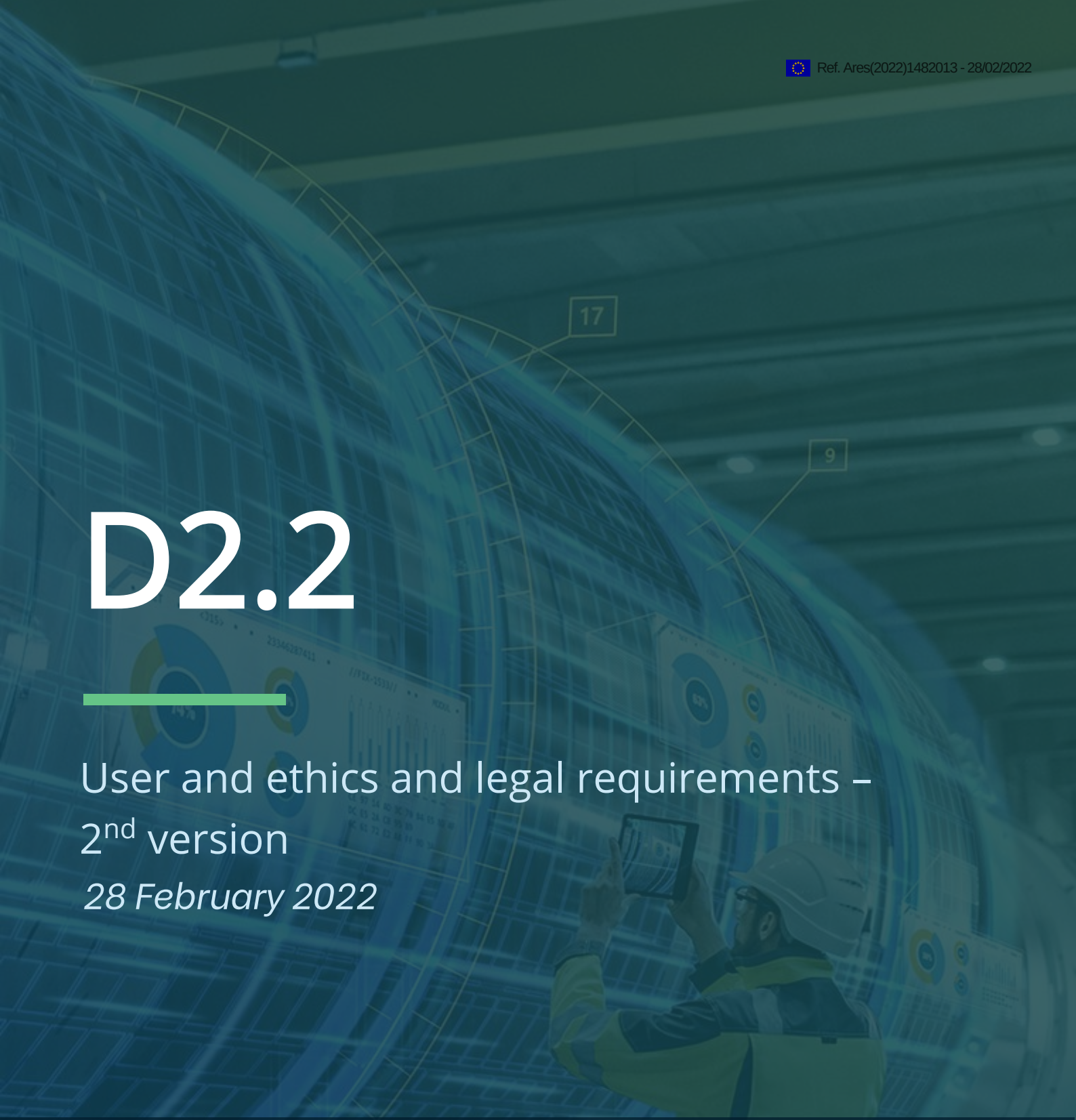

D2.2

User and ethics and legal requirements – 2nd version

28 February 2022

OPTIMAI

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LIST OF ABBREVIATIONS

Abbreviation	Definition
ACC	Accountability
AI	Artificial Intelligence
AIEPS	AI Edge Processing Service module (Acquisition Optimisation)
AIF	Digital Twinning (Digital Twins)
AIT	AI-enabled technologies
AR	Augmented Reality
AWM	Awareness of misuse
BC	Blockchain
CCM	Cloud Computing Modules
CI	Community involvement and development
COM	Competence
CSR	Corporate Social Responsibility
DIG	Dignity
DoA	Description of Action
DPR	Data Protection
Dx.x	Deliverable number x.x
E	Environment
e.g.	Exempli gratia
ECM	Edge Computing Modules
EDN	Equality and non-discrimination
ELPA	Ethical and Legal requirements for Piloting Activities
etc	Et cetera
EUA	End-users' Applications
FiNOT	Future Intelligence Internet of Things (FINoT Platform)
FOP	Fair Operating Practices
FR	Functional Requirement
GPD	Glue/epoxy diffusion
H&S	Health and safety procedures
HMI	Human Machine Interface
HR	Human Rights
HUM	Human Agency and Oversight
i.e.	id est
IC	Circuit
ID	Identification
IMBE	Intelligent Marketplace Back-End
IMCFE	OPTIMAI Intelligent Marketplace Customer Front-end
INT	Integrity
IoT	Internet of Things
IT	Information Technology
KPI	Non-financial reporting
KPIs	Key Performance Indicators
LCP	Liquid Crystal Polymer

LIDAR	Light Detection and Ranging
LP	Labour Practices
MCDR	Middleware Cloud Data Repository (Data Repository)
MID	Middleware
MoSCoW	MoSCoW prioritization method
MRS	Manufacturing (re-) configuration Service
NDI	Diversity, non-discrimination, and fairness
NDP	Use of non-personal data
NFR	Non-Functional Requirement
OMIDES (BE)	Operator-Machine Interaction & Decision Support (OMIDES) Back-End
OMIDES (FE)	OMIDES Front-End
OPTIMAI	Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization
PC	Personal computer
PCB	Printed Circuit Board
PDP	Privacy and data protection
PRI	Privacy and data governance
QCSN	Quality Control Sensors Network
Q-UR	Questionnaire User Requirement
SQC	Smart Quality Control
T	Task
ToF	Time of Flight
TRS	Technical robustness and safety
UI	User Interface
UR	User Requirement
UV	ultraviolet
VID-DD-UR	Video Defect Detection User Requirement
VID-DT–UR	Video Digital Twins User Requirement
VID-OST-UR	Video Optimal Set Up User Requirement
VPN	Virtual Private Network
VSE	Visual Simulation Engine
WEL	Environmental and societal well-being
WOR	Workers' rights
WP	Work Package

Executive summary

The purpose of the deliverable *D2.2 'User and ethics and legal requirements II'* is to identify and analyse the new requirements that have emerged during M7 and M14 and update the previously identified requirements concerning zero defect manufacturing, quality inspection, production re-configuration and other technology needs of the OPTIMAI pilot partners as well as the legal and ethical issues related to the development and implementation of the platform. The analysis of the initial gathered user and ethics and legal requirements is used as the basis of the initial developments and integration activities of the OPTIMAI project. The requirements elicitation and analysis take into account the Description of Action (DoA), the requirements identified and updated from the pilot partners (i.e. manufacturing companies) and the other OPTIMAI partners, based on their knowledge, expertise and more specifically, the needs in the particular domains that the project pursues to address. Additionally, a new set of ethics and legal requirements focusing on the pilot applications is presented. The technological innovation potential requirements identified in the first version of this deliverable, are linked to the state-of-the-art technologies and the identified assets per partner.

The update and refinement of the requirements is based on online and shopfloor meetings, videos and photos from the pilot sites, while the method used will be re-iterated through each of the project phases. The identified requirements are grouped into functional and non-functional requirements. Functional requirements describe what the system should do and are classified according to the components of the OPTIMAI architecture. Non-functional requirements are grouped into KPIs, ethics, legal and technology innovation potential requirements. In total 192 requirements are identified out of which 34 are updated and 65 are new. 148 are prioritised as "Must" (have), 35 as "Should" (have) and 9 as "Could" (have).

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1 Introduction

1.1 OPTIMAI project overview

OPTIMAI is a research project that has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 958264. OPTIMAI is conducted from January 2021 until December 2023. It engages 16 partners (End-users, Technology Providers, Research Institutes, Consultants and Universities) from 8 countries throughout Europe. Further information can be found in the project's website i.e. https://optimai.eu/.

Industry is one of most critical pillars of the European economy since it accounts for more than 80% of EU exports and provides jobs for 20% of the European citizens. As a major driving force of economic growth and prosperity with tangible impacts on all sectors of the economy, the European industry has a long tradition in innovation and high-quality manufacturing, with several European companies being global leaders in their domain. However, the globalisation of the economy has resulted in increased competition from emerging markets in China and elsewhere, posing a major challenge that requires European industries to rapidly evolve and adapt.

Against this backdrop, the OPTIMAI project aims to create a new European industry ecosystem, focused on the development of new solutions to optimise production, reduce defects and improve training to safeguard European industry for generations to come.

The outcomes of the OPTIMAI project will contribute to overcoming the challenges posed to the European industrial sector, capitalising on the unmatched potential for scientific knowledge and innovation capacity already existing within EU member states.

OPTIMAI seeks to research and develop highly innovative technologies for European industries, to integrate these new solutions across a wide variety of industry domains and to provide new training activities that will boost human performance in industry across Europe.

1.2 Purpose

The purpose of this deliverable is to update and refine the functional and non-functional requirements based on the identified user, ethics and legal requirements. More specifically, the user requirements for OPTIMAI are referenced as they have been elicited by the OPTIMAI partners considering also the legal and ethical aspects of the project. These solicited user requirements constitute the basis for defining the functional and non-functional requirements of the OPTIMAI platform. The document also lays the foundation of the potential technological innovations that have been connected to state-of-the-art technologies and developed assets, which are expected to stimulate and materialize the innovation capacity in the market.

1.3 Content and structure

The following section describes the method for gathering and updating the user and ethics and legal requirements. Section 3 presents the results of the requirements identification. A conclusion is provided in Section 4, while Appendix A presents the list of the updated user and ethics and legal requirements.

2 Method for gathering user and ethics and legal requirements

The general approach to the requirements elicitation and update process is following the method applied in D2.1 [1] and includes the following 4 steps:

2.1 Identification and update of stakeholders' needs

The first step is related to the identification of new requirements and the update of the existing stakeholder requirements. The identification and update of requirements is based on three specific sources of information.

a) Questionnaire for user and ethics and legal requirements

The requirements questionnaire developed by WP2 and WP9 partners and completed by all partners in the context of D2.1 [1] of *Task 2.1: Consolidation of user and ethics and legal requirements*, is the main source of information that formulated the first set of user requirements for OPTIMAI taking into account legal and ethical aspects. These requirements are further analysed and updated towards identifying the functional and non-functional requirements of the OPTIMAI platform along with the input that have been collected from the specification of the OPTIMAI use cases in D2.6.

In this deliverable, the new set of legal and ethical requirements solely focus on the internal ethical, legal and societal risks arising directly from the project and within its 36-month duration. On the contrary, external risks are those which may arise because of the use of the OPTIMAI results beyond the project's 36-month duration by future adopters of OPTIMAI solutions.

b) Online and shopfloor meetings

One of the key resources of information for updating the OPTIMAI requirements was the online meetings and teleconferences between project partners. Notes from these meetings have considerably contributed to the identification of new requirements and the update of the existing ones. Furthermore, several meetings with operators and technicians working on specific pilot workstations were conducted, to discuss how the OPTIMAI solutions will be implemented and what are their responsibilities.

c) Videos, photos and related presentations from pilots

Due to the COVID-19 travel restrictions that keep on inhibiting physical meetings and visits to the pilot sites, end-users have managed to provide more videos and photos from the production lines involved in the project in order to help other partners clearly understand where the solutions developed within OPTIMAI will be applied.

2.2 Collaboration, negotiation and agreement

This stage includes collaboration and discussions between partners to foster agreements and establish and update priorities. This stage took place between M7 and M14 and it will continue with workshops between technical partners, end users and ethics and legal partners.

2.3 Requirements' specification

At this stage, requirement engineering processes is conducted in order to ensure a systematic approach to manage the requirements. The requirements' engineering process is defined as a continuous iterative process, driven by the end-users.

2.4 Requirements' validation

This stage closes the loop of the requirements' elicitation process. It includes the iterative pilot evaluation and testing of the identified requirements in order to determine consistency, completeness and suitability.

The requirements elicitation approach (see Figure 1), is an iterative process that will run throughout the project's lifetime. In each cycle subsequent changes will be analysed that will lead to refining of existing requirements as well as the addition of new requirements.

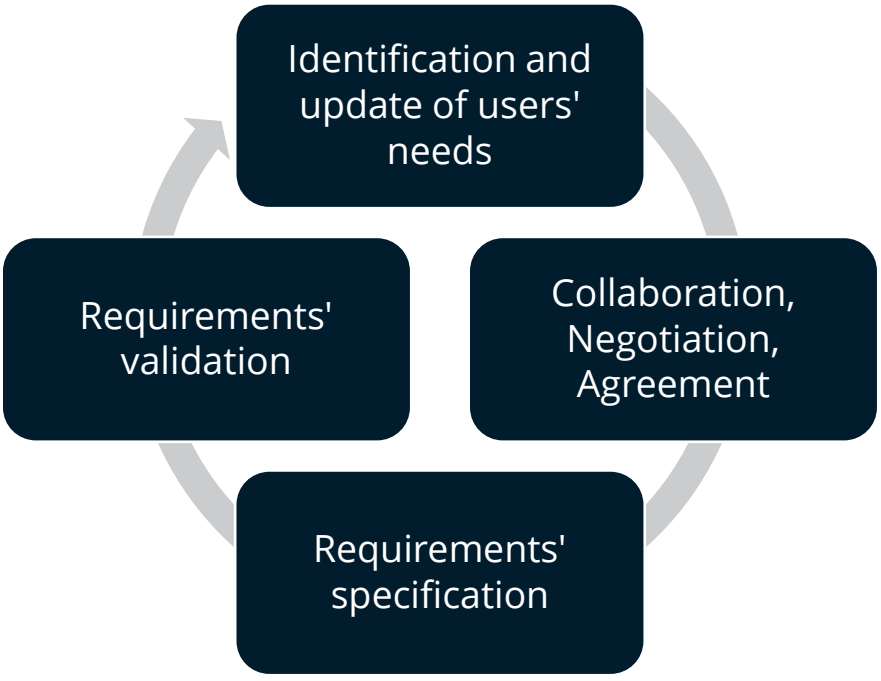


Figure 1: Requirements' elicitation process

2.5 Requirement derivation

As a consolidated outcome of the requirements' sources, a second updated set of user, ethics and legal requirements is identified. Some of the initial identified requirements have already started being implemented, and new and updated requirements, have been added based on the

end-users' feedback, e.g., from user evaluation of the first demos or prototypes. The extracted requirements are related to various aspects of the OPTIMAI solutions. The user and ethics and legal requirements extracted from the questionnaires, the on-line and shopfloor meetings and the videos and photos, are presented and transformed into functional and non-functional requirements based on the components of the updated OPTIMAI architecture. Functional requirements describe what the system should do, and non-functional requirements describe how the system should work. The following figure shows the hierarchy of the requirements analysis.

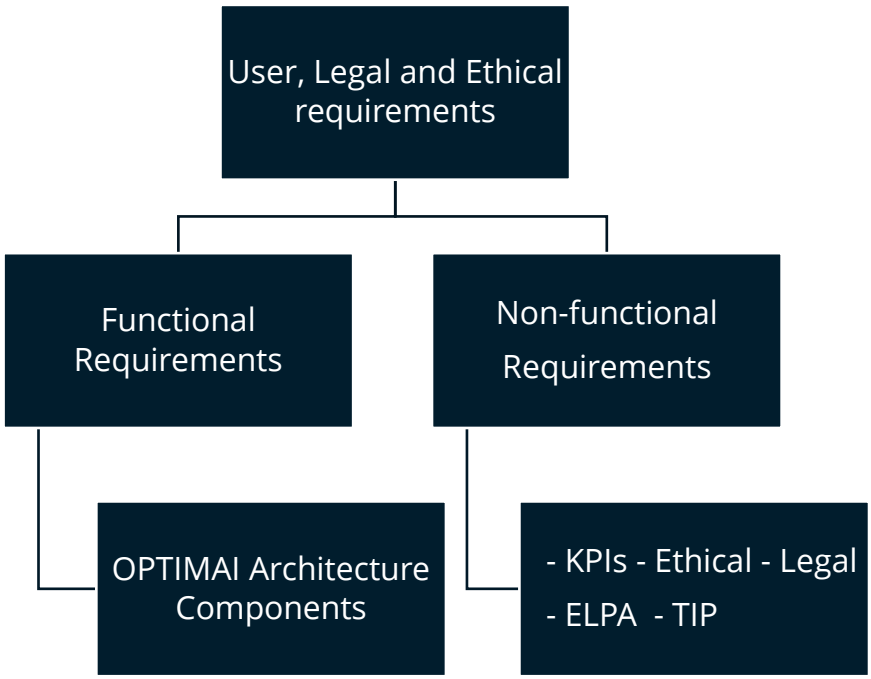


Figure 2: Hierarchy of the requirements analysis

2.6 MoSCoW Method for Requirements Prioritisation

The MoSCoW analysis is a prioritisation method used in management, business analysis and software development to reach a common understanding with stakeholders regarding the importance of each requirement. In the OPTIMAI project, MoSCoW method is used to prioritise the identified requirements for developing OPTIMAI solutions. The MoSCoW method is based on the following priorities:

Must (have): Requirements marked as Must are critical for the pilot partners and also critical to highlight the added value of OPTIMAI. They represent the user's highest priority requirements that the technical partners have to fulfil.

Should (have): Requirements marked as Should are highly important but not critical for the pilot partners. These requirements can be as important as the ones marked as Must, but they are not time-critical and they can be delivered later. They highlight the need for OPTIMAI to fulfil, so that the technical partners guide their efforts also into these.

Could (have): Requirements marked as Could are considered as 'thresholds'. Could requirements are desirable and could improve the user experience, but they are not necessary and only subject to resources availability (time, effort, budget, etc.) they will be addressed by the technical partners.

Would (have): Requirements marked as Would, are considered as requirements that are possible but unlikely to be addressed. They have the lowest priority according to the partners. These requirements will be addressed only if in an iteration of requirements elicitation, they are ranked with a higher priority.

The requirements marked as Must and Should will be selected and implemented first.

3 Results

In this section the results of the updated and new requirements identification are presented as a consolidated outcome of the 'User and ethical and legal requirements' questionnaire, the on-line and shopfloor meetings, the videos and photos and the presentations of the pilot partners. In total, **192** requirements are identified and distributed in three main categories i.e. User requirements, functional and non-functional requirements (see **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** and Figure 1).

Table 1: Requirements' categories

Requirement category		Count	Updated	New
User requirements	Questionnaire User Requirements	14	4	
	Pilots' videos User Requirements	33	10	
Functional Requirements	Functional Requirements	15	15	
Non-Functional Requirements	Key Performance Indicators	18	5	
	Legal requirements	10		
	Ethical Requirements	24		
	Ethical and Legal requirements (Pilot Activities)	65		65
	Technological Innovation Potential	13		
Total		**192**	34	65

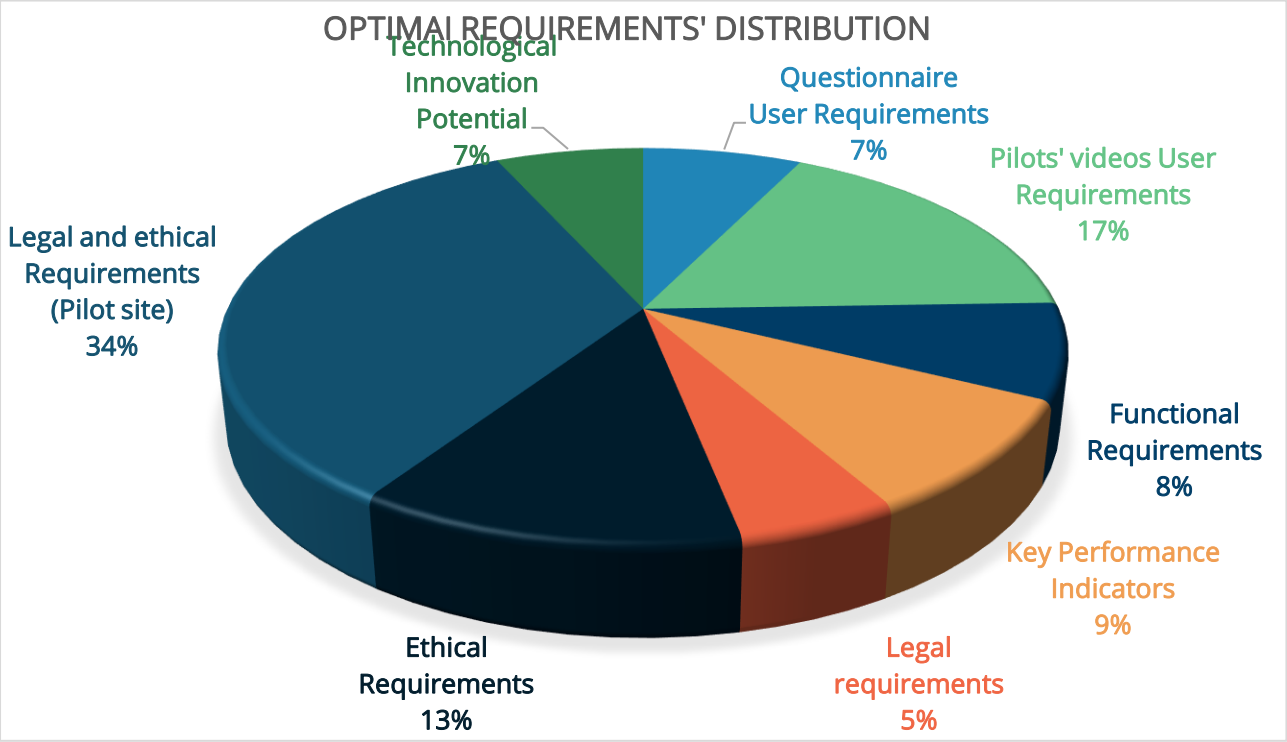


Figure 3: OPTIMAI Requirements' Distribution

Most of the identified requirements are prioritised as Must (see Table 2 and **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**), reflecting that the users are focusing on specifying critical functional and non-functional requirements of high impact for the technical development.

Table 2: Requirements by priority

Requirements by priority	**Count**
Must	148
Should	35
Could	9

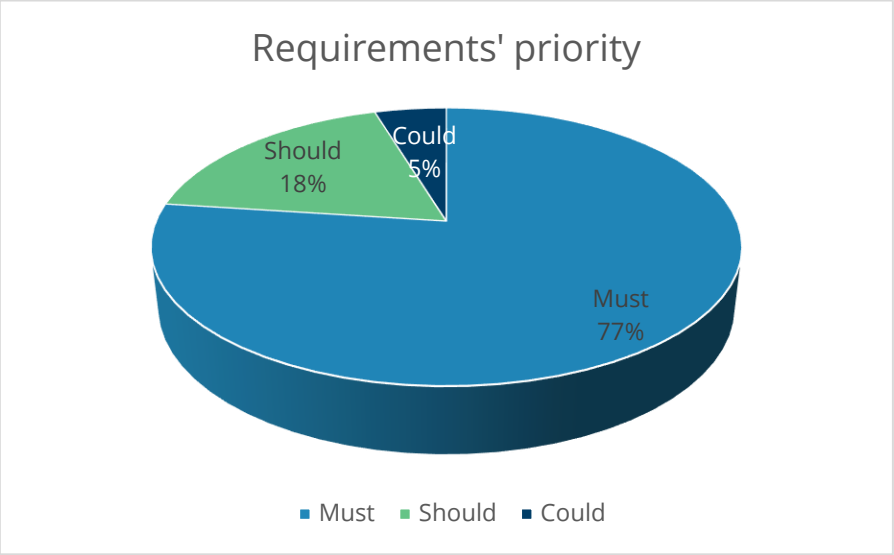


Figure 4: Requirements by priority

3.1 User requirements extracted from questionnaires

The OPTIMAI user requirements are presented in the following tables. Each table contains the ID of the requirement and its name, a brief description and how the requirement can be implemented in OPTIMAI. The number of requirements remained the same as in the first version of this deliverable. Fourteen (14) Questionnaire User Requirements (Q-UR) have been identified from the questionnaire and four (4) of them (Q-UR-3, Q-UR-4, Q-UR-7, Q-UR-10) have been updated upon prior discussion with all partners.

Table 3: Production monitoring and Quality inspection (Q-UR-1)

ID	Q-UR-1	**Requirement**	Production monitoring and Quality inspection	**Priority**
Description	The system shall be able to monitor production and inspect quality issues			Must

Implementation in OPTIMAI	UR-1a: The system shall be able to offer continuous production monitoring and quality inspection functionalities UR-1b: The system shall be able to give feedback from quality control prediction and provide optimum decisions UR-1c: Real time feedback on the process output shall be achieved UR-1d: Monitoring of key process inputs via sensors shall be achieved UR-1e: Combining real time data with historical data to tune the production processes shall be offered UR-1f: The optimisation system shall be able to adapt to production changes as quickly as possible UR-1g: Control settings shall be applied in data collection and analysis UR-1h: Historical data on quality issues shall be analysed to assist decision making UR-1i: Specific production and quality parameters shall be monitored	

Table 4: Visualisation (Q-UR2)

ID	Q-UR-2	**Requirement**	Visualisation	**Priority**
Description	The system shall be able to visualise information from the production line			Must
Implementation in OPTIMAI	UR-2a: The system shall be able to visualise specific characteristics as defined by the manufacturer and the law conditions UR-2b: OPTIMAI shall be able to offer a visual analytics interface that will provide all the necessary product information UR-2c: The system shall be able to visualise production line processes UR-2d: The system shall be able to visualise production through real-time monitoring integrated in the digital twin of the production line UR-2e: The system shall be able to visualise only the necessary information			

Table 5: Data security (Q-UR-3)

ID	Q-UR-3	**Requirement**	Data security	**Priority**
Description	The system shall provide security in all datasets			Must

Implementation in OPTIMAI	UR-3a: The system shall be able to provide secure data exchange/transaction UR-3b: Cyber security threats shall be detected UR-3c: Personnel data must be secure (ensure anonymity)	

Table 6: Data traceability (Q-UR-4)

ID	Q-UR-4	**Requirement**	Data traceability	**Priority**
Description	The system shall provide data traceability			Must
Implementation in OPTIMAI	UR-4a: The system shall be able to ensure near-real-time data traceability in the majority of the datasets			

Table 7: (Near) real-time notifications and alerts (Q-UR-5)

ID	Q-UR-5	**Requirement**	(Near) real-time notifications and alerts	**Priority**
Description	The system shall provide (near) real-time notifications and alerts from data generated from sensors			Must
Implementation in OPTIMAI	UR-5a: The system shall be able to provide real-time sensory data analysis for defect detection & prediction UR-5b: Platform users shall be timely notified about an occurring defect detection UR-5c: Platform users shall be able to resolve the problems that caused the defect without leaving their location at the shop-floor UR-5d: The system shall be able to provide timely notifications and alerts with regard to the manufacturing pipeline UR-5e: The system shall be able to identify design errors and configuration mistakes UR-5f: The system shall be able to store sensors' data UR-5g: The system shall be able to adapt to production changes as quickly as possible.			

Table 8: Virtualisation (Q-UR-6)

ID	Q-UR-6	**Requirement**	Virtualisation	**Priority**
Description	The system shall be able to virtualise production processes			Must

Implementation in OPTIMAI	UR-6a: The system shall be able to virtualise manufacturing processes UR-6b: The virtualisation of the production system will facilitate the production optimization UR-6c: The system shall be able to accelerate production reconfiguration	

Table 9: Control and Recalibration (Q-UR-7)

ID	Q-UR-7	**Requirement**	Control and Recalibration	**Priority**
Description	The system shall be able to control the production line and provide recalibration recommendations			Must
Implementation in OPTIMAI	UR-7a: The system shall be able to provide rapid line qualification and exploration of alternative production scenarios UR-7b: The system shall be able to provide automatic recalibration UR-7c: The system shall provide suggestions regarding the necessary reconfiguration and parameterization in an autonomous way UR-7d: The system shall be able to allow the automatic recalibration to be overwritten by human users. The final decision should be made by the operator			

Table 10: Cyber-threats protection (Q-UR-8)

ID	Q-UR-8	**Requirement**	Cyber-threats protection	**Priority**
Description	The system shall be protected from cyber threats			Must
Implementation in OPTIMAI	UR-8a: The system shall be able to protect the sensors network from cyber-threats UR-8b: The system shall be able to protect the software and hardware components from cyber-attacks UR-8c: The system shall be able to inform the users about security-related alerts in real-time UR-8d: The system shall provide the necessary controls to detect, prevent and mitigate the cyber security threats UR-8e: The system shall provide full visibility regarding the information on risk exposure.			

Table 11: Accessibility (Q-UR-9)

ID	Q-UR-9	Requirement	Accessibility	Priority
Description	Only authorised users shall have access to the OPTIMAI platform			Must
Implementation in OPTIMAI	UR-9a: Only authorised users shall have access to the system UR-9b: All users accessing the system shall be identified with a personal username and a password UR-9c: Only operators who have the correct training shall be signed off to complete a specific task. If they are not trained, they cannot start the activity UR-9d: Quality inspection data shall be accessible only to authorised staff UR-9e: Remote users can only access corporate systems and tools through a VPN.			

Table 12: AR glasses (Q-UR-10)

ID	Q-UR-10	Requirement	AR glasses	Priority
Description	The AR glasses shall provide real-time and accurate information to the employees			Should
Implementation in OPTIMAI	UR-10a: The information that is displayed in the worker's AR glasses field of view, should be as much as needed UR-10b: The information provided to the employee through the AR glasses shall be short and comprehensive UR-10c: The information that is displayed in the worker's AR glasses field of view, should be relevant UR10-d: The information that is displayed in the worker's AR glasses field of view, should provide the right information UR-10e: Based on specific alerts, the operator shall be able to be notified about the actions that need to be performed in the right sequence UR-10f: These settings are then either implemented directly in the plant or they get presented to an operator.			

Table 13: Production Optimisation (Q-UR-11)

ID	Q-UR-11	Requirement	Production Optimisation	Priority
Description	The system shall be able to reconfigure its settings without stopping the production			Must

Implementation in OPTIMAI	UR-11a: Every interaction step in the applications used in the production line should be under the speeding up existing processes microscope UR-11b: Fast conceptual design of the production system UR-11c: Production reconfiguration for new products without stopping the ongoing production, minimizing downtimes and enhancing productivity UR-11d: The optimisation system must be able to adapt to these changes in the plant as quickly as possible UR-11-e: The system shall be able to optimise power unit performance	

Table 14: Defect minimization (Q-UR-12)

ID	Q-UR-12	**Requirement**	Defect minimization	**Priority**
Description	The system shall recognize the possible defects and reduce them			Must
Implementation in OPTIMAI	UR12a: The system shall be able to receive the decision on defect detection with an autonomous way UR-12b: The system shall be able to reduce possible defects UR-12c: The system shall be able to identify specific types of defects UR-12d: OPTIMAI shall be able to simulate specific defect conditions and provide digital twins models			

Table 15: Operator's profile (Q-UR-13)

ID	Q-UR-13	**Requirement**	Operator's profile	**Priority**
Description	The system should not be able to profile operators			Must
Implementation in OPTIMAI	UR-13a: Profiling of operator's performance through defect detection shall be avoided UR-13b: Technicians' experience in reconfiguration and re-adjustments shall be recorded in the system UR-13c: The operators shall have their own unique badge ID which is scanned as part of the data collection for that process step. UR-13d: The system shall allow the operators to import deficiencies data from human inspection (with the aid of microscopes)			

Table 16: Real-time information (Q-UR-14)

ID	Q-UR-14	Requirement	Real-time information	Priority
Description	The system shall provide real-time information about the production			Must
Implementation in OPTIMAI	UR-14a: Real-time information on the configuration of the line shall be provided (reference and task loaded in each production cell as well as associated materials in their feeding peripheries) UR-14b: Material flow analysis to study and evaluate the production system configurations UR-14c: The operator shall be able to see information on an HMI (touch screen) in each production cell and in a plant information screen			

3.2 User requirements extracted from pilots' videos

This section presents the results of the user requirements (URs) extracted from the pilots' videos. The analysis of the requirements is based on the three different use cases that are being implemented in each pilot i.e. 1) Zero defect quality inspection, 2) Production line setup-calibration and 3) Production planning. The user requirements are extracted and updated from videos and photos per process, and they are grouped in three categories based on the use cases i.e. defect detection, optimal set-up and digital twin. Priority levels have been also updated. Ten (10) requirements have been updated based on the end-users' refined needs i.e.: KLEE-VID-OSU-UR2, MTCL-VID-OSU –UR1, MTCL-VID-OSU-UR3, MTCL-VID- DD –UR5, TVES-VID- DD –UR1, TVES-VID- DD –UR2. TVES-VID- DD –UR3, TVES-VID- OSU –UR1, TVES-VID- OSU –UR2, TVES-VID- OSU –UR3.

3.2.1 KLEEMANN: Lift manufacturer

Table 17: Check parts used

PILOT	KLEEMANN - KLEE
User	Operator
Current procedure:	Hydraulic lift Power Unit Quality Control – Check parts used
Current procedure description:	The operator manually inspects the power unit and checks if the right parts have been used. To do so the operator visually inspects and recognizes the parts on the power unit and compare them with the parts referred to the client's order, which is printed on paper. The operator needs to know if the parts are correct or there is any mismatch between the used parts and the parts in the client's order, before continuing to the next steps.

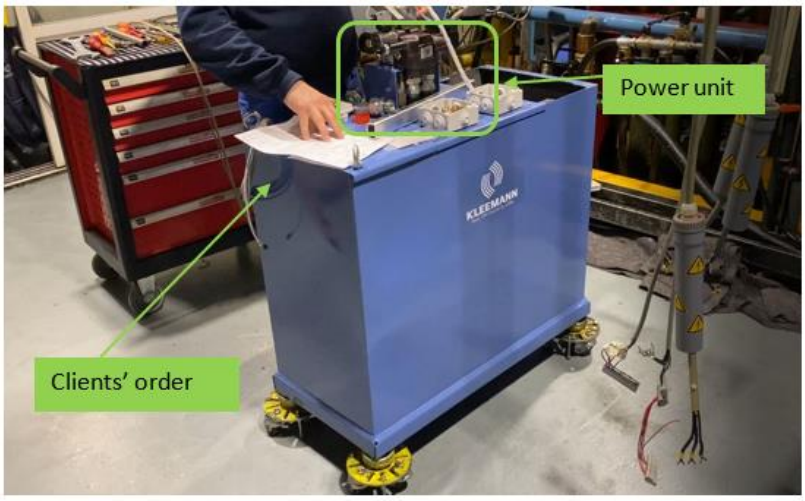
	
User goals:	• Automatically receive the information on whether the correct parts have been used in the produced Hydraulic Lift Power Unit, to minimize the impact of the human error and increase accuracy.

Table 18: Defect detection (KLEE-VID-DD-UR1)

ID	KLEE-VID-DD-UR1	**Requirement**	Defect detection	**Priority**
Description	The user can be aware of whether there is any mismatch between the parts that have been used in the produced Hydraulic Lift Power Unit compared to the parts referred to the client's order, without having to inspect the unit manually.			Could

Table 19: Valve block pressure monitoring

PILOT	KLEEMANN - KLEE
User	Operator
Current procedure:	Hydraulic lift Power Unit Quality Control – Valve block pressure monitoring
Current procedure description:	Once the operator has put into operation the power unit, waits 3 minutes monitoring the pressure of the valve block. In case the pressure of the valve block drops below the operational pressure value (35-40 bar), means that there is a leakage, caused possibly by defected pump.

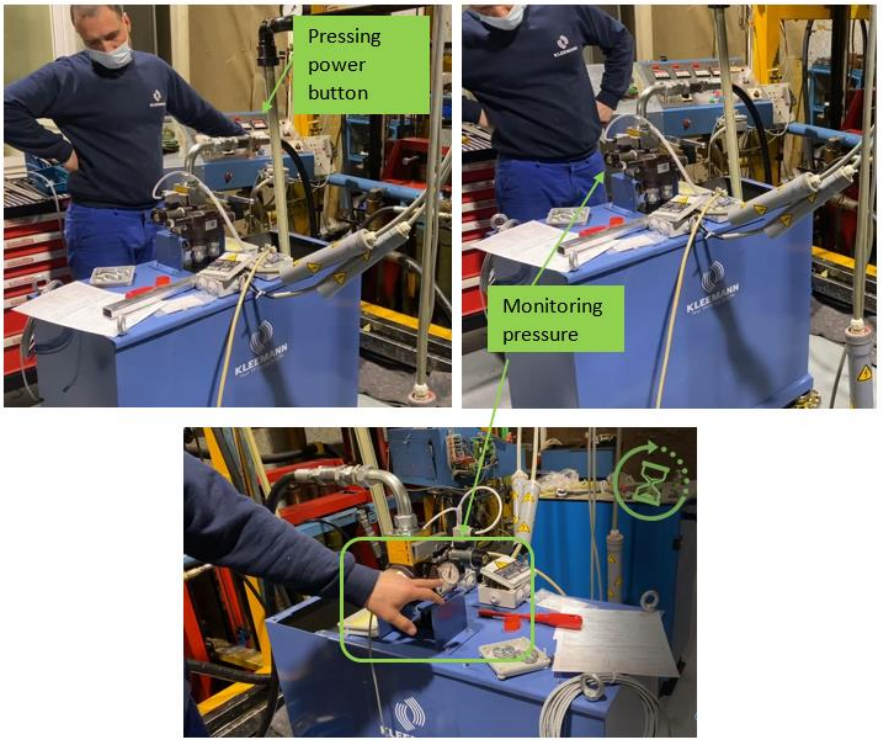
	
User goals:	• During pressure testing it is undesirable to visually inspect the pressure meter in order to save time.

Table 20: Defect detection (KLEE-VID-DD-UR2)

ID	KLEE-VID-DD-UR2	**Requirement**	Defect detection	**Priority**
Description	Monitor the pressure of the hydraulic lift power unit in (near) real time, without visually inspecting it, standing there for 3 minutes, to save time.			Must

Table 21: Defect detection (KLEE-VID-DD-UR3)

ID	KLEE-VID-DD-UR3	**Requirement**	Defect detection	**Priority**
Description	Users must be notified in real time if the pressure of the valve block on the hydraulic lift power unit drops below the operational pressure value.			Must

Table 22: Control – Testing

PILOT	KLEEMANN
User	Operator

Current procedure:	Hydraulic lift Power Unit Quality Control – Testing
Current procedure description:	The operator tests the Hydraulic Lift Power Unit. The operator goes to a separate office area where a computer is installed to monitor the: - velocity of the lift - sound and - pressure, in 2 cases: a) when the lift goes up, b) when the lift goes down. In case the operator notices a variety of values that may indicate a defect, returns to the Hydraulic Lift Power Unit and resolves the issues based on his experience. Then, returns to the office to check again. 

	  Existing sensors (sound, velocity etc.)
User goals:	• During the testing of the lift, users should be able to monitor parameters (e.g. velocity, sound, vibration, pressure etc.) that might indicate a defected unit, without moving to another area, to save time. • It is highly desirable the users to be able to (re)-calibrate the system while monitoring the above measurements in order to rapidly make the optimal set up for the Hydraulic Lift Power Unit. • Users should be able to adjust the testing parameters with Human Computer Interface based on gestures.

Table 23: Optimal setup (KLEE-VID-OSU-UR1)

ID	KLEE-VID-OSU-UR1	**Requirement**	Optimal set up	**Priority**
Description	Users must be able to monitor parameters (e.g. velocity, sound, vibration, pressure etc.), while calibrating the Hydraulic Lift Power Unit.			Must

Table 24: Optimal setup (KLEE-VID-OSU-UR2)

ID	KLEE-VID-OSU-UR2	**Requirement**	Optimal set up	**Priority**
Description	Users must be able to calibrate and recalibrate the Hydraulic Lift Power Unit with Human Computer Interface based on gestures, to rapidly make the optimal set up for the Hydraulic Lift Power Unit. An automatic recalibration functionality should also be provided by the system			Must

Table 25: Defect detection

PILOT	KLEEMANN - KLEE
User	Production Manager
Current procedure:	Hydraulic lift Power Unit Quality Control – Defect detection

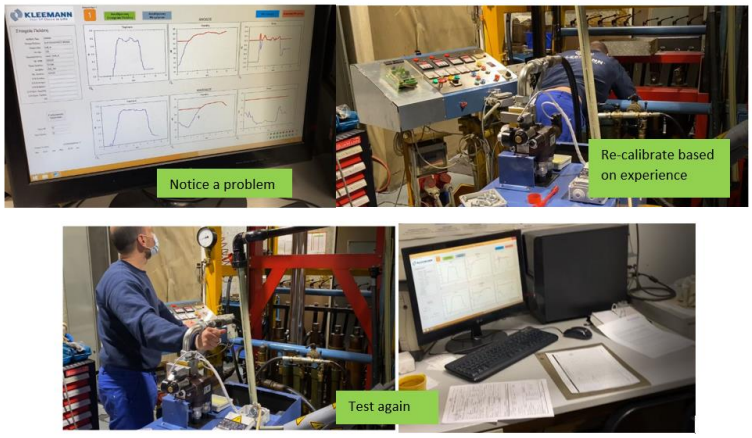
Current procedure description:	During testing, in case that the testing measurements indicate a defect, only the experienced operators know what might do to resolve the issue by experience. 
User goals:	• Any cause of suboptimal performance and the corresponding corrective actions should be notified to the users.

Table 26: Digital twin (KLEE-VID-DT-UR1)

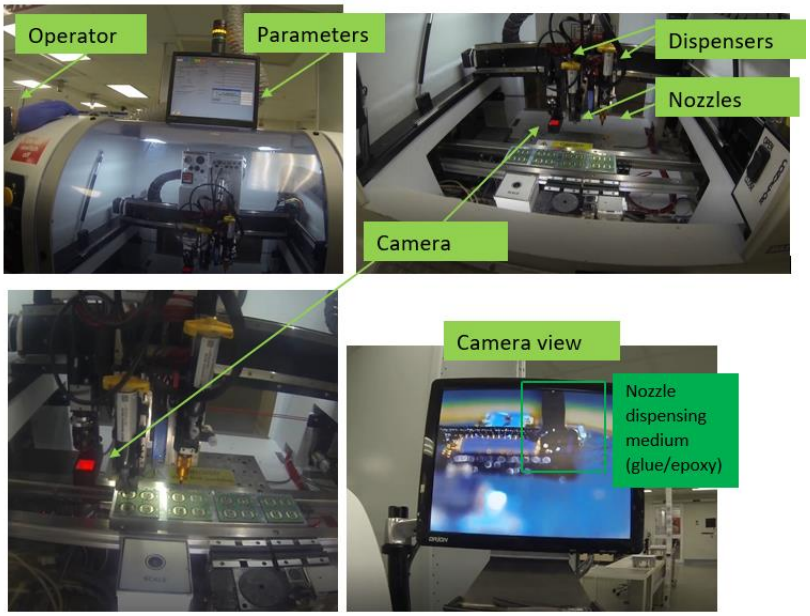
ID	KLEE-VID-DT-UR1	**Requirement**	Digital twin	**Priority**
Description	Users must know the cause of suboptimal performance and the corresponding corrective actions that might resolve the issue.			Must

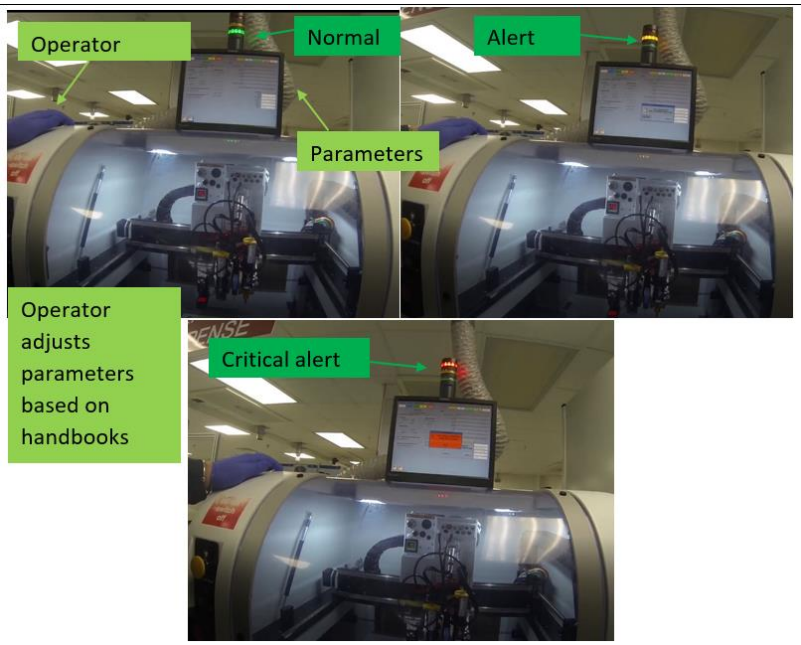
Table 27: User Requirements (UR) exported from videos per process, UR category and Priority (KLEE)

User Requirements (UR) exported from videos per process, UR category and Priority					
Pilot: KLEE	Priority				
UR category	Must	Should	Could	Would	Total
Hydraulic lift Power Unit Quality Control					
Defect detection	2		1		3
Optimal Set Up	2				2
Digital Twin	1				1
Total	5		1		6

3.2.2 MICROSEMI: Microelectronics assembly

Table 28: Glue/epoxy diffusion, GPD dispensing system

PILOT	MICROSEMI - MTCL
User	Operator
Current procedure:	Glue/epoxy diffusion, GPD dispensing system
Current procedure description:	A conductive medium (glue or epoxy) is dispensed on a Liquid Crystal Polymer (LCP) substrate before an Integrated Circuit (IC) is attached. If the medium is not properly diffused in terms of shape and quantity, the entire circuit can be defective (e.g. reduced conductivity, hot spots or short circuits occurrence etc.). During dispensing process, the operator is notified if something is wrong with two types of alert (orange, red). The operator adjusts parameters (e.g. nozzle pressure in glue/epoxy dispense) to resolve dispensing issues that cause defects. 

	 After the dispensing process, the operator conducts the quality control manually, by inspecting the PCB under a microscope. The quality control is performed based on corresponding workbooks.
User goals:	Defect detection/calibration: • Users should be able to visually inspect the circuit in glue/epoxy diffusion step of production, to save time, minimize the impact of a human error and increase accuracy. • Users should be informed about defects detected in (near) real time to rapidly adjust parameters. • Users should be informed about predicted defects to imminently adjust parameters and minimize the production of defected products until the problem is fixed. • Users should be able to adjust critical parameters (e.g. nozzle pressure in glue/epoxy dispense) manually when a defect has been detected or predicted. • Users should be able to rapidly adjust some parameters through Human Computer Interface based on gestures. Calibration/production planning: • Users should know the cause of suboptimal performance and the corresponding corrective actions that might resolve the issue. • Users should be able to test different set up of parameters in the production line, to apply the optimal set up for different types of products, without testing them on the real production line to save time and reduce cost.

	• Users should be able to rapidly set up the production line, by transferring the optimal parameters set up from the virtual testing environment to the real production line. • Users should be able to use the virtual testing environment to simulate not only the machinery, but also the sensors of the production line in order to detect defects in the virtual environment.

Table 29: Defect detection (MTCL-VID- DD -UR1)

ID	MTCL-VID- DD -UR1	Requirement	Defect detection	Priority
Description	During glue/epoxy diffusion (GPD dispensing system), the defect detection should be executed automatically to save time, minimize the impact of a human error, increase accuracy.			Must

Table 30: Defect detection (MTCL-VID- DD -UR2)

ID	MTCL-VID-DD-UR2	Requirement	Defect detection	Priority
Description	When a defect is detected, during glue/epoxy diffusion (GPD dispensing system), users must be able to receive notification in (near) real time, in order to rapidly react to resolve the issue.			Must

Table 31: Defect detection (MTCL-VID- DD -UR3)

ID	MTCL-VID-DD-UR3	Requirement	Defect Detection	Priority
Description	During glue/epoxy diffusion (GPD dispensing system), should be able to know when a defect is possible to happen in order to save time and react accordingly (prediction).			Should

Table 32: Defect detection (MTCL-VID- DD -UR4)

ID	MTCL-VID-DD-UR4	Requirement	Defect Detection	Priority
Description	During glue/epoxy diffusion (GPD dispensing system), should be notified in (near) real time when a defect is predicted that is quite possible to happen in order to save time and react accordingly			Should

Table 33: Optimal setup (MTCL-VID-OSU –UR1)

ID	MTCL-VID-OSU –UR1	Requirement	Optimal set up	Priority
Description	When a defect is detected, during glue/epoxy diffusion (GPD dispensing system), the critical parameters of the dispensing process should be adjusted automatically to save time, minimize the impact of a human error, increase accuracy and for optimal set up			Must

Table 34: Optimal setup (MTCL-VID-OSU –UR2)

ID	MTCL-VID-OSU-UR2	Requirement	Optimal set up	Priority
Description	When a defect is detected, during in glue/epoxy diffusion (GPD dispensing system), users should be able to rapidly adjust some parameters via Human Computer Interface based on gestures.			Should

Table 35: : Optimal setup (MTCL-VID-OSU –UR3)

ID	MTCL-VID-OSU-UR3	Requirement	Optimal set up	Priority
Description	The users should be notified about the cause of suboptimal performance of the GPD dispensing system, and the corresponding corrective actions that might resolve the issue.			Must

Table 36: Digital twin (MTCL-VID-DT-UR1)

ID	MTCL-VID-DT-UR1	Requirement	Digital Twin	Priority
Description	The users should be able to test different set up of parameters in a GPD dispensing system digital replica of the production line to reduce time and cost to find optimal set up of parameters for different products.			Should

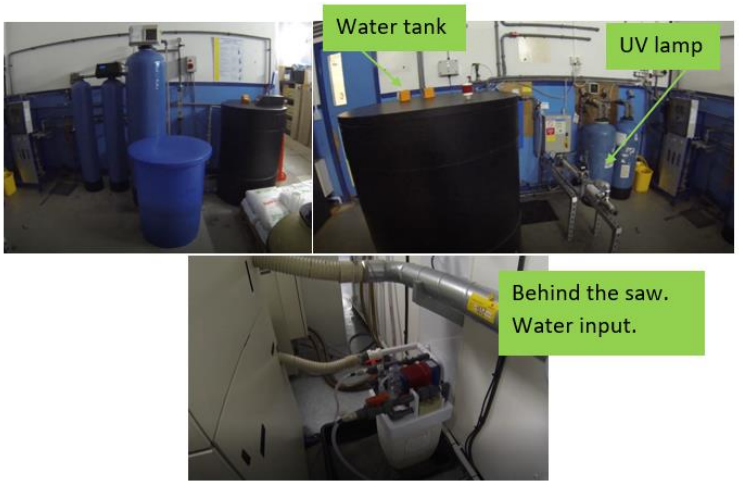
Table 37: : Digital twin (MTCL-VID-DT-UR2)

ID	MTCL-VID-DT-UR2	Requirement	Digital Twin	Priority
Description	Users should be able to rapidly transfer the optimal set up of parameters of GPD dispensing system for different products from the digital replica to the real production line.			Should

Table 38: Digital twin (MTCL-VID-DT-UR3)

ID	MTCL-VID-DT-UR3	**Requirement**	Digital Twin	**Priority**
Description	The GPD dispensing system digital replica of the production line to include machinery and virtual sensors should detect defects in the virtual environment.			Should

Table 39: Wafer sawing

PILOT	MICROSEMI - MTCL
User	Operator
Current procedure:	Wafer sawing
Current procedure description:	During wafer sawing the operator calibrates the system based on the corresponding workbooks. Deficiencies in the sawing process damage the Integrated Circuit (IC), leading to scrap.  An important factor for successful sawing process is the quality of the water used. The water before reaching the sawing machine is being cleaned by living bacterial through a UV lamp. The de-ionized water enters the water tank and then the sawing machine. 

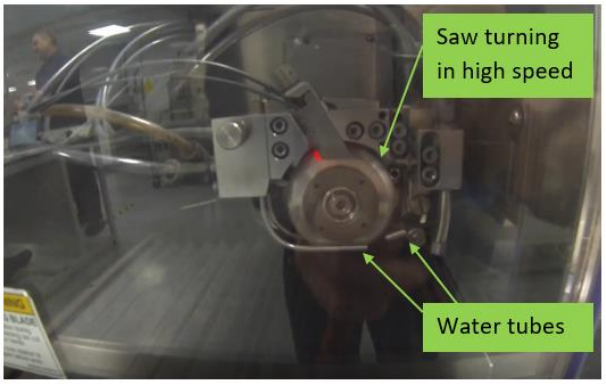
	Important parameters of the sawing process are the speed of the saw, the blade cutting temperature, the quality and proper purring of de-ionized water etc.  The operator conducts the inspection process manually a few days later.
User goals:	• It is desirable the users to monitor parameters that are not currently monitored to increase control of the sawing process and detect unknown possible sources of deficiencies for better quality of products and less scrap. • It is desirable the users to be informed about values of the parameters that indicate sawing deficiencies (e.g. residue resulting from sawing, quality of water, displacement etc.) that can cause defective products. • It is desirable the avoidance of manual detection of defects a few days after the sawing process is complete. • It is desirable the users to be informed when a defective product is detected.

Table 40: Defect detection (MTCL-VID- DD –UR5)

ID	MTCL-VID- DD –UR5	**Requirement**	Defect detection	**Priority**
Description	Users can monitor parameters that are not currently monitored and may indicate sawing deficiencies.			Should

Table 41: Defect detection (MTCL-VID- DD –UR6)

ID	MTCL-VID- DD –UR6	**Requirement**	Defect detection	**Priority**
Description	Users must be notified about parameters that indicate sawing deficiencies (e.g. residue resulting from sawing, quality of water, displacement etc.) that can cause defective products.			Must

Table 42: Defect detection (MTCL-VID- DD –UR7)

ID	MTCL-VID- DD –UR7	Requirement	Defect detection	Priority
Description	The defect detection process to be executed automatically after the wafer sawing process.			Should

Table 43: Defect detection (MTCL-VID- DD –UR8)

ID	MTCL-VID- DD –UR8	Requirement	Defect detection	Priority
Description	Users should be notified about detected defects in (near) real time on products exported from wafer sawing process.			Should

Table 44: Printed Circuit Board (PCB) Routing

PILOT	MICROSEMI - MTCL
User	Operator
Current procedure:	Printed Circuit Board (PCB) Routing
Current procedure description:	During PCB routing deficiencies can cause short circuits that can lead to scrap. Important parameters of the circuit board routing include (e.g. distance between components, routing thickness etc.). 

	
User goals:	• It is desirable the users to be able to monitor parameters that are not currently monitored and may indicate defects during the PCB routing process (e.g. pressure) to increase quality and reduce scrap. • It is desirable the users to automatically be informed about detected defects regarding distance between components, routing thickness etc. in (near) real time.

Table 45: Defect detection (MTCL-VID- DD –UR9)

ID	MTCL-VID- DD –UR9	**Requirement**	Defect detection	**Priority**
Description	Users should be able to monitor parameters during PCB routing process that are not currently monitored and may cause defective products (e.g. pressure).			Should

Table 46: Defect detection (MTCL-VID- DD –UR10)

ID	MTCL-VID- DD –UR10	**Requirement**	Defect detection	**Priority**
Description	Users should be notified about detected defects during the PCB routing process (e.g. distance, routing thickness etc.) in (near) real time.			Should

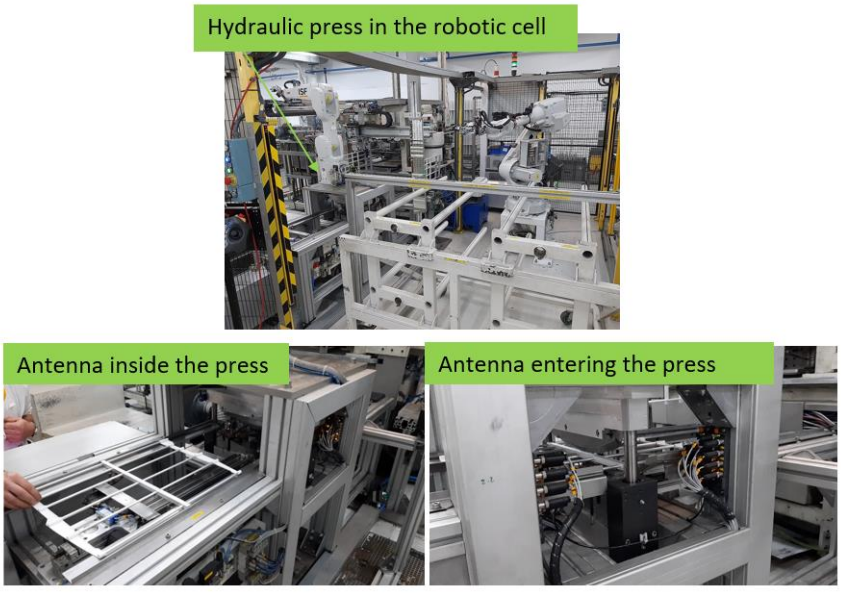
Table 47: User Requirements (UR) exported from videos per process, UR category and Priority (MTCL)

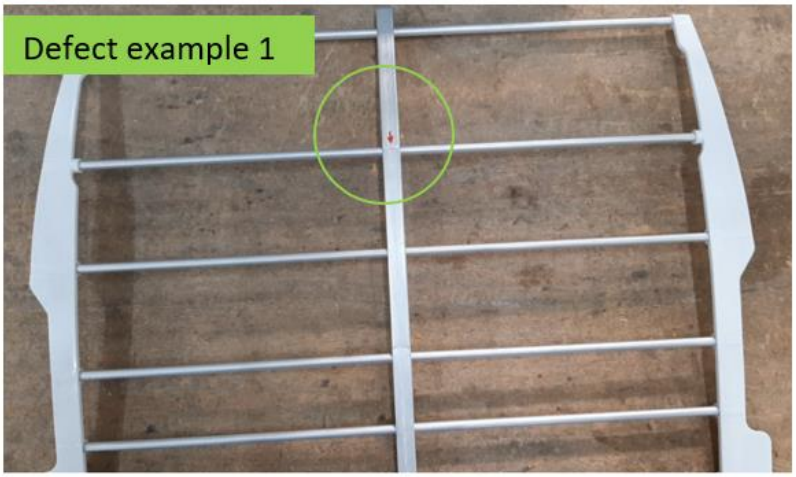
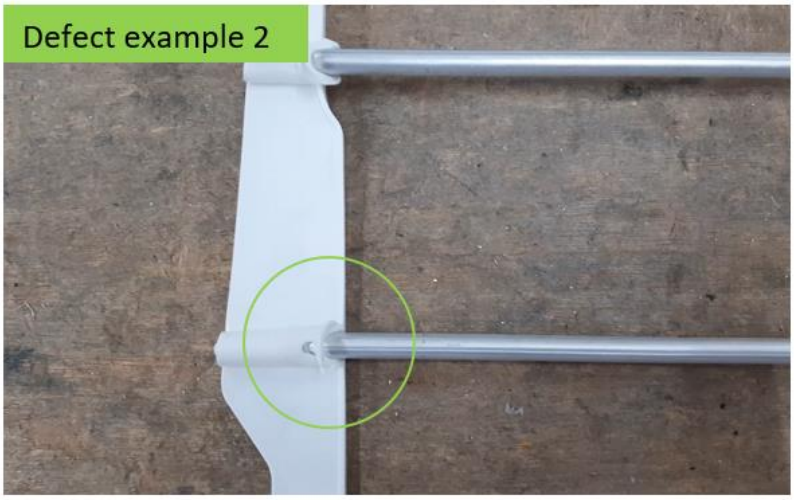
User Requirements (UR) exported from videos per process, UR category and Priority					
Pilot: MTCL	Priority				
UR category	Must	Should	Could	Would	Total
GPD dispensing					
Defect detection	2	2			4
Optimal Set Up	2	1			3

Digital Twin		3			3
Water sawing					
Defect detection	1	3			4
Optimal Set Up					
Digital Twin					
Printed Circuit Board (PCB) Routing					
Defect detection		2			2
Optimal Set Up					
Digital Twin					
Total	3	12	1		16

3.2.3 TELEVES: Antenna manufacturing

Table 48: Antenna line - defect detection

PILOT	TELEVES - TVES
User	Operator
Current procedure:	Antenna line - defect detection
Current procedure description:	In the robotized antenna assembly line, materials used are coming from other sections, as well as materials that are processed in the Antenna Plant itself. Those coming from other sections meet the required quality guarantees, however, there are materials that are processed in the Antenna Plant that might not be detected as defective before entering the line. The Hydraulic press step generates defective antennas which can be reduced. In this step, what caused the defect is not always known. 

	When a defected antenna is detected, the operator removes it from the line to repair.   Antenna line produces many different configurations that involves the use of many different parts were a delayed failure detention can cause a significant scrap. This line is constantly being reused and operated under differing products configurations. This requires the regular break down and set up of equipment on a batch basis.
User goals:	Defect detection: • It is desirable the users to be informed about defective materials entering the antenna line, that currently are not detected. • It is desirable the users to be informed about defective final products (e.g. incorrect assembly) to increase product quality. • It is desirable the users to be able to monitor some parameters that can indicate suboptimal manufacturing (e.g. reduced efficiency by changes between different products assembled on the line, stoppages in inspection systems,

	incidents in material feeding peripherals/ pallet conveyor systems, software/hardware incidents in robotic cells). (Re)-Calibration: • It is desirable some of the parameters of the machinery to be adjusted automatically when defects are detected so that defects are not propagated (so that no more defective parts are produced). • It is desirable some of the machine parameters to be re-calibrated automatically when suboptimal manufacturing is being detected (e.g. reduced efficiency by changes between different products assembled on the line, stoppages in inspection systems, incidents in material feeding peripherals/ pallet conveyor systems, software/hardware incidents in robotic cells). • It is desirable the users to use Human Computer Interface based on gestures to interact with the machinery to save time. Calibration / Production planning: • It is desirable the users to be able to run production scenarios on a digital replica of the antenna line, including machinery, robotic cells and virtual sensors, to save time and reduce cost from testing. • It is desirable the users to test different set up of parameters in the production line, to apply the optimal set up for different types of products, without testing them on the real production line to save time and reduce cost. • It is desirable the users to rapidly set up the production line, by transferring the optimal parameters set up from the virtual testing environment to the real production line. • It is desirable for the users to know the cause of suboptimal manufacturing detected (reduced efficiency, incorrect assembly etc.) and the corresponding corrective actions that might resolve the issue. • It is desirable the users to be informed about predicted upcoming defects through the virtual testing environment.

Table 49: Defect detection (TVES-VID- DD –UR1)

ID	TVES-VID- DD –UR1	Requirement	Defect detection	Priority
Description	Detect at source reflectors with small breaks caused by incorrect folding			Must

Table 50: Defect detection (TVES-VID- DD –UR2)

ID	TVES-VID- DD –UR2	Requirement	Defect detection	Priority
Description	Detect at source reflectors with imperfections in the plastic housings caused by poor insertion of the elements.			Must

Table 51: Defect detection (TVES-VID- DD –UR3)

ID	TVES-VID- DD –UR3	Requirement	Defect detection	Priority
Description	Store information on detected faults.			Must

Table 52: Optimal setup (TVES-VID- OSU –UR1)

ID	TVES-VID- OSU –UR1	Requirement	Optimal set up	Priority
Description	Verify correctly loaded tasks in the different cells of the robotic line and generate alarms when incorrect configurations are detected.			Should

Table 53: Optimal setup (TVES-VID- OSU –UR2)

ID	TVES-VID- OSU –UR2	Requirement	Optimal set up	Priority
Description	Verify the presence of suitable materials in the feeding peripheries and generate alarms when incorrect configurations are detected.			Should

Table 54: Optimal setup (TVES-VID- OSU –UR3)

ID	TVES-VID- OSU –UR3	Requirement	Optimal set up	Priority
Description	Display line configuration information in graphical interface			Should

Table 55: Digital twin (TVES-VID- DT –UR1)

ID	TVES-VID- DT –UR1	Requirement	Digital Twin	Priority

Description	Users must be able to run production scenarios on a digital replica of the antenna line, including machinery, robotic cells and virtual sensors, to save time and reduce cost from testing.	Must

Table 56: Digital twin (TVES-VID- DT –UR2)

ID	TVES-VID- DT –UR2	**Requirement**	Digital Twin	**Priority**
Description	Users must be able to test different set up of parameters in the production line, to apply the optimal set up for different types of products, without testing them on the real antenna line to save time and reduce cost.			Must

Table 57: Digital twin (TVES-VID- DT –UR3)

ID	TVES-VID- DT –UR3	**Requirement**	Digital Twin	**Priority**
Description	Users should be able to rapidly set up the antenna line, by transferring the optimal parameters set up from the virtual testing environment to the real production line.			Should

Table 58: Digital twin (TVES-VID- DT –UR4)

ID	TVES-VID- DT –UR4	**Requirement**	Digital Twin	**Priority**
Description	Users should be able to know the cause of suboptimal manufacturing detected (reduced efficiency, incorrect assembly etc.) in the antenna line and the corresponding corrective actions that might resolve the issue.			Should

Table 59: Digital twin (TVES-VID- DT –UR5)

ID	TVES-VID- DT –UR5	**Requirement**	Digital Twin	**Priority**
Description	Users can be informed about predicted upcoming defects through the virtual testing environment of the antenna line.			Could

Table 60: User Requirements (UR) exported from videos per process, UR category and Priority (TVES)

User Requirements (UR) exported from videos per process, UR category and Priority

Pilot: TVES	Priority				
UR category	Must	Should	Could	Would	Total
Antenna line					
Defect detection	3				3
Optimal Set Up		3			3
Digital Twin	2	2	1		5
Total	5		1		11

Table 61: Total User Requirements (UR) exported from videos per process, UR category and Priority

User Requirements (UR) exported from videos per Pilot, UR category and Priority					
	Priority				
UR category	Must	Should	Could	Would	Total
KLEE					6
Defect detection	2		1		3
Optimal Set Up	2				2
Digital Twin	1				1
MTCL					16
Defect detection	3	7			10
Optimal Set Up	2	1			3
Digital Twin		3			3
TVES					11
Defect detection	3				3
Optimal Set Up		3			3
Digital Twin	2	2	1		5
Total	13	17	3		33

3.3 Functional requirements

The functional requirements have been identified based on the OPTIMAI architecture (Figure 5). In this version the functional requirements have been updated based on the end-user and technical workshops that took place in January 2022.

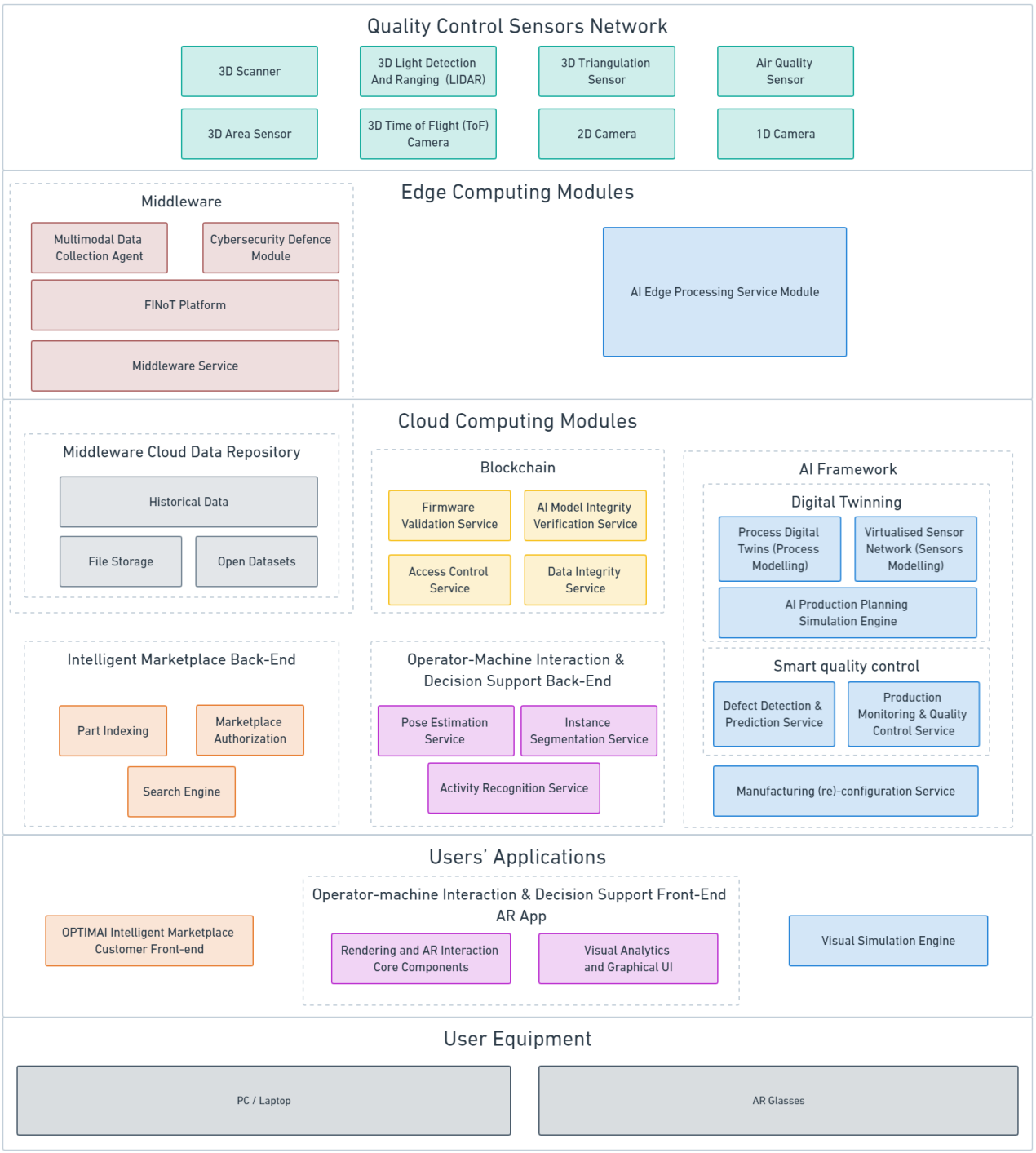


Figure 5: OPTIMAI Architecture

Defining the components and subcomponents associated with each requirement is important to help structure a requirement list and to get a clearer picture of the technical developments that need to be achieved. The associated component defines which Work Package (WP) and Task (T) are involved, and hence determines to whom the requirement is assigned for resolution, typically the WP and T Leader. The following components have been identified based on the OPTIMAI architecture (Table 62) that was developed and analysed in *"D2.4 OPTIMAI Architecture specifications 1st version"* [2].

Table 62: OPTIMAI Architecture components

A/A	OPTIMAI Architecture component	Short
1	Quality Control Sensors Network: • 3D Scanner • 3D Area Sensor • 3D Time of Flight (ToF) Camera • 3D Light Detection And Ranging (LI-DAR) • 3D Triangulation Sensor • 2D Camera • 1D Camera • Air Quality Sensor	QCSN
2	Edge Computing Modules: • **Middleware:** ✓ *Multimodal Data Collection Agent (Multimodal Data Registration)* ✓ *FINoT Platform* ✓ *Middleware Service* ✓ *Cybersecurity Defence Module* • **AI Edge Processing Service module (Acquisition Optimisation)**	ECM MID AIEPS
3	Cloud Computing Modules: • **Middleware Cloud Data Repository (Data Repository)** ✓ *File Storage (Data Collection)* ✓ *Historical Data* ✓ *Open Datasets* • **Blockchain** ✓ *Firmware validation Service* ✓ *AI Model Integrity Verification Service* ✓ *Access Control Service* ✓ *Data Integrity Service* • **Operator-Machine Interaction & Decision Support (OMIDES) Back-End** ✓ *Pose Estimation Service* ✓ *Activity Recognition Service* ✓ *Instance Segmentation Service* • **Intelligent Marketplace Back-End** ✓ *Part Indexing* ✓ *Marketplace Authorisation* ✓ *Search Engine*	CCM MCDR BC OMIDES (BE) IMBE
4	AI Framework: • **Digital Twinning (Digital Twins)** ✓ *Process Digital Twins (Process Modelling)* ✓ *Virtualised Sensor Network (Sensors Modelling)* ✓ *AI Production Planning Simulation Engine* • **Smart Quality Control** ✓ *Defect Detection & Prediction Service*	AIF DT SQC

	✓ *Production Monitoring & Quality Control Service (Production Monitoring)* • Manufacturing (re-) configuration Service	MRS
5	End-users' Applications: • OPTIMAI Intelligent Marketplace Customer Front-end • OMIDES Front-End ✓ *Rendering and AR Interaction Core Components* ✓ *Visual Analytics and Graphical UI* • Visual Simulation Engine	EUA IMCFE OMIDES (FE) VSE

A short high-level overview of the OPTIMAI architecture is provided in the following paragraphs before presenting the updated functional requirements. More information on the OPTIMAI architecture is available in *"D2.4 The OPTIMAI architecture specifications -1st version"* [2].

1. Quality Control Sensors Network Subsystem

The Quality Control Sensors (QCS) Network subsystem involves the IoT sensor devices that will be deployed for collecting the production data. Several types of devices have been identified in the context of Task 3.1 "Multisensorial data acquisition and actuation network", and a complete list of devices and specifications will be provided in D3.1.

2. Edge Computing Modules Subsystem

Edge computing is one of the key-enabling factors for rapid execution of code that was originally intended for Cloud computing resources, on either the devices them-selves, or other devices in close distance such as gateways or personal computers. The edge node architecture is supported by two sub-modules:

i. the **Middleware** sub-module, which is responsible for the real-time sensors' data collection, the cybersecurity of the data as soon as they enter the system, the sensor health monitoring functions and the coordination of the information flows between the edge and cloud modules
ii. the **Artificial Intelligence (AI) Edge Processing Service** sub-module, which is responsible for the AI services on-the-edge, in order to optimize the operational processes of acquisition, detection and analysis

3. Cloud Computing Modules Subsystem

The Cloud Computing Modules subsystem includes the components that will be implemented on a cloud computing environment, because of their storage and computational power (e.g., for processing-heavy AI and other routines) requirements. In support of the cloud computing modules subsystem, the following subsystems and modules are defined:

i. the **Middleware Cloud Data Repository** subsystem, which operates as the centralised storage space of all the data that will be used in the OPTIMAI system

ii. the **Blockchain** subsystem, which maintains a distributed ledger of all critical operations, automates production processes through smart contracts and provides data integrity verification mechanisms
iii. the **Operator-Machine Interaction & Decision Support (OMIDES) Back-End** subsystem, which is responsible for providing the necessary AI routines for processing the visual information obtained from the operator's point of view (with the use of Augmented Reality (AR) glasses), in order to offer a spatial and contextual information output, related to the production line, as identified and communicated by an "augmented" operator
iv. the **Intelligent Marketplace Back-End** subsystem, which enables the storage and transactions of data generated by the users in order to assist the OPTIMAI scrap and AI models marketplace solution

4. AI Framework Subsystem

The **AI Framework** subsystem, enables the production line virtualisation and simulation, provides smart quality control services and calculates production optimization parameters through predictive analytics techniques applied on the cloud resources. It involves three cloud-based AI driven subsystems and components that support the operation of OPTIMAI system:

i. the **Digital Twinning** subsystem provides an AI-powered simulation and virtual representation of the production systems for optimisation analysis
ii. the **Smart Quality Control** subsystem optimizes the production line through data-intensive defect detection and prediction routines
iii. the **Manufacturing (re-)configuration Service** provides the intelligent orchestration of production equipment configuration.

5. End-users' Applications

The End-users' Applications module involves the following two subsystems:

i. the **OPTIMAI Intelligent Marketplace Customer Front-end** sub-system, which is responsible for the end-user UI experience, including item/part listings, user profiles for sellers and buyers, content and feedback pages, guide buyers through the transaction flows and monitoring capabilities
ii. the **OMIDES Front-End** sub-system is responsible for the different applications that will assist operators in the production line processes by providing AR-enabled features realized through the OPTIMAI-developed AR glasses
iii. the **Visual Simulation Engine** sub-system, which is responsible for the front-end visualisation of the Digital Twinning Subsystem. With the use of a 3D graphics engine, the system will allow for the creation of virtual factory layout or development of processes based on tasks. A statistics UI will also be available to enable the performance monitoring of the virtual factory.

The updated **functional requirements** (FR) are presented in the following tables. In this version, the list of the components and the partners, that are responsible for each of the identified requirements are presented.

Table 63: Connectivity (FR-1)

ID	FR-1	**Requirement**	Connectivity	**Priority**	**Component**	**Partner**
Description	The system and the developed sensors shall be able to be connected with other sensors and machines			Must	QCSN ECM MID	EVT FINT ENG
Implementation in OPTIMAI	FR-1a: The sensor system shall by simply connected to the machine controller (PLC) and through the same cable to other systems (SCADA) FR-1b: The developed sensor interface shall be adapted to a bigger variety of sensors such as high accuracy 3D cameras, machine, thermal and hyperspectral sensors. FR-1c: The system shall be able to communicate with the factory machines, shop-floor systems and management systems.		Linked to: Q-UR-5			

Table 64: Data processing (FR-2)

ID	FR-2	**Requirement**	Data processing	**Priority**	**Component**	**Partner**
Description	The system shall be able to process data generated from sensors			Must	ECM MID CCM MCDR	FINT ENG
Implementation in OPTIMAI	FR-2a: The system shall allow sensor data processing on the edge FR-2b: The system shall support fully integrated data acquisition, with embedded		Linked to: MTCL-VID- DD – UR7			

	preprocessing of data (e.g. lightweight AI networks) FR-2c: Inspection data shall be integrated with feedback data				

Table 65: Integration (FR-3)

ID	FR-3	Requirement	Integration	Priority	Component	Partner
Description	The different types of sensors shall be integrated under a common framework			Must	QCSN ECM MID	EVT FINT ENG
Implementation in OPTIMAI	FR-3a: Interfacing with all sensors, machines, actuators		Linked to:			

Table 66: Data management (FR-4)

ID	FR-4	Requirement	Data management	Priority	Component	Partner
Description	The system shall be able to manage the data acquisition and flow to the control and analysis modules			Must	ECM MID	FINT ENG
Implementation in OPTIMAI	FR-4a: The user shall be able to retrieve data regarding the time and production process, allowing the backtracking of possible failures (e.g. defective parts) FR-4b: The information gathered from the various data sources shall be accessible to the end users (e.g. through a QR code in cases that this is applicable, etc.). FR-4c: Middleware for orchestrating data collection FR-4d: Collected data registered in space		Linked to: Q-UR-1 KLEE-VID-DD-UR1 KLEE-VID-DD-UR2 KLEE-VID-OST-UR1 MTCL-VID-DD –UR5 TVES-VID- DD –UR3			

	(production space) and time (timestamp) FR-4e: Data fusion				

Table 67: Cyber-defence (FR-5)

ID	FR-5	Requirement	Cyber-defence	Priority	Component	Partner
Description	The system shall develop a cyber-defence module			Must	ECM MID	FINT
Implementation in OPTIMAI	FR-5a: Middleware shall incorporate a cybersecurity module to protect the sensors network against cyber-threats FR-5b: The system's hardware and software components shall be protected against cyber attacks FR-5c: OPTIMAI security middlebox (OPTIMAISec) will implement the technical controls needed to detect, prevent and mitigate the cyber security threats FR-5d: Deep Neural Network algorithms shall be used for anomaly detection in the network traffic destined or stemming to/from the IoT sensors, machine cameras and AR glasses FR-5e: A dashboard shall be developed for managing the settings and visualizing the alert notifications FR-5f: APIs will be developed for allowing the propagation of the information related to the detected/prevented		Linked to: Q-UR-3 Q-UR-8			

	cyber threats to any authorized visualization, Decision Support System (DSS) or other relevant analysis platform. FR-5g: The HW one will allow primarily for the deployment and realization of the security controls at the edge where the IoT sensors are deployed whereas the virtual one will focus on providing security to the assets living in virtual iKPIastructures (e.g. deployed in a cloud platform).				

Table 68: Recognition (FR-6)

ID	FR-6	Requirement	Recognition	Priority	Components	Partner
Description	The system shall be able to recognise activities, scenes and human recognition			Must	OMIDES (BE)	CERTH
Implementation in OPTIMAI	FR-6a: The system shall be able to separate a particular object from its background and subsequently estimate its pose FR-6b: The system shall be able to recognise human activities within the shop-floor FR-6c: Semantic segmentation shall be performed in real-time based on live-feed from AR glasses		Linked to: Q-UR-12 KLEE-VID-DD-UR1			

Table 69: Interaction (FR-7)

ID	FR-7	Requirement	Interaction	Priority	Component	Partner

Description	The system shall support the interaction of operator and machine		Must	OMIDES (FE)	CERTH FORTH
Implementation in OPTIMAI	FR-7a: The system shall be able to support the fast and accurate interaction of operator and machine	Linked to: TVES-VID-OSU – UR3			

Table 70: Interface (FR-8)

ID	FR-8	**Requirement**	Interface	**Priority**	**Component**	**Partner**
Description	Production Information shall be displayed to the user			Must	OMIDES (FE)	CERTH FORTH
Implementation in OPTIMAI	FR-8a: The system shall be able to display information in the users' field of view through binocular smart glasses lenses. FR-8b: The system shall provide intuitive visual analytics on the workers' AR glasses with respect to the quality level of production	Linked to: KLEE-VID-OST-UR2; MTCL-VID-OSU – UR2; TVES-VID-OSU –UR3				

Table 71: Storage (FR-9)

ID	FR-9	**Requirement**	Storage	**Priority**	**Component**	**Partner**
Description	Data repository			Must	MCDR	FINT
Implementation in OPTIMAI	FR-9a: A data repository shall be established that will be responsible for the management of OPTIMAI's data. FR-9b: The system shall be able to store and retrieve data FR-9c: The insertion of historical data or open datasets shall be supported FR-9d: Standard data formats shall be specified	Linked to: ALL				

Table 72: Integrity, transparency and traceability (FR-10)

ID	FR-10	Requirement	Integrity, transparency and traceability	Priority	Component	Partner
Description	The system shall develop a mechanism that will provide integrity, immutability, transparency and traceability of all critical transactions			Must	BC	CERTH
Implementation in OPTIMAI	FR-10a: Verification mechanisms for the AI models and sensor measurements shall be used FR-10b: A logging/auditing mechanism for the critical operations of the system shall be developed FR-10c: Firmware updates between companies and sensors shall be private and secure FR-10d: All critical operations shall be logged as immutable and verifiable transactions FR-10e: An access control mechanism shall be developed FR-10f: Automation mechanisms shall be developed to enable automation in the processes of the production line		Linked to: Q-UR-4			

Table 73: Marketplace (FR-11)

ID	FR-11	Requirement	Marketplace	Priority	Component	Partner

Description	The system shall develop an intelligent marketplace		Must	IMBE IMCFE	FINT
Implementation in OPTIMAI	FR-11a: The OPTIMAI Marketplace shall enable manufacturing ecosystem players to easily decrease scrap within their production lines and accompanied services. FR-11b: The OPTIMAI Marketplace shall allow customers to register the used raw materials and inputs for each process FR-11c: The OPTIMAI Marketplace shall allow customers to declare the defective products that are produced FR-11d: The OPTIMAI Marketplace shall allow customers to ask for advice regarding alternative methods for exploiting the defective products within their production line FR-11e: The OPTIMAI Marketplace shall allow customers to receive or place offerings for sale or purchase the scrap material from different industries FR-11f: The OPTIMAI Marketplace shall allow customers to browse available algorithms and their capabilities FR-11g: The OPTIMAI Marketplace shall allow customers to search functions and requirements in order to easily deploy them into their production lines	Linked to: TIP-06			

Table 74: Digital twins (FR-12)

ID	FR-12	Requirement	Digital Twins	Priority	Components	Partners
Description	The system shall develop AI enabled digital twin models			Must	AIF (DT)	VIS
Implementation in OPTIMAI	FR-12a: Digital replicas of the manufacturing processes shall be developed in order to connect virtual scenarios with the real production environment. FR-12b: Digital twin models shall be able to identify the source of quality issues and prevent them, mitigating defects as well as saving resources. FR-12c: In-depth primary data together with continually updated real-time processing data shall be used as input for comparison, analysis and optimization. FR-12d: OPTIMAI shall be able to provide predictions and estimations of a physical reading that will occur in the future and compare it with the real value of its physical counterpart. FR-12e: Physical sensors and actuators shall be emulated by virtual sensors that will provide indirect measurements by combining data from different heterogeneous physical sensors, and/or data sources decoupling at the same time the applications and measurements		Linked to: KLEE-VID-DT-UR1; MTCL-VID-DT-UR1; MTCL-VID-DT-UR2; MTCL-VID-DT-UR3; TVES-VID- DT –UR1; TVES-VID- DT –UR2; TVES-VID- DT –UR3; TVES-VID- DT –UR4; TVES-VID- DT –UR5			

	implemented by the physical sensors. FR-12f: OPTIMAI's simulation engine shall be able to incorporate interfaces to the AI models, to enhance quality reducing errors and avoiding downtown manufacturing. FR-12g: OPTIMAI's simulation engine shall be able to perform several simulations in parallel with different configurations to reach the best production plan during runtime operation as well as next-to-real time (~100ms) interaction with the real production environment.				

Table 75: Production Optimisation (FR-13)

ID	FR-13	**Requirement**	Production Optimisation	**Priority**	**Components**	**Partners**
Description	The system shall develop a production optimisation model			Must	AIF (DT, SQC)	VIS CERTH UTH
Implementation in OPTIMAI	FR-13a: Circulation of data across all the OPTIMAI endpoints shall be achieved in order to optimise the resource usage (e.g., network, energy, storage) while guaranteeing the requirements (e.g., latency/freshness of data) of the actuation of production equipment. FR-13b: OPTIMAI shall allow the efficient micro-service execution at edge nodes implementing lightweight stateless operations at edge nodes, collaborating with the cloud workflow		Linked to: Q-UR-7; KLEE-VID-OSU-UR1; KLEE-VID-OSU-UR2; MTCL-VID-OSU – UR1; MTCL-VID-			

	orchestration and monitoring layer, supporting automatic load balancing and self-aware service provisioning reconfiguration FR-13c: Collaborative Filtering based on DNNs as well as Factorizing Machines shall be devised to provide fast context-aware recommendations able to efficiently predict and address emerging defects in production. FR-13d: Equipment parameters based on quality control results shall be directly re-adjusted, using a RL agent without human intervention	OSU – UR2; MTCL-VID-OSU – UR3; TVES-VID-OSU – UR1; TVES-VID-OSU – UR2; TVES-VID-OSU – UR3			

Table 76: Smart quality control (FR-14)

ID	FR-14	**Requirement**	Smart Quality Control	**Priority**	**Components**	**Partners**
Description	A smart quality control system shall be developed for production monitoring and defect detection and prediction			Must	AIF (SQC)	CERTH UTH
Implementation in OPTIMAI	FR-14a: OPTIMAI shall be able to conduct analysis of quality control measurements in the immediate past FR-14b: OPTIMAI shall utilize the digital twins of manufacturing processes under certain parameters FR-14c: OPTIMAI shall be able to process time-series data from one-dimensional signals, image data from cameras or 3D points projections		Linked to: Q-UR-1; Q-UR-12; KLEE-VID-DD-UR2; KLEE-VID-DD-UR3; MTCL-VID- DD -UR1;			

	and point clouds from 3D sensors. FR-14d: OPTIMAI shall be able to capture and exploit cross-sensor correlations in order to improve accuracy and capture the upstream cause of a defect. FR-14e: The identified defects shall be classified into well-established categories and proactive prediction models for early prognostics in manufacturing shall be applied. FR-14f: OPTIMAI shall be able to predict upcoming defects in order to close the loop between defect detection and prediction.	MTCL-VID- DD -UR2; MTCL-VID- DD -UR3; MTCL-VID- DD -UR4; MTCL-VID- DD -UR5; MTCL-VID- DD -UR6; MTCL-VID- DD -UR7; MTCL-VID- DD -UR8; MTCL-VID- DD -UR9; MTCL-VID- DD -UR10			

Table 77: Visualisation and Decision Support (FR-15)

ID	FR-15	Requirement	Visualisation and Decision Support	Priority	Components	Partners
Description	A Visualization and Decision Support system shall be developed to visualise the production monitoring and inspection results			Must	OMIDES (BE) OMIDES (FE)	CERTH FORTH
Implementation in OPTIMAI	FR-15a: AR smart glasses shall be used to present the analytical results from monitoring and inspection and to visualise the analysis results depending on the viewpoint of the operator		Linked to: Q-UR-10; KLEE-VID-DD-UR2; KLEE-VID-DD-UR3; KLEE-VID-OSU-UR1;			

	FR-15b: Decision making shall be supported by the aggregated analytics results and suggestions. FR-15c: The Decision Support System shall import data coming from the AI-based tools and the Human-AI collaboration mechanisms FR-15d: The Decision Support System shall receive data that will be processed in real time FR-15e: The Decision Support System shall integrate assistance solutions for shop-floor operators in decisions related to detection and anticipation of anomalies in the manufacturing processes	KLEE-VID-OSU-UR2; MTCL-VID- DD - UR2; MTCL-VID- DD - UR4; MTCL-VID-OSU – UR1; MTCL-VID-OSU – UR2			

3.4 Non-functional requirements

Non-functional requirements are divided in five main groups i.e. **1) KPIs, 2) Legal requirements, 3) Ethical requirements, 4) Ethical and legal requirements for piloting activities and 5) Technology innovation potential requirements**

3.4.1 KPIs

Based on the end-users' feedback and in line with the OPTIMAI's vision, the identified KPIs have been updated in order to assist in verifying the performance of the developed solution. Five (5) KPIs have been updated i.e. KPI-3, KPI-6, KPI-7, KPI-9 and KPI-18.

Table 78: Network traffic (KPI-1)

ID	KPI-1	**Requirement**	Network traffic	**Priority**
Description	Reduction of sensor network traffic			Should
Implementation in OPTIMAI	KPI-1a: Reduce in network traffic with the use of fog computing > 60%		Linked to: KPI O1.2	

Table 79: Data latency (KPI-2)

ID	KPI-2	**Requirement**	Data latency	**Priority**

Description	Data latency improvement		Should
Implementation in OPTIMAI	KPI-2a: Latency between data acquisition and availability on the middleware < 2 sec	Linked to: KPI O1.2:	

Table 80: Security and privacy (KPI-3)

ID	KPI-3	Requirement	Security and privacy	Priority
Description	Security and privacy improvement			Must
Implementation in OPTIMAI	KPI-3a: Cyber security and privacy threats (e.g. intrusion detection) will be improved > 60%		Linked to: KPI O2.2	

Table 81: Sensor measurements (KPI-4)

ID	KPI-4	Requirement	Sensor measurements	Priority
Description	Sensor measurement improvement			Should
Implementation in OPTIMAI	KPI-4a: Average improvement on sensor measurements via AI-enhanced acquisition > 30%		Linked to: KPI O1.4	

Table 82: Data validity and traceability (KPI-5)

ID	KPI-5	Requirement	Data validity and traceability	Priority
Description	Ensure real-time validity and traceability of collected data			Should
Implementation in OPTIMAI	KPI-5a: At least 10 critical sensors metadata stored into the blockchain		Linked to: KPI O2.1	

Table 83: Process automation (KPI-6)

ID	KPI-6	Requirement	Process automation	Priority
Description	Improvement in process automation			Should
Implementation in OPTIMAI	KPI-6a: Average improvement in process automation > 75% KPI-6b: Improvement in process automation – quality inspection > 50% KPI-6c: Improvement in pressure monitoring automation > 75% KPI-6d: Improvement in calibration automation > 50%		Linked to: KPI O2.3	

Table 84: Equipment productivity (KPI-7)

ID	KPI-7	Requirement	Equipment productivity	Priority
Description	Improvement in equipment productivity			Should
Implementation in OPTIMAI	KPI-7a: Increased equipment productivity via defect prediction and early detection > 10% KPI-7b: Improved final product quality, as measured by speed, vibrations and noise > 5%		Linked to: KPI O3.1 KPI-PS3.3	

Table 85: Defect accuracy (KPI-8)

ID	KPI-8	Requirement	Defect accuracy	Priority
Description	Improvement in the accuracy of defects			Must
Implementation in OPTIMAI	KPI-8a: Classification accuracy of defects > 90%		Linked to: KPI O3.2	

Table 86: Scrap reduction(quality) (KPI-9)

ID	KPI-9	Requirement	Scrap reduction (quality)	Priority
Description	The improved quality production will reduce scrap			Could
Implementation in OPTIMAI	KPI-9a: Reduction of scrap via increased production quality > 40% KPI-9b: Reduction of the materials that arrive at the robotized antenna line with poor quality due to incorrect processing in some machine of the antenna manufacturing plant itself > 70% KPI-9c: Reduction of mismatches > 50% KPI-9d: Speed-up of the quality inspection process (30%)		Linked to: KPI O3.3 KPI-PS1.1 KPI-PS3.2	

Table 87: Scrap reduction (repurposing) (KPI-10)

ID	KPI-10	Requirement	Scrap reduction (repurposing)	Priority
Description	The repurposing of equipment will reduce the produced scrap			Could
Implementation in OPTIMAI	KPI-10a: Reduction of scrap through repurposing > 10%		Linked to: KPI O3.4	

Table 88: Behavioural accuracy (KPI-11)

ID	KPI-11	Requirement	Behavioural accuracy	Priority
Description	Improvement in behavioural accuracy			Should
Implementation in OPTIMAI	KPI-11a: Accuracy in behaviour of digital twins and actual counterparts > 85%		Linked to: KPI O4.1	

Table 89: Rump-up time (KPI-12)

ID	KPI-12	Requirement	Ramp-up time	Priority
Description	Improvement in rump-up time			Should
Implementation in OPTIMAI	KPI-12a: Reduction in ramp-up time during preproduction runs via virtualization > 50%		Linked to: KPI O4.2	

Table 90: Time-to-market (KPI-13)

ID	KPI-13	Requirement	Time-to-market	Priority
Description	Improvement in time-to-market			Could
Implementation in OPTIMAI	KPI-13a: Reduction in time-to-market time through optimized production planning > 25%		Linked to: KPI O4.3	

Table 91: Computer vision (KPI-14)

ID	KPI-14	Requirement	Computer vision	Priority
Description	Improvement of computer vision tasks			Should
Implementation in OPTIMAI	KPI-14a: At least 20 frames-per-second (FPS) rate for all computer vision tasks		Linked to: KPI O5.1	

Table 92: Accuracy (KPI-15)

ID	KPI-15	Requirement	Accuracy	Priority
Description	Accuracy improvement			Must
Implementation in OPTIMAI	KPI-15a: Instance segmentation accuracy > 95% and pose estimate accuracy > 90%		Linked to: KPI O5.2	

Table 93: Interaction accuracy (KPI-16)

ID	KPI-16	Requirement	Interaction accuracy	Priority
Description	Improvement of operator-machine interaction			Must
Implementation in OPTIMAI	KPI-16a: Operator-machine interaction (gesture & activity) accuracy > 95 %		Linked to: KPI O5.3	

Table 94: Interaction latency (KPI-17)

ID	KPI-17	Requirement	Interaction latency	Priority
Description	Improvement of interaction latency			Should
Implementation in OPTIMAI	KPI-17a: Latency from operator-machine interaction < 5 sec		Linked to: KPI O5.4	

Table 95: Automated calibration (KPI-18)

ID	KPI-18	Requirement	Automated calibration	Priority
Description	Improvement of equipment productivity through automated recalibration			Should
Implementation in OPTIMAI	KPI-18a: Increased equipment productivity (yield rate) through automated recalibration > 5% KPI-18b: Improved OEE indicator thanks to the conclusions obtained with the help of the developed systems > 5% KPI-18c: Improved total production capacity > 10%. Optimization of the scheduled downtime of production resources (preventive maintenance, interventions for process improvements or modifications, operator training, etc.). KPI-PS3.1: Speed up calibration of the valve block (40%)		Linked to: KPI O5.5 KPI-PS1.2 KPI-PS1.3	

3.4.2 Legal and Ethical requirements

The first set of OPTIMAI legal and ethical requirements remains the same as in the previous version of this deliverable. Each table contains the ID of the requirement and its name, a brief description and how the requirement can be implemented in OPTIMAI. For the legal requirements, the specific provision in which they are laid down is also included in the table.

These tables provide the general legal and ethical requirements that should be considered throughout the duration of the project. These requirements, along with the use cases definition and the elicitation process (webinar, workshop and dialogue sessions) that was conducted by UAB and TRI with OPTIMAI technical partners and end-users constitute the basis for the development of the Ethical and legal requirements for OPTIMAI piloting activities that will be presented in section 3.4.3.

3.4.2.1 Legal requirements

OPTIMAI legal requirements have been divided into five categories. Namely, i) **Human Rights and Fundamental Rights requirements**; ii) **Data processing requirements**, which include both personal data and non-personal data requirements stemming from the General Data Protection

Regulation and Regulation (EU) 2018/1807 on the free flow of non-personal data, respectively; iii) **AI-enabled technologies requirements**, as laid down in the Proposal of the Artificial Intelligence Act – which, at the time of writing is still at the proposal stage but its obligations are already considered to ensure legal compliance once it enters into force; iv) **Health and safety requirements**; and, v) **Responsible business requirements**.

1. *Human Rights and Fundamental Rights*

Sources:

- Universal Declaration of Human Rights (UDHR)[1]
- International Covenant on Economic, Social and Cultural Rights (ICESCR)[2]
- International Covenant on Civil and Political Rights (ICCPR)[3]
- International Convention on the Protection of the Rights of All Migrant Workers and Members of their Families (ICMW)[4]
- International Convention on the Elimination of All Forms of Racial Discrimination (ICERD)[5]
- Convention on the Elimination of All Forms of Discrimination against Women (CEDAW)[6]
- Convention on the Rights of Persons with Disabilities (CRPD)[7]
- European Convention on Human Rights (ECHR)[8]
- Charter of Fundamental Rights of the European Union (CFREU)[9]

Table 96: Dignity (DIG)

ID	DIG	Requirement	Dignity		Priority
Description	Human dignity				Must
Implementation in OPTIMAI	DIG-R1. The dignity of all human beings must be protected and respected.			Art. 1 UDHR Art. 3 CRPD Art. 1 CFREU	

Table 97: Integrity (INT)

ID	INT	Requirement	Integrity	Priority

[1] https://www.un.org/en/about-us/universal-declaration-of-human-rights
[2] https://www.ohchr.org/en/professionalinterest/pages/cescr.aspx
[3] https://www.ohchr.org/EN/ProfessionalInterest/Pages/CCPR.aspx
[4] https://www.ohchr.org/EN/ProfessionalInterest/Pages/CMW.aspx
[5] https://ohchr.org/EN/ProfessionalInterest/Pages/CERD.aspx
[6] https://www.ohchr.org/EN/ProfessionalInterest/Pages/CEDAW.aspx
[7] https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html
[8] https://www.echr.coe.int/Documents/Convention_ENG.pdf
[9] https://www.europarl.europa.eu/charter/pdf/text_en.pdf

Description	Human physical and mental integrity		Must
Implementation in OPTIMAI	INT-R1. The physical and mental integrity of all human beings must be respected.	Art. 3 CFREU Art. 17 CRPD	

Table 98: Equality and non-discrimination (EDN)

ID	END	Requirement	Equality and non-discrimination	Priority
Description	Equality and non-discrimination			Must
Implementation in OPTIMAI	END-R1. Distinctions made on the basis of sex, race, colour, ethnic or social origin, genetic features, language, religion or belief, political or any other opinion, membership of a national minority, property, birth, disability, age or sexual orientation are prohibited		Art. 2 UDHR Art. 2 ICESCR Art. 26 ICCPR Art. 7 ICMW Art. 1 ICERD Art. 1 CEDAW Art. 5 CRPD Art. 14 ECHR Art. 21 CFREU	
	END-R2. Accessibility of persons with disabilities to technologies should be ensured. Reasonable efforts must be made to design, develop, and deploy OPTIMAI solutions in a way that does not exclude or displace any people with disabilities currently capable of working in the industrial context.		Art. 9 CRPD	

Table 99: Privacy and data protection (PDP)

ID	PDP	Requirement	Privacy and data protection	Priority
Description	Personal data means any information relating to an identified or identifiable natural person ('data subject').			Must
Implementation in OPTIMAI	PDP-R1. Everyone's privacy, family life, home, correspondence and other communications must be respected.		Art. 12 UDHR Art. 17 ICCPR	

		Art. 14 ICMW Art. 22 CRPD Art. 8 ECHR Art. 7 CFREU	
	PDP-R2. Everyone has the right to the protection of their personal data.	Art. 8 CFREU Art. 31 CRPD	

Table 100: Workers' rights (WOR)

ID	WOR	**Requirement**	Workers' rights		**Priority**
Description	Workers' rights				Must
Implementation in OPTIMAI	WOR-R1. Everyone has the right to work and to protection against unemployment. In this regard, OPTIMAI solutions must not put at risk the employment of individuals.			Art. 23 UDHR Art. 6 ICESCR Art. 5 ICERD Art. 11 CEDAW Art. 27 CRPD Art. 15 CFREU	
	WOR-R2. Everyone has the right to just and favourable conditions of work, which respect worker's health, safety and dignity			Art. 23 UDHR Art. 7 ICESCR Art. 25 ICMW Art. 5 ICERD Art. 11 CEDAW Art. 27 CRPD Art. 31 CFREU	
	WOR-R3. Everyone, regardless of their sex, race, colour, ethnic or social origin, genetic features, language, religion or belief, political or any other opinion, membership of a national minority,			Art. 23 UDHR Art. 7 ICESCR	

	property, birth, disability, age or sexual orientation, has the right to equal pay for equal work and equal opportunities	Art. 7 ICMW Art. 5 ICERD Art. 11 CEDAW Art. 27 CRPD Art. 23 CFREU	
	WOR-R4. Everyone has the right to form and to join trade unions for the protection of her or his interests.	Art. 23 UDHR Art. 8 ICESCR Art. 22 ICCPR Art. 26 ICMW Art. 5 ICERD Art. 27 CRPD Art. 11 ECHR Art. 12 CFREU	
	WOR-R5. Disabled workers have the right to continuing training	Art. 27 CRPD	

2. *Data processing activities*

- General Data Protection Regulation (GDPR)[10]
- Regulation (EU) 2018/1807 of the European Parliament and of the Council of 14 November 2018 on a framework for the free flow of non-personal data in the European Union (Regulation (EU) 2018/1807)[11]

Table 101: Data protection (DPR)

ID	DPR	Requirement	Data protection	Priority
Description	Personal data means any information relating to an identified or identifiable natural person ('data subject'). An identifiable natural person is one who can be identified, directly or indirectly, in particular by			Must

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0679&from=EN
[11] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1807&from=EN

	reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person.		
Implementation in OPTIMAI	DPR-R1. Any processing of personal data should be lawful, fair and transparent. For the processing of personal data to be lawful, the specific grounds for the processing must be identified. The processing of personal data is fair when personal data is only handled in ways that people would reasonably expect and not used in ways that have unjustified adverse effects on them. The principle of transparency requires openness about the processing of personal data. Any information and communication relating to the processing of those personal data should be easily accessible and easy to understand. Clear and plain language should be used.	Art. 5 GDPR	
	DPR-R2. Personal data should only be collected for specified, explicit, and legitimate purposes and not further processed in a manner that is incompatible with those purposes; further processing for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes shall, in accordance with Article 89(1), not be considered to be incompatible with the initial purposes.	Art. 5 GDPR	
	DPR-R3. The processing of personal data must be adequate, relevant, and limited to what is necessary in relation to the purposes for which they are processed. Only personal data that is needed to achieve the purpose can be processed. Nor should the data include irrelevant details. Personal data should be processed only if the purpose of the	Art. 5 GDPR	

	processing could not reasonably be fulfilled by other means.		
	DPR-R4. Personal data must be accurate and, where necessary, kept up to date. To this end, reasonable steps must be taken to erase or rectify inaccurate personal data without delay. Personal data will be reviewed and updated as necessary.	Art. 5 GDPR	
	DPR-R5. Personal data must be kept in a form that allows the identification of data subjects for no longer than is necessary for the purposes for which the personal data are processed. Based on the purpose for processing, retention periods should be established.	Art. 5 GDPR	
	DPR-R6. The security and confidentiality of personal data must be ensured. Appropriate technical or organisational measures should be adopted to ensure protection against unauthorised or unlawful access to or use of personal data and the equipment used for the processing and against accidental loss, destruction, or damage.	Art. 5 GDPR	
	DPR-R7. Personal data can only be processed if a valid lawful basis applies. There are six lawful bases for processing: 1. Consent: the individual has given consent to the processing of his/her personal data for a specific purpose. 2. Contract: the processing is necessary for the performance of a contract. 3. Legal obligation: the processing is necessary to comply with the law. 4. Vital interests: the processing is necessary to protect someone's life. 5. Public task: the processing is necessary to perform a task in the public interest or official	Art. 6 GDPR	

	functions. The task or function must have a clear basis in law. 6. Legitimate interests: the processing is necessary for your legitimate interests or the legitimate interests of a third party. However, if there is a good reason to protect individuals' personal data, those legitimate interests must be overridden.		
	DPR-R8. If the processing of personal data relies on consent, the following conditions apply: - Consent must be freely given, specific, informed and unambiguous. - If consent is given in the context of a written declaration that also concerns other matters, the request for consent shall be presented in a manner that is clearly distinguishable from the other matters, in an intelligible and easily accessible form, using clear and plain language. - Data subjects have the right to withdraw their consent at any time without detrimental consequences. Before giving consent, the data subject shall be informed thereof.	Art. 7 GDPR	
	DPR-R9. Processing of sensitive personal data, i.e., personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, and the processing of genetic data, biometric data for the purpose of uniquely identifying a natural person, data concerning health, or data concerning a natural person's sex life or sexual orientation is prohibited. Unless: - the data subject has given explicit consent to the processing of	Art. 9 GDPR	

	those personal data for one or more specified purposes. - processing is necessary for the purposes of carrying out the obligations and exercising specific rights of the controller or of the data subject in the field of employment and social security and social protection law in so far as it is authorised by Union or Member State law or a collective agreement pursuant to Member State law providing for appropriate safeguards for the fundamental rights and the interests of the data subject. - processing is necessary to protect the vital interests of the data subject or of another natural person where the data subject is physically or legally incapable of giving consent. - processing is carried out in the course of its legitimate activities with appropriate safeguards by a foundation, association or any other not-for-profit body with a political, philosophical, religious or trade union aim and on condition that the processing relates solely to the members or to former members of the body or to persons who have regular contact with it in connection with its purposes and that the personal data are not disclosed outside that body without the consent of the data subjects. - processing relates to personal data which are manifestly made public by the data subject. - processing is necessary for the establishment, exercise or defence of legal claims or whenever courts are acting in their judicial capacity.		

	- processing is necessary for reasons of substantial public interest. - processing is necessary for the purposes of preventive or occupational medicine, for the assessment of the working capacity of the employee, medical diagnosis, the provision of health or social care or treatment or the management of health or social care systems and services on the basis of Union or Member State law or pursuant to contract with a health professional. - processing is necessary for reasons of public interest in the area of public health. - processing is necessary for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes in accordance with Article 89(1).		
	DPR-R10. Data subjects have the right to be informed, the right of access, right to rectification, right to erasure, right to restriction of processing, right to object and the right not to be subject to automated decisions	Arts. 13-22 GDPR	
	DPR-R11. Controllers must implement appropriate measures to comply with the data protection by design and data protection by default principles	Art. 25 GDPR	
	DPR-R12. Controllers must keep records of all processing activities under their responsibility.	Art. 30 GDPR	
	DPR-R13. Controllers and processors must cooperate with Data Protection Authorities, upon request.	Art. 31 GDPR	
	DPR-R14. Controllers and processors must implement appropriate technical and organisational measures to ensure a level of security appropriate to the risk, including:	Art. 32 GDPR	

	- the pseudonymisation and encryption of personal data - the ability to ensure the ongoing confidentiality, integrity, availability and resilience of processing systems and services - the ability to restore the availability and access to personal data in a timely manner in the event of a physical or technical incident - a process for regularly testing, assessing and evaluating the effectiveness of technical and organisational measures for ensuring the security of the processing.		
	DPR-R15. Data protection breaches must be communicated to the Data Protection Authority and the data subjects.	Arts. 33-34 GDPR	
	DPR-R16. Data protection impact assessments must be conducted before the deployment of OPTIMAI solutions.	Art. 35 GDPR	

Table 102: Use of non-personal data (NDP)

ID	NPD	**Requirement**	Use of non-personal data	**Priority**
Description	Non-personal data refers to information that does not relate to an identified or identifiable natural person.			Must
Implementation in OPTIMAI	NPD-R1. Data must be made available to competent authorities upon request.		Art. 5 Regulation (EU) 2018/1807	

3. *AI-enabled technologies*

- Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on Artificial Intelligence (Artificial Intelligence Act) and amending certain Union Legislative Acts, COM(2021) 206 final, 21.04.2021.[12]

Table 103: AI-enabled technologies (AIT)

ID	AIT	**Requirement**	AI-enabled technologies	**Priority**

[12] https://eur-lex.europa.eu/resource.html?uri=cellar:e0649735-a372-11eb-9585-01aa75ed71a1.0001.02/DOC_1&format=PDF

Description	Artificial intelligence system means software that is developed with one or more of the following techniques and approaches: (a) Machine learning approaches, including supervised, unsupervised and reinforcement learning, using a wide variety of methods including deep learning; (b) Logic-and knowledge-based approaches, including knowledge representation, inductive (logic) programming, knowledge bases, inference and deductive engines, (symbolic) reasoning and expert systems; (c) Statistical approaches, Bayesian estimation, search and optimization methods And that for a given set of human-defined objectives, generate outputs such as content, predictions, recommendations, or decisions influencing the environments they interact with.		Must
Implementation in OPTIMAI	AIT-R1. The following artificial intelligence practices are prohibited: (a) the placing on the market, putting into service or use of an AI system that deploys subliminal techniques beyond a person's consciousness in order to materially distort a person's behaviour in a manner that causes or is likely to cause that person or another person physical or psychological harm. (b) the placing on the market, putting into service or use of an AI system that exploits any of the vulnerabilities of a specific group of persons due to their age, physical or mental disability, in order to materially distort the behaviour of a person pertaining to that group in a manner that causes or is likely to cause that person or another person physical or psychological harm; (c) the placing on the market, putting into service or use of AI systems by public authorities or on their behalf for the evaluation or classification of the trustworthiness of natural persons over a certain period of time based on their	Art. 5 Artificial Intelligence Act Proposal	

	social behaviour or known or predicted personal or personality characteristics.		
	AIT-R2. Assessment of whether OPTIMAI solutions are considered high-risk AI system. In the employment context, AI systems intended to be used for making decisions on promotion and termination of work-related contractual relationships, for task allocation and for monitoring and evaluating performance and behaviour of persons in such relationships, are considered high-risk.	Art. 6 and Annex III Artificial Intelligence Act Proposal	
	AIT-R3. If OPTIMAI solutions are deemed to be high-risk, measures to address the following requirements must be in place: - A risk management system shall be established, implemented, documented and maintained. - Training, validation and testing data sets shall be subject to appropriate data governance and management practices. - Technical documentation of the system - The system must be designed and developed with capabilities enabling record-keeping. - The system must be designed and developed to ensure a high degree of transparency that enables users to interpret the system's output and use it appropriately. - The system must be designed and developed in such a way that enables human oversight. Thereby, including appropriate human-machine interface tools. - The system must be accurate, robust and cyber secure.	Arts. 8-15 Artificial Intelligence Act Proposal	
	AIT-R4. Providers of high-risk AI systems must, upon request by a national competent authority, provide that	Arts. 23 Artificial	

	authority with all the information and documentation necessary to demonstrate the conformity of the high-risk AI system with the above-mentioned requirements	Intelligence Act Proposal	

4. *Health and safety procedures*

Relevant EU health and safety directives:

- Framework Directive (Directive 89/391/EEC)[13]
- Workplace requirements (Directive 89/654/EEC)[14]
- Work equipment (Directive 2009/104/EC)[15]
- Personal Protective Equipment (PPE) (Directive 89/656/EEC)[16]

Table 104: Health and safety procedures (H&S)

ID	H&S	**Requirement**	Health & safety procedures	**Priority**
Description	Respect for safety and health requirements.			Must
Implementation in OPTIMAI	H&S-R1. H&S require from the OPTIMAI partners fulfilment of the fundamental principles related to safety and health at the workplace, such as technical maintenance of equipment and devices, emergency exits, adequate hygiene and employer responsibilities to address them; employer duties regarding safety and suitability of the equipment used by staff in the course of their work, covering such issues as periodic and special inspections of the equipment by competent persons, the use of ergonomic equipment where possible and the appropriate training of workers to use the equipment.			

5. *Responsible business*

- Non-Financial Reporting Directive (KPID) Directive 2014/95/EU[17]
- A proposal for a Corporate Sustainability Reporting Directive (CSRD)[18]

[13] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A31989L0391
[14] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31989L0654
[15] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0104
[16] https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:31989L0656
[17] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014L0095
[18] https://ec.europa.eu/info/publications/210421-sustainable-finance-communication_en#csrd

- The Commission's proposal for a Corporate Sustainability Reporting Directive (CSRD)[19]

Table 105: Non-financial reporting (KPI)

ID	KPI	Requirement	Non-financial reporting	Priority
Description	Certain large companies must disclose information on the way they operate and manage social and environmental challenges. This helps investors, civil society organisations, consumers, policy makers and other stakeholders to evaluate the non-financial performance of large companies and encourages these companies to develop a responsible approach to business.			Should
Implementation in OPTIMAI	KPI-R1. Under Directive 2014/95/EU, large companies have to publish information related to: • environmental matters • social matters and treatment of employees • respect for human rights • anti-corruption and bribery • diversity on company boards (in terms of age, gender, educational and professional background) After adoption of the CSRD, ALL large companies will be obliged to publish such information and follow EU sustainability reporting standards.			

3.4.2.2 Ethical requirements

Ethical requirements have been organised in three categories: i) **Responsible Research Innovation requirements**, which apply to all OPTIMAI research activities; ii) **Responsible Research Innovation in Industry requirements**, which also apply to all OPTIMAI research activities with a particular focus on the industrial context in which OPTIMAI is developed; and, iii) **Technical requirements**, which should be followed when designing, developing and deploying OPTIMAI technical solutions. The purpose of these technical requirements is to put in practice the ethical principles identified by the AI – High-Level Expert Group on Artificial Intelligence and the IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, "Ethically Aligned Design". These ethical principles are: i) human autonomy, ii) prevention of harms, iii) fairness and, iv) transparency/explicability.

1. ***Responsible Research Innovation requirements***

Sources:

[19] https://ec.europa.eu/info/publications/210421-sustainable-finance-communication_en#csrd

- European Commission (2013). *Ethics for Researchers*[20]
- European Code of Conduct for Research Integrity (ALLEA 2017)[21]
- EU Ethical Responsible Research and Innovation Framework (RRI)[22]
- RRI Tools[23]

Table 106: Integrity (RRI-I)

ID	RRI-I	**Requirement**	Integrity	**Priority**
Description	Research activities are conducted according to the highest standards of practice and minimising risks of adverse/harmful results or consequences.			Must
Implementation in OPTIMAI	RRI-I-R1. OPTIMAI research activities should minimise potential risks to researchers and research participants. In particular, measures to protect vulnerable people and ensure their safety and wellbeing should be put in place. RRI-I-R2. Conflicts of interest should be properly identified and avoided. RRI-I-R3. OPTIMAI researchers should avoid misconduct when carrying out OPTIMAI research activities. RRI-R4. OPTIMAI researchers should put in practice all necessary safeguards to ensure confidentiality when processing personal data and in particular sensitive data during the course of the research activities.			

Table 107: Reliability (RRI-R)

ID	RRI-R	**Requirement**	Reliability	**Priority**
Description	The quality of the design, the methodology, the analysis and the use of resources in the research should be ensured.			Must
Implementation in OPTIMAI	RRI-R1. OPTIMAI research activities should be conducted ensuring quality of the design, the methodology, the analysis and the use of resources. RRI-R2. Outcomes drawn from OPTIMAI research activities should be accurate, e.g., methods, results, conclusions, and implications.			

[20] https://ec.europa.eu/research/participants/data/ref/fp7/89888/ethics-for-researchers_en.pdf
[21] http://www.allea.org/wp-content/uploads/2017/03/ALLEA-European-Code-of-Conduct-for-Research-Integrity-2017-1.pdf
[22] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation
[23] https://rri-tools.eu/

Table 108: Honesty (RRI-H)

ID	RRI-H	**Requirement**	Honesty	**Priority**
Description	Developing, undertaking, reviewing, reporting, and communicating the research in a transparent, fair, full and unbiased manner			Must
Implementation in OPTIMAI	RRI-H-R1. OPTIMAI research activities should be conducted, reported and communicated in a transparent, fair and unbiased manner.			

Table 109: Respect (RRI-RP)

ID	RRI-RP	**Requirement**	Respect	**Priority**
Description	Research activities should be carried out with respect for research colleagues, research participants, society and the environment.			Must
Implementation in OPTIMAI	RRI-RP-R1. OPTIMAI research activities should be carried out with respect for research colleagues, research participants, society and the environment.			

Table 110: Accountability (RRI-A)

ID	RRI-A	**Requirement**	Accountability	**Priority**
Description	Researchers should be held accountable for their research. This includes being accountable for publication, management and organisation, training activities, supervision and for the wider impacts of the research.			Must
Implementation in OPTIMAI	RRI-A-R1. OPTIMAI researchers should be accountable for the impact of their research activities. RRI-A-R2. OPTIMAI researchers should be held accountable for publication, management and organisation, training activities, monitoring and for the wider impacts of the research.			

Table 111: Diversity and inclusiveness (RRI-D&I)

ID	RRI-D&I	**Requirement**	Diversity and inclusiveness	**Priority**
Description	Involve early a wide range of actors and publics in R&I practice, deliberation, and decision-making to yield more useful and higher quality knowledge. This strengthens democracy and broadens sources of expertise, disciplines and perspectives.			Must

Implementation in OPTIMAI	RRI-D&I-R1. OPTIMAI researchers should engage relevant stakeholders in the R&I process; including internal stakeholders (project partners, multidisciplinary consortium including Social, Sciences and Humanities researchers) and external stakeholders (end-users, employees, etc.).	

Table 112: Anticipation and reflection (RRI-A&R)

ID	RRI-A&R	**Requirement**	Anticipation and reflection	**Priority**
Description	Envision impacts and reflect on the underlying assumptions, values, and purposes to better understand how R&I shapes the future. This yields valuable insights and increases our capacity to act on what we know.			Must
Implementation in OPTIMAI	RRI-A&R-R1. OPTIMAI R&I processes and their outcomes (tech solutions) should be subjected to integrated impact assessment addressing ethical, legal (including human rights and data protection), societal and environmental aspects, both positive and negative to ensure societal desirability and ethical acceptability of OPTIMAI's solutions. This process should involve all OPTIMAI partners regardless of their expertise.			

Table 113: Openess and transparency (RRI-O&T)

ID	RRI-O&T	**Requirement**	Openness and transparency	**Priority**
Description	Communicate in a balanced and meaningful way, methods, results, conclusions, and implications to enable public scrutiny and dialogue. This benefits the visibility and understanding of R&I.			Must
Implementation in OPTIMAI	RRI-O&T-R1. OPTIMAI should establish meaningful means of communication and dialogue with relevant publics ensuring that OPTIMAI and its stakeholders are mutually responsive.			

Table 114: Responsiveness and adaptation to change (RRI-R&A)

ID	RRI-R&A	**Requirement**	Responsiveness and adaptation to change	**Priority**

Description	Be able to modify modes of thought and behaviour, overarching organizational structures, in response to changing circumstances, knowledge, and perspectives. This aligns action with the needs expressed by stakeholders and publics.	Must
Implementation in OPTIMAI	RRI-R&A-R1. An agile approach to R&I development and integrated impact assessment should be applied.	

2. *Responsible Research Innovation in Industry requirements*

Sources:

- United Nations Guiding Principles on Business and Human Rights[24]
- United Nations Global Compact[25]
- OECD Guidelines for Multinational Enterprises (OECD Guidelines)[26]
- The ILO Tri-partite Declaration of Principles on Multinational Enterprises and Social Policy, and the ILO Core Conventions and the Declaration on Fundamental Principles and Rights at Work (Instruments of the ILO)[27]
- ISO 26000 Guidance Standard on Social Responsibility (ISO 26000)[28]
- Social Accountability 8000[29]
- OHSAS 18001[30]
- ISO 14001 and Eco-Management and Audit Scheme[31]
- UN Sustainable Development Goals (SDGs)[32]

Table 115: Human Rights (RRI-I-HR)

ID	RRI-I-HR	**Requirement**	Human Rights	**Priority**
Description	Due diligence, human rights risk situations, discrimination of vulnerable groups, fundamental principles and rights at work.			Must
Implementation in OPTIMAI	RRI-I-HR-R1. To develop mechanisms to fulfil the state duty to protect against human rights abuses, the corporate responsibility to respect human rights, and the need to help victims achieve remedy related to			

[24] https://www.ohchr.org/Documents/Publications/GuidingPrinciplesBusinessHR_EN.pdf
[25] https://www.unglobalcompact.org/
[26] https://mneguidelines.oecd.org/mneguidelines/
[27] https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/---multi/documents/publication/wcms_094386.pdf and https://www.ilo.org/declaration/thedeclaration/textdeclaration/lang--en/index.htm
[28] https://www.iso.org/iso-26000-social-responsibility.html
[29] https://sa-intl.org/programs/sa8000/
[30] https://www.nqa.com/en-us/certification/standards/ohsas-18001
[31] https://ec.europa.eu/environment/emas/join_emas/emas_iso_14001_en.htm
[32] https://sdgs.un.org/goals

	the development and use of new and emerging technologies relevant for OPTIMAI that may have negative impacts on individual's human rights (due diligence) resulting from the Consortium Partner's decisions and activities related to the technological development of OPTIMAI solutions.	

Table 116: Corporate Social Responsibility (RRI-I-CSR)

ID	RRI-I-CSR	**Requirement**	Corporate Social Responsibility	**Priority**
Description	Integrate social and environmental concerns in companies' business operations and in their interaction with their stakeholders on a voluntary basis.			Could
Implementation in OPTIMAI	RRI-I-CSR-R1. To develop and implement mechanisms and actions over and above companies' legal obligations towards society and the environment ensuring that technology developed and used within the industry context is responsible, sustainable, socially desirable and ethically acceptable.			

Table 117: Labour Practices (RRI-I-LP)

ID	RRI-I-LP	**Requirement**	Labour Practices	**Priority**
Description	Conditions at work and social protection, health and safety at work, human development and training in the workplace, social dialogue.			Must
Implementation in OPTIMAI	RRI-I-LP-R1. To eliminate discrimination in hiring and dismissal. RRI-I-LP-R2. To comply with laws and regulations on the rights of unions and collective bargaining, and social protection (e.g., medical coverage, disability leave). RRI-I-LP-R3. To minimise health and safety risks of the research activities; provide safety equipment and training. RRI-I-LP-R4. To avoid contracting with suppliers or sub-contractors who use unfair or abusive labour practices. RRI-I-LP-R5. All workers should have just and favourable conditions at work.			

Table 118: Community involvement and development (RRI-I-CI)

ID	RRI-I-CI	Requirement	Community involvement and development	Priority
Description	Community involvement, employment creation and skills development, technology development and access, health.			Could
Implementation in OPTIMAI	RRI-I-CI-R1. Job creation, skill development, and provision of health, welfare- among other services - should be integrated into the core "business model". RRI-I-CI-R2. The need to evaluate the economic, social, and environmental impacts of the research. RRI-I-CI-R3. Consider "social investment" iKPIastructures directed to improve quality of life, and which will increase the capacity of the community to develop sustainably.			

Table 119: Fair operating practices (RRI-I-FOP)

ID	RRI-I-FOP	Requirement	Fair operating practices	Priority
Description	Anti-corruption, fair competition, promoting social responsibility, respect property rights.			Must
Implementation in OPTIMAI	RRI-I-FOR-R1. Protect consumers' health and safety; design and test products to ensure this. RRI-I-FOR-R2. Eliminate or minimise negative health and environmental impacts of products and services. RRI-I-FOR-R3. Pay particular attention to the information needs of vulnerable individuals. RRI-I-FOR-R4. Create mechanisms to track decisions and their implementation, to ensure accountability and follow-through. RRI-I-FOR-R5. Develop incentives for performance on social responsibility. RRI-I-FOR-R6. Practice and promote ethical behaviour, accountability and transparency.			

Table 120: Environment (RRI-I-E)

ID	RRI-I-E	Requirement	Environment	Priority
Description	Sustainable resource use, climate change mitigation, protection of the environment, for instance in the context of Sustainable Development Goals (SDGs).			Should

Implementation in OPTIMAI	RRI-I-E-R1. Prevent pollution; reduce emissions of pollutants into the air, water and soil as much as possible. RRI-I-E-R2. Use sustainable, renewable resources whenever possible. RRI-I-E-R3. Practice life-cycle approach to reduce waste, re-use products or components, and re-cycle materials. RRI-I-E-R4. Consider energy consumption given resource-intensive computing processes. RRI-I-E-R5. Practice green procurement (e.g., evaluating suppliers of goods and services on their environmental impacts).	

3. Technical Development requirements

Sources

- Ethics Guidelines for Trustworthy AI – High-Level Expert Group on Artificial Intelligence[33]
- Assessment List for Trustworthy AI – High-Level Expert Group on Artificial Intelligence[34]
- IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, "Ethically Aligned Design"[35]
- Guidelines for the Ethical Development of AI and Big Data Systems: An Ethics by Design approach – SHERPA Project[36]

Table 121: Human agency and oversight (HUM)

ID	HUM	**Requirement**	Human agency and oversight	**Priority**
Description	AI systems should support human autonomy and decision-making, as prescribed by the principle of respect for human autonomy. This requires that AI systems should both act as enablers to a democratic, flourishing and equitable society by supporting the user's agency and foster fundamental rights and allow for human oversight.			Must
	HUM-R1. OPTIMAI solutions should be conceived as a complement to workers with the aim of augmenting and enhancing their skills. HUM-R2. Measures against coercion, threats to mental health and surveillance should be put in place.			

[33] https://digital-strategy.ec.europa.eu/en/policies/expert-group-ai
[34] https://digital-strategy.ec.europa.eu/en/policies/expert-group-ai
[35] https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/other/ead1e.pdf
[36] https://project-sherpa.eu/wp-content/uploads/2019/12/development-final.pdf

Implementation in OPTIMAI	HUM-R3. Legal, social and ethical impact assessments should be conducted to weigh the intended benefits of the deployment of technology in the workplace against the possible negative consequences for employees' ethical values and fundamental rights. HUM-R4. Employees' voluntariness must be ensured. HUM-R5. Training sessions to ensure that workers know and understand how the system works and how to interact with the technology. HUM-R6. Implementation of human-centric design principles from the design phase. HUM-R7. Use of appropriate human-machine interfaces. HUM-R8. Workers must have the expertise, necessary competencies, and authority to exercise human control effectively. HUM-R9. Training sessions to ensure that workers have the expertise, necessary competencies, and authority to exercise human control effectively.	

Table 122: Technical robustness and safety (TRS)

ID	TRS	**Requirement**	Technical robustness and safety	**Priority**
Description	Technical robustness requires that AI systems be developed with a preventative approach to risks and in a manner such that they reliably behave as intended while minimising unintentional and unexpected harm, and preventing unacceptable harm. This should also apply to potential changes in their operating environment or the presence of other agents (human and artificial) that may interact with the system in an adversarial manner. In addition, the physical and mental integrity of humans should be ensured.			Must
Implementation in OPTIMAI	TRS-R1. OPTIMAI solutions must be protected against vulnerabilities and possible unintended applications of the system and potential misuse. TRS-R2. Fallback plans should be put in place to address potential problems. This includes the minimisation of unintended consequences and errors. TRS-R3. Processes should be designed and implemented to clarify and assess potential risks. TRS-R4. Reliability and reproducibility of OPTIMAI solutions should be ensured.			

	TRS-R5. Employees should be able to trust the system. However, employees must be trained to avoid overreliance.	

Table 123: Privacy and data governance (PRI)

ID	PRI	**Requirement**	Privacy and data governance	**Priority**
Description	Closely linked to the principle of prevention of harm is privacy, a fundamental right particularly affected by AI systems. Prevention of harm to privacy also necessitates adequate data governance that covers the quality and integrity of the data used, its relevance in light of the domain in which the AI systems will be deployed, its access protocols and the capability to process data in a manner that protects privacy.			Must
Implementation in OPTIMAI	PRI-R1. Data must be gathered lawfully. PRI-R2. Biases, inaccuracies, errors and mistakes should be addressed prior to training. PRI-R3. At each step of the development, processes and data sets should be tested and documented. PRI-R4. Protocols governing data access should be implemented.			

Table 124: Transparency (TRA)

ID	TRA	**Requirement**	Transparency	**Priority**
Description	This requirement is closely linked with the principle of explicability and encompasses transparency of elements relevant to an AI system: the data, the system and the business models.			Must
Implementation in OPTIMAI	TRA-R1. In order to ensure the traceability of OPTIMAI solutions, all processes and decisions made by the AI system, including the datasets used should be documented. TRA-R2. Understandable explanations related to technical processes, related human decisions and decisions made by AI system should be provided to those direct or indirectly affected. The degree of to which explicability is needed is highly dependent on the context and the severity of the consequences if that output is erroneous or otherwise inaccurate. Explanations should be adapted to the explanation's recipient.			

	TRA-R3. Explainability and interpretability of the AI system should be considered from the designing phase. TRA-R4. Capabilities and limitations of the AI system should be clearly communicated to the end-users.	

Table 125: Diversity, non-discrimination, and fairness (NDI)

ID	NDI	Requirement	Diversity, non-discrimination, and fairness	Priority
Description	In order to achieve Trustworthy AI, we must enable inclusion and diversity throughout the entire AI system's life cycle. Besides the consideration and involvement of all affected stakeholders throughout the process, this also entails ensuring equal access through inclusive design processes as well as equal treatment. This requirement is closely linked with the principle of fairness.			Must
Implementation in OPTIMAI	NDI-R1. OPTIMAI solutions must be user-centric and designed to be used by different end-users, with independence of their age, gender, abilities/characteristics and disabilities. NDI-R2. An assessment of whether persons/groups might be disproportionally affected by OPTIMAI solutions should be conducted. NDI-R3. Mechanisms to flag bias/discrimination/poor performance of OPTIMAI solutions should be implemented. NDI-R4. Processes to test and monitor potential biases of OPTIMAI solutions should be implemented. NDI-R5. Diversity and representativeness of different users should be ensured in the datasets for developing OPTIMAI solutions. NDI-R6. Mechanisms should be put in place to ensure the involvement of different stakeholders (technical developers, workers, ethical and legal experts).			

Table 126: Environmental and societal well-being (WEL)

ID	WEL	Requirement	Environmental and societal well-being	Priority
Description	The broader society, other sentient beings and the environment should be also considered as stakeholders throughout the AI system's life cycle. Sustainability and ecological responsibility of AI			Could

	systems should be encouraged, and research should be fostered into AI solutions addressing areas of global concern, such as, for instance the Sustainable Development Goals (SDGs). Ideally, AI systems should be used to benefit all human beings, including future generations.	
Implementation in OPTIMAI	WEL-R1. Measures to reduce the environmental impact of the system should be adopted. WEL-R2. The need to assess the impact of the system at the individual and societal level.	

Table 127: Accountability (ACC)

ID	ACC	**Requirement**	Accountability	**Priority**
Description	The requirement of accountability complements the above requirements and is closely linked to the principle of fairness. It necessitates those mechanisms be put in place to ensure responsibility and accountability for AI systems and their outcomes, both before and after their development, deployment and use.			Must
Implementation in OPTIMAI	ACC-R1. Impact Assessments should be carried out to identify, assess and minimise potential negative impacts of OPTIMAI solutions. ACC-R2. OPTIMAI solutions should be accessible to operators with different capabilities and skills ensuring that they have sufficient competences to understand the impact and consequences of OPTIMAI solutions. ACC-R3. OPTIMAI solutions should improve quality of life and not cause harm to anyone. In particular, the impact of OPTIMAI solutions in terms of equality, employment, worker well-being, privacy and trust. ACC-R4. Trade-offs between relevant values and interests should be identified and assessed in case of conflict. ACC-R5. Mechanisms should be foreseen to redress decisions made by OPTIMAI solutions and by the humans operating them. To that end, the entity accountable for the decision must be identifiable, and the decision-making processes should be explicable.			

Table 128: Awareness of misuse (AWM)

ID	AWM	**Requirement**	Awareness of misuse	**Priority**

Description	Creators shall guard against all potential misuses and risks of A/IS in operation (e.g., hacking, misuse of personal data, system manipulation, or exploitation of vulnerable users).	Must
Implementation in OPTIMAI	AWM-R1. Technical developers of OPTIMAI solutions should anticipate and reflect their potential risks of misuse. AWM-R2. Technical developers should be aware of the potential misuse, and they should adopt ways to minimise them from the design stage. AWM-R3. Technical developers should raise awareness about the potential misuse of OPTIMAI solutions in an informed manner by: i) providing ethics training and security awareness; ii) and, delivering this training in scalable and effective ways according to the implementation context of the solution.	

Table 129: Competence (COM)

ID	COM	**Requirement**	Competence	**Priority**
Description	Creators shall specify and operators shall adhere to the knowledge and skill required for safe and effective operation.			Should
Implementation in OPTIMAI	COM-R1. Technical developers should specify the types and levels of knowledge necessary to understand and operate OPTIMAI solutions for both the individual components and for the entire systems. COM-R2. Technical developers should integrate safeguards against the incompetent use of OPTIMAI solutions. COM-R3. Policies explaining how OPTIMAI solutions work should be created. COM-R4. Operators of OPTIMAI solutions should, before operating the system, make sure that they have the necessary competencies.			

3.4.3 Ethical and legal requirements for OPTIMAI piloting activities

A set of initial legal and ethical requirements for piloting sites has been identified and provided in D9.2 ('Report on OPTIMAI ethical, legal and societal risks – 1st version') and D9.6 ('Report on the OPTIMAI Regulatory Model – 2nd version'). These requirements have been identified as a result of the ethical, legal and societal impact assessment conducted by WP9 partners and presented in D9.2, and the mitigation measures proposed by technical partners and end-users.

The following tables present these ethical and legal requirements, which must be observed before the start of the piloting activities. Ethical and legal requirements have been classified

according to the clusters of technologies used for the impact assessment in D9.2. Each requirement has been codified considering: (i) the activity in which these requirements must be observed, in this case the piloting activities (PA); (ii) the type of risk, whether it is internal (i) or external[37] (a); (iii) the technology, i.e. Artificial Intelligence (AI), Digital Twins & Virtualisation (DT), IoT & Sensors (IoT), Wearables & AR (AR), Blockchain (B); and, iv) the number of the requirement (R1, R2, R3,…). All requirements are prioritised as "Must".

These initial requirements will be further developed in D7.3 ('Ethics recommendations and regulatory framework') to be submitted in M18.

Table 130: Artificial Intelligence: Requirements to address internal risks in the piloting activities

Artificial Intelligence
Privacy and Data Protection
PAi-AI-R1: Data collected for training and testing algorithms should be limited to a strict minimum.
PAi-AI-R2: Before starting the piloting activities, human operators and persons at risk of data capture must be notified about: the piloting activities; the types of data being collected on site, who the data controller is, the purpose of data collection and their right to withdraw.
PAi-AI-R3: All personal data should be anonymised or pseudonymised, stored securely and transmitted and made accessible only to those researchers who are authorised to access the data for achieving the OPTIMAI objectives.
Equality, Fairness, and Non-Discrimination
PAi-AI-R4: Operators participating in training OPTIMAI AI tools should be diverse and inclusive of different genders, ethnicities, body types and disabilities.
PAi-AI-R5: The recording of machine and equipment data should be prioritised over human movements and human activity.
PAi-AI-R6: Synthetic data that is representative should be utilised where it is reasonable to do so.
PAi-AI-R7: Controlled laboratory conditions should be established to generate data compensating for lack of diversity or certain disabilities.
Human Agency and Oversight, Accountability, Transparency and Accuracy
PAi-AI-R8: Wearable AR glasses should display a notification to the operator to inform them that they are interacting with AI tools.
PAi-AI-R9: To maintain satisfactory human control over autonomous processes guided by AI, human operators should be able to initiate or terminate these processes themselves through gesture recognition or other means.
PAi-AI-R10: Human operators must be trained in the correct use of the AI, as well as informed of its capabilities and limitations.
Pai-AI-R11: Training and training materials should provide operators with at least a high-level explanation about how AI tools come to a decision.
PAi-AI-R12: OPTIMAI AI Tools should ensure that at least high-level explanations are available to human operators for AI output.
PAi-AI-R13: The project should follow the Human-Centred Artificial Intelligence approach, thus ensuring, to the greatest extent possible, the reliability, safety, transparency, and trustworthiness of the developed AI technologies.

[37] In D9.2 and D9.6 a distinction has been made between internal and external risks. D2.2 solely focuses on the internal risks, which cover the ethical, legal and societal risks arising directly from the project and within its 36 month duration. On the contrary, external risks are those which may arise because of the use of the OPTIMAI results beyond the project's 36 month duration by future adopters of OPTIMAI solutions.

Meaningful Work and Impact on Work and Skills
PAi-AI-R14: Voluntary participation and withdrawal from testing OPTIMAI AI tools at pilot sites must be ensured.
PAi-AI-R15: Direct feedback from operators after they have tested the OPTIMAI AI Tools should be collected.
PAi-AI-R16: Training to operators should be delivered in accessible and multi-lingual formats.
Security, Health and Safety
PAi-AI-R17: End-users should conduct safety impact assessments before initiating testing activity of OPTIMAI tools involving human operators
PAi-AI-R18: End-users should secure their operations with physical and logical firewalls, and any other security measure as necessary.
Environment
PAi-AI-R19: In the event of sub-optimal performance of the AI leading to manufacturing waste, related processes should be terminated and tools refined.

Table 131: Digital Twins & Virtualisation: Requirements to address internal risks in the piloting activities

Digital Twins & Virtualisation
Privacy and Data Protection
PAi-DT-R1: Virtualised human agents should not be designed or perform in a way that may refer to identifiable workers in a specific context.
Equality, Fairness, and Non-Discrimination
PAi-DT-R2: Human agents represented in the virtual environment should be diverse and inclusive to the greatest extent possible without infringing on the privacy of any current employees/operators, even if this does not represent the workforce of the site where the tool is deployed.
PAi-DT-R3: Simulations should account for the capabilities of workers with disabilities.
Human Agency and Oversight, Accountability, Transparency and Accuracy
PAi-DT-R4: Operators should be able to understand the logic underlying simulations. At least high-level explanations should be provided to operators.
PAi-DT-R5: Multi-lingual and appropriately accessible training and materials should be made available to users of the system.
PAi-DT-R6: Users of the systems should always be in control of processes related to the tool and should always possess the ultimate authority when making decisions and initiating or terminating production processes.
PAi-DT-R7: Feedback from users and operators regarding how the tool impacted their work, especially from the perspective of agency and autonomy should be collected.
PAi-DT-R8: Logs of the tools' operations should be kept.
Meaningful Work and Impact on Work and Skills
PAi-DT-R9: DT and Virtualisation tools should be a complement to operators' work and should not excessively reduce opportunities for creativity and problem-solving.
PAi-DT-R10: Feedback of operators after they have tested the technology in order to understand how they perceive it has affected their experience of meaning and value at work, should be collected.
Security, Health and Safety
PAi-DT-R11: Accurate virtual replicas of the manufacturing environment should be ensured.
PAi-DT-R12: Access to the tool should be restricted only to qualified and authorised users in the pilot sites and research staff working on the project.

Table 132: IoT & Sensors: Requirements to address internal risks in the piloting activities

IoT & Sensors
Privacy and Data Protection
PAi-IoT-R1: Data minimisation must be ensured. Any personal data or identifiers that may be collected during the operations should be anonymised or deleted.
PAi-IoT-R2: Operators and employees in the manufacturing environment must be notified about data collection and informed consent procedures must be put in place for any activity that requires personal data processing. If applicable, legitimate interest assessment should be conducted.
PAi-IoT-R3: Technical partners should guide end users through the appropriate placement and use of sensor devices.
Equality, Fairness, and Non-Discrimination
PAi-IoT-R4: Devices must be accessible to operators, considering any disabilities they may have that could challenge setting them up, modifying them or interacting with them in legitimate ways.
Human Agency and Oversight, Accountability, Transparency and Accuracy
PAi-IoT-R5: Sensors should support or compliment human workers rather than outright replace them.
PAi-IoT-R6: Detailed logs of sensor data flow should be maintained and their accuracy and performance regularly monitored.
PAi-IoT-R7: Technical partners should endeavour to support explainability, transparency and auditability of algorithms utilised in the security middlebox.
Meaningful Work and Impact on Work and Skills
PAi-IoT-R8: Acceptance of sensors and IoT devices should be fostered by providing meaningful information about their purpose and the types of data they process.
PAi-IoT-R9: Devices should be used as intended, i.e., support production optimisation. Under no circumstances should devices be used to monitor worker performance or non-production related activities.
PAi-IoT-R10: IoT and sensor devices should complement rather than replace human operators' skills.
PAi-IoT-R11: Feedback from operators and employees regarding the impact on the nature of work should be obtained
Security, Health and Safety
PAi-IoT-R12: End users should provide safety information relating to the correct and safe use of sensors that can cause harm or injury from misuse.
PAi-IoT-R13: Health and safety risk assessment should be performed by qualified staff at pilot sites.
PAi-IoT-R14: IoT devices should follow best practice security standards. Examples of mitigation measures preserving security include: consensus about data to be communicated, data logging, cryptographic hash to prevent unwanted data from being communicated, and encrypted communication. Furthermore, sensors should be secured with different root passwords per sensor, communication should be via secure channels, frequent vulnerability assessments should be conducted, patching should be regular, installation of sensors should be in a protected space.
Environment
PAi-IoT-R15: Sensor and IoT performance should be consistently monitored and any devices contributing to sub-optimal production should be appropriately addressed.

Table 133: Wearables & AR: Requirements to address internal risks in the piloting activities

Wearables & AR
Privacy and Data Protection

PAi-AR-R1: Operators, users and other employees who may be in their field of view, must be informed of the data collection and processing capabilities (and reasons for data collection) of the wearable glasses.
PAi-AR-R2: Informed consent procedures must be in place.
PAi-AR-R3: Only necessary data should be collected and unnecessary personal data anonymised, pseudonymised or destroyed as soon as possible.
PAi-AR-R4: Two-factor authentication for access to wearables should be prioritised over biometric access unless biometric access demonstrably provides more security in this instance, and that such a level of enhanced security is necessary.
Equality, Fairness, and Non-Discrimination
PAi-AR-R5: Testing and design should be inclusive and involve as diverse a workforce as possible, with reasonable accommodations made for different physiological attributes (weight, height, head-shape) levels of ability (eye-sight etc.), and religious attire, especially such that current members of the workforce are not excluded from using OPTIMAI tools.
PAi-AR-R6: Extra measures should be taken towards inclusive design where the workforce of the pilot sites is particularly unrepresentative of the wider population.
PAi-AR-R7: The feedback of women and under-represented groups should be proactively sought.
Human Agency and Oversight, Accountability, Transparency and Accuracy
PAi-AR-R8: Requirements outlined in relation to IoT and AI should be observed.
Meaningful Work and Impact on Work and Skills
PAi-AR-R9: Multilingual and accessible training should be provided to operators.
PAi-AR-R10: Feedback should be collected directly from operators and others directly or indirectly affected by wearables and AR in the pilot sites on how the use of these tools has changed the nature of their work and whether these changes are positive or negative.
Security, Health and Safety
PAi-AR-R11: The AR UI should be designed in order to be minimally intrusive both from a field of view perspective and in terms of the amount of information that is being presented to operators.
PAi-AR-R12: Health and safety risk assessments should be conducted in order to ensure the health and safety of operators in the manufacturing environment.
PAi-AR-R13: Best practice methods for securing the devices from attack or modification should be adopted.

Table 134: Blockchain: Requirements to address internal risks in the piloting activities

Blockchain
Privacy and Data Protection
PAi-B-R1: Personal information should be kept off the blockchain.
PAi-B-R2: Persons who could potentially be re-identified from the recording of time-stamps should be notified and off-chain worker scheduling information should be deleted by end users when it has outlived its use.
Pai-B-R3: Private permissioned blockchain should be used.
Meaningful Work and Impact on Work and Skills
PAi-B-R4: Multilingual and access training or training materials should be made available for end users.
Security, Health and Safety
PAi-B-R5: Appropriate measures should be taken to safeguard the blockchain key from theft or loss, particularly from malicious actors.
Environment
PAi-B-R6: An environmentally low impact blockchain platform should be chosen for OPTIMAI.

3.4.4 Technological innovation potential

In this section the technological innovation potential of OPTIMAI is analysed focusing on its ability to stimulate innovation capacity in the market. Specifically, in the following subsections all the key innovation technologies of the project are analysed, highlighting their potential contribution to the project's exploitable assets, so as to bring to the surface the requirements that should be considered in this deliverable for defining the functional requirement for the OPTIMAI platform as well as to provide insight for the definition of the business model and the exploitation plan, which will be devised in the context of WP8.

Since the early inception of OPTIMAI, the technological innovation potential has been clustered in the following topics:

- *Decision support framework for early notifications.*
- *Secure and adaptive multi-sensorial network and fog computing framework.*
- *Blockchain-enabled ecosystem*.
- *Intelligent marketplace for AI, supporting agent-based brokering*.
- *Digital twin for simulation and forecasting*.
- *Embedded cybersecurity for IoT devices*.
- *On-the-fly reconfiguration of production equipment*.

The following sub-sections detail the key innovation features of each of the above technological potentials that will stimulate OPTIMAI's innovation capacity in the market. Furthermore, a list of pertinent non-functional requirements is provided that need to be taken into consideration in the OPTIMAI design and implementation phase, for their successful realization. The list of the technological innovation potential requirements remains the same as in the previous version of this deliverable. The section concludes with a synthesis of the technological innovation potential requirements with the state-of-the-art innovations and the exploitable assets per partner.

3.4.4.1 Decision support framework for early notifications

It is envisioned that a main innovation breakthrough of the OPTIMAI project is its Artificial Intelligence (AI) decision support mechanisms. These mechanisms will act as key enablers for the automatic and concurrent multi objective decision making, based on the diversity of sensors data that will be collected during the course of the project, as well as the production aspects that will be analysed during the user requirements analysis and use cases description.

AI technologies have attracted attention in the field of smart manufacturing, resulting in significant changes in the field, and in particular: (i) integration of smart devices integrating AI technologies has led to increased accuracy and reliability, (ii) autonomous decision-making capabilities foster more reasonable dynamic behaviours, and (iii) AI-enabled data processing methods have promoted accuracy and efficiency [3]. Challenges in this context have been identified as follows: susceptibility of AI algorithms to small variations caused from machine to machine, data quality for training the AI algorithms and cybersecurity risks stemming from the increasing use of connected technologies [4]. A cornerstone for the success of AI-enabled

solutions in the field of manufacturing is the successful collaboration between humans and machines, demanding "human-in-the-loop" approaches, allowing humans to interact efficiently and effectively with the decision-making system [5]. In the context of decision-making for smart manufacturing, the following requirements have also been identified [6]: asset management referring to manufacturing equipment and tools, infrastructure, applications and software to meet product needs; information and data formats; and data availability and integrity in terms of both semantics and completeness. Important for decision support for fully autonomous maintenance activities is also the ability to provide procedural structure to data for reuse and communication [7].

Based on the above discussion, the following requirements should be addressed by the OPTIMAI technologies:

Table 135: Collaboration between Human and AI (TIP-01)

ID	TIP-01	Requirement	Collaboration between Human and AI	Priority
Description	The employed AI solutions should be designed and developed based on approaches that consider putting humans-in-the-loop so that the operators will interact efficiently and effectively with the envisioned decision-making system.			Should

Table 136: Decision making tailored for smart manufacturing (TIP-02)

ID	TIP-02	Requirement	Decision making tailored for smart manufacturing	Priority
Description	The system should provide the necessary mechanisms so as to address the efficient asset management of the manufacturing ecosystem. Furthermore, it is of immense importance the decision-making algorithms to ensure data integrity and provide structure to data for reuse and communication.			Should

3.4.4.2 Secure and adaptive multi-sensorial network and fog computing framework

An end-to-end fog computing infrastructure will be developed enabling the continuous production monitoring and quality inspection, moving forward the system's intelligence at the low-cost programmable logic IoT devices, enabling this way the delivery of high-performance predictive analytics, in a timely manner, regarding the health of the manufacturing process.

The challenges for OPTIMAI to achieve the aforementioned goals can be classified in three main categories: (a) challenges in data acquisition, (b) challenges in data pre-processing and storage and (c) challenges in data analytics [8]. In respect of the first category, appropriate mechanisms should be employed capable to gather and fuse data originating from heterogenous sources

(e.g., IoT devices, sensors, SCADA, etc.) catering any inconsistencies and conflicts of data representation. Regarding the second category, the systems should ensure mechanisms that will facilitate the efficient data integration, redundancy reduction and data cleaning and compression, through the envisaged fog computing framework, leveraging the data pre-processing across the whole infrastructure, from the edge devises to the cloud core, distributing this way the computation consumption needed and thus improving its reliability, scalability and efficiency. Furthermore, with respect to the challenging data analytics that is required to be addressed, efficient data mining schemes, temporal and spatial data corelation as well as the necessary vertical mechanisms for ensuring data privacy and security should be taken into account.

To that end, the following requirements should be addressed by OPTIMAI:

Table 137: Robust and secure IoT network and fog infrastructure (TIP-03)

ID	TIP-03	Requirement	Robust and secure IoT network and fog infrastructure	Priority
Description	The system should provide a scalable and resilient end-to-end infrastructure, regarding the integration, pre-processing, analysis and provision of the heterogeneous data that are made available by the diversity of devices that are co-located in the shop-floor.			Must

3.4.4.3 Blockchain-enabled ecosystem

Indisputably, manufacturing IoT frameworks and smart analytical systems such as OPTIMAI need to guaranty the secure data exchange having as objectives the security, privacy, traceability, integrity, compatibility and interoperability of data storage and exchange for industries. This effort will be supported by cryptographic techniques and Distributed Ledgers as well as smart contracts.

A success factor for cloud manufacturing systems is the transition from a centralized approach towards establishing a new type of trustable platforms, such as blockchain cloud manufacturing with the aim of developing peer to peer and decentralized network infrastructures [9]. An additional factor that needs to be considered by contemporary distributed cloud manufacturing platforms is the need for the integration of smart contracts towards the improvement of the security of transactions as each item can only be received by the buyer who has signed the relevant contract with the seller; allowing the system to identify fraudulent transactions or misplaced items [10]. To that end, Smart contracts should be implemented and embedded into the system to provide incentives to enable blockchain to govern progress of a business process.

An immense need of Industry 4.0 is to ensure the secure exchange and sharing of sensitive data (e.g., firmware updates) not only between companies but also amongst sensors that are employed in the same company in a private and secure way via the usage of digital identities, and appropriate encryption and data integrity verification mechanisms. Furthermore, since AI

constitute an integral part of the contemporary manufacturing industry, it is necessary the existence of mechanisms that can ensure their integrity and validate that the correct AI models are used for predicting the decision choices/configurations to be made within the production line.

Hence, as per the above-mentioned discussion, the following requirements should be addressed by the OPTIMAI technologies:

Table 138: Decentralized secure and trustworthy cloud infrastructure (TIP-04)

ID	TIP-04	Requirement	Decentralized secure and trustworthy cloud infrastructure	Priority
Description	The system should be built upon a decentralized cloud-based infrastructure capable to safeguard the integrity, immutability and transparency of sensitive transactions that are made between the components through block-chain approaches.			Must

Table 139: Smart contract support (TIP-05)

ID	TIP-05	Requirement	Smart contract support	Priority
Description	The support of smart-contracts for specific business wide transactions can leverage the incentives and trust provided to 3rd parties increasing this way the market potential of the envisaged system.			Could

3.4.4.4 Intelligent Marketplace for AI, supporting agent-based brokering

It constitutes a key constituent of the OPTIMAI ecosystem, that will create a new market share opportunity based on the secure and transparent exchange of scrap for re-user as well as manufacturing related AI models. Furthermore, the innovation potential of the Intelligent Marketplace for AI is further reinforced by its agent-based, brokering module that will employ syntactic and semantic matching (taxonomy-based and feature-based) for providing the best possible suppliers to fulfil a request for an AI service or discarded part.

To exploit the full potential of the European data economy and to ensure competitive advantage of Europe over China and the US and others, sustainable industrial data spaces and marketplaces need to be developed, considering non-personal data as well as the management of personal data (as e.g., mydata, but also other personal identifiable information), to be launched and marketed and successfully operated. Platforms need to be built where data can be traded and exchanged in a trustworthy and secure way providing clear legal and ethical frameworks. In these frameworks data-based services and related software & tools can be offered and easily used, where data professionals can receive training to improve their knowledge and skills. They also enable the connection between industries as well as the

connection between industry and science and thereby enable the exploration of other marketplaces and data spaces. In short, they offer a landscape of data spaces where demand and supply meet and create business and value together.

A big potential for the realization of such marketplaces in the manufacturing industry can be easily conceived if someone considers that scrap for one company can constitute cheap raw material for another one. In addition, many companies that have invested in AI-based decision-making mechanisms can achieve return on investment if they can offer them as a value-added side product to other companies to which they can be applied.

Based on the above discussion, the following requirements should be addressed by the OPTIMAI technologies:

Table 140: Support of trustworthy, secure and legitimate interchange of manufacturing products and software (TIP-06)

ID	TIP-06	Requirement	Support of trustworthy, secure and legitimate interchange of manufacturing products and software	Priority
Description	The system should encompass the necessary mechanisms which will ensure the integrity and trustworthiness of the envisioned marketplace considering non-personal data as well as the management of personal data, legal and ethical frameworks, where data-based services and related software & tools can be offered and easily used.			Should

3.4.4.5 Digital Twin for Simulation and Forecasting

Coupled with AI capabilities Digital Twin constitutes the perfect means for performing accurate assessment of industrial production processes, machines or production lines, and thus constitutes an appealing innovation asset of the project.

Digital Twin has been identified as a “breakthrough technological development that has the potential to transform the landscape of manufacturing today and tomorrow” [11]. In the current technological context, Digital Twin has been referred to as the biggest technology trend disrupting engineering and design in 2020 [12]. In the context of manufacturing, Digital Twin and data-driven production operations, supported by connectivity and data tracking throughout the complete manufacturing process, enable the radical transformation of factory operations supporting tracing product fault sources, analysing production efficient bottlenecks and predicting future resource requirements. As a result, a digital twin may be applied to enhance simulation, traceability and to support the offering of value-added services along the lifecycle [13].

In order to achieve its potential, real-time data, integration, and fidelity are the requirements mostly dealt with and valued by the literature [13]. Additional requirements stemming from literature research include interconnection, information transparency, decentralized decisions, and technical assistance [14]. An analysis based on the phases of the digital twin lifecycle [15] pointed out that an important challenge that needs to be addressed by digital twins is the lack of mechanisms that convey elements of prediction quality, such as prediction uncertainty and model accuracy, with respect to the application environment.

Based on the above discussion, the following requirements should be addressed by the OPTIMAI technologies:

Table 141: Digital Twins as a means for improving the manufacturing process (TIP-07)

ID	TIP-07	Requirement	Digital Twins as a means for improving the manufacturing process	Priority
Description	The envisaged digital twin component should consider the following aspects with regard to the envisioned effective predictive analytics: • real-time data integration and fidelity • efficient interconnection mechanisms with the rest OPTIMAI technical components • decentralized decisions and technical assistance • address potential prediction uncertainties provided by the employed AI			Must

3.4.4.6 Embedded Cybersecurity for IoT devices

Addressing the fundamental requirement for data privacy and protection, the OPTIMAI security middlebox will not only ensure the seamless and trusted service provisioning over different data but it will also enable the dynamic and secure coupling of embedded devices involved in the manufacturing process, providing this way extended meta-services that can further leverage the efficiency of the manufacturing process.

Cybersecurity is beyond doubt a fundamental concern for any Information Technology (IT) application or service. In fact, it has been pointed out that it constitutes the key to unlocking demand in the IoT field [16]. In the context of Industry 4.0, it is noted that the advancements brought by IoT would be jeopardized by cybersecurity breaches, which would have critical impact on the business model and loss of competitiveness [17]. Cyber-risks no longer affect only the IT, but in this context have considerable impact in production systems and products [18]. Cybersecurity threats in an Industry 4.0 factory have been classified as cyber espionage, denial-of-service attacks, exploitation of vulnerabilities in the supply chain, and advanced persistent threats [17]. The architectural design of IoT-based cybersecurity requires accessibility, integrity, availability, scalability, confidentiality, and interoperability among heterogeneous smart devices [19]. Cybersecurity should be addressed at all layers of the IoT environment (e.g., sensing layer,

network layer, middleware layer, and application layer) and appropriate countermeasures should be applied at each layer for addressing potential security attacks [19].

The emerging requirements as per the above-mentioned discussion are the following:

Table 142: Resilient IoT based cybersecurity (TIP-08)

ID	TIP-08	Requirement	Resilient IoT based cybersecurity	Priority
Description	The envisaged components pertaining to the interoperability and management of the IoT components, sensors and devices that constitute the main provenance of data collection should be designed toward maximizing the accessibility, integrity, availability, scalability, confidentiality, and interoperability amongst these devices.			Must

Table 143: Horizontal cybersecurity (TIP-09)

ID	TIP-09	Requirement	Horizontal cybersecurity	Priority
Description	The system should address cybersecurity at all layers of the IoT environment (e.g., sensing layer, network layer, middleware layer, and application layer) and appropriate countermeasures should be applied at each layer for addressing potential security attacks.			Must

3.4.4.7 On-the-fly reconfiguration of production equipment

Constituting one of the fundamental innovation potentials of OPTIMAI, this module will foster the human-machine symbiosis in the shop floor, putting the operators in the loop of decision making, which is fostered by the AI and AR technologies. To that end, the operators will be able to acquire through AR the necessary autonomous analysis reporting regarding the quality inspection of the manufacturing process provided by AI, while they will be able to re-configure on-the-fly the production process without needing to leave the shop-floor.

The use of AR in the context of smart manufacturing has constituted a major achievement in the industry domain; its application in the shop floor is expected to enhance the productivity, robustness and efficiency of the manufacturing process [20]. In more detail, although several isolated solutions for machine monitoring, scheduling and maintenance support have been implemented and reported in literature, there is a notable scarcity of unified approaches integrating communication between operational planning and maintenance planning [21], a gap which has the potential to be addressed by the proposed OPTIMAI solutions.

In this context, two major challenges have been identified for the use of AR technology, namely the generation of content (instructions, animations, and virtual objects) and its application on top of the real world, requiring appropriate virtual models of the shop-floor [22]. At the same

time, in order to address the needs of workers in the shop-floor, Augmented Reality Smart Glasses have been identified as a powerful technology that can effectively and efficiently support workers through various tasks, such as assembly, maintenance, quality control, and material handling [23]. An important aspect that should be taken into consideration during the design of the AR User Interfaces is that information content should be kept as minimum as possible, since the idea is to enhance the world, not block it out with lots of graphic objects. Furthermore, with regard to the AR tracking system, and in order to achieve reliability in the industrial environment, marker-less approaches are preferrable to mitigate problems introduced by dust and dirt to marker-based tracking solutions [24]. With regard to user input, prominent interaction methods have been identified to include gesture recognition, gaze-based input, or discrete hardware solutions [24].

Table 144: Communication between operational planning and maintenance planning (TIP-10)

ID	TIP-10	Requirement	Communication between operational planning and maintenance planning	Priority
Description	The system should encompass all the necessary back-end infrastructure to support effective communication between operational planning and maintenance planning.			Must

Table 145: Content delivered through the AR solution (TIP-11)

ID	TIP-11	Requirement	Content delivered through the AR solution	Priority
Description	The content delivered through the AR solution should be appropriate for the task at hand, keeping information as minimum as possible to achieve the task execution in an effective and efficient manner.			Must

Table 146: Marker-less AR tracking (TIP-12)

ID	TIP-12	Requirement	Marker-less AR tracking	Priority
Description	A marker-less solution to AR tracking should be supported, in order to increase the reliability of the approach in the industrial context.			Must

Table 147: Efficient user input (TIP-13)

ID	TIP-13	Requirement	Efficient user input	Priority

Description	The user input methods supported should be appropriate for the current task, such as gesture-based or gaze-based interactions, each one as needed (e.g. when the worker's hands are occupied gaze-based interactions should be preferred).	Should

3.4.4.8 Linking technological innovation potential with state-of-the-art technologies and exploitation assets

In this section, the technological innovation potential is aligned with the state-of-the-art analysis and the exploitation assets that have been identified by each partner. To ensure that the project has a dedicated focus on the successful implementation of the innovation potential requirements, the OPTIMAI consortium has created the following table for mapping and managing the innovation potential activities. This table demonstrates the strong alignment between the project's innovations, the state-of-the-art innovations and the assets that will be developed by each of the partners. It also reflects the strength within and cross Work Package connection by capitalising the results and highlights of D2.4 [2] and D8.5.

Furthermore, according to a recent Forbes article [12], the top ten technology trends of the fourth industrial revolution include: AI and Machine Learning, IoT, Big Data, Blockchain, cloud and edge computing, robots and cobots, autonomous vehicles, 5G networks, genomics and gene editing, as well as quantum computing. The OPTIMAI solutions are totally aligned with these technology trends, capitalizing the majority of the aforementioned technologies and innovations. Last but not least, the technologies employed for the OPTIMAI solutions are identified as emerging technologies and trends for the next 8 years[38] demonstrating the high potential for technological impact.

Table 148: OPTIMAI's technological innovation potential

OPTIMAI Technological Innovation Potential (ID)	**State-of-the-art innovations (D2.3)** [25]	**Exploitation assets per partner (T8.5)**
Decision support framework for early notifications (TIP-01, TIP-02)	• AI for quality control • AI for augmented reality • AI for computer vision	• Integrated OPTIMAI platform (CERTH) • AR Interaction & Decision Support (CERTH) • AI framework for quality control (CERTH) • On-the-edge processing component (ENG)
Secure and adaptive multi-sensorial network and fog computing framework (TIP-03)	• AI-enhanced metrology sensors	• Middleware and Data repository (FINT) • Industrial vision sensors with AI-processing and

[38] https://www.gartner.com/smarterwithgartner/4-impactful-technologies-from-the-gartner-emerging-technologies-and-trends-impact-radar-for-2021/

	• Unobtrusive monitoring and sensing	seemless process integration (EVT)
Blockchain-enabled ecosystem (TIP-04, TIP-05)	• OPTIMAI's blockchain-enabled ecosystem • Distributed Ledger Technologies	• Middleware and Blockchain framework (CERTH)
Intelligent marketplace for AI, supporting agent-based brokering (TIP-06)	• Secure data trading	• Intelligence Marketplace (FINT) • Middleware and Data repository (FINT)
Digital twin for simulation and forecasting (TIP-07)	• AI-enhanced digital twins • Deep reinforcement learning for digital twins simulation • Virtualization in smart manufacturing	• Virtualization and simulation environment (virtual twins) (VIS) • Simulation engine (VIS)
Embedded cybersecurity for IoT devices (TIP-08, TIP-09)	• AI-enhanced IoT and edge devices • Secure data trading	• Security Middlebox (FINT) • Middleware and Data repository (FINT)
On-the-fly reconfiguration of production equipment (TIP-10, TIP-11, TIP-12, TIP-13)	• Deep learning methods for AR • Deep learning-based object detection and instance segmentation with wearable AR technology • Ubiquitous augmented reality • Real-time optimization of the production schedules	• GUI toolkit (FORTH) • Decision-maker for adaptive context-aware interactive AR (FORTH) • Recommender system for operators at the shop floor (FORTH) • Augmented Reality Glasses for Industrial Applications (YBQ)

4 Conclusion and Future Steps

In conclusion, this deliverable describes the effort spent from M7 to M14 and represents the current status of T2.1 of WP2. More specifically, it has updated the functional and non-functional requirements based on the identified user, ethics and legal requirements extracted from the questionnaires, the on-line and shopfloor meetings and the videos and photos. In total, 192 requirements were identified of which 33 are updated and 65 are added. The requirements are categorized in user requirements, functional requirements and non-functional requirements including KPIs, legal, ethical and technological innovation potential requirements. The capitalisation of developed technologies is demonstrated with the alignment of the technological innovation potential, the state-of-the-art analysis and the exploitation assets that have been identified by each partner. This deliverable formulates the updated list of user and ethics and legal requirements for the development of the OPTIMAI platform.

A necessary step for monitoring the performance of each of the identified requirements is to perform iterations for both requirements and use-cases in order to obtain more complete view of the deployed solutions. The iterative process will be performed by conducting end-user workshops in order to determine the context of use of the OPTIMAI requirements for each of the use cases. New requirements may emerge during the project's lifetime, while existing requirements may be reformulated to enhance clarity and accuracy. The list of requirements will be continuously expanded, updated and refined, particularly in connection with user evaluation of the OPTIMAI components. The user involvement will enable further updates of the requirements that will be based on actual end user needs and expectations of the OPTIMAI solutions.

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Appendix A: OPTIMAI requirements

	Requirement Category	Requirement ID	Description	Priority
1	Questionnaire User Requirements	Q-UR-1	The system shall be able to monitor production and inspect quality issues.	Must
2		Q-UR-2	The system shall be able to visualise information from the production line	Must
3		Q-UR-3	The system shall provide security in all datasets	Must
4		Q-UR-4	The system shall provide data traceability	Must
5		Q-UR-5	The system shall provide (near) real-time notifications and alerts from data generated from sensors	Must
6		Q-UR-6	The system shall be able to virtualise production processes	Must
7		Q-UR-7	The system shall be able to control the production line and provide recalibration recommendations	Must
8		Q-UR-8	The system shall be protected from cyber threats	Must
9		Q-UR-9	Only authorised users shall have access to the OPTIMAI platform	Must
10		Q-UR-10	The AR glasses shall provide real-time and accurate information to the employees	Should
11		Q-UR-11	The system shall be able to reconfigure its settings without stopping the production	Must
12		Q-UR-12	The system shall recognize the possible defects and reduce them	Must
13		Q-UR-13	The system should not be able to profile operators	Must
14		Q-UR-14	The system shall provide real-time information about the production	Must
15	Pilots' videos User Requirements	K -VID-DD-UR1	The user can be aware of whether there is any mismatch between the parts that have been used in the produced Hydraulic Lift Power Unit compared to the parts referred to the client’s order, without having to inspect the unit manually.	Could
16		KLEE-VID-DD-UR2	Monitor the pressure of the hydraulic lift power unit in (near) real time, without visually inspecting it, standing there for 3 minutes, to save time.	Must
17		KLEE-VID-DD-UR3	Users must be notified in real time if the pressure of the valve block on the hydraulic lift power unit drops below the operational pressure value.	Must
18		KLEE-VID-OSU-UR1	Users must be able to monitor parameters (e.g. velocity, sound, vibration, pressure etc.), while calibrating the Hydraulic Lift Power Unit.	Must

19		KLEE-VID-OSU-UR2	Users must be able to calibrate and recalibrate the Hydraulic Lift Power Unit with Human Computer Interface based on gestures, to rapidly make the optimal set up for the Hydraulic Lift Power Unit. An automatic recalibration functionality should also be provided by the system	Must
20		KLEE-VID-DT-UR1	Users must know the cause of suboptimal performance and the corresponding corrective actions that might resolve the issue.	Must
21		MTCL-VID- DD -UR1	During glue/epoxy diffusion (GPD dispensing system), the defect detection should be executed automatically to save time, minimize the impact of a human error, increase accuracy.	Must
22		MTCL-VID-DD-UR2	When a defect is detected, during glue/epoxy diffusion (GPD dispensing system), users must be able to receive notification in (near) real time, in order to rapidly react to resolve the issue.	Must
23		MTCL-VID-DD-UR3	During glue/epoxy diffusion (GPD dispensing system), should be able to know when a defect is possible to happen in order to save time and react accordingly (prediction).	Should
24		MTCL-VID-DD-UR4	During glue/epoxy diffusion (GPD dispensing system), should be notified in (near) real time when a defect is predicted that is quite possible to happen in order to save time and react accordingly	Should
25		MTCL-VID-OSU –UR1	When a defect is detected, during glue/epoxy diffusion (GPD dispensing system), the critical parameters of the dispensing process should be adjusted automatically to save time, minimize the impact of a human error, increase accuracy and for optimal set up	Must
26		MTCL-VID-OSU-UR2	When a defect is detected, during in glue/epoxy diffusion (GPD dispensing system), users should be able to rapidly adjust some parameters via Human Computer Interface based on gestures.	Should
27		MTCL-VID-OSU-UR3	The users should be notified about the cause of suboptimal performance of the GPD dispensing system, and the corresponding corrective actions that might resolve the issue.	Must
28		MTCL-VID-DT-UR1	The users should be able to test different set up of parameters in a GPD dispensing system digital replica of the production line to reduce time and cost to find optimal set up of parameters for different products.	Should
29		MTCL-VID-DT-UR2	Users should be able to rapidly transfer the optimal set up of parameters of GPD dispensing system for different products from the digital replica to the real production line.	Should
30		MTCL-VID-DT-UR3	The GPD dispensing system digital replica of the production line to include machinery and virtual sensors should detect defects in the virtual environment.	Should
31		MTCL-VID- DD –UR5	Users can monitor parameters that are not currently monitored and may indicate sawing deficiencies.	Should
32		MTCL-VID- DD –UR6	Users must be notified about parameters that indicate sawing deficiencies (e.g. residue resulting from sawing, quality of water, displacement etc.) that can cause defective products.	Must
33		MTCL-VID- DD –UR7	The defect detection process to be executed automatically after the wafer sawing process.	Should

34		MTCL-VID- DD –UR8	Users should be notified about detected defects in (near) real time on products exported from wafer sawing process.	Should
35		MTCL-VID- DD –UR9	Users should be able to monitor parameters during PCB routing process that are not currently monitored and may cause defective products (e.g. pressure).	Should
36		MTCL-VID- DD –UR10	Users should be notified about detected defects during the PCB routing process (e.g. distance, routing thickness etc.) in (near) real time.	Should
37		TVES-VID- DD –UR1	Detect at source reflectors with small breaks caused by incorrect folding	Must
38		TVES-VID- DD –UR2	Detect at source reflectors with imperfections in the plastic housings caused by poor insertion of the elements.	Must
39		TVES-VID- DD –UR3	Store information on detected faults.	Must
40		TVES-VID-OSU –UR1	Verify correctly loaded tasks in the different cells of the robotic line and generate alarms when incorrect configurations are detected.	Should
41		TVES-VID-OSU –UR2	Verify the presence of suitable materials in the feeding peripheries and generate alarms when incorrect configurations are detected	Should
42		TVES-VID-OSU –UR3	Display line configuration information in graphical interface	Should
43		TVES-VID- DT –UR1	Users must be able to run production scenarios on a digital replica of the antenna line, including machinery, robotic cells and virtual sensors, to save time and reduce cost from testing.	Must
44		TVES-VID- DT –UR2	Users must be able to test different set up of parameters in the production line, to apply the optimal set up for different types of products, without testing them on the real antenna line to save time and reduce cost.	Must
45		TVES-VID- DT –UR3	Users should be able to rapidly set up the antenna line, by transferring the optimal parameters set up from the virtual testing environment to the real production line.	Should
46		TVES-VID- DT –UR4	Users should be able to know the cause of suboptimal manufacturing detected (reduced efficiency, incorrect assembly etc.) in the antenna line and the corresponding corrective actions that might resolve the issue.	Should
47		TVES-VID- DT –UR5	Users can be informed about predicted upcoming defects through the virtual testing environment of the antenna line.	Should
48	Functional Requirements	FR-1	The system and the developed sensors shall be able to be connected with other sensors and machines	Must
49		FR-2	The system shall be able to process data generated from sensors	Must
50		FR-3	The different types of sensors shall be integrated under a common framework	Must
51		FR-4	The system shall be able to manage the data acquisition and flow to the control and analysis modules	Must
52		FR-5	The system shall develop a cyber-defence module	Must
53		FR-6	The system shall be able to recognise activities, scenes and human recognition	Must

54		FR-7	The system shall support the interaction of operator and machine	Must
55		FR-8	Production Information shall be displayed in the user	Must
56		FR-9	Data repository	Must
57		FR-10	The system shall develop a mechanism that will provide	Must
58		FR-11	The system shall develop an intelligent marketplace	Must
59		FR-12	The system shall develop AI enabled digital twin models	Must
60		FR-13	The system shall develop a production optimisation model	Must
61		FR-14	A smart quality control system shall be developed for production monitoring and defect detection and prediction	Must
62		FR-15	A Visualization and Decision Support system shall be developed to visualise the production monitoring and inspection results	Must
63	KPIs	KPI-1	Reduction of sensor network traffic	Should
64		KPI-2	Data latency improvement	Should
65		KPI-3	Security and privacy improvement	Must
66		KPI-4	Sensor measurement improvement	Should
67		KPI-5	Ensure real-time validity and traceability of collected data	Should
68		KPI-6	Improvement in process automation	Should
69		KPI-7	Improvement in equipment productivity	Should
70		KPI-8	Improvement in the accuracy of defects	Must
71		KPI-9	The improved quality production will reduce scrap	Could
72		KPI-10	The repurposing of equipment will reduce the produced scrap	Could
73		KPI-11	Improvement in behavioral accuracy	Should
74		KPI-12	Improvement in rump-up time	Should
75		KPI-13	Improvement in time-to-market	Could
76		KPI-14	Improvement of computer vision tasks	Should
77		KPI-15	Accuracy improvement	Must
78		KPI-16	Improvement of operator-machine interaction	Must
79		KPI-17	Improvement of interaction latency	Should
80		KPI-18	Improvement of equipment productivity through automated recalibration	Should
81	Legal requirements	DIG	Human dignity	Must
82		INT	Human physical and mental integrity	Must
83		END	Equality and non-discrimination	Must
84		PDP	Personal data means any information relating to an identified or identifiable natural person ('data subject').	Must
85		WOR	Workers' rights	Must
86		DPR	Data protection	Must
87		NPD	Non-personal data refers to information that does not relate to an identified or identifiable natural person	Must
88		AIT	AI-enabled technologies	Must
89		H&S	Respect for safety and health requirements	Must
90		KPI	Non-financial reporting	Should

91	Ethical requirements	RRI-I	Research activities are conducted according to the highest standards of practice and minimising risks of adverse/harmful results or consequences.	Must
92		RRI-R	The quality of the design, the methodology, the analysis and the use of resources in the research should be ensured.	Must
93		RRI-H	Developing, undertaking, reviewing, reporting, and communicating the research in a transparent, fair, full and unbiased manner	Must
94		RRI-RP	Research activities should be carried out with respect for research colleagues, research participants, society and the environment.	Must
95		RRI-A	Researchers should be held accountable for their research. This includes being accountable for publication, management and organisation, training activities, supervision and for the wider impacts of the research.	Must
96		RRI-D&I	Involve early a wide range of actors and publics in R&I practice, deliberation, and decision-making to yield more useful and higher quality knowledge. This strengthens democracy and broadens sources of expertise, disciplines and perspectives.	Must
97		RRI-A&R	Envision impacts and reflect on the underlying assumptions, values, and purposes to better understand how R&I shapes the future. This yields valuable insights and increases our capacity to act on what we know.	Must
98		RRI-O&T	Communicate in a balanced and meaningful way, methods, results, conclusions, and implications to enable public scrutiny and dialogue. This benefits the visibility and understanding of R&I.	Must
99		RRI-R&A	Be able to modify modes of thought and behaviour, overarching organizational structures, in response to changing circumstances, knowledge, and perspectives. This aligns action with the needs expressed by stakeholders and publics	Must
100		RRI-I-HR	Due diligence, human rights risk situations, discrimination of vulnerable groups, fundamental principles and rights at work.	Must
101		RRI-I-CSR	Integrate social and environmental concerns in companies' business operations and in their interaction with their stakeholders on a voluntary basis.	Could
102		RRI-I-LP	Conditions at work and social protection, health and safety at work, human development and training in the workplace, social dialogue.	Must
103		RRI-I-CI	Community involvement, employment creation and skills development, technology development and access, health.	Could
104		RRI-I-FOP	Anti-corruption, fair competition, promoting social responsibility, respect property rights.	Must
105		RRI-I-E	Sustainable resource use, climate change mitigation, protection of the environment, for instance in the context of Sustainable Development Goals (SDGs)	Should

106		HUM	AI systems should support human autonomy and decision-making, as prescribed by the principle of respect for human autonomy. This requires that AI systems should both act as enablers to a democratic, flourishing and equitable society by supporting the user's agency and foster fundamental rights, and allow for human oversight.	Must
107		TRS	Technical robustness requires that AI systems be developed with a preventative approach to risks and in a manner such that they reliably behave as intended while minimising unintentional and unexpected harm, and preventing unacceptable harm. This should also apply to potential changes in their operating environment or the presence of other agents (human and artificial) that may interact with the system in an adversarial manner. In addition, the physical and mental integrity of humans should be ensured.	Must
108		PRI	Closely linked to the principle of prevention of harm is privacy, a fundamental right particularly affected by AI systems. Prevention of harm to privacy also necessitates adequate data governance that covers the quality and integrity of the data used, its relevance in light of the domain in which the AI systems will be deployed, its access protocols and the capability to process data in a manner that protects privacy.	Must
109		TRA	This requirement is closely linked with the principle of explicability and encompasses transparency of elements relevant to an AI system: the data, the system and the business models	Must
110		NDI	In order to achieve Trustworthy AI, we must enable inclusion and diversity throughout the entire AI system's life cycle. Besides the consideration and involvement of all affected stakeholders throughout the process, this also entails ensuring equal access through inclusive design processes as well as equal treatment. This requirement is closely linked with the principle of fairness.	Must
111		WEL	Environmental and societal well-being	Could
112		ACC	Accountability	Must
113		AWM	Awareness of misuse	Must
114		COM	Competence	Must
115	Legal and ethical Requirements (Pilot site)	PAi-AI-R1	Data collected for training and testing algorithms should be limited to a strict minimum	Must
116		PAi-AI-R2	Before starting the piloting activities, human operators and persons at risk of data capture must be notified about: the piloting activities; the types of data being collected on site, who the data controller is, the purpose of data collection and their right to withdraw	Must
117		PAi-AI-R3	All personal data should be anonymised or pseudonymised, stored securely and transmitted and made accessible only to those researchers who are authorised to access the data for achieving the OPTIMAI objectives	Must
118		PAi-AI-R4	Operators participating in training OPTIMAI AI tools should be diverse and inclusive of different genders, ethnicities, body types and disabilities	Must

119		PAi-AI-R5	The recording of machine and equipment data should be prioritised over human movements and human activity	Must
120		PAi-AI-R6	Synthetic data that is representative should be utilised where it is reasonable to do so	Must
121		PAi-AI-R7	Controlled laboratory conditions should be established to generate data compensating for lack of diversity or certain disabilities	Must
122		PAi-AI-R8	Wearable AR glasses should display a notification to the operator to inform them that they are interacting with AI tools	Must
123		PAi-AI-R9	To maintain satisfactory human control over autonomous processes guided by AI, human operators should be able to initiate or terminate these processes themselves through gesture recognition or other means	Must
124		PAi-AI-R10	Human operators must be trained in the correct use of the AI, as well as informed of its capabilities and limitations	Must
125		Pai-AI-R11	Training and training materials should provide operators with at least a high-level explanation about how AI tools come to a decision	Must
126		PAi-AI-R12	OPTIMAI AI Tools should ensure that at least high-level explanations are available to human operators for AI output	Must
127		PAi-AI-R13	The project should follow the Human-Centred Artificial Intelligence approach, thus ensuring, to the greatest extent possible, the reliability, safety, transparency, and trustworthiness of the developed AI technologies	Must
128		PAi-AI-R14	Voluntary participation and withdrawal from testing OPTIMAI AI tools at pilot sites must be ensured.	Must
129		PAi-AI-R15	Direct feedback from operators after they have tested the OPTIMAI AI Tools should be collected	Must
130		PAi-AI-R16	Training to operators should be delivered in accessible and multi-lingual formats	Must
131		PAi-AI-R17	End-users should conduct safety impact assessments before initiating testing activity of OPTIMAI tools involving human operators	Must
132		PAi-AI-R18	End-users should secure their operations with physical and logical firewalls, and any other security measure as necessary	Must
133		PAi-AI-R19	In the event of sub-optimal performance of the AI leading to manufacturing waste, related processes should be terminated and tools refined	Must
134		PAi-DT-R1	Virtualised human agents should not be designed or perform in a way that may refer to identifiable workers in a specific context	Must
135		PAi-DT-R2	Human agents represented in the virtual environment should be diverse and inclusive to the greatest extent possible without infringing on the privacy of any current employees/operators, even if this does not represent the workforce of the site where the tool is deployed	Must
136		PAi-DT-R3	Simulations should account for the capabilities of workers with disabilities	Must

137		PAi-DT-R4	Operators should be able to understand the logic underlying simulations. At least high-level explanations should be provided to operators	Must
138		PAi-DT-R5	Multi-lingual and appropriately accessible training and materials should be made available to users of the system	Must
139		PAi-DT-R6	Users of the systems should always be in control of processes related to the tool, and should always possess the ultimate authority when making decisions and initiating or terminating production processes	Must
140		PAi-DT-R7	Feedback from users and operators regarding how the tool impacted their work, especially from the perspective of agency and autonomy should be collected	Must
141		PAi-DT-R8	Logs of the tools' operations should be kept	Must
142		PAi-DT-R9	DT and Virtualisation tools should be a complement to operators' work and should not excessively reduce opportunities for creativity and problem-solving	Must
143		PAi-DT-R10	Feedback of operators after they have tested the technology in order to understand how they perceive it has affected their experience of meaning and value at work, should be collected	Must
144		PAi-DT-R11	Accurate virtual replicas of the manufacturing environment should be ensured	Must
145		PAi-DT-R12	Access to the tool should be restricted only to qualified and authorised users in the pilot sites and research staff working on the project	Must
146		PAi-IoT-R1	Data minimisation must be ensured. Any personal data or identifiers that may be collected during the operations should be anonymised or deleted	Must
147		PAi-IoT-R2	Operators and employees in the manufacturing environment must be notified about data collection and informed consent procedures must be put in place for any activity that requires personal data processing. If applicable, legitimate interest assessment should be conducted	Must
148		PAi-IoT-R3	Technical partners should guide end users through the appropriate placement and use of sensor devices	Must
149		PAi-IoT-R4	Devices must be accessible to operators, considering any disabilities they may have that could challenge setting them up, modifying them or interacting with them in legitimate ways	Must
150		PAi-IoT-R5	Sensors should support or compliment human workers rather than outright replace them	Must
151		PAi-IoT-R6	Detailed logs of sensor data flow should be maintained and their accuracy and performance regularly monitored	Must
152		PAi-IoT-R7	Technical partners should endeavour to support explainability, transparency and auditability of algorithms utilised in the security middlebox	Must
153		PAi-IoT-R8	Acceptance of sensors and IoT devices should be fostered by providing meaningful information about their purpose and the types of data they process	Must

154		PAi-IoT-R9	Devices should be used as intended, i.e., support production optimisation. Under no circumstances should devices be used to monitor worker performance or non-production related activities	Must
155		PAi-IoT-R10	IoT and sensor devices should complement rather than replace human operators' skills	Must
156		PAi-IoT-R11	Feedback from operators and employees regarding the impact on the nature of work should be obtained	Must
157		PAi-IoT-R12	End users should provide safety information relating to the correct and safe use of sensors that can cause harm or injury from misuse.	Must
158		PAi-IoT-R13	Health and safety risk assessment should be performed by qualified staff at pilot sites	Must
159		PAi-IoT-R14	IoT devices should follow best practice security standards. Examples of mitigation measures preserving security include: consensus about data to be communicated, data logging cryptographic hash to prevent unwanted data from being communicated, and encrypted communication. Furthermore, sensors should be secured with different root passwords per sensor, communication should be via secure channels, frequent vulnerability assessments should be conducted, patching should be regular, installation of sensors should be in a protected space	Must
160		PAi-IoT-R15	Sensor and IoT performance should be consistently monitored and any devices contributing to sub-optimal production should be appropriately addressed	Must
161		PAi-AR-R1	Operators, users and other employees who may be in their field of view, must be informed of the data collection and processing capabilities (and reasons for data collection) of the wearable glasses	Must
162		PAi-AR-R2	Informed consent procedures must be in place.	Must
163		PAi-AR-R3	Only necessary data should be collected and unnecessary personal data anonymised, pseudonymised or destroyed as soon as possible.	Must
164		PAi-AR-R4	Two-factor authentication for access to wearables should be prioritised over biometric access unless biometric access demonstrably provides more security in this instance, and that such a level of enhanced security is necessary.	Must
165		PAi-AR-R5	Testing and design should be inclusive and involve as diverse a workforce as possible, with reasonable accommodations made for different physiological attributes (weight, height, head-shape) levels of ability (eye-sight etc.), and religious attire, especially such that current members of the workforce are not excluded from using OPTIMAI tools	Must
166		PAi-AR-R6	Extra measures should be taken towards inclusive design where the workforce of the pilot sites is particularly unrepresentative of the wider population.	Must
167		PAi-AR-R7	The feedback of women and under-represented groups should be proactively sought.	Must
168		PAi-AR-R8	Requirements outlined in relation to IoT and AI should be observed.	Must

169		PAi-AR-R9	Multilingual and accessible training should be provided to operators.	Must
170		PAi-AR-R10	Feedback should be collected directly from operators and others directly or indirectly affected by wearables and AR in the pilot sites on how the use of these tools has changed the nature of their work and whether these changes are positive or negative	Must
171		PAi-AR-R11	The AR UI should be designed in order to be minimally intrusive both from a field of view perspective and in terms of the amount of information that is being presented to operators	Must
172		PAi-AR-R12	Health and safety risk assessments should be conducted in order to ensure the health and safety of operators in the manufacturing environment.	Must
173		PAi-AR-R13	Best practice methods for securing the devices from attack or modification should be adopted.	Must
174		PAi-B-R1	Personal information should be kept off the blockchain.	Must
175		PAi-B-R2	Persons who could potentially be re-identified from the recording of time-stamps should be notified and off-chain worker scheduling information should be deleted by end users when it has outlived its use.	Must
176		Pai-B-R3	Private permissioned blockchain should be used.	Must
177		PAi-B-R4	Multilingual and access training or training materials should be made available for end users.	Must
178		PAi-B-R5	Appropriate measures should be taken to safeguard the blockchain key from theft or loss, particularly from malicious actors	Must
179		PAi-B-R6	An environmentally low impact blockchain platform should be chosen for OPTIMAI.	Must
180	Technological innovation potential requirements	TIP-01	The employed AI solutions should be designed and developed based on approaches the consider putting humans-in-the-loop so that the operators to interact efficiently and effectively with the envisioned decision-making system.	Should
181		TIP-02	The system should provide the necessary mechanisms so as to address the efficient asset management of the manufacturing ecosystem. Furthermore, it is of immense importance the decision-making algorithms to ensure data integrity and provide structure to data for reuse and communication.	Should
182		TIP-03	The system should provide a scalable and resilient end-to-end infrastructure, regarding the integration, pre-processing, analysis and provision of the heterogeneous data that are made available by the diversity of devices that are co-located in the shop-floor.	Must
183		TIP-04	The system should be built upon a decentralized cloud based infrastructure capable to safeguard the integrity, immutability and transparency of sensitive transactions that are made between the components through block-chain approaches.	Must
184		TIP-05	The support of smart-contracts for specific business wide transactions can leverage the incentives and trust provided to 3rd parties increasing this way the market potential of the envisaged system	Could

185		TIP-06	The system should encompass the necessary mechanisms which will ensure the integrity and trustworthiness of the envisioned marketplace considering non-personal data as well as the management of personal data, legal and ethical frameworks, where data based services and related software & tools can be offered and easily used	Should
186		TIP-07	The envisaged digital twin component should consider the following aspects with regard to the envisioned effective predictive analytics: • real-time data integration and fidelity • efficient interconnection mechanisms with the rest OPTIMAI technical components • decentralized decisions and technical assistance • address potential prediction uncertainties provided by the employed AI	Must
187		TIP-08	The envisaged components pertaining to the interoperability and management of the IoT components, sensors and devices that constitute the main provenance of data collection should be designed toward maximizing the accessibility, integrity, availability, scalability, confidentiality, and interoperability amongst these devices.	Must
188		TIP-09	The system should address cybersecurity at all layers of the IoT environment (e.g., sensing layer, network layer, middleware layer, and application layer) and appropriate countermeasures should be applied at each layer for addressing potential security attacks.	Must
189		TIP-10	The system should encompass all the necessary back-end infrastructure to support effective communication between operational planning and maintenance planning.	Must
190		TIP-11	The content delivered through the AR solution should be appropriate for the task at hand, keeping information as minimum as possible to achieve the task execution in an effective and efficient manner	Must
191		TIP-12	A marker-less solution to AR tracking should be supported, in order to increase the reliability of the approach in the industrial context.	Must
192		TIP-13	The user input methods supported should be appropriate for the current task, such as gesture-based or gaze-based interactions, each one as needed (e.g. when the worker's hands are occupied gaze-based interactions should be preferred).	Should