optimisation reasoning rules according to the achieved results for machine parameters calibration, line setup and line reconfiguration. Its objective is to speed up the reconfiguration processes of the production lines.
- **WHO:** Production Managers of manufacturing companies of any industrial sector.
- **HOW:** This multi-media user guide takes different information from the manufacturing line. Based on historical data taken from the manufacturing lines a model is derived. Because of this model **i4Q**^{LRG} provide optimization reasoning rules to measure the machine

parameters and line configuration. Thanks to these guidelines we increased productivity and reduce the efforts for manufacturing line reconfiguration through AI.

- **WITH:** i4Q[LRG] can be deployed on premise server or use in Cloud.
- **INPUT:** A search element, such as the name of the algorithm.
- **OUTPUT**: Operational data and optimised production schedules.

Explanation for technologists

- **WHAT:** This multi-media user guide can be used through a website. You will collect different forms and provide a guideline.
- **HOW:** The guideline implementation requires that clients assign a data quality manager or similar responsible for data quality.
- **INTERFACES:** An interactive website where information can be consulted and viewable as PDFs, as a single page HTML or eReaders
- **DEPENDENCIES:** It is interoperable with i4Q Manufacturing Line Reconfiguration Toolkit
- **WITH**: NA.

4.1.22 i4Q Manufacturing Line Data Certification Procedure

Explanation for end-users

- **WHAT:** Guideline for certification and audit procedure + digital assistant. The procedure describes the logical sequence of the activities to be performed, elements of the manufacturing resources to be audited (sensors, controls, software, etc.), calibration devices to be used and tests to be performed as well as the frequency with which the procedure is to be performed. This procedure also serves as a basis to complement existing quality certifications (i.e. ISO 9000) introducing as a new factor to consider: the quality of the data generated during manufacturing processes. The procedure addresses: definition and vocabulary, frame and application areas, prerequisites, planning, implementation, controlling, improvement and documentation of data driven qualification, reconfiguration, and quality control. It can be used as a basis for future standardisation in European Committee for Standardization or National Standardisation. This digital assistant (chatbot or voicebot) for audits and certification provides audit procedure information to users and allows them to monitor the audit progress.
- **WHO:** Internal or external auditors.
- **HOW:** A clear and strict workflow is described. The guideline is a document containing a step-by-step procedure. The procedure describes the logical sequence of the activities to be performed, elements of the manufacturing resources to be audited (sensors, controls, software, etc.), calibration devices to be used and tests to be performed as well as the frequency with which the procedure is to be performed. The procedure addresses: definition and vocabulary, frame and application areas, prerequisites, planning, implementation, controlling, improvement and documentation of data driven qualification, reconfiguration, and quality control. Users access the assistant via mobile device app or browser. The write or talk to the assistant about the audit procedure in natural language.

- **WITH:** Stand-alone but the document is based on the final state when all i4Q Solutions are implemented. The assistant is a stand-alone software that uses the guideline's content and workflows in its dialogs.
- **INPUT:** NA.
- **OUTPUT**: NA.

Explanation for technologists

- **WHAT:** Guideline document + digital assistant.
- **HOW:** To be determined when Basic Technologies from Pilot- and Development-Side are defined. The assistant is an AI that responds to user utterances according to rules and trained example conversations.
- **INTERFACES:** To be determined when basic Technologies from Pilot- and Development-Side are defined. The assistant may interact with other i4Q Solutions via REST APIs or a message broker.
- **DEPENDENCIES:** To be determined when basic Technologies from Pilot- and Development-Side are defined.
- **WITH:** To be determined when basic Technologies from Pilot- and Development-Side are defined. The digital assistant uses the open-source assistant framework Rasa.

4.2 i4Q Standards

Standardisation is an important and helpful tool to make project results known outside the project and to strengthen the dissemination and application of the developed solutions in the industry. Furthermore, standardisation is a widely accepted tool for lowering trade barriers due to an agreement on field-specific terminologies, methodologies, construction methods and a wide range of other criteria. For these reasons, it is essential that applicable standards are taken into account in the development of i4Q Solutions and that identified gaps are ideally closed, based on the project results. This is exactly what Task 7.6 Standardisation will address. The goals of this task are to connect to standardisation forums and to monitor the project to ensure compliance of the project results with existing standards.

In the first step, a standards research is carried out to identify all existing standards and ongoing developments of standards at national, European and international level and the associated committees which are relevant for i4Q Project. The identified standards and committees are then evaluated by the members of the consortium. The evaluated results will be distributed within the consortium to be taken into account in the implementation of the project activities.

In addition, the project will also actively contribute to standardisation by e.g., participating at ISO and CEN working groups, as far as appropriate, and possibly prepare to undertake input to the standardisation process. To this purpose, in the second step up to M18, project-specific standardisation needs which go beyond existing standards will be collected and assessed through a workshop and discussions with the project partners. For example, in T5.5, an audit procedure is to be developed in the context of ISO 9000 and ISO 19011, which can possibly be the basis for a new standard or supplement the existing standards. It is planned that the audit procedure serves as a foundation for the start of a standardisation process.

Once suitable project results are identified, the necessary activities will be initiated to contribute with these results to standardisation. This can be for example the application for and implementation of a CEN workshop for the preparation of a CEN Workshop Agreement (CWA) or active engagement in the European standardisation process, in specific in CEN and CENELEC.

In order to achieve these goals, it is necessary that all i4Q partners from WP3 to WP7 support this task, regardless of if they have person months on the specific task.

5. Milestones and Deliverables

All work packages have clear milestones and all tasks have deliverables, which are the official outputs of the project. A number of high-level milestones have been adopted ensuring that each major cycle of the project is completed on time.

The list of the project's milestones (MS) is presented in the ***Table 3***.

Milestone number	Milestone title	WP number	Lead beneficiary	Due date (in months)	Means of verification
MS1	Project planning and management structure set-up.	WP9	1-CERTH	1	This milestone defines the project planning, the project management structure set-up, and provides the Project monitoring, control, quality and communication Handbook.
MS2	Project Vision Consensus established.	WP1	1-CERTH	3	The Project Vision Guide document will be signed by all partners of the project.
MS3	Project Dissemination Strategy implemented.	WP7	16-INTEROP-VLAB	3	Here, the Project Dissemination Strategy will be defined, the i4Q website will be set up and running, and the initial release of the public part of the dissemination materials will be available
MS4	Requirements identified and assessed.	WP1	1-CERTH	6	A list of requirements with average assessment from all partners valorisation will be published in the i4Q Project website.
MS5	Architectural and methodological foundations for	WP2	9-UPV	9	Here a detailed specification of the i4Q technical

Milestone number	Milestone title	WP number	Lead beneficiary	Due date (in months)	Means of verification
	the framework delivered.				architecture will be released, together with the Framework of the Project. A definition of the digital models and ontologies for industrial components will be addressed.
MS6	Freedom to operate of the KERs confirmed.	WP8	15-FBA	12	In this milestone an analysis report that confirms the FTO will be provided.
MS7	Exploitation strategy plan developed.	WP8	15-FBA	12	Exploitation strategy
MS8	Periodic progress reports and cost statements released for year 1.	WP9	1-CERTH	12	In this milestone the periodic progress reports including the Financial Statements are submitted and approved by EC for the first year of the project.
MS9	Standardisation needs identified.	WP7	17-DIN	18	Minutes of standardisation workshop and list of proposed standardisation needs.
MS10	i4Q Solutions 1st Release.	WP3, WP4, WP5	4-ITI	18	Software R1 will be ready for installation/use by Pilots.
MS11	i4Q Solutions 2nd Release.	WP3, WP4, WP5	4-ITI	24	Software R2 will be ready for installation/use by Pilots.
MS12	i4Q Solutions addressed to each Pilots tested	WP6	6-EXOS	24	Video report of the i4Q Solutions is

Milestone number	Milestone title	WP number	Lead beneficiary	Due date (in months)	Means of verification
	in factory equipment.				being tested in factory equipment.
MS13	Periodic progress reports and cost statements released for year 2.	WP9	1-CERTH	24	Periodic Progress Reports including Financial Statements submitted and approved by EC for year 2.
MS14	i4Q Solutions Intermediate Releases.	WP3, WP4, WP5	4-ITI	27	Software intermediate releases will be ready for installation/use by Pilots.
MS15	i4Q Solutions Intermediate Releases v2.	WP3, WP4, WP5	11-UNINOVA	30	Software intermediate releases ready for installation/use by Pilots.
MS16	i4Q Solutions Intermediate Releases v3.	WP3, WP4, WP5	7-IKERLAN	33	Software intermediate releases ready for installation/use by Pilots.
MS17	i4Q Solutions addressed to each Pilots running in production.	WP6	6-EXOS	36	This milestone includes video report of the i4Q Solutions running in real production.
MS18	Creation of i4Q start-up.	WP8	15-FBA	36	i4Q start-up creation statutes.
MS19	i4Q Solutions final Releases.	WP3, WP4, WP5	4-ITI	36	Software final releases will be ready for installation/use by Pilots.
MS20	Periodic progress reports and cost statements	WP9	1-CERTH	36	Periodic progress reports including financial statements

Milestone number	Milestone title	WP number	Lead beneficiary	Due date (in months)	Means of verification
	released for year 3.				submitted and approved by EC for year 3.
MS21	i4Q Solutions addressed to each Pilots validated in test production.	WP6	6-EXOS	30	Video report of the i4Q Solutions being used in test production will be available.

Table 3. List of milestones.

The project's deliverables (D) are listed in the table below (***Table 4***).

Deliverable Number	Deliverable Title	WP	Lead Beneficiary	Due Date	
D1.1	Project Vision Guide Document	WP1	CERTH	3	Mar-21
D2.1	i4Q Reference Architecture and Viewpoints Analysis	WP2	ENG	3	Mar-21
D2.2	Digital Models and Ontologies	WP2	EXOS	3	Mar-21
D9.1	Project Handbook	WP9	CERTH	3	Mar-21
D1.2	Benchmarking of Digital Technologies with potential to i4Q	WP1	CERTH	4	Apr-21
D1.3	Demonstration Scenarios and Monitoring KPIs Definition	WP1	UPV	4	Apr-21
D1.4	Requirements Analysis and Functional Specification	WP1	TUB	4	Apr-21
D1.5	Data Management Plan	WP1	ITI	6	Jun-21
D8.1	Report on KERs and Business Model Canvas	WP8	FBA	6	Jun-21
D9.8	Short Interim Management Report v1	WP9	CERTH	6	Jun-21
D2.3	Report on Business Viewpoint	WP2	ENG	7	Jul-21
D10.1	H - Requirement No. 1	WP10	CERTH	8	Aug-21
D1.8	Demonstration Scenarios and Monitoring KPIs Definition v2	WP1	UPV	9	Sep-21
D1.9	Requirements Analysis and Functional Specification v2	WP1	TUB	9	Sep-21
D2.4	Report on Usage Viewpoint	WP2	ITI	9	Sep-21

Deliverable Number	Deliverable Title	WP	Lead Beneficiary	Due Date	
D2.5	Functional Specifications	WP2	UPV	9	Sep-21
D2.6	Technical Specifications	WP2	EXOS	9	Sep-21
D2.7	i4Q Reference Architecture and Viewpoints Analysis v2	WP2	ENG	9	Sep-21
D1.6	Regulation and Trustworthy System	WP1	TUB	12	Dec-21
D1.7	Data Management Report	WP1	ITI	12	Dec-21
D7.3	Industrial Advisory Board and Workshops Feedback Report	WP7	IKERLAN	12	Dec-21
D7.4	Standardisation Plan and Status Report	WP7	DIN	12	Dec-21
D7.5	Target-Driven Dissemination Strategy, Plan, and Reporting v1	WP7	IVLAB	12	Dec-21
D7.6	Website and Materials Production v1	WP7	IVLAB	12	Dec-21
D8.2	Plan for Exploitation and Dissemination of Results - PEDR	WP8	KBZ	12	Dec-21
D8.3	FTO Analysis Report	WP8	IVLAB	12	Dec-21
D9.9	Short Interim Management Report v2	WP9	CERTH	12	Dec-21
D2.1	i4Q Reference Architecture and Viewpoints Analysis	WP2	ENG	3	Mar-21
D2.2	Digital Models and Ontologies	WP2	EXOS	3	Mar-21
D9.1	Project Handbook	WP9	CERTH	3	Mar-21
D3.1	i4Q Data Quality Guidelines	WP3	BIBA	18	Jun-22
D3.2	i4Q QualiExplore for Data Quality Factor Knowledge	WP3	BIBA	18	Jun-22
D3.3	i4Q Blockchain Traceability of Data	WP3	IBM	18	Jun-22
D3.4	i4Q Trusted Networks with Wireless & Wired Industrial Interfaces	WP3	ITI	18	Jun-22
D3.5	i4Q Cybersecurity Guidelines	WP3	IKERLAN	18	Jun-22
D3.6	i4Q IIoT Security Handler	WP3	IKERLAN	18	Jun-22
D3.7	i4Q Guidelines for Building Data Repositories for Industry 4.0	WP3	ITI	18	Jun-22
D3.8	i4Q Data Repository	WP3	ITI	18	Jun-22

Deliverable Number	Deliverable Title	WP	Lead Beneficiary	Due Date	
D4.1	i4Q Data Integration and Transformation Services	WP4	CERTH	18	Jun-22
D4.2	i4Q Services for Data Analytics	WP4	UNINOVA	18	Jun-22
D4.3	i4Q Big Data Analytics Suite	WP4	UNINOVA	18	Jun-22
D4.4	i4Q Analytics Dashboard	WP4	UNINOVA	18	Jun-22
D4.5	i4Q AI Models Distribution to the Edge	WP4	IBM	18	Jun-22
D4.6	i4Q Edge Workloads Placement and Deployment	WP4	IBM	18	Jun-22
D4.7	i4Q Infrastructure Monitoring	WP4	CERTH	18	Jun-22
D4.8	i4Q Digital Twin	WP4	IKERLAN	18	Jun-22
D5.1	i4Q Data-Driven Continuous Process Qualification	WP5	TUB	18	Jun-22
D5.2	i4Q Rapid Quality Diagnosis	WP5	CERTH	18	Jun-22
D5.3	i4Q Prescriptive Analysis Tools	WP5	IKERLAN	18	Jun-22
D5.4	i4Q Manufacturing Line Reconfiguration Guidelines	WP5	UPV	18	Jun-22
D5.5	i4Q Manufacturing Line Reconfiguration Toolkit	WP5	UPV	18	Jun-22
D5.6	i4Q Manufacturing Line Data Certification Procedure	WP5	TUB	18	Jun-22
D6.1	Pilot 1: Fidia - Smart Quality in CNC Machining	WP6	FIDIA	18	Jun-22
D6.2	Pilot 2: Biesse - Diagnostics and IoT Services	WP6	BIESSE	18	Jun-22
D6.3	Pilot 3: Whirlpool - White Goods Product Quality	WP6	WHI	18	Jun-22
D6.4	Pilot 4: Factor - Aeronautics and Aerospace Metal Parts Quality	WP6	FACTOR	18	Jun-22
D6.5	Pilot 5: RiaStone - Advanced In-line Inspection for incoming Prime Matter Quality Control	WP6	RIAS	18	Jun-22
D6.6	Pilot 6: Farplas - Automatic Advanced Inspection of Automotive Plastic Parts	WP6	FARPLAS	18	Jun-22
D7.1	Impact Activities	WP7	KBZ	18	Jun-22
D7.2	Clustering and Regional Interactions	WP7	FBA	18	Jun-22

Deliverable Number	Deliverable Title	WP	Lead Beneficiary	Due Date	
D9.2	Strategic and Operational Coordination	WP9	CERTH	18	Jun-22
D9.3	Technical WP Reports	WP9	UPV	18	Jun-22
D9.4	Ops Setup and Quality Control Report	WP9	UPV	18	Jun-22
D3.9	i4Q Data Quality Guidelines v2	WP3	BIBA	24	Dec-22
D3.10	i4Q QualiExplore for Data Quality Factor Knowledge v2	WP3	BIBA	24	Dec-22
D3.11	i4Q Blockchain Traceability of Data v2	WP3	IBM	24	Dec-22
D3.12	i4Q Trusted Networks with Wireless & Wired Industrial Interfaces v2	WP3	ITI	24	Dec-22
D3.13	i4Q Cybersecurity Guidelines v2	WP3	IKERLAN	24	Dec-22
D3.14	i4Q IIoT Security Handler v2	WP3	IKERLAN	24	Dec-22
D3.15	i4Q Guidelines for Building Data Repositories for Industry 4.0 v2	WP3	ITI	24	Dec-22
D3.16	i4Q Data Repository v2	WP3	ITI	24	Dec-22
D4.9	i4Q Data Integration and Transformation Services v2	WP4	CERTH	24	Dec-22
D4.10	i4Q Services for Data Analytics v2	WP4	UNINOVA	24	Dec-22
D4.11	i4Q Big Data Analytics Suite v2	WP4	UNINOVA	24	Dec-22
D4.12	i4Q Analytics Dashboard v2	WP4	UNINOVA	24	Dec-22
D4.13	i4Q AI Models Distribution to the Edge v2	WP4	IBM	24	Dec-22
D4.14	i4Q Edge Workloads Placement and Deployment v2	WP4	IBM	24	Dec-22
D4.15	i4Q Infrastructure Monitoring v2	WP4	CERTH	24	Dec-22
D4.16	i4Q Digital Twin v2	WP4	IKERLAN	24	Dec-22
D5.7	i4Q Data-Driven Continuous Process Qualification v2	WP5	TUB	24	Dec-22
D5.8	i4Q Rapid Quality Diagnosis v2	WP5	CERTH	24	Dec-22
D5.9	i4Q Prescriptive Analysis Tools v2	WP5	IKERLAN	24	Dec-22
D5.10	i4Q Manufacturing Line Reconfiguration Guidelines v2	WP5	UPV	24	Dec-22

Deliverable Number	Deliverable Title	WP	Lead Beneficiary	Due Date	
D5.11	i4Q Manufacturing Line Reconfiguration Toolkit v2	WP5	UPV	24	Dec-22
D5.12	i4Q Manufacturing Line Data Certification Procedure v2	WP5	TUB	24	Dec-22
D6.7	i4Q Solutions Demonstrator	WP6	EXOS	24	Dec-22
D6.9	Continuous Integration and Validation	WP6	ITI	24	Dec-22
D8.9	FTO Analysis Report v2	WP8	IVLAB	24	Dec-22
D9.10	Short Interim Management Report v3	WP9	CERTH	24	Dec-22
D6.17	Continuous Integration and Validation v2	WP6	ITI	30	Jun-23
D8.4	Report of the Customer Discovery Process	WP8	FBA	30	Jun-23
D8.5	Sustainability Analysis report	WP8	KBZ	30	Jun-23
D8.6	Go-to-market Plan	WP8	FBA	30	Jun-23
D8.7	IPR protection Strategy Report	WP8	LIF	30	Jun-23
D8.8	Investors Involvement Report	WP8	FBA	30	Jun-23
D9.11	Short Interim Management Report v4	WP9	CERTH	30	Jun-23
D1.10	Regulation and Trustworthy System v2	WP1	TUB	36	Dec-23
D1.11	Data Management Report v2	WP1	ITI	36	Dec-23
D6.8	i4Q Solutions Handbook	WP6	ITI	36	Dec-23
D6.10	i4Q Solutions Demonstrator v3	WP6	EXOS	36	Dec-23
D6.11	Pilot 1: Fidia - Smart Quality in CNC Machining v2	WP6	FIDIA	36	Dec-23
D6.12	Pilot 2: Biesse - Diagnostics and IoT Services v2	WP6	BIESSE	36	Dec-23
D6.13	Pilot 3: Whirlpool - White Goods Product Quality v2	WP6	WHI	36	Dec-23
D6.14	Pilot 4: Factor - Aeronautics and Aerospace Metal Parts Quality v2	WP6	FACTOR	36	Dec-23
D6.15	Pilot 5: RiaStone - Advanced In-line Inspection for incoming Prime Matter Quality Control v2	WP6	RIAS	36	Dec-23

Deliverable Number	Deliverable Title	WP	Lead Beneficiary	Due Date	
D6.16	Pilot 6: Farplas - Automatic Advanced Inspection of Automotive Plastic Parts v2	WP6	FARPLAS	36	Dec-23
D6.18	Continuous Integration and Validation v3	WP6	ITI	36	Dec-23
D7.7	Impact Activities v2	WP7	KBZ	36	Dec-23
D7.8	Clustering and Regional Interactions v2	WP7	FBA	36	Dec-23
D7.9	Industrial Advisory Board and Workshops Feedback Report v2	WP7	IKERLAN	36	Dec-23
D7.10	Standardisation Plan and Status Report v2	WP7	DIN	36	Dec-23
D7.11	Target-Driven Dissemination Strategy, Plan, and Reporting v4	WP7	IVLAB	36	Dec-23
D7.12	Website and Materials Production v4	WP7	IVLAB	36	Dec-23
D8.10	Report of the Customer Discovery Process v2	WP8	FBA	36	Dec-23
D8.11	Sustainability Analysis report v2	WP8	KBZ	36	Dec-23
D8.12	Go-to-market Plan v2	WP8	FBA	36	Dec-23
D8.13	IPR protection Strategy Report v2	WP8	LIF	36	Dec-23
D8.14	Investors Involvement Report v2	WP8	FBA	36	Dec-23
D8.15	Plan for Exploitation and Dissemination of Results - PEDR v3	WP8	KBZ	36	Dec-23
D9.5	Strategic and Operational Coordination v2	WP9	CERTH	36	Dec-23
D9.6	Technical WP Reports v2	WP9	UPV	36	Dec-23
D9.7	Ops Setup and Quality Control Report v2	WP9	UPV	36	Dec-23

Table 4. List of deliverables' details.

6. Risks

The critical implementation risks and mitigation actions of the project are presented below:

1. Failures to meet milestones (Medium) [WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9]. The project management methodology used for i4Q includes high visibility of progress, early identification of problems and risks, and allow for quick response to changes or deviations that may affect the plan of the project. The Technical Manager ™ is a key figure in the process of collaboration with the Work Package Leader (WPL) in the early detection and resolution of problems.
2. Lack of coordination or poor communication (Low) [WP9]. The Project Coordinator (PC) has adequate know-how and extensive experience in managing projects and all participants have already participated in several projects. The general organisational, management structure and procedures include several management bodies and roles whose coordinated work is meant to ensure a smooth execution of the project. The risk of poor communication will be managed through frequent meetings and fluent communication in order to promote the collaboration and organisation among partners.
3. Under/over estimation of effort (High) [WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9]. This risk will be handled by monitoring the planned versus the actual effort required by each task. Indicators and statistics will be included in the Periodic Project Reports.
4. Deliverable failure due to missed deadline or poor deliverable quality (Medium) [WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9]. Quality management and assurance procedures will be implemented. An internal peer review procedure will ensure that each deliverable is systematically validated by at least another partner. WPL will overview their related tasks and deliverables. The TM will make a final check of the deliverables for consistency and readability. Where necessary, the WPL, the TM and the PC can request further work from partners on a deliverable, to ensure that it complies with the project's contractual requirements. Moreover, the Quality Control Manager (QCM) will be in charge of monitoring the overall quality management of the project results, including the deliverables and KPIs.
5. Lack of required know-how (Low) [WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9]. Partners have been carefully identified so as to fulfil the required demands for skills and expertise, based on capabilities that have been clearly demonstrated during successful development of several projects of similar scale and complexity in the past.
6. Loss of Beneficiary (Low) [WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9]. In case expertise for the stopped activity can be found within the i4Q consortium, the associated work and funding will be distributed among the remaining partners. In case such corrective measure is not applicable, the consortium will look for another organisation with similar competences and characteristics, either subcontracting a third party, or bringing a new partner into the consortium, upon consultation with the Project Officer.
7. Loss of required know-how due to departure of key personnel (High) [WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9]. The consortium members commit to identify and properly allocate alternative personnel should key personnel depart from the project. A familiarisation plan will be set up to allow easy integration of new people in the project.

The amount of time needed to train new resources to work on the project will be defined and considered as part of the internal partners' staffing plan.

8. Unclear Requirements (Medium) [WP1]. The aim to address heterogeneous and diverse business scenarios could lead to unclear or incomplete requirements identification. To prevent this risk, a whole work package (WP1) is dedicated to the analysis of industrial scenarios and requirements with specific tasks dedicated to characterisation of users' scenarios (T1.3) and to the overall requirements specification (T1.4). Frequent meetings and workshops will be dedicated to the elicitation of requirements and clarification of the technologies applied with the proactive involvement both of end users from each of the selected pilot scenarios and the partners in charge of the innovation activities.
9. Lack of generality of identified requirements (Medium) [WP1, WP6]. The selected pilots cover a representative sample of European enterprises. They are companies with different background, needs and requirements that belong to different sectors and from different countries. However, during the proposal phase, when the description of the demonstration activities has been done and the first set of requirements has been defined, similarities among their needs have arisen. Therefore, during the project development and more specifically in WP1, the work package will monitor that the identified requirements are matched with the general requirement of European companies to be focused on those that are extensive in Europe.
10. Inadequacy of selected technologies (Medium) [WP2, WP3, WP4, WP5, WP6]. The i4Q Solutions will be built on top of an existing solutions and adding technologies developed in EU project results (ZDMP, QU4LITY, vf-OS, Daedalus, FAR-EDGE, BOOST 4.0, BEinCPPS, C2NET, CREMA, SERENA, PROGRAMS, MUSKETEER, NIMBLE, MANU-SQUARE) in which some i4Q partners have participated with a key role.
11. Other similar solutions already present on the market (High) [WP1, WP8]. i4Q specifically tailors a solution for SMEs by considering affordability, accessibility and ease of use of the provided services. Currently no such solution has been identified by the consortium which both covers the whole range of i4Q foreseen capabilities minimizing all kinds of initial investments. The consortium will closely monitor the market to promptly identify possible competitors and envision future evolutions of the i4Q offer to differentiate from the existing solutions.
12. Difficulties in exploitation (Low) [WP8]. This risk is handled by the development of a detailed Exploitation Business Plan and Business Model and the definition of the i4Q exploitation strategy (T8.1). These activities will perform the classification of the potential exploitable results, the project partners that will invest time and effort in each result, intentions of each partner with regard to the dissemination and use of all results and conflicts of interest and weaknesses related to exploitation issues.
13. IPR problems arising during exploitation (Medium) [WP8]. The Consortium Agreement (CA) will constitute the primary source to resolve IPR issues. The GA may be involved if any conflict remains. Moreover, the IMC and the LM will be also focused on IPR issues to manage the explicit rules concerning IPR ownership (T8.3), access rights to background and foreground, and the protection of IPRs and confidential information. Any conflicts that cannot be resolved through the principles above will be handled according to the dispute resolution provision set forth in the Consortium Agreement.

14. Poor or ineffective dissemination (Low) [WP7]. A common consortium strategy for dissemination and outreach of the project results and the implementation of impact activities to enable dissemination are among the specific goals of WP7. The i4Q consortium will periodically review and assess the dissemination strategy considering both the level of dissemination and the target audience. Dissemination KPIs will be agreed and will be tracked carefully.

7. Conclusions

Deliverable D1.1 serves as a project vision guide document and provides an overview of the main aspects of i4Q Project. The main goal of this deliverable is to map the solutions offered by technology providers to the requirements of the pilots. The vision of the project was clearly explained and the i4Q Solutions were listed and described in a what/ who/ how approach.

More specifically, i4Q Project aims to provide a solution consisting of IoT-based Reliable Industrial Data Services (RIDS), which will be a complete package consisting of 22 i4Q Solutions, 17 software tools and 5 guidelines, namely; i4Q^{QE} QualiExplore for Data Quality Factor Knowledge, i4Q^{DQG} Data Quality Guidelines, i4Q^{BC} Blockchain Traceability of Data, i4Q^{TN} Trusted Networks with Wireless & Wired Industrial Interfaces, i4Q^{SH} IIoT Security Handler, i4Q^{CSG} Cybersecurity Guidelines, i4Q^{DR} Data Repository, i4Q^{DRG} Guidelines for building Data Repositories for Industry 4.0, i4Q^{DIT} Data Integration and Transformation Services, i4Q^{DA} Services for Data Analytics, i4Q^{BDA} Big Data Analytics Suite, i4Q^{AD} Analytics Dashboard, i4Q^{AI} AI Models Distribution to the Edge, i4Q^{EW} Edge Workloads Placement and Deployment, i4Q^{IM} Infrastructure Monitoring, i4Q^{DT} Digital Twin simulation services, i4Q^{PQ} Data-driven Continuous Process Qualification, i4Q^{QD} Rapid Quality Diagnosis, i4Q^{PA} Prescriptive Analysis Tools, i4Q^{LRT} Manufacturing Line Reconfiguration Toolkit, i4Q^{LRG} Manufacturing Line Reconfiguration Guidelines, i4Q^{LCP} Manufacturing Line Data Certification Procedure. These solutions will be able to manage the huge amount of industrial data coming from cheap cost-effective, smart, and small size interconnected factory devices for supporting manufacturing online monitoring and control. Solutions are explained thoroughly in this deliverable, with explanations regarding both the end-users and the technologists.

The i4Q Framework will also guarantee data reliability with functions grouped into five basic capabilities around the data cycle: sensing, communication, computing infrastructure, storage, and analysis and optimization. i4Q Solutions will be validated in pre-defined use cases. Six Pilots are envisioned for the validation of i4Q Solutions, namely; Pilot 1: Smart Quality in CNC Machining, Pilot 2: Diagnostics and IoT Services, Pilot 3: White Goods Product Quality, Pilot 4: Aeronautics and Aerospace Metal Parts Quality, Pilot 5: Advanced In-line Inspection for incoming Prime Matter Quality Control, Pilot 6: Automatic Advanced Inspection of Automotive Plastic Parts. It is clear that the selected pilots represent different industrial sectors and activities, such as white goods, wood equipment, metal machining, ceramics pressing, plastic injection, metal equipment. Pilots are summarised in Section 2 of this deliverable. All of them are representative of high-tech manufacturing sectors characterised by an increasing demand for high quality products and a need for factories digitisation and data reliability.

Last but not least, in this deliverable (Section 5) the 21 project's milestones and the 119 project deliverables are presented, as well as the critical implementation risks and mitigation actions (Section 6).