D2.1

User and ethics and legal requirements – 1st version

30 June 2021

OPTIMAI

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 958264

DOCUMENT SUMMARY INFORMATION

Grant Agreement No	958264	**Acronym**	OPTIMAI
Full Title	Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization		
Start Date	01/01/2021	**Duration**	36 months
Deliverable	D2.1 User and ethics and legal requirements I		
Work Package	WP 2 User requirements, Technical Specifications and Use case analysis		
Nature		**Dissemination Level**	
Lead Beneficiary			
Authors	Theofilos Mastos (KLEE)		
Co-authors	Emma Teodoro (UAB) Andrea Guillén (UAB) Agata Gurzawska (TRI) Paul Hayes (TRI) George Margetis (FORTH) Stavroula Ntoa (FORTH)		

DISCLAIMER

The OPTIMAI Project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 958264. The sole responsibility for the content of this document lies with the authors. It does not necessarily reflect the opinion of the European Union. The European Commission is not responsible for any use that may be made of the information contained herein.

DOCUMENT HISTORY

Version	Date	Changes	Contributor(s)
V0.1	01/04/2021	Initial Deliverable Structure	Theofilos Mastos (KLEE) George Margetis (FORTH)
V0.2	31/05/2021	50% of the deliverable content	Theofilos Mastos (KLEE) Emma Teodoro (UAB) Andrea Guillén (UAB) Agata Gurzawska (TRI) Paul Hayes (TRI)
V1.0	10/06/2021	Internal Review Version	Theofilos Mastos (KLEE)
v1.1	15/06/2021	1st version with suggested revisions	Christina Tsita (CERTH)
v1.2	20/06/2021	2nd version with suggested revisions	George Margetis (FORTH) Stavroula Ntoa (FORTH)
V1.5	29/06/2021	Revisions after internal review	Theofilos Mastos (KLEE)
V2.0	30/06/2021	Quality check	Sabrina Verardi (ENG)
V2.1	30/06/2021	Final version for submission	Theofilos Mastos (KLEE)

PROJECT PARTNERS

Logo	Partner	Country	Short name
	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS	Greece	**CERTH**
	FINT FUTURE INTELLINGENCE LIMITED	Cyprus	**FINT**
	IDRYMA TECHNOLOGIAS KAI EREVNAS	Greece	**FORTH**
	EVT EYE VISION TECHNOLOGY GMBH	Germany	**EVT**
	VISUAL COMPONENTS OY	Finland	**VIS**
	YOUBIQUO SRL	Italy	**YBQ**
	PANEPISTIMIO THESSALIAS	Greece	**UTH**
	ENGINEERING – INGEGNERIA INFORMATICA SPA	Italy	**ENG**
	UNIMETRIK SA	Spain	**UNIMET**
	UNIVERSITAT POLITECNICA DE VALENCIA	Spain	**UPV**
	Carr Communications Limited	Ireland	**CARR**
	UNIVERSIDAD AUTONOMA DE BARCELONA	Spain	**UAB**
	TRILATERAL RESEARCH LIMITED	Ireland	**TRI**
	KLEEMANN HELLAS –INDUSTRIAL COMMERCIAL SOCIETE ANONYME FOR MECHANICAL CONSTRUCTION SA	GREECE	**KLEE**
	TELEVES SA	Spain	**TVES**
	MICROCHIP TECHNOLOGY CALDICOT LIMITED	United Kingdom	**MTCL**

LIST OF ABBREVIATIONS

Abbreviation	Definition
OPTIMAI	Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization
WP	Work Package
Dx.x	Deliverable number x.x
IoT	Internet of Things
AI	Artificial Intelligence
IT	Information Technology
AR	Augmented Reality
Q-UR	Questionnaire User Requirement
VID-DD-UR	Video Defect Detection User Requirement
VID-OST-UR	Video Optimal Set Up User Requirement
VID-DT–UR	Video Digital Twins User Requirement
FR	Functional Requirement
NFR	Non-Functional Requirement

Executive summary

The purpose of the deliverable *D2.1 'User and ethics and legal requirements I'* is to gather and analyse the 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 kicks off the relevant development and integration activities in the OPTIMAI project. The requirements elicitation and analysis take into account the Description of Action (DoA), the requirements identified 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, ethics and legal requirements, as well as technological innovation potential requirements are identified and included in this document.

The initial identification of requirements is based on questionnaires, online meetings and videos 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 127 requirements are identified out of which 81 are prioritised as "Must" (have), 36 as "Should" have and 10 as "Could" have.

Table of contents

LIST OF FIGURES

LIST OF TABLES

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 define 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 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 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 user and ethics and legal requirements questionnaire template.

Method for gathering user and ethics and legal requirements

The general approach to the requirements elicitation process includes the following 4 steps:

1.4 Initial identification of stakeholders' needs

The first step is related to the initial identification of stakeholder requirements. The identification of requirements is based on three specific sources of information.

a) Questionnaire for user and ethics and legal requirements

A requirements questionnaire is designed by WP2 and WP9 partners in the context of *Task 2.1: Consolidation of user and ethics and legal requirements*, which aims to formulate the user requirements for OPTIMAI taking into account legal and ethical aspects. These user requirements elicited through the questionnaires are then analysed towards identifying the functional and non-functional requirements of the OPTIMAI platform along with the input that have be collected from the specification of the OPTIMAI use cases. Hence through the questionnaire an initial identification of the following aspects has been achieved: a) the current manufacturing and business processes, b) the problems and deficiencies in existing systems, c) the OPTIMAI opportunities and objectives, d) the human participation issues and e) the data processing issues. The questionnaire is structured in 4 parts i.e. 1) General OPTIMAI questions, 2) End user requirements, 3) Human participation and 4) Data processing. The questionnaire template can be found in the Appendix section.

Legal and ethical requirements have been extracted according to the following three tasks:

- *Knowledge acquisition*

Within the 'User and ethical and legal requirements' questionnaire (Task 2.1), two specific sets of ethical (focused on human participation) and legal questions (focused on data processing) were included to gather relevant information from OPTIMAI technical partners and end-users to ultimately enable the identification of ethical and legal requirements.

- *Identification of legal and ethical sources*

Based on the general ethical and legal framework identified for the project in D9.1 and the information gathered as a result of the knowledge acquisition stage, UAB and TRI specified the legal and ethical sources from which the OPTIMAI legal and ethical requirements should stem from.

- *Definition of the requirements*

From the legal and ethical sources, the requirements that should be observed in OPTIMAI were identified and defined. To that end, an ID was assigned to each requirement and a set of implementation actions to operationalise them was provided.

b) WP2 Online meetings

Notes from the project teleconferences have also contributed to the initial identification of user needs.

c) Videos and related presentations from pilots

Due to the COVID-19 travel restrictions, end-users have managed to provide videos 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.

1.5 Collaboration, negotiation and agreement

This stage includes collaboration and discussions between partners to foster agreements and establish priorities. This stage will take place between M7 and M9 and it will be based on workshops.

1.6 Requirements' specification

At this stage, requirement engineering processes will be conducted in order to ensure a systematic approach to manage the requirements.

1.7 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.

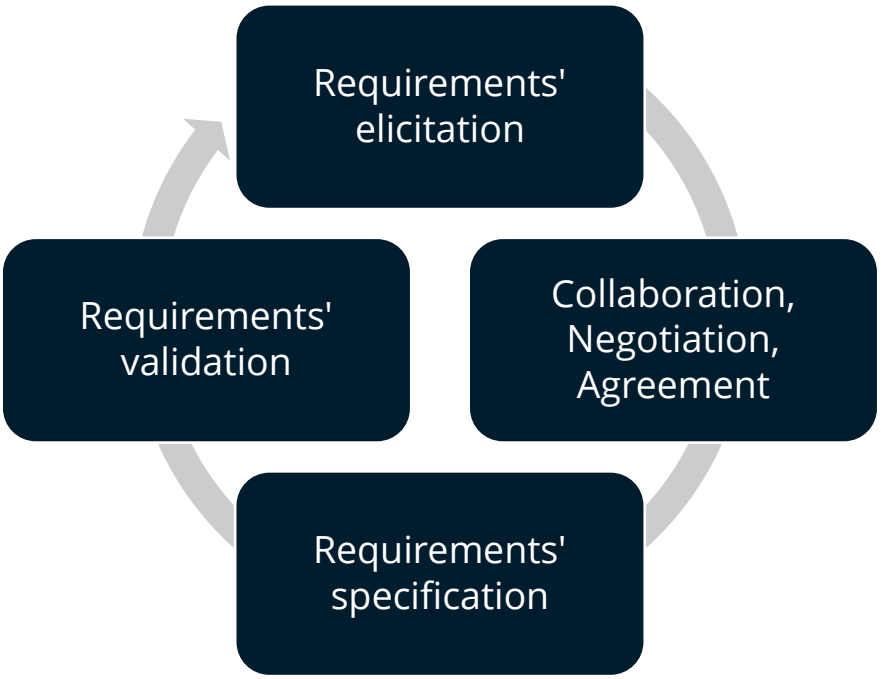


Figure 1: Requirements' elicitation process

1.8 Requirement derivation

As a consolidated outcome of the requirements' sources, an initial set of user, ethics and legal requirements is identified. The identified requirements will be implemented in the course of the project, and new requirements, if necessary, will be added based on the user 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, videos, on-line meetings are provided and then these requirements are transformed into functional and non-functional requirements based on the components of the OPTIMAI architecture. Functional requirements describe what the system should do, and non-functional requirements describe how the system works. The following figure shows the hierarchy of the requirements analysis.

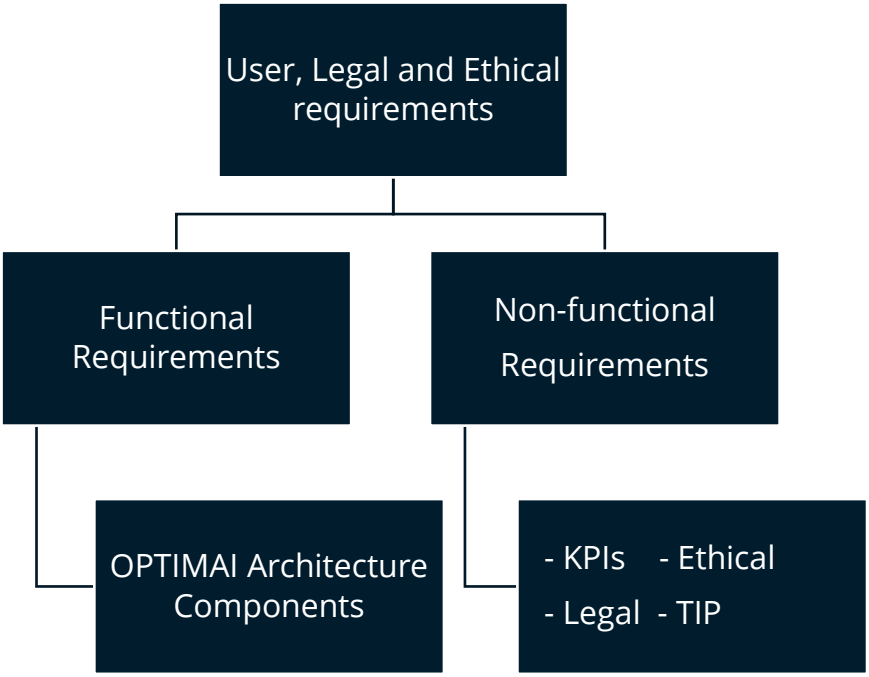


Figure 2: Hierarchy of the requirements analysis

1.9 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.

Results

In this section the results of the requirements identification are presented as a consolidated outcome of the 'User and ethical and legal requirements' questionnaire, the WP2 online meeting and the videos and presentations of the pilot partners. In total, 127 requirements are identified and distributed in three main categories i.e. User requirements, functional and non-functional requirements (see Table 1 and Figure 1).

Table 1: Requirements' categories

Requirement by category		**Count**
User requirements	Questionnaire User Requirements	14
	Pilots' videos User Requirements	33
Functional Requirements	Functional Requirements	15
Non-Functional Requirements	Key Performance Indicators	18
	Legal requirements	10
	Ethical Requirements	24
	Technological Innovation Potential	13
	Total	**127**

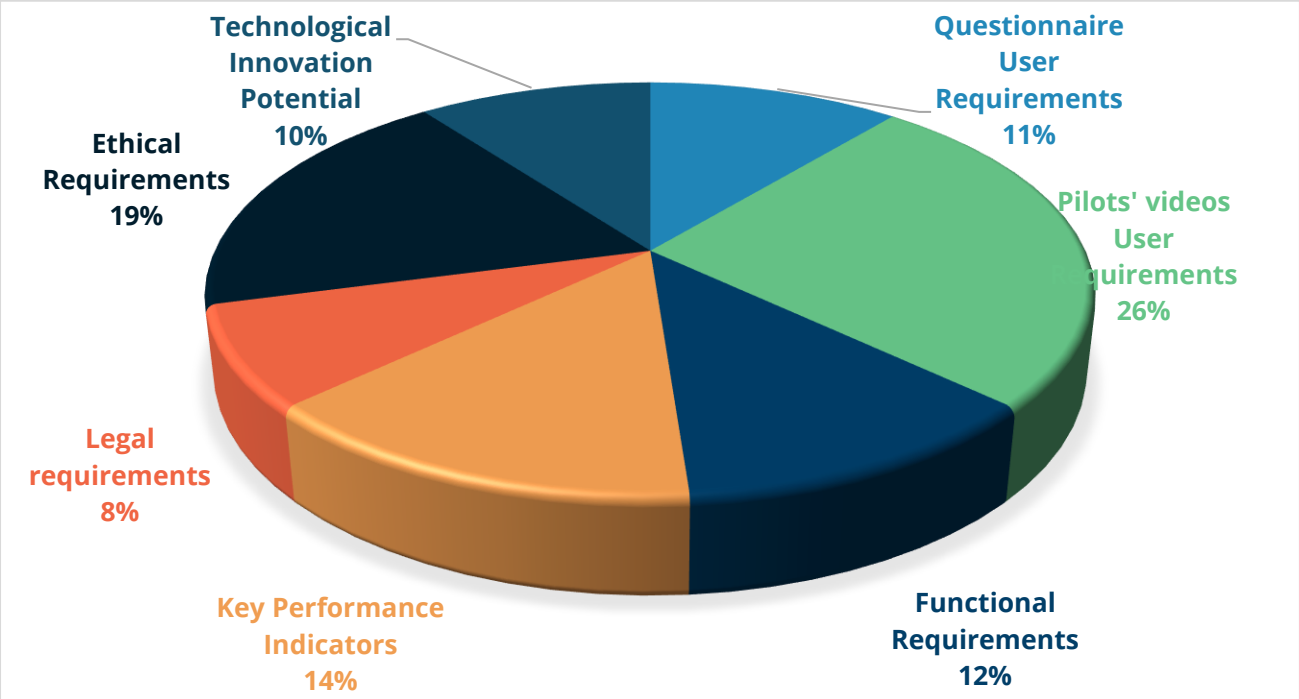


Figure 3: OPTIMAI Requirements' Distribution

Most of the identified requirements are prioritised as Must (see Table 2 and Figure 4), 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	81
Should	36
Could	10

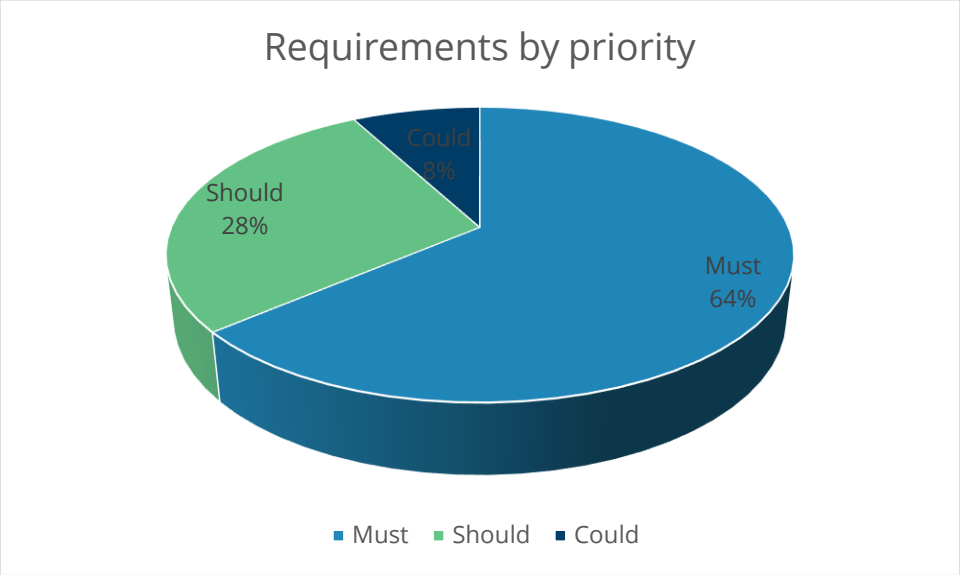


Figure 4: Requirements by priority

1.10 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. 14 requirements have been identified from the questionnaire. These requirements will be updated in the next version of this deliverable (D2.2) according to the project's developments and the user's feedback. Each Questionnaire User Requirement (Q-UR) is identified by at least one user.

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 colleciton 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			

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 real-time data traceability			

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 prodcution 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 advices			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 automated recalibration UR-7c: The system shall provide suggestions regarding the necessary reconfiguration and parameterization in an autonomous way			

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 user name 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 adequate 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 neededUR-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 sequenceUR-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 defect 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			

1.11 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 will be examined in each pilot i.e. 1) Zero defect quality inspection, 2) Production line setup-calibration and 3) Production planning. The user requirements are extracted from videos 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 are also established in each of the requirements.

1.11.1 KLEEMANN: Lift manufacturer

Table 17: Check parts used

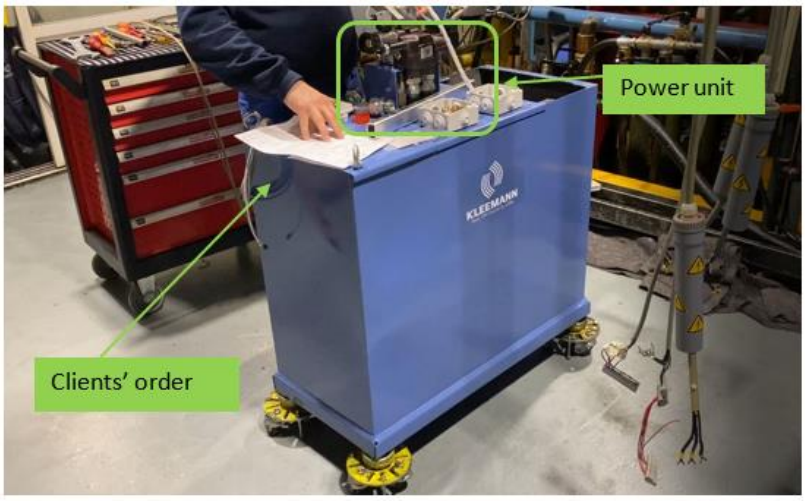
PILOT	KLEEMANN - KLEE
User	Operator
Current procedure:	Hydraulic lift Power Unit Quality Control – Check parts used
Current procedure description:	The operator manually inspects the power unit and checks if the right parts have been used. To do so the operator visually inspects and recognizes the parts 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

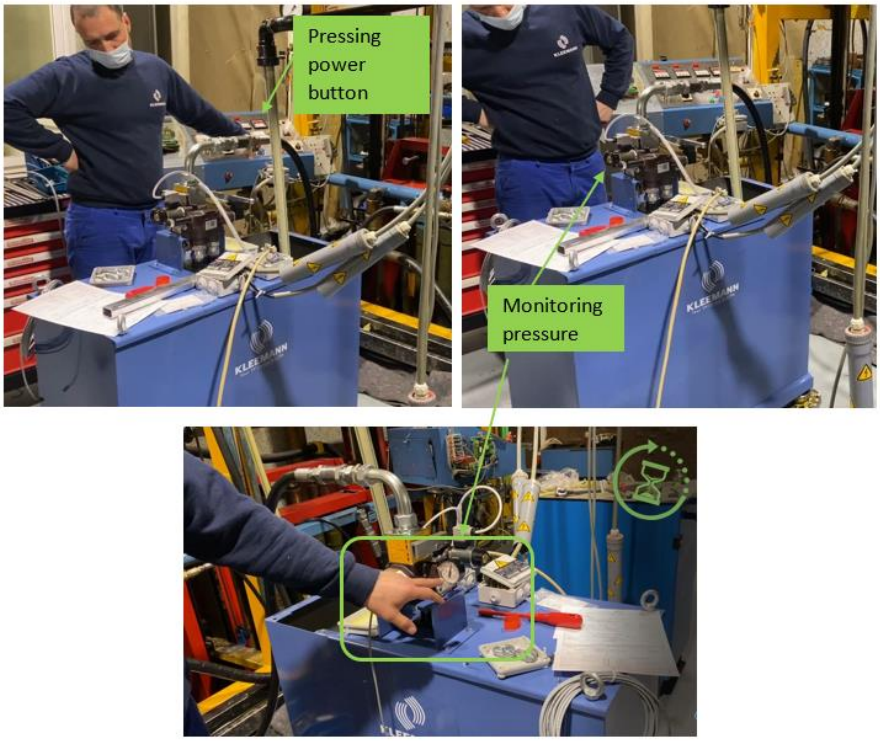
PILOT	KLEEMANN - KLEE
User	Operator
Current procedure:	Hydraulic lift Power Unit Quality Control – Valve block pressure monitoring
Current procedure description:	Once the operator has put into operation the power unit, waits 3 minutes monitoring the pressure of the valve block. In case the pressure of 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.

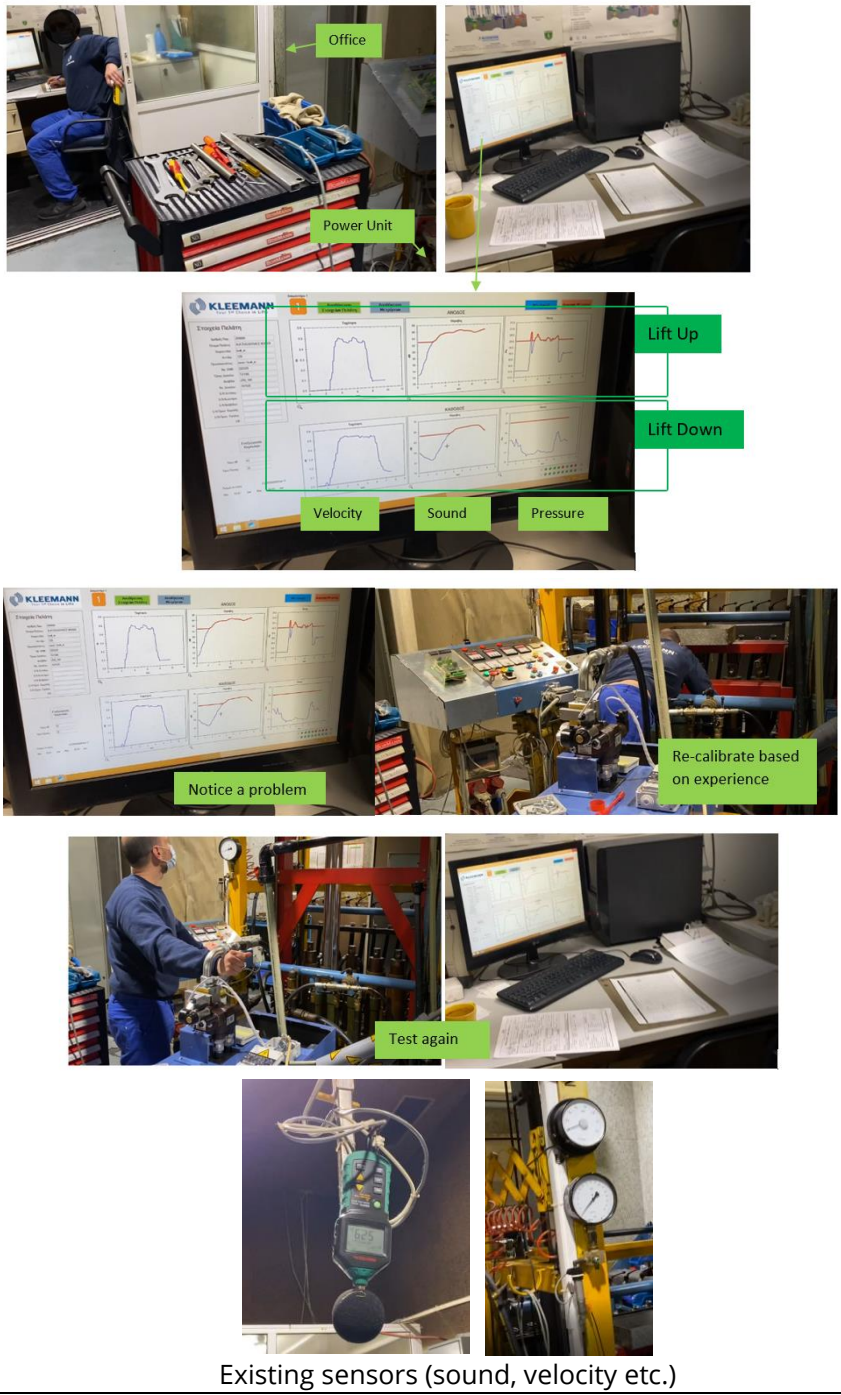
	 Existing sensors (sound, velocity etc.)
User goals:	• During the testing of the lift, users should be able to monitor parameters (e.g. velocity, sound, vibration, pressure etc.) that might indicate a defected unit, without moving to another area, to save time. • It is highly desirable the users to be 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.			Must

Table 25: Defect detection

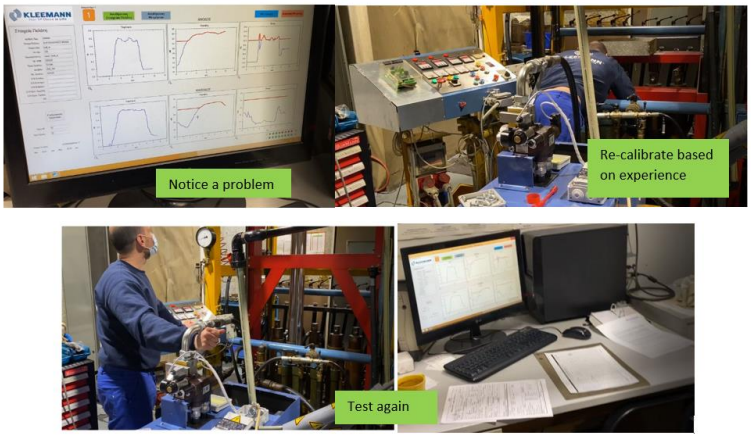
PILOT	KLEEMANN - KLEE
User	Production Manager
Current procedure:	Hydraulic lift Power Unit Quality Control – Defect detection
Current procedure description:	During testing, in case that the testing measurements indicate a defect, only the experienced operators know what might do to resolve the issue 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

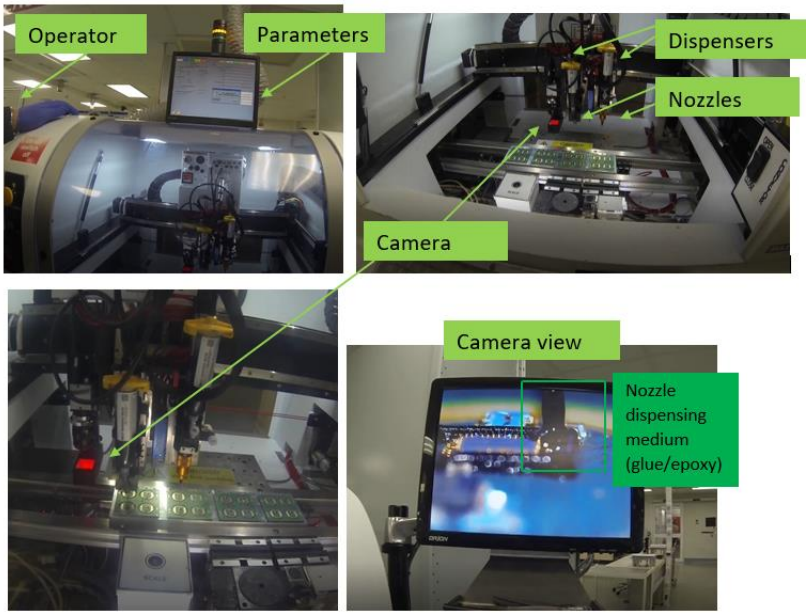
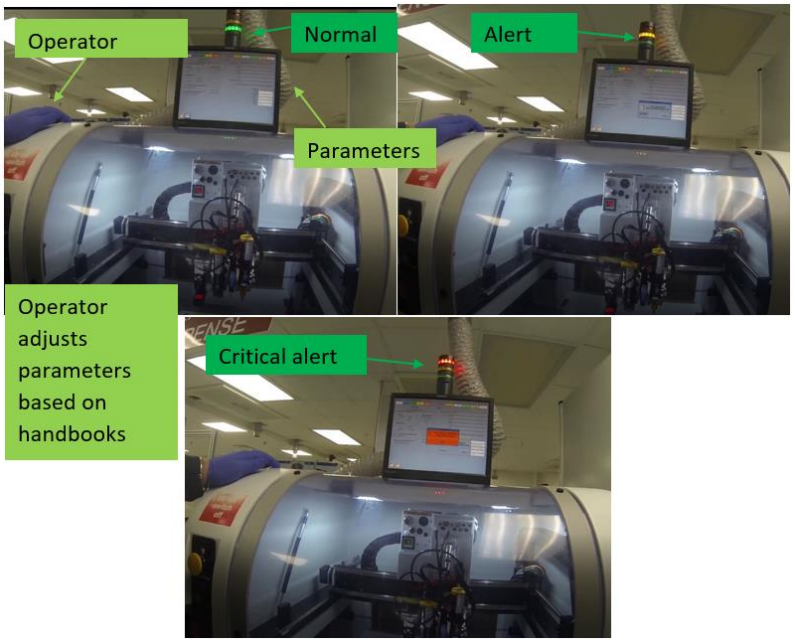
Table 27: User Requirements (UR) exported from videos per process, UR category and Priority (KLEE)

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**

1.11.2 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			Should

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.			Should

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)

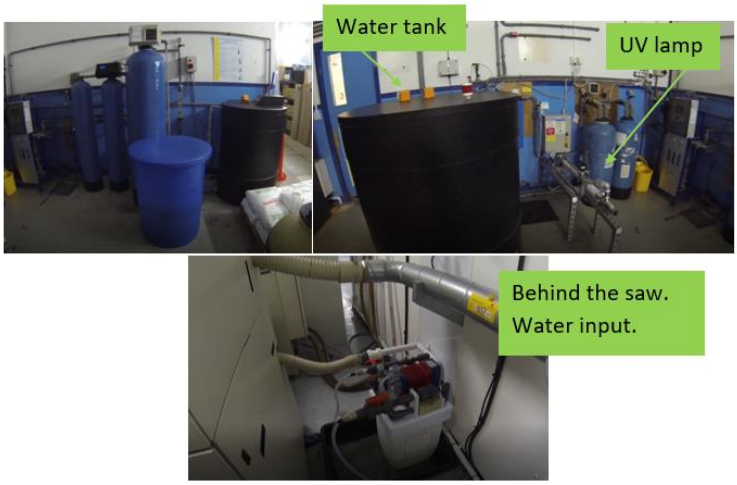
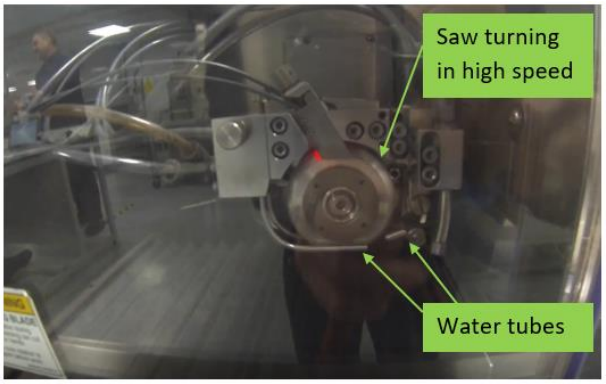
ID	MTCL-VID-DT-UR2	**Requirement**	Digital Twin	**Priority**
Description	Users should be able to rapidly transfer the optimal set up of parameters of GPD dispensing system for different products from the digital replica to the real production line.			Should

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.			Could

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

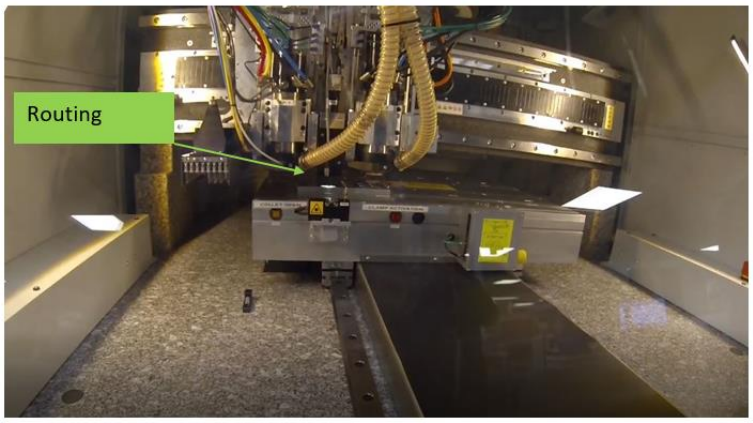
PILOT	MICROSEMI - MTCL
User	Operator
Current procedure:	Printed Circuit Board (PCB) Routing
Current procedure description:	During PCB routing deficiencies can cause short circuits that can lead to scrap. Important parameters of the circuit board routing include (e.g. distance between components, routing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

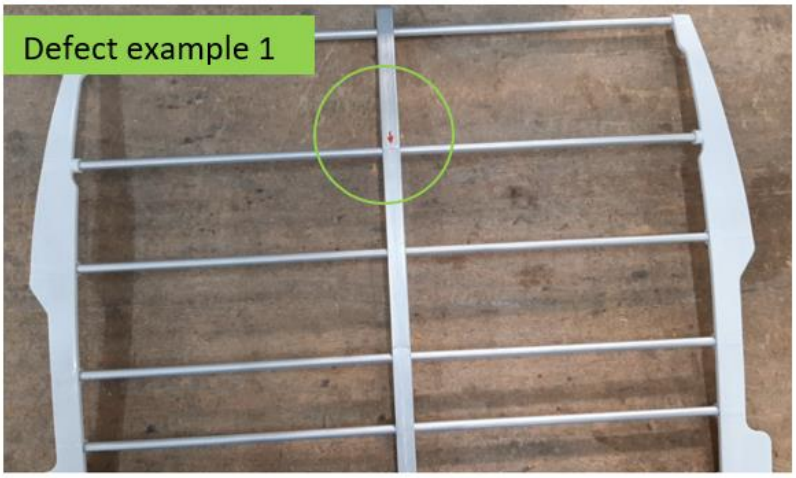
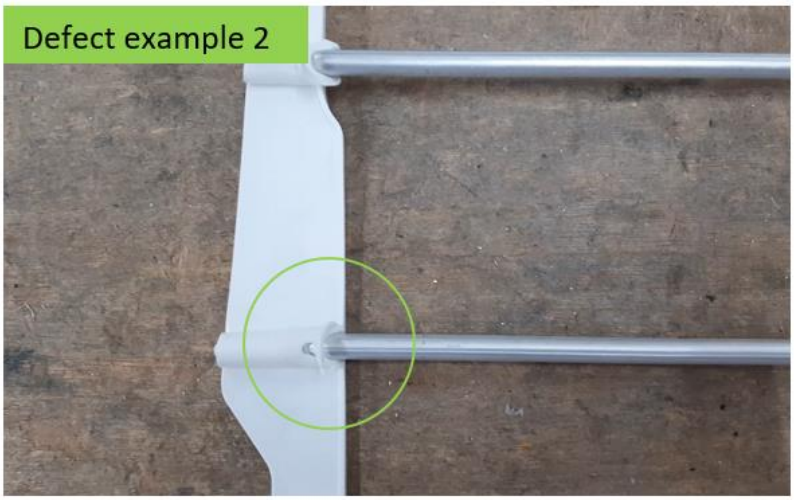
Table 47: User Requirements (UR) exported from videos per process, UR category and Priority (MTCL)

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		3			**3**
Digital Twin		3			**3**
Water sawing					
Defect detection	1	2	1		**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**

1.11.3 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 is not always known what caused the defect. Hydraulic press in the robotic cell  Antenna inside the press  Antenna entering the press  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	• Users must be notified about defective materials entering the antenna line.			Must

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

ID	TVES-VID- DD –UR2	Requirement	Defect detection	Priority
Description	• Users must be notified about defective products (e.g. incorrect assembly) to increase product quality in the antenna line.			Must

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

ID	TVES-VID- DD –UR3	Requirement	Defect detection	Priority
Description	• Users must be able to monitor some parameters that can indicate suboptimal manufacturing (e.g. reduced efficiency by changes betwenn different products assembled on the line, stoppages in inspection systems, incidents in material feeding peripherals/ pallet conveyor systems, software/hardware incidents in robotic cells).			Must

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

ID	TVES-VID- OSU –UR1	Requirement	Optimal set up	Priority
Description	• Some of the parameters of the machinery should be adjusted automatically when defects are detected in the antenna line.			Should

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

ID	TVES-VID- OSU –UR2	Requirement	Optimal set up	Priority
Description	• Some of the machine parameters should 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).			Should

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

ID	TVES-VID-OSU –UR3	Requirement	Optimal set up	Priority
Description	• Users should be able to use Human Computer Interface based on gestures to interact with the machinery.			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	6	1		**10**
Optimal Set Up		3			**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**

1.12 Functional requirements

Functional requirements have been organised in eight component categories based on the OPTIMAI architecture (Figure 5).

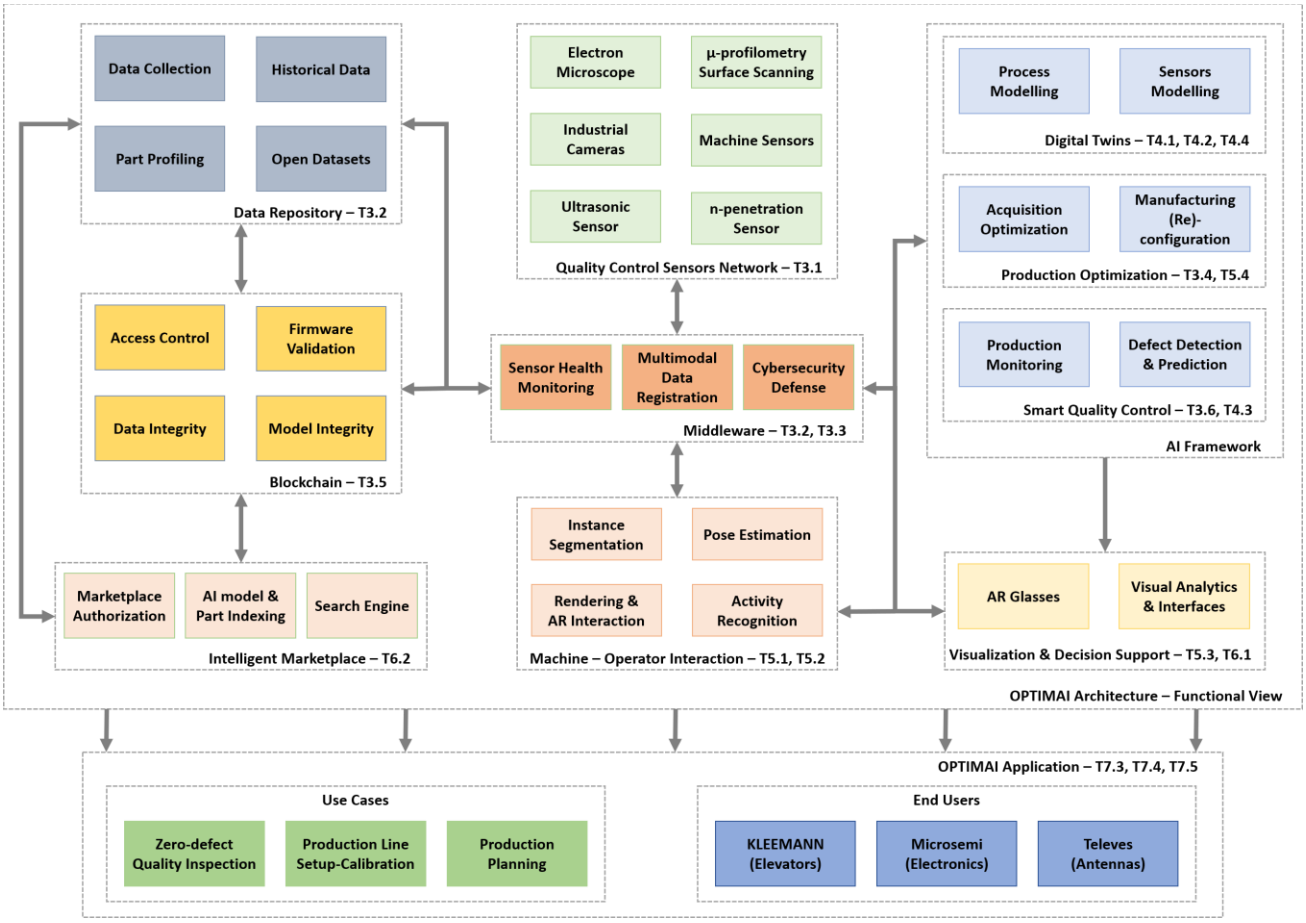


Figure 5: OPTIMAI Architecture

Defining the component 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, T Leader. The following components have been identified based on the OPTIMAI architecture (Table 62Table 62)

Table 62: OPTIMAI Architecture components

A/A	OPTIMAI Architecture component	Short	Related tasks
1	**Quality Control Sensor Network:** • Various sensors according to pilot	**QCSN**	T3.1
2	**Middleware** • Multimodal Data Registration • Sensor Health Monitoring • Cybersecurity module	**MID**	T3.2, T3.3

3	**Machine-Operator Interface** • Instance Segmentation • Pose Estimation • Activity Recognition • Rendering & AR interaction	**MOI**	T5.1, T5.2
4	**Data Repository** • Data Collection • Historical Data • Part Profiling • Open Datasets	**DR**	T3.2
5	**Blockchain** • Access Control • Firmware Validation • Data Integrity • Model Integrity	**BC**	T3.5
6	**Intelligent Marketplace** • Marketplace Authorization • AI model & Part Indexing • Search Engine	**IM**	T6.2
7	**AI framework**		

	• Smart Quality Control
	  ○ Production Monitoring
	  ○ Defect Detection & Prediction
		SQC	T3.6, T4.3

	• Production Optimization
	  ○ Acquisition Optimization
	  ○ Manufacturing (Re)-configuration
		PO	T3.4, T5.4

	• Digital Twins
	  ○ Process Modelling
	  ○ Sensors Modelling
		DT	T4.1, T4.2, T4.4

8	**Visualization & Decision Support** • AR Glasses • Visual Analytics & Interfaces	**VDS**	T5.3, T6.1

1. Quality Control Sensor Network (Task 3.1)

The key goal of task 3.1 is to develop the right sensors for the right task and to facilitate an easy-to-use inspection of production parts. The developed sensors should be easily connected with other devices and allow for data processing on the edge. As a result, this task will offer the manufacturer the ability to monitor production data in real time and minimise defects as early as possible. Integration of inspection and feedback data, is also important for the implementation of this component.

The following **functional requirements** (FR) are identified within the Quality Control Sensor Network component.

Table 63: Connectivity (FR-1)

ID	FR-1	**Requirement**	Connectivity	**Priority**
Description	The system and the developed sensors shall be able to be connected with other sensors and machines			Must
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**
Description	The system shall be able to process data generated from sensors			Must
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 preprocessing of data (e.g. lightweight AI networks) FR-2c: Inspection data shall be integrated with feedback data		Linked to: MTCL-VID-DD –UR7	

2. Middleware (Tasks 3.2, 3.3)

The purpose of middleware layer is to integrate the different types of sensors that will be developed under a common framework and provide data management functionalities such as collecting and forwarding quality inspection and production data, to ensure the correct data registration in time. Furthermore, a cybersecurity module will be developed within the middleware layer, in order to protect the sensors network from cyber-attacks.

The key goals of these tasks are summarised in the following objectives:

- **Middleware for orchestrating data collection**

- **Interfacing with all sensors, machines, actuators**
- **Collected data registered in space (production space) and time (timestamp)**
- **Data fusion**
- **Cyber-defense module**

The following functional requirements (FR) are identified within the Middleware component.

Table 65: Integration (FR-3)

ID	FR-3	**Requirement**	Integration	**Priority**
Description	The different types of sensors shall be integrated under a common framework			Must
Implementation in OPTIMAI	FR-3a: Interfacing with all sensors, machines, actuators		Linked to: Q-UR-2	

Table 66: Data management (FR-4)

ID	FR-4	**Requirement**	Data management	**Priority**
Description	The system shall be able to manage the data acquisition and flow to the control and analysis modules			Must
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 (production space) and time (timestamp) FR-4e: Data fusion		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	

Table 67: Cyber-defence (FR-5)

ID	FR-5	**Requirement**	Cyber-defence	**Priority**
Description	The system shall develop a cyber-defence module			Must
Implementation in OPTIMAI	FR-5a: Middleware shall incorporate a cybersecurity module to protect the sensors network against cyber-threats		Linked to: Q-UR-3 Q-UR-8	

	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 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).		

The following non-functional requirements (KPI) are identified within the Middleware component.

3. Machine-Operator Interface (Tasks 5.1, 5.2)

The machine-operator component includes computer vision techniques that enable the recognition of scenes and activities in order to support augmented reality functionalities such as the re-adjustment or re-calibration of production equipment. Furthermore, human activity recognition such as operator gestures, will be implemented in order to support the fast and accurate interaction between operator and machine. The aforementioned information will be displayed in a graphical user interface (GUI). The developed GUI will provide only the necessary information and analysis of possible defects.

The following functional requirements (FR) are identified within the Machine Operator Interface component.

Table 68: Recognition (FR-6)

ID	FR-6	**Requirement**	Recognition	**Priority**
Description	The system shall be able to recognise activities, scenes and human recognition			Must
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**
Description	The system shall support the interaction of operator and machine			Must
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**
Description	Production Information shall be displayed in the user			Must
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	

4. Data Repository (Task 3.2)

Data repository is the component that is responsible for the project's data management The insertion of online and historical data as well as open datasets in a standard data format will be supported by the repository.

The following **functional requirements** are included in the Data Repository component.

Table 71: Storage (FR-9)

ID	FR-9	Requirement	Storage		Priority
Description	Data repository				Must
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	

5. Blockchain (Task 3.5)

This purpose of this blockchain is to:

1) log all critical operations as immutable and verifiable transactions in a blockchain network
2) develop an automated procedure through smart contracts, in order to perform several production processes
3) design an access control mechanism that will allow only authorized users to perform critical operations
4) encompass integrity verification mechanisms for the deployed software and firmware, the AI models and for the sensor measurements
5) use an external database to store the massive amount of sensor measurements
6) ensure private and secure firmware updates between companies and sensors based on digital identities

The following functional requirements are included in the Blockchain component

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

ID	FR-10	Requirement	Integrity, transparency and traceability		Priority
Description	The system shall develop a mechanism that will provide integrity, immutability, transparency and traceability of all critical transactions				Must
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			Linked to: Q-UR-4	

	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		

6. Intelligent Marketplace (Task 6.2)

The key goal of the development of the intelligent marketplace component is to reduce the wasted resources. This will be achieved through the recording and indexing of defective parts in order to be re-used for R&D testing, refurbishing and other purposes. The intelligent marketplace will support the sharing of AI algorithms, in order to help other organisations, use the AI models for defect detection and prediction.

Although not mentioned by any of the users directly, an intelligent marketplace will be developed in order to reduce the generation of waste in the long term. The following functional requirements are included in the intelligent marketplace component.

Table 73: Marketplace (FR-11)

ID	FR-11	**Requirement**	Marketplace	**Priority**
Description	The system shall develop an intelligent marketplace			Must
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	Linked to: TIP-06		

	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		

7. AI Framework

An AI framework will be developed in the OPTIMAI that will include AI techniques implemented in the manufacturing processes. The developed AI framework includes the following three components.

a) Digital Twins (Tasks 4.1, 4.2, 4.4)

The main purpose of digital twins is to enable process and sensor modelling through the digitisation and simulation of various production aspects. More specifically, this component will digitize and simulate the behavior and properties of; i) manufactured parts, ii) production processes and iii) sensors, in order to identify quality related issues and prevent them.

Table 74: Digital twins (FR-12)

ID	FR-12	**Requirement**	Digital Twins	**Priority**
Description	The system shall develop AI enabled digital twin models			Must
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.		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	

	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 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.		

b) Production Optimization (Tasks 3.4, 5.4)

With the use of digital twins, the production optimisation component will offer the end-users, the ability to analyse the impact of different production parameters and select the optimal ones based on defect and waste minimisation and resource savings. Key characteristics of this component is the real-time, automated re-configuration of the manufacturing process and the optimization of acquisition conditions such as exposure time, resolution etc., during quality control and data collection.

Table 75: Production Optimisation (FR-13)

ID	FR-13	**Requirement**	Production Optimisation	**Priority**
Description	The system shall develop a production optimisation model			Must
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.		Linked to: Q-UR-7; KLEE-VID-OSU-UR1; KLEE-VID-OSU-UR2; MTCL-VID-OSU –UR1;	

	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 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	MTCL-VID-OSU –UR2; MTCL-VID-OSU –UR3; TVES-VID-OSU –UR1; TVES-VID-OSU –UR2; TVES-VID-OSU –UR3	

c) Smart Quality Control (Tasks 3.6, 4.3)

Smart Quality Control focuses on production monitoring and defect detection and prediction. Signals from sensors will be analysed with the use of deep models that will identify, localize and predict defects. More specifically, quality control measurements will be analysed in the immediate past and digital twin models will be used to model manufacturing processes under certain parameters.

Table 76: Smart quality control (FR-14)

ID	FR-14	**Requirement**	Smart Quality Control	**Priority**
Description	A smart quality control system shall be developed for production monitoring and defect detection and prediction			Must
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 and point clouds from 3D sensors.		Linked to: Q-UR-1; Q-UR-12; KLEE-VID-DD-UR2; KLEE-VID-DD-UR3; MTCL-VID-DD -UR1; MTCL-VID-DD -UR2;	

	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 -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	

8. Visualization & Decision Support (Tasks 5.3, 6.1)

The focus of the Visualization and Decision Support component is to provide a visualisation of the data analysis of the production monitoring and inspection results. AR glasses will be used as a device of visualisation and visual interfaces will be developed in order to support the decision making based on the aggregated analysis of the results.

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

ID	FR-15	**Requirement**	Visualisation and Decision Support	**Priority**
Description	A Visualization and Decision Support system shall be developed to visualise the production monitoring and inspection results			Must
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 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		Linked to: Q-UR-10; KLEE-VID-DD-UR2; KLEE-VID-DD-UR3; KLEE-VID-OSU-UR1; KLEE-VID-OSU-UR2; MTCL-VID-DD -UR2; MTCL-VID-DD -UR4;	

	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	MTCL-VID-OSU –UR1; MTCL-VID-OSU –UR2	

1.13 Non-functional requirements

Non-functional requirements are divided in four main groups i.e. **1) KPIs, 2) Legal requirements**, **3) Ethical requirements and 4) Technology innovation potential requirements**

1.13.1 KPIs

Based on the user requirements identified in the previous section and in the OPTIMAI's vision, specific KPIs that will assist in verifying the performance of the developed solution are identified. The identified KPIs are extracted from the objectives of OPTIMAI's project as described in the DoA.

Table 78: Network traffic (KPI-1)

ID	KPI-1	**Requirement**	Network traffic	**Priority**
Description	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: Average improvement of system security and privacy > 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%		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%		Linked to: KPI O3.1	

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%		Linked to: KPI O3.3	

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 behavioral 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%		Linked to: KPI O5.5	

1.13.2 Legal and Ethical requirements

The OPTIMAI legal and ethical requirements are subsequently presented in tables. 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 will be updated in D2.2 according to the project's developments. The current general legal and ethical requirements will be refined in D2.2 after an elicitation process (webinar, workshop and dialogue sessions) that will be conducted by UAB and TRI in the forthcoming months with OPTIMAI technical partners and end-users.

1.13.2.1

1.13.3 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	

[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

Table 97: Integrity (INT)

ID	INT	Requirement	Integrity	Priority
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, property, birth, disability, age or sexual orientation, has the right to equal pay for equal work and equal opportunities	Art. 23 UDHR Art. 7 ICESCR 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. <u>Data processing activities</u>

- 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**

[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

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 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.		Must
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.	Art. 5 GDPR	

	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 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 securety 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.	Art. 6 GDPR	

	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 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	Art. 9 GDPR	

	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 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: - 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.	Art. 32 GDPR	
	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**
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		Art. 5 Artificial Intelligence Act Proposal	

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

	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 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.	Arts. 8-15 Artificial Intelligence Act Proposal	

	- 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.		
	AIT-R4. Providers of high-risk AI systems must, upon request by a national competent authority, provide that authority with all the information and documentation necessary to demonstrate the conformity of the high-risk AI system with the above-mentioned requirements	Arts. 23 Artificial 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.			

[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

5. Responsible business

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

1.13.4 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

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

Design". These ethical principles are: i) human autonomy, ii) prevention of harms, iii) fairness and, iv) transparency/explicability.

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

Sources:

- 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

[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/

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.	

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

[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

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 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.			

[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-R2. Measures against coercion, threats to mental health and surveillance should be put in place. 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 that 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.			

1.13.5 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 section concludes with a discussion on the current technological trends and a brief highlight of the current market environment, as a testimonial of the innovation potential of the OPTIMAI technologies. More detailed elaboration on these aspects will be contributed in the context of WP8, which is responsible for the dissemination, commercialization, and exploitation strategies.

1.13.5.1 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, which will act as key enabler 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 (Wan et al., 2018). 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 (Lee et al., 2018). 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 (Zhong et al., 2017). In the context of decision-making for smart manufacturing, the following requirements have also been identified (Helu et al., 2016): 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 (Turner et al. 2019).

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

Table 130: 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 the consider putting humans-in-the-loop so that the operators to interact efficiently and effectively with the envisioned decision-making system.			Should

Table 131: 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

1.13.5.2 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 classified in three main categories: (a) challenges in data acquisition, (b) challenges in data pre-processing and storage and (c) challenges in data analytics (Dai et. al. 2020). 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 132: 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

1.13.5.3 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 their transition from a centralized approach towards approaches establish a new type of trustable platforms as blockchain cloud manufacturing with aiming to developed peer to peer and decentralized network infrastructures (Li et. al. 2018). An additional factor that need 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 (Abeyratne and Monfared 2016). To that end, Smart contracts should be implemented and be 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 the 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 133: 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 134: 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

1.13.5.4 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, where 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 – places that 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, 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 135: 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

1.13.5.5 Digital Twin for Simulation and Forecasting

Coupled with AI capabilities it 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" (Lu et al., 2020). In the current technological context, digital twin has been referred to as the biggest technology trend disrupting engineering and design in 2020 (Marr, 2019). 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 (Durão et al., 2018).

In order to achieve its potential, real-time data, integration, and fidelity are the requirements mostly dealt with and valued by the literature (Durão et al., 2018). Additional requirements stemming from literature research include interconnection, information transparency, decentralized decisions, and technical assistance (Sandkuhl & Stirna, 2020). An analysis based on the phases of the digital twin lifecycle (Moyne et al., 2020) 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 136: 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

1.13.5.6 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 leverage further 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 (Ali, Bosche, & Ford, 2018). 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 (Mullet, Sondi, & Ramat, 2021). Cyber-risks no longer affect only the IT, but in this context have considerable impact in production systems and products (Poppensieker & Riemenschnitter, 2018). 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 (Mullet, Sondi, & Ramat, 2021). The architectural design of IoT-based cybersecurity requires accessibility, integrity, availability, scalability, confidentiality, and interoperability among heterogeneous smart devices (Lu & Da Xu, 2018). 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 (Lu & Da Xu, 2018).

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

Table 137: 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 138: 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

1.13.5.7 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 will be able to re-configure of 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 (Wang, Yew, Ong, & Nee, 2020). 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 (Mourtzis, Vlachou, Zogopoulos, & Xanthi, 2017), 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 (Url, Vorraber, & Gasser, 2019). 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 (Syberfeldt, Danielsson, & Gustavsson, 2017). 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 in order to achieve reliability of in the industrial environment, marker-less approaches are preferrable to mitigate problems introduced by dust and dirt to marker-based tracking solutions (Masood & Egger, 2019). With regard to user input, prominent interaction methods have been identified to include gesture recognition, gaze-based input, or discrete hardware solutions (Masood & Egger, 2019).

Table 139: 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 140: 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 141: 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 142: 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.			Should

	when the worker's hands are occupied gaze-based interactions should be preferred).	

1.13.5.8 Technological trends and market needs

According to the innovation map provided by StartUsInsights[37], derived by working with a dedicated big data and AI-powered platform covering more than 1 million startups around the world, the key trends and innovations in Industry 4.0 in 2021 include (Figure 6): security, transparency and privacy; edge, fog, and cloud computing, AI, human augmentation and extended reality, network and connectivity, advanced robotics, internet of everything, digital twin, 3D printing, as well as big data and analytics. It is evident that OPTIMAI is totally aligned with this map, capitalizing the majority of the aforementioned technological trends and innovations.

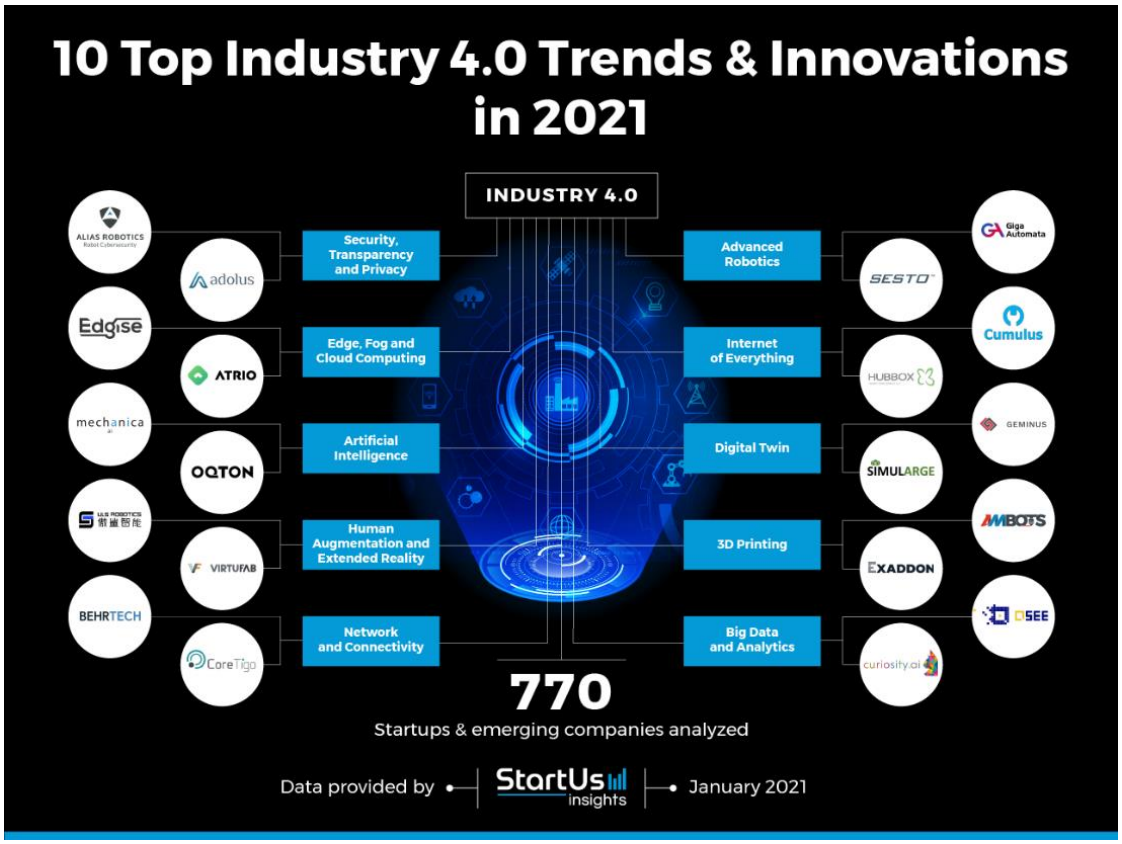


Figure 6: Top Industry 4.0 Trends and Innovations in 2021

Furthermore, according to a recent Forbes article (Marr, 2020), 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.

[37] https://www.startus-insights.com

As analysed in the preceding section, the innovation potential of OPTIMAI is built upon most of the aforementioned technology trends, with the exception of robots, autonomous vehicles, genomics and quantum computing, which are beyond the scope of the project in terms of application domain.

Finally, besides the industrial context, it is notable that the technologies employed for the OPTIMAI solutions are identified as emerging technologies and trends for the next 8 years, according to the impact radar provided by Gartner[38] (Figure 7). In particular, the following OPTIMAI technologies are identified to have very high impact potential, as follows: Deep Neural Networks and Edge AI have very high impact potential for the next year; distributed ledgers, composite AI and IoT platform have very high potential for technological impact within the next 3 to 6 years; and finally AR cloud is expected to have very high potential for impact within the next 6 to 8 years. Additionally, OPTIMAI technologies with high impact potential for the next 3 to 6 years include distributed cloud, smart contract, digital twin, and smart personalization, while for the next 6 to 8 years high impact potential is expected by AI-generated composite applications.

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

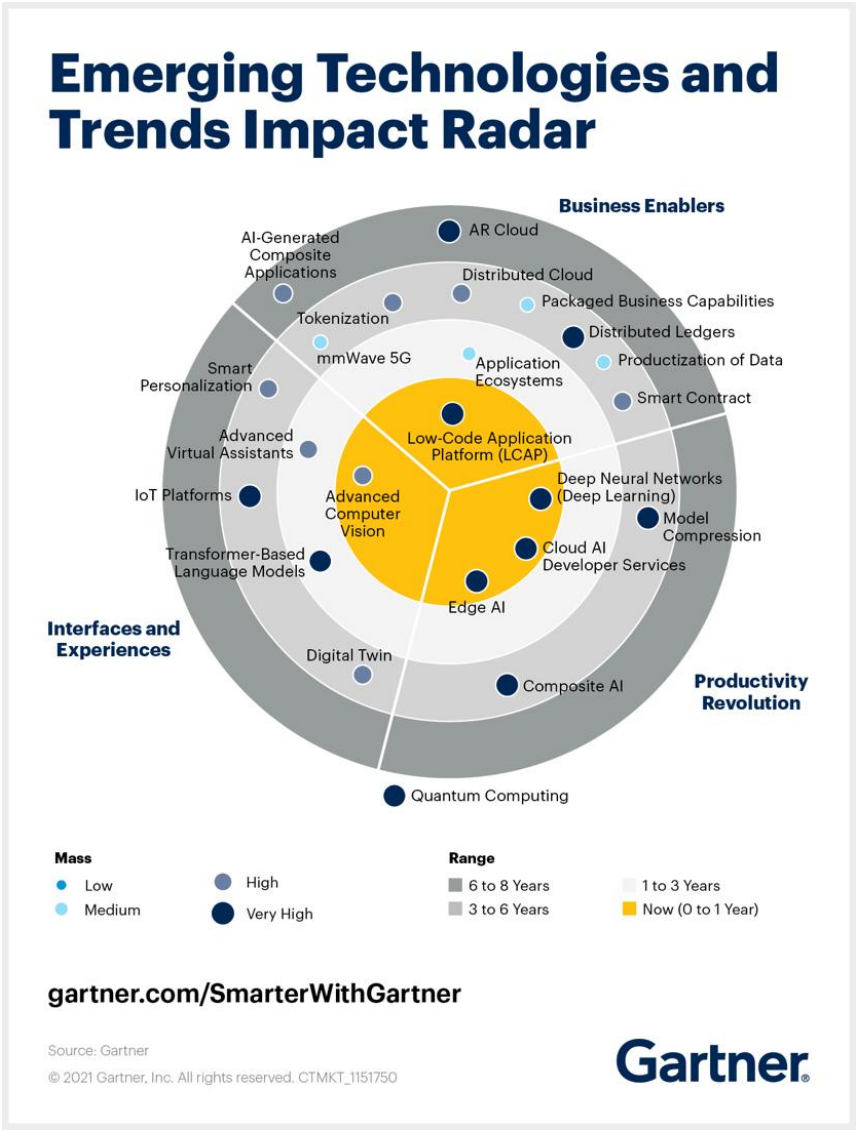


Figure 7: Emerging Technologies and Trends Impact Radar

Conclusion and Future Steps

In conclusion, this deliverable describes the effort spent from M1 to M6 and represents the current status of T2.1 of WP2. More specifically, it defines the functional and non-functional requirements based on the identified user, ethics and legal requirements extracted from questionnaires, pilots' videos and WP2 online meetings. In total, 127 requirements were identified and categorized in user requirements, functional requirements and non-functional requirements including KPIs, legal, ethical and technological innovation requirements. This deliverable formulates the initial list of user and ethics and legal requirements and constitutes the basis for the development of the OPTIMAI platform.

The next major step is to organise dedicated end-user workshops in order to determine the context of use of the initial list of OPTIMAI requirements for each of the use cases. The early user involvement will enable the elicitation of requirements based on actual end user needs and expectations of the OPTIMAI solutions. New requirements may emerge during the project's lifetime, while existing requirements may be reformulated to enhance clarity and accuracy. An iterative approach will be adopted meaning that the initial set of requirements will be continuously expanded, updated and refined, particularly in connection with user evaluation of the OPTIMAI components. This will be documented in the future deliverable D2.2 User and ethics and legal requirements - 2nd version due in M14.

References

Abeyratne, S. A., & Monfared, R. P. (2016). Blockchain ready manufacturing supply chain using distributed ledger. International Journal of Research in Engineering and Technology, 5(9), 1-10.

Ali, S., Bosche, A., & Ford, F. (2018). Cybersecurity Is the Key to Unlocking Demand in the Internet of Things. Bain and Company: Boston, MA, USA.

Dai, H. N., Wang, H., Xu, G., Wan, J., & Imran, M. (2020). Big data analytics for manufacturing internet of things: opportunities, challenges and enabling technologies. Enterprise Information Systems, 14(9-10), 1279-1303.

Durão, L. F. C., Haag, S., Anderl, R., Schützer, K., & Zancul, E. (2018, July). Digital twin requirements in the context of industry 4.0. In IFIP International Conference on Product Lifecycle Management (pp. 204-214). Springer, Cham.

Helu, M., Libes, D., Lubell, J., Lyons, K., & Morris, K. C. (2016). Enabling smart manufacturing technologies for decision-making support. In ASME 2016 international design engineering technical conferences and computers and information in engineering conference. American Society of Mechanical Engineers Digital Collection.

Lee, J., Davari, H., Singh, J., & Pandhare, V. (2018). Industrial Artificial Intelligence for industry 4.0-based manufacturing systems. Manufacturing letters, 18, 20-23.

Li, Z., Barenji, A. V., & Huang, G. Q. (2018). Toward a blockchain cloud manufacturing system as a peer to peer distributed network platform. Robotics and computer-integrated manufacturing, 54, 133-144.

Lu, Y., & Da Xu, L. (2018). Internet of Things (IoT) cybersecurity research: A review of current research topics. IEEE Internet of Things Journal, 6(2), 2103-2115.

Lu, Y., Liu, C., Kevin, I., Wang, K., Huang, H., & Xu, X. (2020). Digital Twin-driven smart manufacturing: Connotation, reference model, applications and research issues. Robotics and Computer-Integrated Manufacturing, 61, 101837.

Marr, B. (2019). The 5 Biggest Technology Trends Disrupting Engineering and Design in 2020. Forbes Magazine, Nov. Retrieved from: https://www.forbes.com/sites/bernardmarr/2019/11/22/the-5-biggest-technology-trends-disrupting-engineering-and-design-in-2020/#5d754a3a676a

Masood, T., & Egger, J. (2019). Augmented reality in support of Industry 4.0—Implementation challenges and success factors. Robotics and Computer-Integrated Manufacturing, 58, 181-195.

Mourtzis, D., Vlachou, E., Zogopoulos, V., & Xanthi, F. (2017). Integrated production and maintenance scheduling through machine monitoring and augmented reality: An Industry 4.0 approach. In IFIP International Conference on Advances in Production Management Systems (pp. 354-362). Springer, Cham.

Moyne, J., Qamsane, Y., Balta, E. C., Kovalenko, I., Faris, J., Barton, K., & Tilbury, D. M. (2020). A requirements driven digital twin framework: Specification and opportunities. IEEE Access, 8, 107781-107801.

Mullet, V., Sondi, P., & Ramat, E. (2021). A Review of Cybersecurity Guidelines for Manufacturing Factories in Industry 4.0. IEEE Access, 9, 23235-23263.

Poppensieker, T., & Riemenschnitter, R. (2018). A new posture for cybersecurity in a networked world. McKinsey. March.

Robertson, S., & Robertson, J. (2012). Mastering the requirements process: Getting requirements right. Addison-wesley.

Sandkuhl, K., & Stirna, J. (2020). Supporting early phases of digital twin development with enterprise modeling and capability management: requirements from two industrial cases. In Enterprise, Business-Process and Information Systems Modeling (pp. 284-299). Springer, Cham.

Syberfeldt, A., Danielsson, O., & Gustavsson, P. (2017). Augmented reality smart glasses in the smart factory: Product evaluation guidelines and review of available products. IEEE Access, 5, 9118-9130.

Turner, C. J., Emmanouilidis, C., Tomiyama, T., Tiwari, A., & Roy, R. (2019). Intelligent decision support for maintenance: an overview and future trends. International Journal of Computer Integrated Manufacturing, 32(10), 936-959.

Url, P., Vorraber, W., & Gasser, J. (2019). Practical Insights On Augmented Reality Support for Shop-Floor Tasks. Procedia Manufacturing, 39, 4-12.

Wan, J., Yang, J., Wang, Z., & Hua, Q. (2018). Artificial intelligence for cloud-assisted smart factory. IEEE Access, 6, 55419-55430.

Wang, X., Yew, A. W. W., Ong, S. K., & Nee, A. Y. C. (2020). Enhancing smart shop floor management with ubiquitous augmented reality. International Journal of Production Research, 58(8), 2352-2367.

Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of industry 4.0: a review. Engineering, 3(5), 616-630.

Appendix A: OPTIMAI requirements questionnaire

13th April 2021

Questionnaire for D2.1 User and ethics and legal requirements I

(This version has been prepared by KLEE, UAB and TRI)

Introduction

The following questionnaire is designed in the context of *Task 2.1: Consolidation of user and ethics and legal requirements,* which aims to formulate the user requirements for OPTIMAI taking into account legal and ethical aspects. These user requirements will constitute the basis for defining the functional and non-functional requirements of the OPTIMAI platform along with the input that will be collected for the specification of the OPTIMAI UCs.

The purpose of this questionnaire is to provide an initial identification of: a) the current manufacturing and business processes, b) the problems and deficiencies in existing systems, c) the OPTIMAI opportunities and objectives, d) the human participation issues and e) the data processing issues. The questionnaire is structured in 4 parts i.e. 1) General OPTIMAI questions, 2) End user requirements, 3) Human participation and 4) Data processing.

End users (KLEE, MTCL, TVES) should provide their answers in all sections. All other partners should answer sections 1, 3 and 4.

Please be as much specific and accurate as possible in order to help each other realise the first set of OPTIMAI requirements.

Please complete the questionnaire by **April 23, 2021.**

Thank you very much for your input

General OPTIMAI questions (Open ended)

1) Please describe the current production/manufacturing processes of your company (end-users)

2) Please describe the advantages of a production optimization system (all)

3) Please identify the possible gaps and problems of a production optimization system (all)

4) Please describe the measures that you have adopted to ensure security in data transactions, accountability and traceability (all)

5) Please describe the measures or systems in place to ensure the integrity and resilience of the system against potential attacks (all)

6) Please describe what zero defect manufacturing means to your organization. Please provide specific KPIs and metrics/measures related to zero-defect manufacturing (end-users)

7) Please describe how feedback and reconfiguration of production parameters improve quality and optimize production (end-users)

8) Please describe the measures that you have adopted to reduce the environmental impact of your current production/manufacturing processes? (end-users)

9) Please describe the possible factors and risks that may affect the implementation of OPTIMAI (e.g. legal, ethical, technical, organizational, cultural, environmental, social, etc.) (all)

End user requirements

Use Case 1 (UC1) – Zero defect quality inspection: focusses on detecting defects, analysing their causes and predicting emerging deficiencies.

1) How do you detect the defects in the production line now?

2) What are the most common types of defects?

3) How often do they happen?

4) What are the most common causes of defects?

5) Do you currently have a method to predict deficiencies?

6) Do your current quality inspection processes align with relevant standards or widely adopted protocols (e.g. cybersecurity, data governance, health and safety procedures, ...)? If so, please identify which ones.

7) What types of sensors will be installed?

Use Case 2 (UC2) – Production line setup-calibration: will develop an automated quality control loop between inspection and machine setup and build a context aware interaction environment for operator and production equipment.

1) How quality inspection and production data are collected?

2) What are the most critical parameters that need to be adjusted?

3) What type of feedback information will be needed in order to be notified about an occurring or upcoming defect?

4) How would you recalibrate the system and what actions are needed for recalibration?

5) What is the interaction between the operator and production equipment?

6) Do your current processes align with relevant standards or widely adopted protocols? If so, please identify which ones.

7) What types of sensors will be installed?

Use Case 3 (UC3) – Production planning: targets the virtualization of the production line that will enable cheap, fast and efficient production planning

1) What systems do you use for the production planning and control (SCADA, EMS, ERP etc.)?

2) How is the production line visualized and how do you desire to visualize it through OPTIMAI?

3) Do you currently use any technology related to digital twining and simulation?

4) Do your current production planning processes align with relevant standards or widely adopted protocols? If so, please identify which ones.

5) What types of sensors will be installed?

Human participation

Please specify for each Use Case:

1) What will be the level of involvement of human operators? What tasks will they perform?

2) Will the OPTIMAI solution enhance or augment human capabilities?

3) What will be the interaction between human operators and the different technologies that will be deployed in OPTIMAI?

4) Will the different technologies implemented in each use be designed to ensure accessibility for all human operators (including people with visual/hearing disability, limited movements, handicapped, …)?

5) Will the different processes of each Use Case be accessible to humans with different capabilities (e.g. visual/hearing disability, limited movements, …)?

6) Do you think there could be persons or groups who might be disproportionately affected by the potential negative implications of the OPTIMAI solution? Please consider this question both during the project as part of OPTIMAI research activities and once OPTIMAI is used on the market after the project ends.

7) What mechanisms and measures can you identify to ensure human control or oversight? Do you plan to implement mechanisms to log when, where, how, by whom and for what purpose data was accessed?

8) What technical and organisational measures will be implemented to safeguard the rights and freedoms of the humans involved in the piloting activities (e.g. ensure voluntary participation, equality, dignity, confidentiality; prevent discrimination;...)?

9) What safety measures can you identify to ensure human operator's well-being?

10) How do you plan to guarantee that the participation of human operators will be voluntary?

11) Could you identify the procedures/criteria/requirements to recruit the humans participating in the piloting activities?

12) In addition to technical training regarding the functionalities of OPTIMAI, what other issues should be included in the training sessions designed for the human operators?

Data Processing

Please specify for each Use Case:

1) What data is *needed* for the research?

2) Who will be primarily making decisions about the data collection and processing in your organisation?

3) For what task or activity do you need the *personal* data, if any?

4) What types of *personal* data, if any, will you process? (Examples include name and surname, home address, email address, identification card number, location data, etc.) and what is the purpose of collecting personal data?

5) How will you collect this *personal* data? Do you collect/process *personal* data from data subjects indirectly? and from which source(s), e.g. online data sources? Do you have a relationship with third party data owners (e.g. a contract) - or do you intend to have one?

6) Will you process any special categories of *personal* data within the meaning of Art. 9 GDPR (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)? What is the purpose of collecting this *personal* data?

7) How is the *personal* data relevant and limited to the purposes of the project?

8) What other kinds of data not already indicated will you be collecting and/or processing? And from which source(s), e.g. online data sources? Do you have a relationship with third party data owners (e.g. a contract) - or do you intend to have one?

9) What kinds of data, including *personal*, will sensors in particular be collecting?

10) Will the partner carry out profiling? (For example, from GDPR Recital 71, "Such processing includes 'profiling' that consists of any form of automated processing of personal data evaluating the personal aspects relating to a natural person, in particular to analyse or predict aspects concerning the data subject's performance at work, economic situation, health, personal preferences or interests, reliability or behaviour, location or movements, where it produces legal effects concerning him or her or similarly significantly affects him or her")

11) How will you store *personal* data? In what format? Will any data be entrusted to a subcontractor for storing or other processing purposes? Please describe information systems and location of the server/cloud server or portable digital device (e.g. mobile phone or tablet) in case of digital data collection and describe the physical location in case of data collections on paper. Also, please document if you are not (yet) in a position to answer.

12) How will you store other data? In what format? Will any data be entrusted to a subcontractor for storing or other processing purposes? Please describe information systems and location of the server/cloud server or portable digital device (e.g. mobile phone or tablet) in case of digital data collection and describe the physical location in case of data collections on paper. How will it be integrated and validated?

13) With whom are you going to share *personal* data?

14) With whom are you going to share *all* data?

15) Who will have access to *personal* data within your organisation?

16) What security measures will be implemented to prevent unauthorised access to personal data or the equipment used for processing?

17) What anonymisation/pseudonymisation techniques will be used?

18) Are you planning to produce any audio-visual material from the activity? (e.g. photos, videos)

19) What will you do with the collected *personal* data after the end of the project? Please document if you are not (yet) in a position to answer

20) Will you use any naming convention for data?

21) Will you use any data or metadata vocabulary or interoperability standard?