Project Acronym: STAR
Grant Agreement number: 956573 (H2020-ICT-2020-1 – Research and Innovation Action)
Project Full Title: Safe and Trusted Human Centric Artificial Intelligence in Future Manufacturing Lines
Project Coordinator: Netcompany-Intrasoft

Funded by the Horizon 2020 Framework Programme of the European Union

DELIVERABLE

D2.10 - Report on Co-Design Workshops and Focus Groups-Final version

Dissemination level	PU -Public
Type of Document	Report
Contractual date of delivery	30/03/2022
Deliverable Leader	University of Groningen (RuG)
Status - version, date	Final - V1.0, 25/05/2023
WP / Task responsible	WP2
Keywords:	co-creation, user studies, human-centric AI

Executive Summary

This deliverable provides an overview of the Co-Design and Feedback Workshops which have been specified, organised, and conducted during the whole course of the STAR project. Three comprehensive co-creation workshops were organised throughout the different phases of the project, namely the 'definition and design' phase, the 'early development and testing' phase, and the 'final development and testing' phase. Each workshop addressed distinct objectives as required for the further development of the STAR components, and its application in the three use cases, thereby linking and reconciling pilot partners needs and requirements with STAR technical partners and opportunities. The objective of the (1) Definition and Design phase workshops was to steer the STAR project design towards Human-Centricity by involving multi-stakeholder's viewpoints in co-creation sessions. The workshop primarily focused on defining, reconciling and linking pilot partners use cases and requirements with potential technical components to be developed in the different work packages. The workshop involved representatives of different functions and roles in which would be relevant to designing an AI-enabled solution for manufacturing lines, as expressed within the consortium partnership, including different roles within the manufacturing stakeholders, technology providers, research organisations, as well as legal and ethics experts. The workshop outcomes were analysed to offer a synthesis of what constitutes the collective creation of the multi-stakeholders view of user requirements, expressed as user stories, components and functionality needed to meet these requirements, alongside with proposed scenarios of human AI synergies, and the prospective outcomes and impact of that synergy in terms of both human factors and work design, as well as operational performance, including the key elements of trust, safety, and security. The deliverable informed the development of STAR components, contributing to the overall platform needs and will also feed into shaping the evaluation methodology of the STAR results.

The physical workshop held during the (2) 'Early Development and Testing Phase' focused on reflecting on the updated use cases, including a mapping of the STAR components to pilot's use cases and a reflection on the success criteria. Pilot partners presented any potential updates and changes and open changes, and technical partners could provide relevant input. The main finding of the workshop included a clear mapping of technical components to use cases. The final physical workshop held during the (3) 'Final Development and Testing Phase' focused on addressing potential technical issues, a reflection on the mapping of the use cases to the STAR components, and a more in-depth discussion of the success criteria defined for the socio-technical evaluation. The workshop concluded that initially defined KPI's are primarily still valid, but sometimes incomprehensive and require further updates. For all pilot partners it was found that they need to closely define relevant criteria to assess the economic and financial performance of implementing and operating STAR components, in addition to more closely consider human-centric criteria that enable the design of work systems that increase motivation, trust and well-being.

Deliverable Leader:	RuG (University of Groningen)
Contributors:	PCL, DFKI, IBER
Reviewers:	R2M, PLC
Approved by:	Charalampos Ipektsidis (INTRA)

Document History			
Version	**Date**	**Contributor(s)**	**Description**
0.1	21/04/2023	RuG	Initial structure
0.2	25/04/2023	PCL, DFKI, IBER	Content from workshops (phase 2)
0.3	03/05/2023	PCL, DFKI, IBER	Content from workshops (phase 3)
0.4	17/05/2023	RuG, R2M, IBER	Addressed review comments and final editing and revision
1.0	25/05/2023	INTRA	QA and final submitted version

Table of Contents

EXECUTIVE SUMMARY 2
1 INTRODUCTION 9
2 DEFINITION AND DESIGN PHASE WORKSHOP 10
2.1 WORKSHOP PREPARATION 10
2.1.1 Proposed workshop objective 10
2.1.2 Preparation survey 10
2.1.3 Workshop inputs and structure 24
2.2 PCL WORKSHOP 27
2.2.1 Preparatory phase 27
2.2.2 Workshop agenda 27
2.2.3 Virtual collaboration board setup 28
2.2.4 Workshop execution 29
2.2.5 Workshop outcomes 32
2.2.6 Proposed Human-AI synergy outcomes 40
2.2.7 Workshop evaluation 43
2.3 DFKI WORKSHOP 45
2.3.1 Preparatory phase 45
2.3.2 Workshop Agenda 45
2.3.3 Virtual collaboration board setup 46
2.3.4 Workshop execution 46
2.3.5 Workshop outcomes 48
2.3.6 Proposed Human-AI synergy outcomes 52
2.3.7 Workshop evaluation 54
2.4 IBER-OLEFF WORKSHOP 55
2.4.1 Preparatory phase 55
2.4.2 Workshop Agenda 55
2.4.3 Virtual collaboration board setup 55
2.4.4 Workshop execution 56
2.4.5 Workshop outcomes 56
2.4.6 Proposed Human-AI synergy outcomes 62
2.4.7 Workshop evaluation 64
2.5 OVERALL WORKSHOP CONCLUSIONS 65
3 EARLY DEVELOPMENT AND TESTING PHASE WORKSHOP 67
3.1 WORKSHOP PREPARATION 67
3.1.1 Proposed workshop objective 67
3.1.2 Workshop input and structure 67
3.1.3 Workshop agenda 69
3.2 WORKSHOP OUTCOMES 70
3.2.1 Workshop IBER 70
3.2.2 Workshop PLC 71
3.2.3 Workshop DFKI 74
3.3 OVERALL WORKSHOP CONCLUSIONS 78
4 FINAL DEVELOPMENT AND TESTING PHASE WORKSHOP 79
4.1 INTERNAL STAR CO-CREATION WORKSHOP 79
4.1.1 Proposed workshop objective 79
4.1.2 Workshop input and structure 79
4.1.3 Workshop agenda 80
4.1.4 Internal Workshop outcomes 80

4.1.5 Overall internal workshops conclusions....84
4.2 EXTERNAL CO-CREATION WORKSHOP 84
4.2.1 Proposed workshop objective....84
4.2.2 Workshop structure and content....84
4.2.3 Workshop agenda....85
4.3 WORKSHOP OUTCOMES 86
4.3.1 Outcomes poll questions presented during workshop....86
4.3.2 Outcomes survey external workshop....88
4.4 WORKSHOP EVALUATION 91

5 OVERALL CONCLUSIONS 93

APPENDIX 96

PREPARATORY SURVEY FOR WORKSHOPS 96
Part 0 96
Part 1 Task scenarios between AI and humans....96
Part 2 Human and job effects....96
Part 3 Operational effects of AI....97
Part 4 Success criteria to guide the design, development and deployment....98

Table of Figures

FIGURE 1: INFLUENCING FACTORS OF AI-ENABLED SOCIOTECHNICAL SYSTEM PERFORMANCE 12
FIGURE 2: DESIGN PROCESS (ADAPTED FROM NEUMANN ET AL., 2021) 13
FIGURE 3: THE DIFFERENT STAGES OF EACH PILOT CASE WORKSHOP 25
FIGURE 4: WORKSHOP ACTIVITIES, INPUTS AND OUTPUTS...26
FIGURE 5: EXAMPLES OF HUMAN-AI SYNERGIES 26
FIGURE 6: EXAMPLES OF HUMAN-AI SYNERGY IMPACT CRITERIA 27
FIGURE 7: EXAMPLE OF VIRTUAL COLLABORATION BOARD SETUP 29
FIGURE 8: EXAMPLE OF CO-CREATION ACTIVITIES DURING THE WORKSHOP 30
FIGURE 9: EXAMPLE OF LINKING USER STORIES WITH USER CATEGORIES AND COMPONENTS..............................31
FIGURE 10: FINAL COLLABORATION BOARD OF PCLCO-CREATION WORKSHOP 32
FIGURE 11: DFKI PRESENTING THE PILOT CASE AND ITS USE CASES...47
FIGURE 12: DFKI PILOT CO-CREATION OUTCOMES ON FINAL COLLABORATION BOARD 48
FIGURE 13: IBER-OLEFF PRESENTING THE PILOT CASE AND ITS USE CASES 56
FIGURE 14: FINAL COLLABORATION BOARD FROM THE IBER-OLEFF CO-CREATION WORKSHOPS 57
FIGURE 15: OUTCOMES WORDCLOUD POLL: WHAT IS HUMAN-CENTRICITY?...87
FIGURE 16: OUTCOMES RATING IMPORTANCE OF ETHICS- AND TRUST CRITERIA..87
FIGURE 17: OUTCOMES RATING IMPORTANCE OF MOTIVATIONAL AND WELL-BEING CRITERIA 88
FIGURE 18: APPLICABLE CHARACTERISTICS OF TRUST AT WORKSHOP'S DEMONSTRATED USE CASES......................90
FIGURE 19: APPLICABLE CHARACTERISTICS OF TRUST FOR INCREASED USEFULNESS DUE TO HUMAN-AI COLLABORATION 91

List of Tables

TABLE 1: PCL TASK SCENARIOS 14
TABLE 2: IBER-OLEFF TASK SCENARIOS 15
TABLE 3: DFKI TASK SCENARIOS 15
TABLE 4: 'AI IN GENERAL' TASK SCENARIOS 16
TABLE 5: OVERVIEW OF EXPECTED HUMAN AND JOB EFFECTS PER PILOT 16
TABLE 6: OVERVIEW IMPORTANCE OF CONSIDERATION OF OPERATIONAL EFFECTS PER PILOT SITE 21
TABLE 7: GENERAL SUCCESS CRITERIA 22
TABLE 8: ADDITIONAL SUCCESS CRITERIA 22
TABLE 9: CO-CREATION ACTIVITY PRODUCES NEW AND UPDATED USER STORIES CONTENT 33
TABLE 10: PCL PILOT CO-CREATION WORKSHOP EVALUATION 44
TABLE 11: DFKI PILOT PCL PILOT CO-CREATION WORKSHOP EVALUATION 54
TABLE 12: EVALUATION OF IBER-OLEFF PILOT CO-CREATION WORKSHOP 64
TABLE 13: STRUCTURE AND FORMAT WORKSHOP 2 67
TABLE 14: AGENDA WORKSHOP 2 69
TABLE 15: IBER MAPPING USE CASES AND STAR COMPONENTS 71
TABLE 16: PLCS MAPPING USE CASES AND STAR COMPONENTS 73
TABLE 17: PLC – IDENTIFIED SUCCESS CRITERIA 74
TABLE 18: UPDATED USER STORIES OF USE CASE 1 – DFKI 74
TABLE 19: OLD USER STORIES OF USE CASE 2 – DFKI 75
TABLE 20: UPDATED USER STORIES OF USE CASE 2 – DFKI 75
TABLE 21: NEW USER STORIES OF USE CASE 3 – DFKI 76
TABLE 22: DFKI MAPPING USE CASES AND STAR COMPONENTS 77
TABLE 23: DFKI IDENTIFIED SUCCESS CRITERIA 78
TABLE 24: WORKSHOP 3 STRUCTURE 79
TABLE 25: AGENDA WORKSHOP 3 – INTERNAL 80
TABLE 26: FEEDBACK KEY PERFORMANCE INDICATOR - IBER 80
TABLE 27: FEEDBACK KEY PERFORMANCE INDICATOR - DFKI 82
TABLE 28: FEEDBACK KEY PERFORMANCE INDICATOR - PLC 83
TABLE 29: WORKSHOP STRUCTURE AND CONTENT – EXTERNAL STAR WORKSHOP 85
TABLE 30: AGENDA WORKSHOP 2 - EXTERNAL 86
TABLE 31: EXTERNAL WORKSHOP SURVEY OUTCOMES 88
TABLE 32: BACKGROUND OF RESPONDENTS 91
TABLE 33: OUTCOMES WORKSHOP EVALUATION 92

Definitions, Acronyms and Abbreviations

Acronym/ Abbreviation	Title
AI	Artificial Intelligence
IT	Information Technology
OT	Operational Technology
SOP	Specific to Operations
SR	Simulated Reality
VR	Virtual Reality
W1	Definition and Design Workshops (project Design phase)
xAI	Explainable Artificial Intelligence

1 Introduction

The user studies and co-design sessions of the project have been identified as driving the development of the project's technologies and pilots based on human-centricity, trust and safety. Therefore, a number of user-studies and co-design sessions have been defined as part of D2.8 (User Studies and Co-Design for Human – Centred AI), pertaining to a number of consecutive workshops held for the different phases of the project throughout M1 to M27.

This report summarises the preparation, outcomes and evaluation of the workshops conducted for each of these phases. Specifically, this includes the workshops held during the 'Definition and Design Phase Workshops', the 'Early Development and Testing Phase', and the 'Final Development and Testing Phase' of the STAR components.

The workshops help during the 'Definition and Design Phase Workshops' includes the output of a survey distributed among project participants with the aim to collect preparatory information to prepare content for the online workshop executed via MIRO online visual collaboration platform. During the online workshop, participants co-created content on different sub-boards containing 'seeding' information from the survey and earlier deliverables containing placeholders for user stories, components/functionality that can be used or is required to implement the user requirements as expressed in the user stories, and a structure to host the contributing participants view on the involved AI-Human Interaction, and anticipated outcomes/success criteria. To validate and edit the functional requirement as defined in the use cases, participants first worked on the user stories, followed by defining and linking required components and functionality to the user stories. Then, participants co-created different collaboration scenarios based on relevant success criteria, addressing how (1) humans can help/augment the AI, (2) where AI technology can help/augment humans, and (3) the optimal interaction. Participants were able to propose, represent, interrogate and reflect on the different scenarios, while proposing ideas and visions which are based on the actual use context, and different criteria and anticipated outcomes. The physical workshop held during the 'Early Development and Testing Phase' focused on reflecting on the updated use cases presented by the pilot leads, including a mapping and linking of the relevant STAR components fulfil the (updated) requirements of the pilot's use cases, and a reflection of the defined success criteria. Pilot partners presented any potential updates and changes, and technical partners could provide important input and considerations. The final physical workshop held during the 'Final Development and Testing Phase' focused on addressing potential technical issues, a reflection on the mapping of the use cases to the STAR components, and an in-depth discussion of the key performance objectives defined for the socio-technical evaluation.

This report summarises the preparation and the outcome of the workshops executed for the three pilot cases PCL, DFKI, and IBER-OLEFF during the three main phases of the project, namely the 'Definition and Design Phase' (Section 2), the 'Early Development and Testing Phase' (Section 3) and the 'Final Development and Testing Phase' (Section 4). The contents contained in this report constitute input that needs to be taken into account in Deliverables D2.5 (final version of Data Models and Data collection), D2.10 (final version of Report on Co-Design and workshops and Focus Groups), D6.3 and D6.4 (STAR platform), the D6.5-D6.10 demonstrator deliverables, and the D6.11-12 evaluation deliverables (Ref 2). It can also be consulted during the development of STAR components, contributing to the overall platform needs and success criteria.

2 Definition and Design Phase Workshop

2.1 Workshop preparation

For each pilot site one Design stage (W1) co-creation workshop took place. Due to the COVID-19 restrictions, it was not possible to hold the workshops with physical presence. Therefore, available collaborative working tools were evaluated (see D2.8) and the MIRO on-line visual collaboration platform was selected to facilitate the co-creation collaboration activity.

In preparation of the workshop, a survey was distributed among STAR partners. It aimed at seeding the workshops with initial concepts and ideas to seed into the workshops. These targeted user requirements, as well as an initial pool of concepts regarding the envisaged Human-AI synergies for each use case and for each pilot of the project. The survey was designed accordingly to identify user-centred viewpoints, expressed via user stories, along with identifying components and functionality appropriate for meeting the requirements of the user stories, alongside their envisaged outcomes, in terms of work design and human factors, as well as operational performance targets. The survey also sought to identify the starting points for the foreseen human-AI synergies to meet the production requirements for the pilot use cases.

2.1.1 Proposed workshop objective

The objective of the workshop was to co-create and refine the pilot partners use cases and their requirements in relation to the envisioned STAR components, including a preliminary mapping of technical components. Furthermore, relevant success criteria were defined to measure the success of the project in relation to pilot partners requirements, including specifying the different interaction scenarios between AI and humans in the different use cases.

2.1.2 Preparation survey

The content of the survey addressed the following three use cases:

- PCL: Human-Robot collaboration for quality inspection
- IBER-Oleff: Human-centred AI for agile manufacturing of automotive parts
- DFKI: Human-behavior prediction and safe zone detection

To prepare for the definition and design workshop (W1), project participants were asked to fill in the survey for every specific use case they are involved in to obtain the specific requirements for each individual use case. It was also possible to fill in the survey for AI technology in general. The survey recorded 19 usable responses from the different project participants. Before the start of the questions, respondents were asked to indicate the use case addressed in the survey. This allowed them to tailor their responses to a specific use case. Respondents were able to provide answers for multiple pilot sites. 5 responses were collected for Phillips, 1 for DFKI, and 1 for IBER. 11 responses indicated no specific use case, but AI in general.

2.1.2.1 Introduction survey

The survey is designed to aid the design of human-centric, safe and trusted AI system as defined in the STAR project. To steer AI-based systems development in this project towards meeting stated aims (e.g., human-centric, trusted, safe), it is necessary to jointly consider human, technical, and operational factors as early in the design process as possible. The interaction between human and non-human actors (i.e., technological, including AI,) will aim at a positive impact on technical, operational and human performance, and ultimately determine the overall system performance. By identifying envisioned human, as well as technical and operational effects, success criteria can be identified that ultimately guide the system designers to jointly pay attention to different contributing factors early on in the design process. The main aim of this survey is to identify the desired effects of the deployment of human-centric, safe, and trusted AI systems in specifically the pilot cases of the STAR project. The outcome is intended will provide input for the definition and design workshop (W1) (D2.9). Moreover, it is aimed at providing valuable input for the development of the design targets for the AI deployment. The terms "success criteria", "performance targets" and "effects" are considered to carry similar semantics and will be employed to set targets for the AI-deployment and the overall system evaluation.

2.1.2.2 Background survey

Modern and future manufacturing environments are not simply technical systems but complex socio-technical ones. While physical technical systems include components (e.g. hardware, software) and have implications for procedures and processes, the procedures and processes themselves are not part of their definition but change depending on the organisational context. Conversely, socio-technical systems include both technical systems and people. People are expected to understand the purpose of the system (which technical systems do not) and are integral part of organisational operational processes, which are often governed by regulations and rules. To steer AI-based systems development in this project towards meeting stated aims (e.g., human-centric, trusted, safe), it is necessary to jointly consider human, technical, and operational factors as early in the design process as possible. The interaction between human and non-human (i.e., technological, including AI, actors) will aim at a positive impact on technical, operational and human performance, and ultimately determine the overall system performance. By identifying envisioned human, as well as technical and operational effects, success criteria can be identified that ultimately guide the system designers to jointly pay attention to different contributing factors early on in the design process. Modern manufacturing systems are complex sociotechnical systems. Such systems are developed to tackle problems that are so complex and involve so many entities that there is no single specification uniformly suitable for all cases (Sommerville, 2015). **Therefore, the aim of this survey is to:**

- identify desired effects of the deployment of human-centric, safe and trusted AI systems in specifically the pilot cases of the STAR project,
- to steer STAR direct design and development activities for the pilot cases in a way that takes into account the aforementioned factors (i.e., desired human, technical and operational effect.

Both the above targets are served by utilising the survey outcomes as initial "seeding" ideas for the co-creation workshops to follow. Considering the diversity of the application cases in the manufacturing sector, as evidenced also in the STAR project cases, there can be no single definition of success criteria which would be generally applicable (Sommerville, 2015). Instead, success criteria are linked to whether or not the system is effective when deployed, when assessed against organisational objectives. This implies that although goals and success criteria can be broadly derived from the survey outcomes, these will be put into test and further processing during the co-creation workshops. The stakeholders involved in the workshops will be able to revisit them, bearing in mind organisational and business goals.

Modern manufacturing environments are not simply technical systems but complex sociotechnical ones. In sociotechnical systems, human actors hold a key role with implications for system performance, alongside the physical technical systems. This is illustrated in Figure 1, where a sociotechnical cyber physical production system is seen to be composed of human and non-human actors, with technical actors falling under operational and information technology (OT/IT). The caveat is that the boundaries between these are increasingly blurred: IT and OT are converging, and human operators are increasingly enabled by IT and OT, with the latest additional being AI-enablement of human and non-human actors. The overall achieved functional system performance (e.g., production throughout, product quality, etc) is deeply influenced by non-functional system performance and organisational evolving objectives, as well as work on environment, job characteristics, and effects of the overall work design on humans, as conceptually shown in Figure 1.

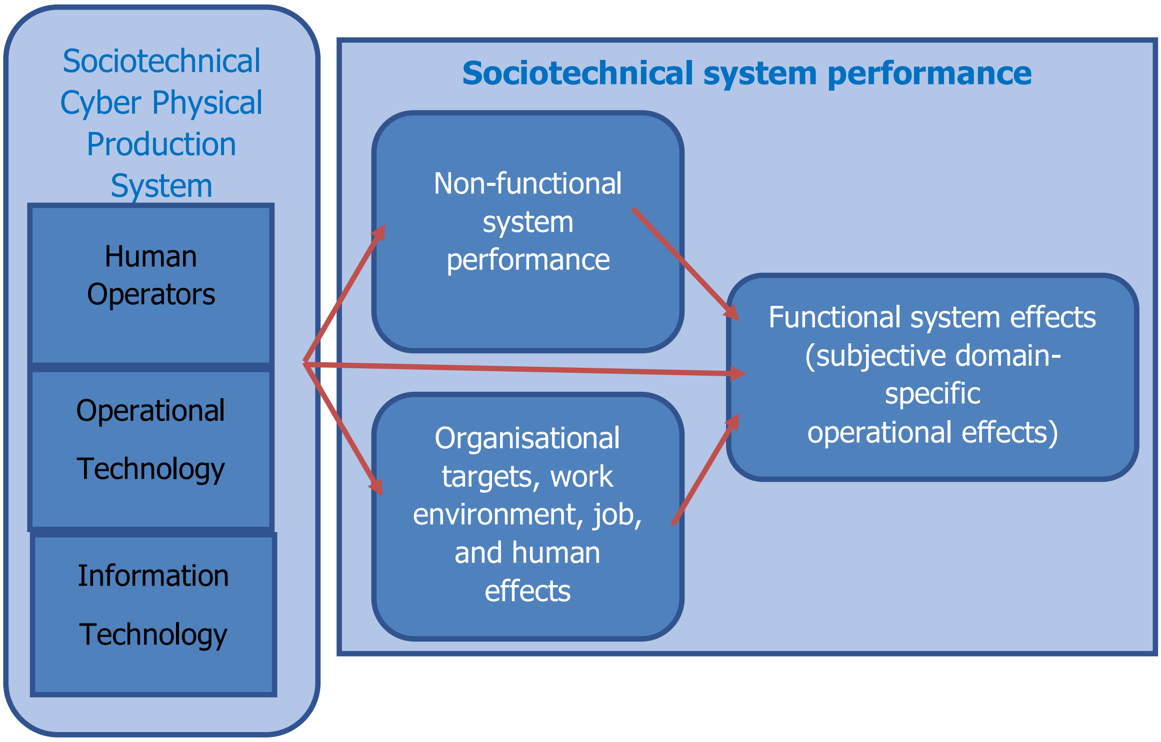


Figure 1: Influencing factors of AI-enabled sociotechnical system performance

Non-functional performance can be considered to include (Sommerville, 2015) Reliability; Usability; Volume/Throughput; Repairability; Security/Safety.

Human factors effects (performance) as specified in D2.8, will include: engagement; trust; intrusiveness; likeability; cognitive overhead; physical overhead; safety; ease of use; explainability; security; and enriched jobs. Note that security and safety are of direct relevance to human factors, but they are also considered as overall system non-functional performance targets, as they are also relevant to the physical/cyber-physical assets of the production environment.

The functional system effects are broadly considered to fall under process quality, efficiency, flexibility and costs (D2.8) but need to be specified in the context of the specific targeted application domain. Therefore, these are subjective, rather than objective, and are linked to organisational goals.

It is worth noting that the individual actors (human and non-human) have a joint influence on the sociotechnical system performance. For example, system reliability is linked to hardware, software, and operator reliability. Ease of use refers to the interface between a human and a non-human actor: it is perceived by the human actor in relation to the use of the non-human production asset that it refers to.

The above can be considered to motivate a design process for AI-enabled systems. Specifically, the design process needs to consider the impact of design choices in terms of human effects, changes to the environment and work design, and overall operational effects, all of which make a contribution towards the performance targets (Figure 2).

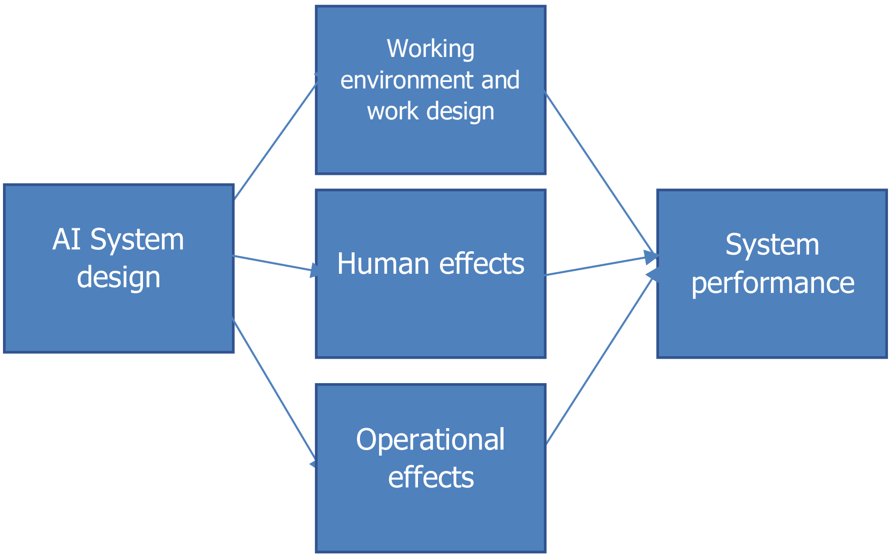


Figure 2: Design process (adapted from Neumann et al., 2021)

2.1.2.3 Structure of the survey

The survey addresses different categories of questions. To tailor the questions to a specific pilot site, respondents are first asked to select the pilot site, or to answer the questions for AI technology in general. The survey questions can be found in the Appendix.

The different categories of questions include:

Part 0: Background survey respondent

Part 1: Task scenarios between AI and humans

We identify four different task scenarios that are relevant in the context of AI and which are important to consider during the design and development phase. Per scenario, please provide concrete and relevant examples of future tasks at the selected pilot site that fall within these categories.

Part 2 Human and job effects

The questions focus on rating the importance of considering a number of human and job effects during the design, development and deployment of the selected pilot site with the corresponding AI solution.

Part 3 Operational effects of AI

The questions focus on rating the importance of considering a number of operational factors during the design, development and deployment of an AI system in manufacturing.

Part 4 Success criteria to guide the design, development and deployment

In this section, respondents are asked to rate the importance of success criteria to guide successful design, development and deployment of the AI technology.

Success criteria are generic and can guide the system designers to jointly pay attention to different contributing factors (human, technical and operational) early on in the design process. They are derived from the envisioned human, technical and operational effects examined in parts 3 and 4 of the survey.

2.1.2.4 Survey results

The survey recorded 19 usable responses from the different project participants. Before the start of the questions, respondents were asked to indicate the pilot site addressed in the survey. This allowed them to tailor their responses to a specific use case. Respondents were able to provide answers for multiple use cases. Five responses were collected for PCL Phillips, one for DFKI, and one for IBER. Eleven responses indicated no specific pilot site, but addressed AI deployment in manufacturing in general.

- Part 1 Task scenarios between AI and humans

The respondents identified the following task scenarios per pilot site (Table 1-Table 4).

Table 1: PCL task scenarios

AI substitutes humans	AI augments humans in tasks	Human augments AI in tasks	Integrated AI & human perform task collaboratively
In clerical tasks	For decision making in strategic decisions		
- Part detection & automated part handling (partly AI / partly robotics)	- Safety risk detection and reaction - Mental health monitoring	- Human input for low confidence decisions / sampling by AI Quality inspection	- Quality control systems
1) Visual inspection of very common defect/non-defect cases 2) Repetitive Pick and Place of objects on the QA line	AI can be more consistent and detect smaller defects the human might miss	1) Human points out correct solution when AI is uncertain about a certain inspection 2) Human provides initial input to help AI adjust more quickly to a new environment (e.g., pick and place in a different production line) 3) Human can take part in identification and correction of cases where the AI is highly confident but wrong	AI can make use of intelligent methods to make the most of the human input provided. The human can help the AI with corner cases and high-risk decisions. Both the above happen in a continuous bi-directional feedback loop.

Vision systems and Artificial intelligence (e.g. CNN) can be applied to inspect items and to verify items conformity.	AI supports humans in the decision-making system. Decisions can be: Item in vs out of quality Tasks scheduling & and planning (e.g., cobot handles the part and human performs quality check vs vice versa) Cobot parameters definition (e.g. movement speed, pose estimation, safety zone)	Humans instruct AI based system on which items are in and out of quality. Humans instruct AI based system on which is his/her current status (e.g. activities, fatigue level, emotion) to train or improve accuracy.	AI detects possible non-conformities. Human evaluates if items are out or in quality.

Table 2: IBER-OLEFF task scenarios

AI substitutes humans	AI augments humans in tasks	Human augments AI in tasks	Integrated AI & human perform task collaboratively
-	Nowadays the training of HRs in the various production processes is planned and carried out in advance, in accordance with appropriate operational methods. The flexibility of human resources training, to accommodate an agile production, can be achieved with the help of artificial intelligence platforms. These platforms can contribute, on the one hand, to the improvement of operative methods and consequently the reduction of human errors associated with learning and assimilation, and, on the other hand, due to continuous monitoring of production processes, in reducing human errors associated with overspecialisation, which usually occurs when an operator is performing the same functions in the same workplaces over a given period of time. Practically the phenomenon can be described as the loss of operator concentration due to overconfidence, with consequences on productivity and quality of work performed.	-	-

Table 3: DFKI task scenarios

AI substitutes humans	AI augments humans in tasks	Human augments AI in tasks	Integrated AI & human perform task collaboratively
			The use case deals with this category. AI does not substitute the human, but acts as a complementary actor.

Table 4: 'AI in general' task scenarios

AI substitutes humans	AI augments humans in tasks	Human augments AI in tasks	Integrated AI & human perform task collaboratively
- moving and storing goods in logistic (using AI and Robots)	- AI-controlled semi-autonomous robotic arm performs drilling, screwing, etc, simplifying the job of the operator	- Human revision of AI based quality inspections	- Scheduling of works and workers, management of the operations, planning
- XAI system could give good introspection into behaviour of ML models and could therefore replace or help a data scientist	- human planners often take fixed, pre-calculated normatives and other values within the production unit; AI can help human planners provide better plans by checking the schedules, assessing the personnel skills, predicting collisions regarding human resources and so on.	- by obtaining reasoning, why a particular model would give certain predictions (e. g. by explanations or by relevant data instances), one might detect a flaw in the reasoning (e. g. taking irrelevant data, unfair data etc.); models might be fixed based on this input	- in maintenance tasks an operator often fixes the problem and notes the intervention down into a legacy system (sometimes even a piece of paper); an AI system, that would keep and collect this knowledge in an automated manner, could assist for faster and better future interventions
Robotic cell does a quality inspection for a part or product.	AI system suggests maintenance schedule for an asset.	Robotic call doing quality inspection and consulting a human worker when not sure.	A repetitive part of a task (e.g., polishing, grinding) is done by robots. Humans coordinate the robots.

- Human and job effects

Respondents were asked to rate the expected positive or negative impact of the adoption of the AI solution on a number of jobs and human related factors, as well as rating the importance of their consideration in the design of the technology. Table 5 summarises the expected human and job effects per pilot site, and for AI in general. A 5-point Likert scale was selected to answer this question, 1 being the lowest, and 5 being the highest.

Table 5: Overview of expected human and job effects per pilot

Effects	Pilot Case	Expected impact	Negative or positive outcome	Importance of consideration during design of AI 1 (unimportant) to 5 (important)
	Phillips:5 IBER: 1 DFKI: 1 AI in general: 11	1 (significantly lower) to 5 (significantly higher)	1 (negative) to 5 (positive)	
Job autonomy	Phillips	3.2	4.5	3.33
	IBER	3	5	4

	DFKI	4	5	4
	AI in general	3.72	4.45	4.45
Task variety	Phillips	4	4.6	3.4
	IBER	4	5	4
	DFKI	3	3	3
	AI in general	4.36	4.36	4.54
Feedback from the job	Phillips	3.6	3.8	3.2
	IBER	4	5	4
	DFKI	5	5	4
	AI in general	4.63	4.9	4.5
Job complexity	Phillips	3.4	3.8	3.6
	IBER	3	5	4
	DFKI	2	5	4
	AI in general	3.90	-	4.63
Specialisation	Phillips	3.5	4	3.2
	IBER	4	5	4
	DFKI	2	2	3
	AI in general	4.54	4.81	4.72
Problem solving req.	Phillips	4	3.8	3.6
	IBER	5	5	5
	DFKI	2	2	2
	AI in general	4.45	5	4.63
Information processing req.	Phillips	3.6	4.4	3.2
	IBER	3	3	n/a
	DFKI	2	5	3
	AI in general	4.09	5	4.63
Skills variety	Phillips	3.8	3.4	3.4
	IBER	4	5	4

	DFKI	2	4	4
	AI in general	4.54	4.72	4.45
Interdependence	Phillips	3.25	2.8	3.8
	IBER	3	5	3
	DFKI	4	4	4
	AI in general	4.09	4.54	4.27
Social support	Phillips	2.4	2.8	2.5
	IBER	3	5	4
	DFKI	1	1	4
	AI in general	4	3.09	4.18
Feedback from others	Phillips	2.5	3.25	3.2
	IBER	3	4	3
	DFKI	4	4	2
	AI in general	4.18	4.54	4.09
Physical demands	Phillips	2	4.2	3.4
	IBER	3	3	n/a
	DFKI	2	5	3
	AI in general	3.90	4.09	4.27
Well-being	Phillips	4	-	3.4
	IBER	3	-	n/a
	DFKI	3	-	2
	AI in general	4.54	-	4.36
Safety	Phillips	4.2	-	3.8
	IBER	4	-	3
	DFKI	5	-	4
	AI in general	4.81	-	4.54
Fatigue	Phillips	2.2	-	3.8
	IBER	4	-	4

	DFKI	4	-	4
	AI in general	4.18	-	4.45
Mental workload	Phillips	3	4.2	3.2
	IBER	3	3	n/a
	DFKI	2	3	3
	AI in general	4.18	4.90	4.36
Trust	Phillips	3	3	3.8
	IBER	3	3	n/a
	DFKI	4	4	3
	AI in general	4	4.18	4.72
Usability	Phillips	4	3.8	3.8
	IBER	3	3	n/a
	DFKI	4	4	3
	AI in general	5.09	4.90	4.36
Situation awareness	Phillips	3.4	4	3.4
	IBER	4	3	n/a
	DFKI	3	5	4
	AI in general	4.72	4.81	4.09
Explainability	Phillips	3.6	3.6	3.8
	IBER	3	3	n/a
	DFKI	5	5	4
	AI in general	4.18	4.18	4.09
Motivation	Phillips	3.6	3.8	3.2
	IBER	3	3	n/a
	DFKI	4	4	3
	AI in general	4.63	4.90	4.27
Intrusiveness perceived by user	Phillips	3.74	2.25	3.25
	IBER	5	1	4

	DFKI	2	3	2
	AI in general	4.09	4.36	4.27
Ergonomics	Phillips	4.25	4.25	3.75
	IBER	3	3	n/a
	DFKI	3	3	2
	AI in general	5	5.09	4.54
Job satisfaction	Phillips	4	-	3.6
	IBER	3	-	n/a
	DFKI	4	-	4
	AI in general	4.81	-	4.73
Additional human- or job-related factors not previously mentioned?	Phillips	Participation of worker in the continuous improvement of the AI system, opportunities to share/enhance his/her expertise, make suggestions etc.	/	/
	IBER	/		/
	DFKI	/	/	/
	AI in general	Privacy (e.g.: In environments involving cameras)	Transparency of the System to the End-Users will be a key for adoption and acceptance of the AI despite other properties.	- Accountability for accidents caused by robots - Accountability for decisions made by AI - Job replacement (possibly more among lower-skilled workers which may increase social inequality)

○ Operational effects

Respondents were asked to rate the importance of considering a number of operational factors during the design, development and deployment of the AI solution (Table 6). summarises the importance of considering the impact on the indicated operational effect during the design and adoption of the AI solution.

Table 6: Overview importance of consideration of operational effects per pilot site

Effects	Pilot Case	Importance of consideration 1 (unimportant) to 5 (very important)
Productivity	Phillips	4
	IBER	3
	DFKI	4
	AI in general	4.82
Process quality	Phillips	4
	IBER	3
	DFKI	4
	AI in general	5
Process efficiency	Phillips	4
	IBER	3
	DFKI	4
	AI in general	4.9
Process flexibility	Phillips	4
	IBER	3
	DFKI	4
	AI in general	4.63
Operational costs	Phillips	4.4
	IBER	4
	DFKI	3
	AI in general	4.90
Process time/speed	Phillips	3.6
	IBER	4
	DFKI	4
	AI in general	4.72

- Generic success criteria

Respondents were asked to rate the importance of **generic success criteria** to guide the successful design, development and deployment of an AI solution. The responses are independent of the use cases.

Table 7: General success criteria

	Importance of consideration
Reliability	4.64
Performance	4.35
Human safety	4.86
Technical safety	4.57
Environmental safety	4.35
Security	4.35
Usability	4.29
Job enrichment	3.93
Physical support	4.07
Cognitive support	3.79
Social support	3.79

The following additional generic success criteria not mentioned in the survey were identified by respondents (Table 8).

Table 8: Additional success criteria

Respondents	Additional generic success criteria
1	Acceptance and Trust
2	Explanatory comments on the above: - Environmental safety is a top priority because given that it is a long-term project and that AI (production and training) and digital data (processing and storage) can have negative effects on the environment, it is essential to align the project with the sustainability objectives of Europe. - Security is a top priority, since security is a prerequisite to all others; marking security as 'moderately important' would have an impact on all other factors. - Usability is a top priority because it includes safety in the explanation. - Job enrichment is a top priority, given that this project is human-centric, and that we have to think of the role we want AI to play in our lives. Human agency has priority. It is also suggested to consider the recently launched proposed regulation of AI ('Artificial Intelligence Act').

	https://digital-strategy.ec.europa.eu/en/library/proposal-regulation-european-approach-artificial-intelligence
3	Important criteria for success are accountability, trust and transparency. Moreover, it is suggested to consider the newly proposed regulation on AI in the project https://digital-strategy.ec.europa.eu/en/library/proposal-regulation-european-approach-artificial-intelligence

2.1.2.5 Analysis of survey results and conclusion

The survey served to identify the desired effects of the deployment of human-centric, safe, and trusted AI systems in specifically the pilot cases of the STAR project. It thereby addressed a number of job characteristics and human factors, specifically the effect of AI and the importance of considering it in the design of the AI systems. The survey did not have a sufficient number of responses to allow statistical inference, yet primarily provided input for the definition and design workshop (W1) (D2.9). It provided the following insight:

- The survey provided content for the workshops in the form of starting placeholders for user stories, functionality, and AI-Human interaction, as well as outcomes (human, operational) and success criteria
- Respondents expect AI to have a positive impact on all included job characteristics and human factors, suggesting an overall job enrichment and positive individual outcomes for human workers due to the AI adoption. Respondents expect positive effects on:
    - Job autonomy
    - Task variety
    - Feedback from the job
    - Job complexity
    - Specialisation
    - Problem solving requirements
    - Information processing requirements
    - Skills variety
    - Interdependence
    - Social support
    - Feedback from others
    - Physical demands
    - Well-being
    - Safety
    - Fatigue
    - Mental workload
    - Trist
    - Usability
    - Situation awareness
    - Explainability
    - Motivation
    - Intrusiveness
    - Ergonomics
    - Job satisfaction

- Project participants characterise the consideration of all operational effects included in the survey as important to consider during the design of the AI system (scoring 3 or higher).
- Reliability, human safety and technical safety were found to be the most important success criteria to guide the successful design, development and deployment of an AI solution, whereas job enrichment, cognitive support and social support were found to be the least important.

The responses obtained through this survey enabled an initial understanding of requirements and expectations for each pilot case and were processes as initial "seeding" of ideas for the co-creation workshops, as described next.

2.1.3 Workshop inputs and structure

Each W1 comprised a process wherein:

1. An agenda was agreed among partners, including the time, duration, objectives of the workshop (as specified in D2.8) and participants (see table).

2. Initialisation of a MIRO board with "seeding" information and knowledge, arising from early project deliverables and the STAR partners survey outcomes, which were outlined earlier in this report, and included process workflows for the targeted use cases, draft user stories, and some of the key survey concepts. Each workshop collaboration board consisted of multiple sub-boards, with initialised structure to contain placeholders for user stories, components/functionality that can be used or is required to implement the user requirements as expressed in the user stories, and a structure to host the contributing participants view on the involved AI-Human Interaction, and anticipated outcomes/success criteria. The structure was:

    a. User stories per Use Case
    b. Scenarios (AsIs/ToBe) as process workflows
    c. Initial Components per Use Case
    d. AI substitutes humans in tasks (placeholder)
    e. AI augments humans in tasks (placeholder)
    f. Humans augment AI in tasks (placeholder)
    g. Integrated AI+humans perform tasks (placeholder)
    h. Effects (work design +human factors) (placeholder)
    i. List of operational effects (placeholder)
    j. List of success criteria (placeholder)

3. Conducting of the workshop with the multiple steps included in the agenda:

    a. at first participants worked on the user stories
    b. then moved on to work towards defining components and functionality needed to satisfy the requirements as expressed in the user stories
    c. the next step was to link the components and functionality with the user stories

In this way, the co-creation workshop evaluated, validated, or edited the functional and non-functional requirements as expressed in the user stories.

4. Work on the linked user stories and components to identify aspects of AI-human collaboration, and anticipated outcomes / success criteria. In this stage, the participants co-created different collaboration scenarios based on the relevant success criteria. Scenarios address approaches regarding how (1) humans can help/augment the AI, (2) where AI technology can help/augment humans, and (3) the optimal interaction. Participants were able to propose, represent, interrogate and reflect on the different scenarios, while proposing ideas and visions which are based on the actual use context, and different criteria and anticipated outcomes.

5. A workshop evaluation activity, using an on-line evaluation survey.

A typical workshop structure is seen in Figure 3.

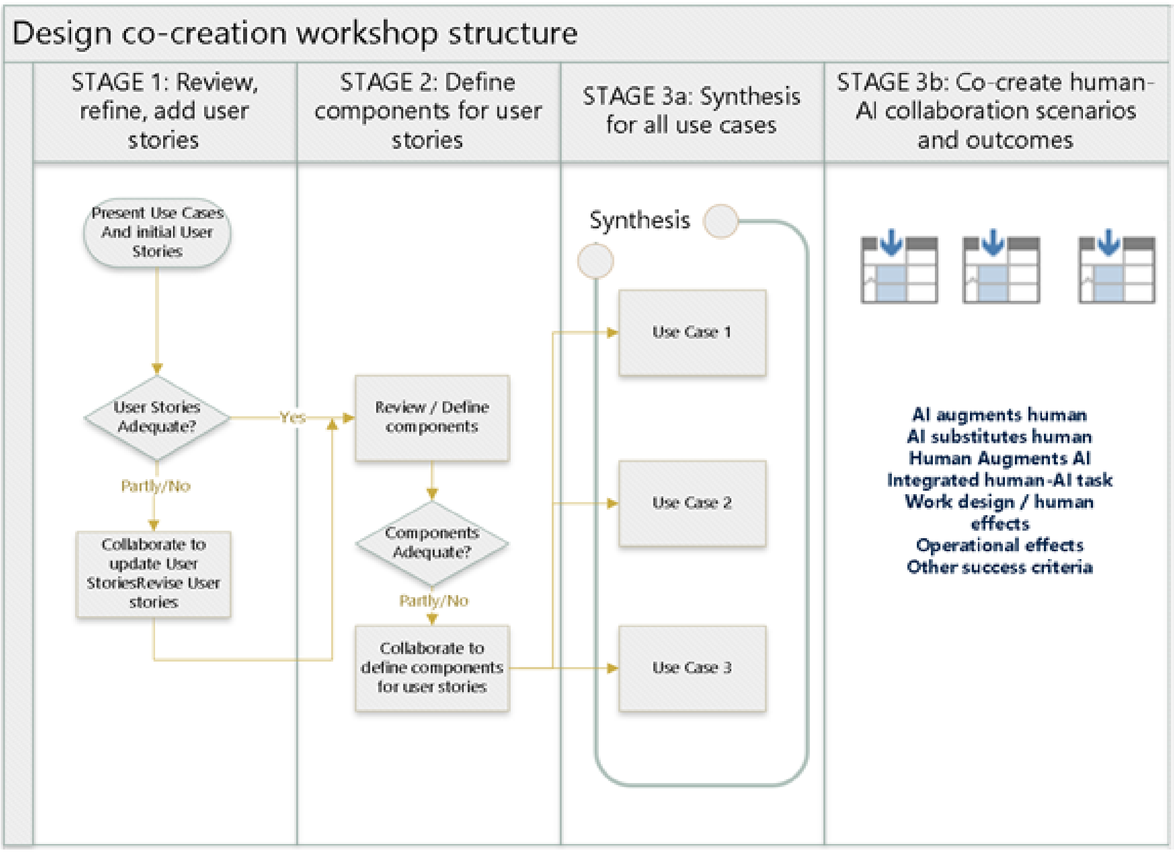


Figure 3: The different stages of each pilot case workshop

At the start of each workshop, the inputs fed into it, the activities planned to take place during the workshop, and the expected outcomes were communicated to the participants, as seen in

INPUTS

Process Workflow As Is and Draft Scenarios

Draft User Stories

SURVEY concepts

DURING WORKSHOP

Seeding co-creation workshop with initial

[User Stories] [Components / Actors / Partners] [AI-Human Interaction] [Success Criteria]

Link/Add/Delete/Update/ Prioritise [User Stories][Components/Actors/Partners][AI-Human Int][Success Criteria]

OUTPUT

[Updated User Stories] [Workflows as ToBe – Processed Scenarios] [Validated Success Criteria]

Figure 4: Workshop activities, inputs and outputs

The workshop methodology was explained further, providing some examples; for example, for the Human-AI synergies, relevant examples were shown to the participants, as seen in Figure 5.

PLC - AI substitutes humans	AI augments humans in tasks	Human augments AI in tasks	Integrated AI & human perform tasks collaboratively
Vision systems and Artificial intelligence (e.g. CNN) can be applied to inspect items and to verify items conformity.	AI supports human in the decision making system. Decisions can be: Item in vs out of quality Tasks scheduling and planning (e.g. cobot handles the part and human performs quality check vs viceversa) Cobot parameters definition (e.g. movement speed, pose estimation, safety zone)	Human instructs AI based system on which items are in and out of quality. Human instructs AI based system on which is his/her current status (e.g. activities, fatigue level, emotion) to train or improve accuracy.	AI detects possible non-conformities. Human evaluates if items are out or in quality.
	Recommendations to the decision-makers	Active learning tasks for manufacturing/logistics	
1) Visual inspection of very common defect/non-defect cases 2) Repetitve Pick and Place of objects on the QA line	AI can be more consistent and detect smaller defects the human might miss	1) Human points out correct solution when AI is uncertain about a certain inspection 2) Human provides initial input to help AI adjust more quickly to a new environment (e.g. pick and place in a different production line) 3) Human can take part in identification and correction of cases where the AI is highly confident but wrong	AI can make use of intelligent methods to make the most of the human input provided. The human can help the AI with corner cases and high risk decisions. Both the above happen in a continuous bi-directional feedback loop.

Figure 5: Examples of Human-AI synergies

Other examples illustrated the relevance of different outcome expectations, regarding both application domain-specific ones, such as performance, which is only defined taking the scope of the targeted application domain into account; or generic ones, such as security, usability, etc. (Figure 6).

Figure 6: Examples of Human-AI synergy impact criteria

Common "semantics" were employed across all workshops, for example employing board collaboration virtual stickers with different colours, indicating the different categories of users expressing requirements in the form of user stories. The starting categories of users were organisational, technical, and operational users. Similarly, coloured stickers were employed for other categories of content, such as Human-AI types of synergies, outcomes/effects of human – AI synergy, etc. Based on the above input for each workshop, the details of the co-creation activities of each pilot workshop are provided next.

2.2 PCL workshop

2.2.1 Preparatory phase

The workshop took place on 29/4/2021. In preparation for the workshop PCL and RuG organised bilateral meetings and collaborated to prepare the proposed agenda and an initial setup for the MIRO collaboration boards. Microsoft Teams was employed in parallel for shared presentations and the discussion.

2.2.2 Workshop agenda

Opening	08:30 – 08:40
As-is scenario	08:40 – 08:45
To-be scenario	08:45 – 08:50
STAR Use-cases	08:50 – 08:55
Current pilot idea / overview	08:55 – 09:00
Introduction to the workshop	09:00 – 09:10
Workshop UC1	09:10 – 09:50
Workshop UC2	09:50 – 10:30
Workshop UC3	10:30 – 11:10
Development of collaboration scenarios	11:10 – 11:40
Evaluation	11:40 – 12:00
Closing	12:00

2.2.3 Virtual collaboration board setup

A virtual collaboration board was set up, following the structure described in section 3.2.

An example of the initial setup of the board for the user stories activities is shown in Figure 7.

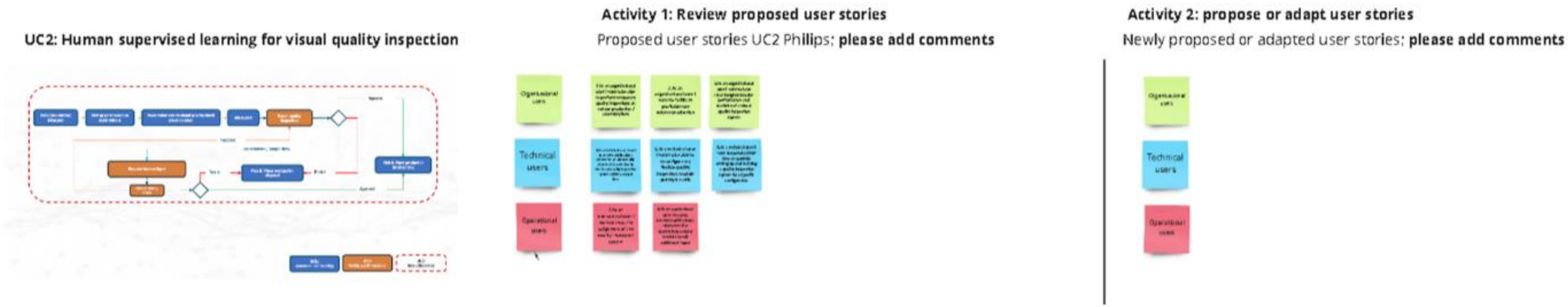


Figure 7: Example of virtual collaboration board setup

The collaboration board contained a process workflow for the targeted application of the use case. It also contained stickers with different colours, indicating the different categories of users expressing requirements in the form of user stories. The starting categories of users were organisational, technical, and operational users.

2.2.4 Workshop execution

The workshop had a duration of 4.5h and 29 participants from all partners took part. PCL opened the workshop presenting the use cases and their requirements. Starting with the vision and goals of the different use-cases supported by visualisation by presenting the current processes (as-is scenario) vs. the expected future processes (to-be scenario) which was used as a basic introduction to all participants to the different PCL use-cases and the vision regarding these specific use-cases.

Then, RuG described the process to be followed during the execution of the workshop, using the MIRO collaboration boards. Following the agenda, the participants engaged in a highly participatory co-creation collaboration activity for the user stories (Figure 8), components and the linkage between components and user stories (Figure 9).

Figure 8: Example of co-creation activities during the workshop

The process was repeated for each use case, contributing to revising the user stories and components and their linkages.

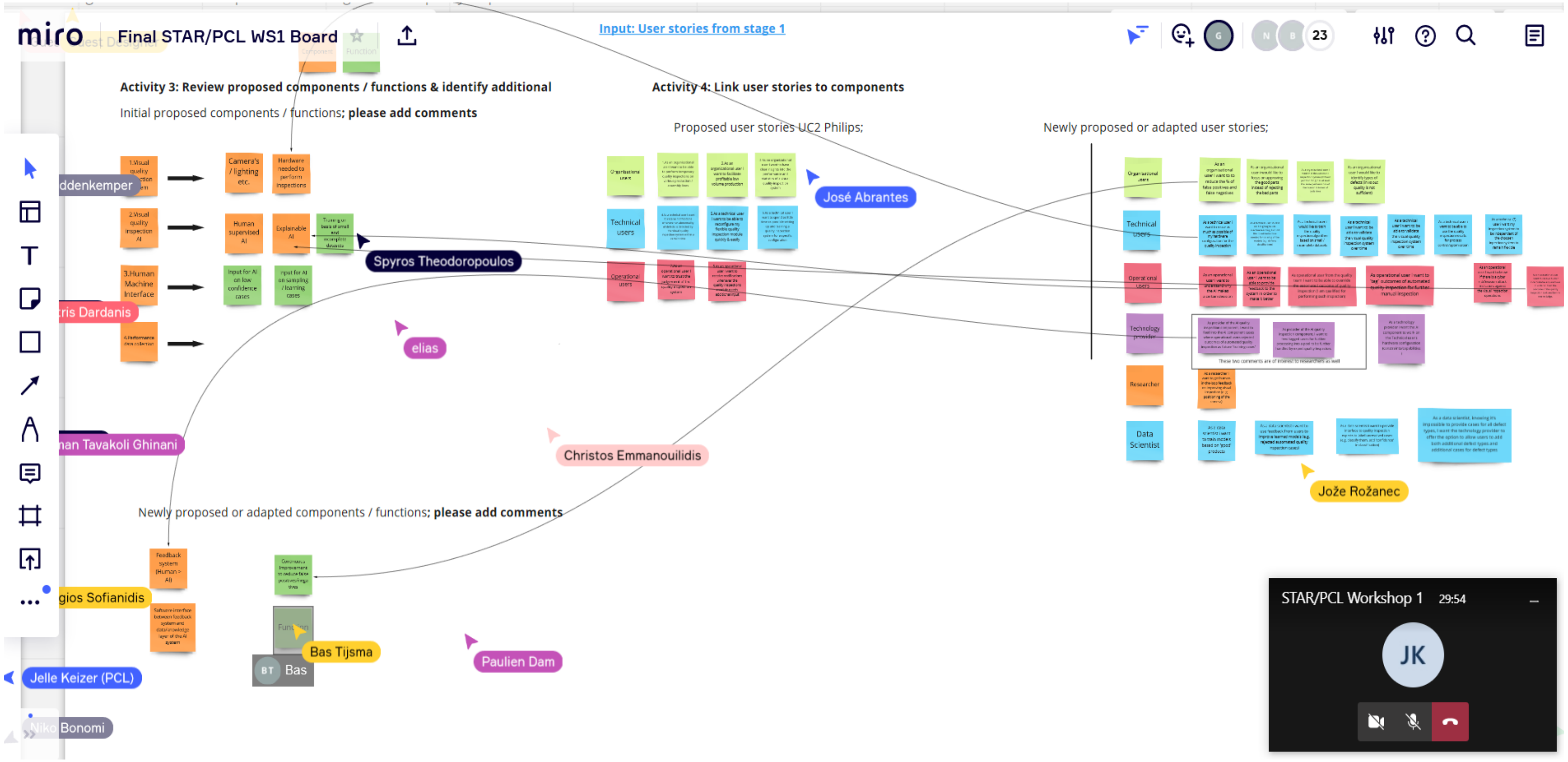


Figure 9: Example of linking user stories with user categories and components

2.2.5 Workshop outcomes

After all use cases were examined, the final stage brought all use cases together and the participants worked together to define the AI-human collaboration scenarios that were envisaged, alongside targeted outcomes (Figure 10).

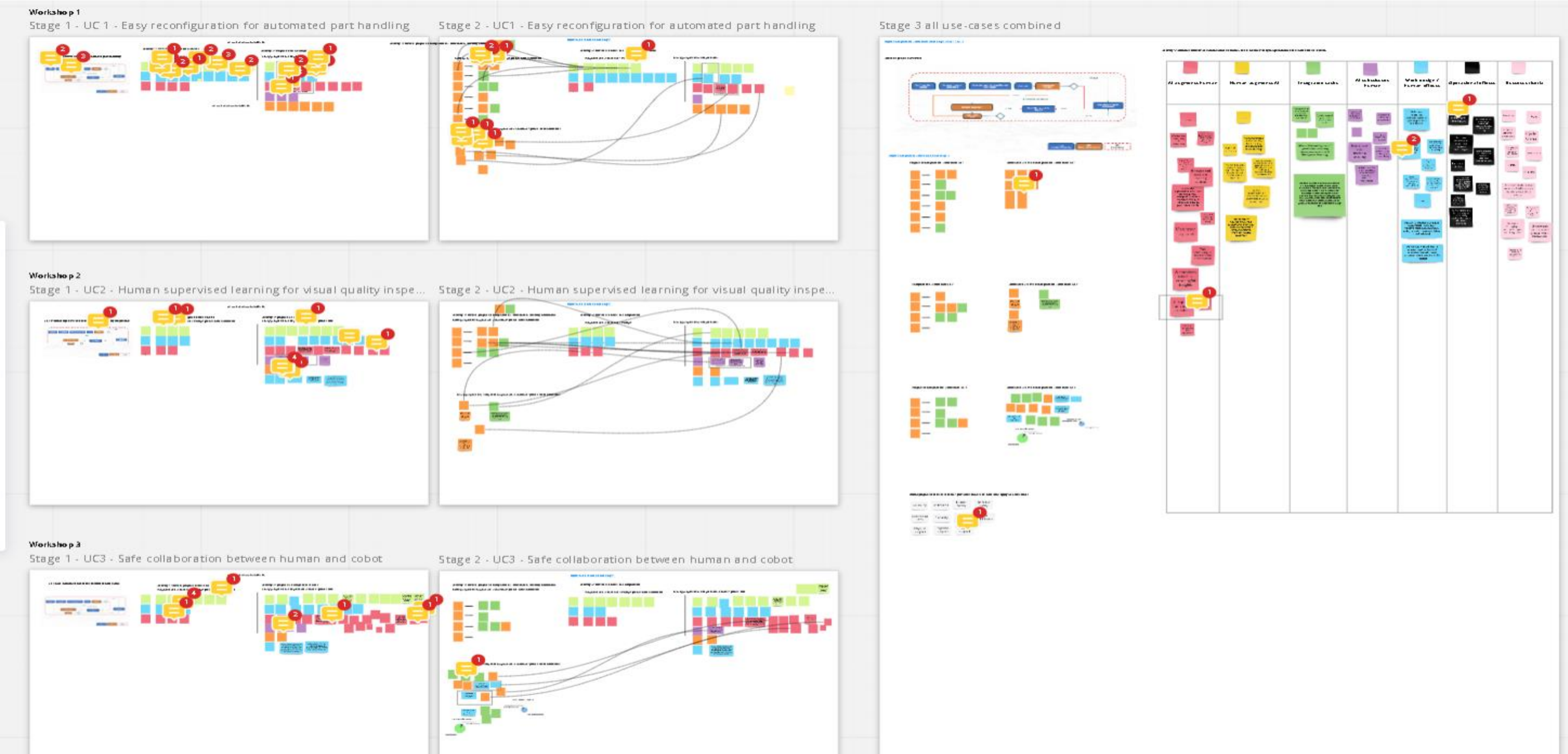


Figure 10: Final collaboration board of PCLco-creation workshop

The motivating effect of the appropriate preparation and sharing of application-relevant insights from the Use Case, as well as the ease of use of the employed collaboration platform, created a highly exciting environment for very effective and engaging collaboration.

While it is of particular interest to analyse the outcomes in qualitative terms, even a quantitative analysis produced impressive results. For example, just for the user stories and components alone, the following quantitative results were produced, as a result of the collaboration activity (Table 9):

Table 9: Co-creation activity produces new and updated user stories content

	UC1	UC2	UC3
User Stories			
Old	14	8	11
Total (inc new/modified)	**36**	**40**	**45**
Components			
Old	14	10	10
Total (inc new/modified)	**24**	**17**	**26**

The achieved outcome confirmed that the mitigation approach to involve online collaboration tools proved to be very effective. This was further confirmed after the workshop evaluation. While the added value contributed during the workshop has been evident, for brevity, in the consequent presentation of the results, the report only concentrates on the finally produced content of the co-creation activity.

2.2.5.1 Use Case 1

Use case 1 revolved around the topic of easy reconfiguration for automated part handling. As described earlier, during the workshop collaborative input was gathered regarding the user stories, the relevant components of the use-case and the link between these 2. The outcomes of this part of the workshop are shown below.

User Stories

Organisational User

I want to automate complex part handling
I want a part handling module that detects incoming parts
I want to implement this part handling module easily in different production setups
I want to automatically generate robot instructions based on the incoming part detection
I want real-time insight into the performance of the system
I don't want to invest in technical users (engineers) in order to save operational users
I require this solution to be safe
I want to be able to compare different configurations

I want to have alternatives (e.g. manual configuration) in case of breakdowns or downtime (e.g. maintenance/reconfiguration)
I want to have minimal setup times
I want to keep the cycle time for automated part handling low
I want this system to be compatible with existing manufacturing systems & processes
I want to facilitate profitable low volume production

Technical User

I want to be able to reconfigure the flexible part handling system quickly and easily for a new process
I want to be able to setup my new production run during the current production run
I want to be able to prepare reconfiguration of the part handling module in the virtual domain
I want to be able to simulate and validate my next production setup in the virtual domain
I want to be able to monitor the current configuration and performance of the production line / module
I want to be able to save configurations which are/can be used more often and have the best performance
I want to be able to deploy saved configurations easily (maybe even faster than new configurations)
I want to receive notifications if there is a situation the needs immediate attention
I have an interest in explanation of what failed and why
I want the part handling system to be able to handle multiple sides of parts
I would like to avoid complex vision systems for part orientation and I would prefer to use physical systems to reduce orientation variability and a smart end effector (e.g. force sensors)

Operational User

I don't want to be dependent on technical users to run production
I want clear instructions on how to solve problems/malfunctions
I want to be able to setup my next production run during my previous production run
I want to have a dashboard showing key process information and raise my attention when there is something that needs attention
I want to know which task the automated cell is performing and what movements the automated cell is about to make
I want to know if my system is compromised by e.g. a cyber risk/attack on any of the components of the entirety of the system

I want to have access to emergency stops at all time (in general I want to be able to work safely)
I want to reduce the number of stressful tasks I need to perform

Technology Provider

I want my systems to use reliable and accurate industrial data

Researcher

I want to have access to performance data for analyzing and improvements
I want to have the possibility to try new idea's/solutions without stopping production
I want to have access to user feedback easily in order to come up with new solutions/prototyping
I want to have access to the data from manual quality check to improve system in uncertainty estimation
I want to have access to product specifications to be able to apply different techniques/criteria based on product type/specification etc.

Components

Cobots OMRON TM5 - 700 (2x)
Multifunctional gripper for OMRON TM5 - 700
Gripper exchange system
Part detection system
Automated part handling system
Integrated system
Offline programming system
Virtual commissioning module
Performance data collection system
Performance data dashboarding system
Event detection / warning system
Interfaces both digital and physical between elements of the entire module
Safety system
Performance data collection long-term storage system
Testbed for improvements, prototyping etc.

Back-up system
CE certification
Internal handling within the module
Part supply system
Outfeed / part storage system
Orchestrator / software
Human - Machine Interface

2.2.5.2 Use Case 2

Use case 2 revolved around the topic of human supervised learning for visual quality inspections. As described earlier, during the workshop collaborative input was gathered regarding the user stories, the relevant components of the use-case and the link between these 2. The outcomes of this part of the workshop are shown below.

User stories

Organisational User

I want to reduce the number of false positives / negatives (%)
I would like to focus on approving good parts instead of rejecting bad parts
I want the automatic visual quality control to reach the same performance as human actors in terms of cycle time
I would like to identify types of defects (other than OK – Not OK)
I would like an objective quality inspection system instead of subjective measurements which vary between human inspectors

Technical User

I want to reuse as much as possible of my hardware configuration for different quality inspections (on different processes)
I want to train the visual quality inspection system algorithm based on small / incomplete datasets
I want to be able to use the quality inspection results for process control / optimisation
I want the quality inspection system to be independent of the chosen process to remain flexible
I want that the inspection system does not need part manipulation in order to have a complete inspection (all sides, parts, surfaces)
I want the camera(s) to be able to identify defects with one shot with a high resolution (without a mechatronic system to move the camera around)

I expect the AI system to improve over time as more data becomes available
I want human input for the AI system in order to make it better and secure quality (e.g. in low confidence cases)

Operational User

I want to understand why the AI makes a certain decision
I want to provide feedback to the system in low confidence cases and to make the system better
I want to be able to override the automated outcome of a quality inspection (qualified worker to do this, e.g. Quality Team)
I want to minimise feedback interactions
I want to "tag" outcomes of automated quality inspection for further inspection (e.g. sampling)
I want to know when the system is compromised (e.g. cyber risk/attack again the system)
I want to know how the AI system is working (e.g. create visual representation of taken photo + defect detected)

Technology Provider (Data Scientist)

I want to train models based on good products
I want to use feedback from user to improve learned models (e.g. rejected automated quality inspection cases)
I want to provide an interface to quality inspection experts to label unresolved cases (e.g. classification, and add confidence to classification)
I want to be able to add additional defect types and additional cases for defect types

Researcher

I want to get human-in-the-loop feedback on improving visual inspection (e.g. positioning of the camera)
I want to retrain the system with new observations to improve it

Components

Camera(s)
Lighting for quality inspection
Additional sensors / quality inspection hardware

AI Algorithm for quality inspection
Human Supervised Learning system / feedback system
Human Machine Interface
(Performance) data collection system
Dashboarding
Software interface between feedback system & data/knowledge layer of AI
Safety - AI Cyber defence evaluation and risk awareness system
Interaction system where operator can manually "tag" parts for further inspection (e.g. unresolved cases)
Interface to AI where defect types can be added along with cases for "new" defect types

2.2.5.3 Use Case 3

Use case 3 revolved around the topic of safe collaboration between human and cobot. As described earlier, during the workshop collaborative input was gathered regarding the user stories, the relevant components of the use-case and the link between these 2. The outcomes of this part of the workshop are shown below.

User Stories

Organisational User

I would like to improve the well-being of my workers in order to reduce turnover and improve performance
I want user data to be secured and in compliance with GDPR
I would like to have a quick and simple dashboard to supervise the system
I want an overview of statistics / KPI"s regarding mental and physical "stress" of workers in order to improve my processes
I want my employees to be qualified for the tasks they are assigned to / are performing
I want to promote task rotation in order to increase the skills of employees
I would like employees to feel safe and satisfied through their involvement with the cobot
I want cobots to handle tasks with a higher performance than workers alone
I want to assess workers' satisfaction and well-being and have their feedback on it

Technical User

I want to detect the fatigue and stress level of an active operator

I want to have a clear view of the state of the cobot and its operations
I want to be able to assign tasks to multiple entities in order to reduce job assignment constraints
I want to be able to lock and tag out the machine in order to perform maintenance / make changes
I would like to easily setup rules to manage task assignments
I want any new systems to be deployed securely and safely with fair additional technical effort from our side

Operational User

I want to be safe when I'm working close to a cobot
I don't want to wear intrusive wearable sensors
I want support to determine priorities in complex environments
I want to have access to an EM Stop at all times
I want to be able to raise attention / alert level of cobot in a simple way (voice, button, gestures)
I want to be scheduled tasks when my current task is completed / about to be completed
I want to be able to get instructions and support for a problem at hand (e.g. via VR / SR / Digital instructions / SOP)
I want automatic systems that adapt their behaviour based on my personal needs, conditions and behaviours and not the other way around
I want to work together with a cobot where the cobot can step in when I'm busy and vice-versa
I would like to have a natural and friendly interaction with cobots
I would like to have the choice on the level of confidentiality / anonymisation of my sensitive data when shared within the company or to other sources
I want the cobot to perform ergonomic part presentation (e.g., if I'm 180cm it should present the part at the appropriate height)
I want to know if there is a cyber risk against decision making algorithms, I'm working with
I would like to raise alerts or notifications in case of problems with the system to allow an AI module or other human to intervene and fix the issue
I want to know how data from my activities is used in order to trust the system
I would like the system to detect and suggest my next step in process (e.g. for new employees)

Technology Provider / Data Scientist

I would like all human sensor data to go through the same architecture in a way that it is easy to track and / or extend the system

I want data about the shopfloor context in order to build an effective system
I want to feed into AI learning cases when operators raised alert / safety level, even if AI system OK-ed the case regarding safety
I want to integrate new data and retrain the system to improve performance and accuracy

Researcher

I would like to have a testbed where models can be tested and user feedback can be easily obtained

Components

Safety zone detection system
Task scheduling for human/cobot collaboration
Safety system override
Messaging / alert system
Lighting system for cobot (e.g. URING)
Event detection system
Data management system
Safety Dashboarding system
Human Digital Twin Dashboarding system
Human digital twin system
Operator support system
Training platform

2.2.6 Proposed Human-AI synergy outcomes

2.2.6.1 Categorisation of Human-AI collaboration activities

AI augments humans

Co-creation workshop addition
Cobot extend the part to human in an ergonomic way (e.g. based on worker position or anthropometric data)
AI supports in planning & scheduling
AI provides on the job instructions to human operator
Recommend decision-making options

AI provides explanations to human users (e.g. you attempted to enter a red zone, the part was rejected due to poor colour match)
Objective decisions (based on data)
Operator support
Task scheduling for human-cobot collaboration
AI translates data into meaningful insights
AI support human skill evolution
On-line training of new operators

Human augments AI

Co-creation workshop addition
Human provides active learning feedback (e.g. labelling cases) for AI learning)
High risk decisions
Human provides implicit feedback (in general, related to UI implementation and how AI forecasts / insights are presented)
Human provides implicit feedback (e.g. raising alert level) for AI reinforcement learning
Human supervision of both robotics operation as well as automated quality inspection
Human expert expands knowledge model of AI actor (e.g. adds more process / component states, which are hard to predefine)

Integrated Human and AI tasks

Co-creation workshop addition
Non-conformity detection by AI, Human to evaluate in or out quality
xAI (unclear)
AI out of knowledge zone (novel case detected); human to examine and label (active learning) (this is actually relevant to human aiding AI)
AI actor alone does not know in advance all knowledge entities. Human actor cannot translate alone observed cases to knowledge entities but can define the knowledge entities. Jointly the human and AI actors allow the overall system to learn more than each actor could achieve alone and the overall learning cannot be performed without the integrated learning task (Not possible to assign this to a simple case of AI aiding humans or humans aiding AI, as it is an evolving process with deep integration of human and AI activities)

AI substitutes human

Co-creation workshop addition
Inspection of items and verification of conformity
Repetitive pick and place tasks
Storing goods
Human task scheduling and support (Not clear substitution case but could be listed as AI supporting humans)
Basic, low-risk decision-making
In tasks where injury or fatigue is more likely
Detect training and up-skilling opportunities based on detected weaknesses (Not clear substitution case but could be listed as AI supporting humans)

Expected outcomes on human and work design effects

Co-creation workshop addition
Shift from repetitive operator tasks to system guidance by operator
Learning curve, operators will need training to learn new ways of working
Operator can support a larger and more complex environment (e.g. multiple cells or lines)
Reduce worker's complacency, boredom and distraction
In the beginning fear of losing out (being replaced) by AI
Automatically choose the correct worker for the correct task/job
Remove wearing tasks assigned to operators (e.g. reduce repetitive tasks, non-ergonomic tasks, tasks that require to follow a defined pace)
Workers can be alerted to support each other with stress/fatigue alerts are issued or when specific skill is needed

Expected outcomes on operational performance

Co-creation workshop addition
Human cycle time vs. cobot cycle time targets
Improved agility in operation, potentially reducing the Idea 2 Market lead time
Human accuracy vs automated inspection system accuracy
Easy & cheaper reconfiguration between different production runs
Increased output
Compliance with quality standards and norms (degree at which a human respect the defined way to accomplish its task)

Consistence in work and quality control (partly removing the subjectiveness of the human)
Reactive automated safety systems instead of human forced safety measures
Human operators focus on high-value tasks, making their work also more enjoyable.

Success criteria

Co-creation workshop addition	**Analysis – how to measure?**
Acceptance	Part of acceptance testing
Trust	Part of the evaluation methodology, perhaps through survey
Easy to use for everyone	Usability testing / survey
Cycle times	Measurement / recording of cycle times
Quality detection & learning improvement compared to current scenario	Measurement / estimation / recording of false quality passes & false rejections
Transparency	Part of the evaluation methodology, perhaps through survey
Safety	Recording of incidents / Survey
Flexibility	Successful reconfiguration cases / survey
Successful education on what AI offers both to company and to worker	To be explored
Pull from the shop floor: operators are asking for the solutions	Recording of pull cases from shop floor
Demonstration of how AI could work in synergy with human	Through the pilot demonstrators
Greater throughput per person per working time	Throughput measurements vs working time
Greater job satisfaction / greater work motivation.	Part of the evaluation methodology, perhaps through survey
Process reliability & potential unsupervised operations on the long term?	Incident recording / Survey

2.2.7 Workshop evaluation

The workshop was evaluated by means of a survey distributed at the end of the workshop. A total of 12 workshop participants executed the survey. The survey included closed questions (Q2-Q8; Q10), as well as open questions (Q9, Q11). A 5-point Likert scale was adopted ranging from poor to excellent (Q2), and from strongly disagree to strongly agree (Q3-8, Q10). An overview of the questions and the responses are shown in Table 10.

Overall, the workshop was positively evaluated as indicated by a 4.33 overall score of the workshop. The objective, which was clearly stated, was also met. The workshop was well organised and perceived as useful and relevant. Respondents agreed that they had sufficient opportunity to contribute to the workshop. Instructions were clear and finally, the workshop met respondents' expectations. Respondents listed a few aspects which they liked best and found most useful, namely the usage of the MIRO board, which allowed for collaboration and interaction as well as a better understanding of the cases. Recommendations for improvements include the definition of used terminology before co-creation activities, an ice-breaking activity at the start of the workshop, and information on the use cases sent before the meeting to be able to prepare but also to use during the workshop.

Table 10: PCL pilot co-creation workshop evaluation

Question	**Mean response** 1 strongly disagree -5 strongly agree
Q2 - Overall, how would you rate this workshop?	4.33
Q3 - The objectives of the workshop were clearly stated.	4.50
Q4 - The objectives of the workshop were met.	4.67
Q5 - The workshop was well organised.	4.83
Q6 - The workshop was useful and relevant.	4.75
Q7 - I had sufficient opportunity to contribute to this workshop.	4.75
Q8 - The instructions were clear.	4.50
Q10 - The workshop met my expectations.	4.58
Q9 - What do you like best or find most useful in this workshop?	Using Miro, allowed for quick interactions and a better understanding of the use cases. Allowing partners to add content, comments and questions enabled partners to understand the main motivations.
	The collaboration within miro works great! It brought many new/additional insights from different perspectives which is very useful for the next steps in maturing the pilot use-cases as well as the alignment between STAR partners.
	I really like the Miro Board, a great tool for interactive collaboration, where it's easy for everyone to contribute.
	The collaboration through the Miro board.
	The tool capabilities and the way the boards were set up connecting with each other
	Very productive session, the tool helped to achieve a lot.
Q11 - Do you have any ideas or suggestions for the improvement of future co-creation workshops?	Not really, all went pretty smooth from what I could see. Great preparation. Maybe it could

	help to provide a description/definition for some of the terminology used. For instance, the different user groups. I believe that people may have anticipated the user categories differently.
	Perhaps a quick introduction round or fun introduction game to 'break the ice' and warm up the meeting.
	Not of any I can think right now. Of course a live meeting would be the best.
	No, it was really good
	Maybe a PowerPoint presentation sent with the Use Case in advance would be good. It is great to have the entry presentation but it could help to be able to go back to it to remember while working with Miro.

2.3 DFKI workshop

2.3.1 Preparatory phase

The workshop took place on 11/5/2021. In preparation for the workshop, DFKI and RuG organised a bilateral meeting and collaborated to prepare the proposed agenda and an initial setup for the MIRO collaboration boards. Microsoft Teams was employed in parallel for shared presentations and the discussion.

2.3.2 Workshop Agenda

13:00 – 13:05 – Opening Section

13:05 – 13:20 – Introduction of DFKI Use Case (DFKI)

13:20 – 13:45 – THALES Simulation Software with real-world projects (THALES)

13:45 – 13:55 – Human activity and emotional state recognition with existing projects (DFKI)

13:55 – 14:00 – 5 Minutes Break

14:00 – 14:30 – Workshop UC1 – Human intention recognition

Stage 1 – User Stories

Stage 2 – Components / functions

14:30 – 15:00 – Workshop UC2 – Robot reconfiguration based on the dynamic layout

Stage 1 – User Stories

Stage 2 – Components / functions

Stage 3 – Combination of scenarios and effects

15:00 – 15:20 – Development of collaboration scenarios

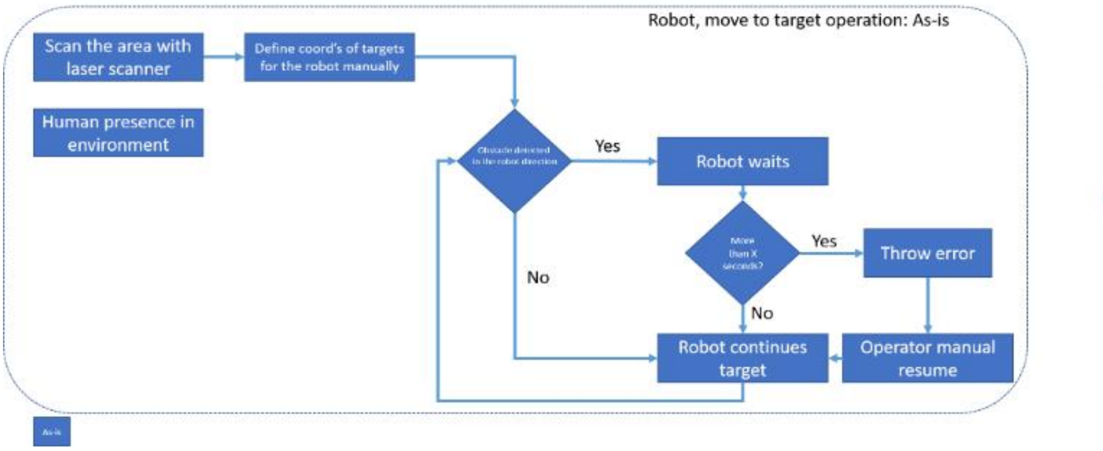
15:20 – 15:30 – Evaluation and Close up

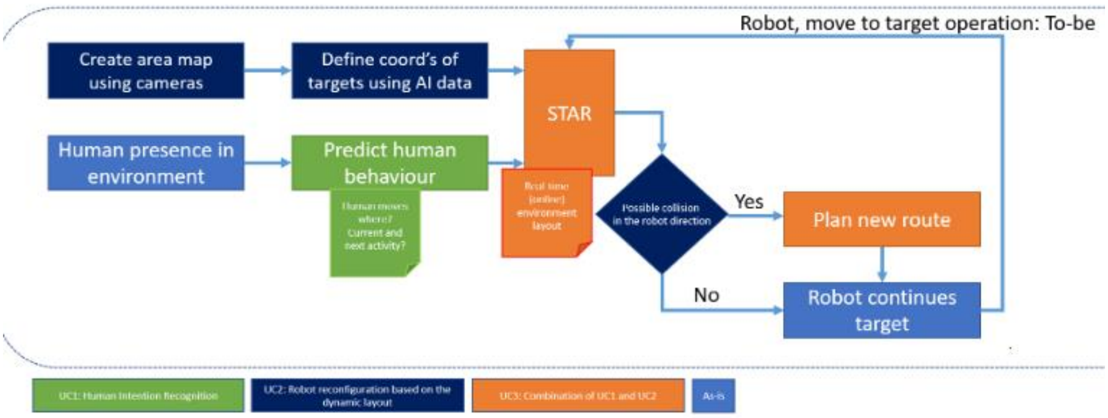
2.3.3 Virtual collaboration board setup

A virtual collaboration board was set up, following the structure described in section 3.2, similar to the structure of the PCL workshop.

2.3.4 Workshop execution

The workshop had a duration of 2.5h and 20 participants from the STAR project partners contributed to it. DFKI opened the workshop by presenting the use cases and their requirements. THALES was then invited to present their simulation environment for joint activity scenarios between humans and robots.





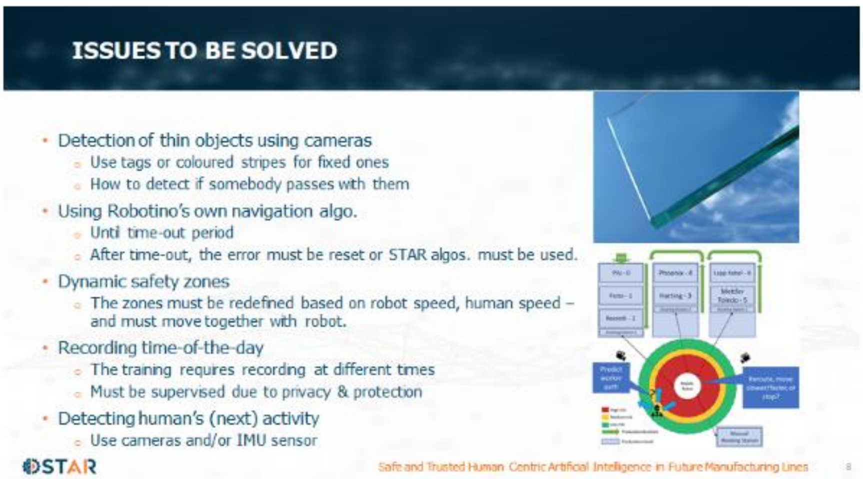


Figure 11: DFKI presenting the pilot case and its use cases

The DFKI co-creation workshop followed a similar pattern with that of the PCL one. RuG described the process to be followed, using the MIRO collaboration boards. Following the agenda, the participants contributed to the co-creation collaboration activity for the user stories, components and the linkage between components and user stories.

2.3.5 Workshop outcomes

The final MIRO collaboration board after the intense co-creation activity can be seen below.

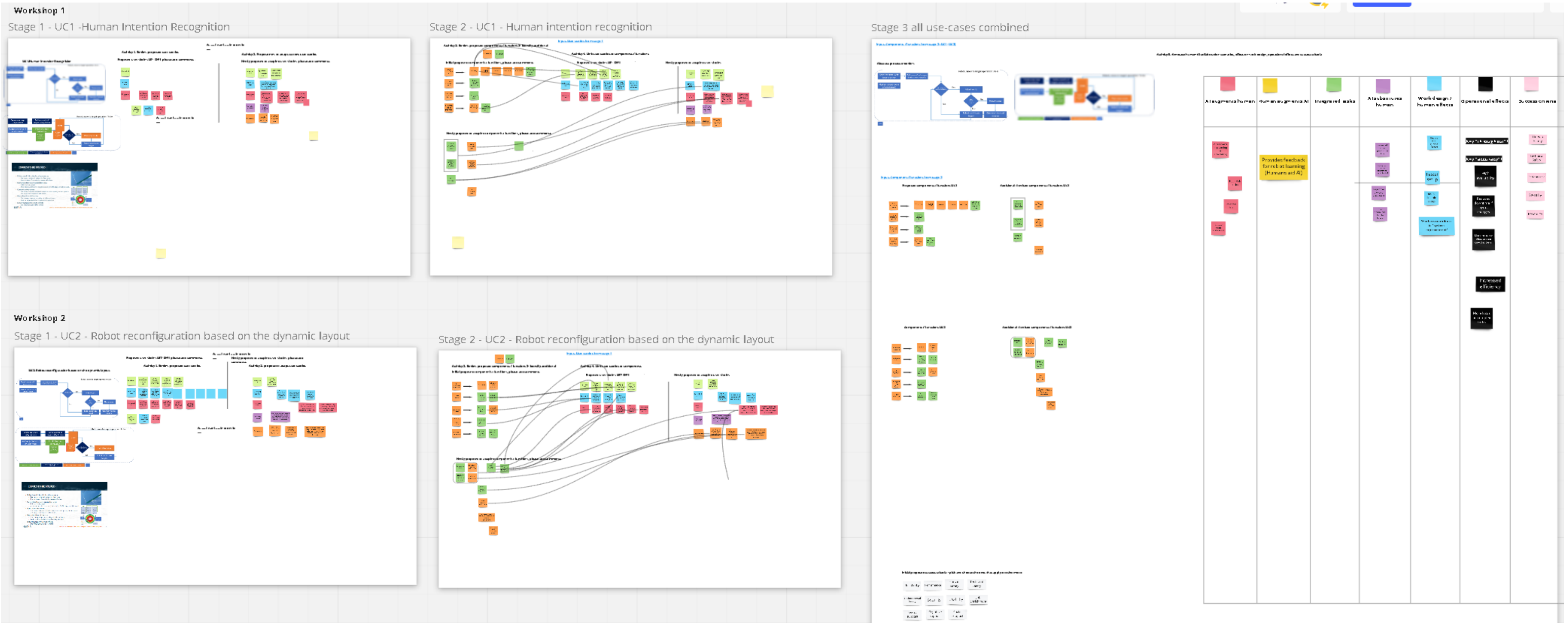


Figure 12: DFKI pilot co-creation outcomes on final collaboration board

The final co-creation activity outcomes are presented next.

2.3.5.1 Use Case 1

Human intention recognition: the use case is about anticipating human behaviour. This will be of use as part of the human-robot collaboration management, for example in mobile robot re-routing.

User Stories

Organisational User

I want to reduce the re-pathing time for robot
I want to reduce downtime in case of routing error
I want to keep the environment safe for the human
I want to keep the equipment safe
I want to predict human movement intention in order to plan an optimal robot route without collision risk
I want to be able to set up a new workflow/business process for the human-robot interaction environment to respond to production reconfiguration needs

Technical User

I want to be able to monitor the path of the Robot dynamically.
I want to be able to localise the Robot in the path to the target.
I want to be informed about any collision that happens.
I want to be able to simulate the production line with any permanent changes.
I want to be informed if the re-routing does not happen in a certain period of time.
I want an interface to enable me to create a structure for Business Process / Activities / Tasks so that I can deal with production reconfiguration situations

Operational User

I want to be informed about any delay in the process.
I want to be able to define activities so as to prepare for solution reconfiguration
I want to be able to issue a STOP/ALERT if I feel in danger
I want to trust the system to correctly identify my intention in order to prevent a robot colliding with me
I want clear instructions on how to do routines or solve malfunctions.
I want to access a dashboard to monitor the flow of the process online.

Technology Provider

I want to make sure I provide devices which help the customer
I want to continuously improve the system by comparing the determined intention vs. the actual movement performed
I want an interface to enable me to create a structure for Business Process / Activities / Tasks so that I can deal with production reconfiguration situations

Researcher

I would like all events (e.g., human robot activities) to be recorded as possible contributors to reinforcement learning

Components

Voice interaction component
Component for defining business process and linking to activities tasks
Physical distributed emergency button components
Status monitor
Event detection component

2.3.5.2 Use Case 2

Robot reconfiguration based on the dynamic layout: this is about managing the robot reconfiguration as part of an overall production process reconfiguration, linked to simulation of the production processes, optimisation of path planning and safe human-robot collaboration.

User Stories

Organisational User

I want to understand the impact of errors
I want to keep the equipment safe
I want to reduce downtime in case of routing error
I want to keep the environment safe for the human
I want to reduce the setup time to reconfigure the robot

Technical User

I want to easily reconfigure the robot
I want to get more feedback in case of an error
I want to have a reliable system
I want to be informed about any collision happens.
I want to be able to simulate the production line with any permanent changes.
I want to be informed if the rerouting does not happen in a certain period of time.
I want to be able to monitor the path of the Robot dynamically.
I want to be able to localise the Robot in the path towards the target.
I want to monitor the current status of all the robots: current position, autonomy left, type (linked ability to perform a task), current task handled (path planned)

Operational User

I want to start production as soon as possible
I want to solve the problems faster, preferably myself
I want to feel safe working with robot
I want to have a reliable system
I want my system to adapt to different conditions (light, crowd)
I want to be able to "instruct" a robot to stop in case of perceived risk to safety
I want the system to detect my intended activity without usage of tags and stripes
Provide a current list of tasks to be performed by the fleet

Technology Provider (Data Scientist)

I want operational, technical, and organisational users to state which are "events of interest" according to their viewpoints so that these can be recorded
Replanning of the navigation based on obstacles

Researcher

I would like to approximate uncertainty for any unforeseen situation that happens.
I want to enable operational users to indicate when robot action is wrong or right (to feed into reinforcement learning)

Components

Robotino's laser scanner
Visualisation components
Plans a route avoiding obstacles
Collusion detection
Determine the positions of the modules with AI
Creates an online map of the area
Simulates the navigation in digital twin
Initiate robot connection
Send the commands to the Robot
Newly proposed or adapted components / functions; please add comments
Emergency stop
Physical stop button components
Auto-configuration for fast setup
Status monitor
Human feedback to robot
Voice interface
Distribution over obstacle detection instead of single detection.
Event detection component
Business process, activity, task definition / configuration component
Component to link event logs to states

2.3.6 Proposed Human-AI synergy outcomes

2.3.6.1 Categorisation of Human-AI collaboration activities

AI augments humans

Co-creation workshop addition
AI supports in planning & scheduling
AI supports human in high-risk decisions
Support towards risks prevention
Assist human’s awareness of whole environment

Objective decisions (based on data)
Operator support

Human augments AI

Co-creation workshop addition
Human provides feedback for robot learning
High risk decisions

Integrated Human and AI tasks

Co-creation workshop addition
None

AI substitutes human

Co-creation workshop addition
Unlimited active production line
Faster and more accurate in repetitive tasks / repetitive pick and place tasks
Offers more security and failure free operation on tasks

Expected outcomes on human and work design effects

Co-creation workshop addition
Reduces operators' physical fatigue
Faster and easier setup
Workers contribute to "system improvement"

Expected outcomes on operational performance

Co-creation workshop addition
High availability
Reduced downtime if layout changes
More secure resource allocation on complex tasks
Easy & cheaper reconfiguration between different production runs

Increased efficiency
More focus on complex tasks

Success criteria

Co-creation workshop addition	Analysis – how to measure?
Human Safety	Recording of incidents / Survey
Technical Safety	Recording of incidents
Performance	Part of the evaluation methodology
Security	Part of the evaluation methodology
Reliability	Part of the evaluation methodology
Transparency	Part of the evaluation methodology, perhaps through survey
Overall Safety	Recording of incidents / Survey
Flexibility	Successful reconfiguration cases / survey

2.3.7 Workshop evaluation

The workshop was evaluated by means of a survey distributed at the end of the workshop. A total of 12 workshop participants executed the survey. The survey included closed questions (Q2-Q8; Q10), as well as open questions (Q9, Q11). A 5-point Likert scale was adopted ranging from poor to excellent (Q2), and from strongly disagree to strongly agree (Q3-8, Q10). An overview of the questions and the responses are shown in Table 11.

Overall, the workshop was positively evaluated as indicated by a 4.33 overall score of the workshop. The objective, which was clearly stated, was also met. The workshop was well organised and perceived as useful and relevant. Respondents agreed that they had sufficient opportunity to contribute to the workshop. Instructions were clear and finally, the workshop met respondents' expectations. Respondents listed a few aspects which they liked best and found most useful, namely the usage of the MIRO board, which allowed for collaboration and interaction as well as a better understanding of the cases. Recommendations for improvements include the definition of used terminology before co-creation activities, an ice-breaking activity at the start of the workshop, and information on the use cases sent before the meeting to be able to prepare but also to use during the workshop.

Table 11: DFKI pilot PCL pilot co-creation workshop evaluation

Question	Mean response 1 strongly disagree -5 strongly agree
Q2 - Overall, how would you rate this workshop?	4.33
Q3 - The objectives of the workshop were clearly stated.	4.67

Q4 - The objectives of the workshop were met.	4.50
Q5 - The workshop was well organised.	4.50
Q6 - The workshop was useful and relevant.	4.50
Q7 - I had sufficient opportunity to contribute to this workshop.	4.50
Q8 - The instructions were clear.	4.33
Q10 - The workshop met my expectations.	4.67
Q9 - What do you like best or find most useful in this workshop?	The board
Q11 - Do you have any ideas or suggestions for the improvement of future co-creation workshops?	More time

2.4 IBER-OLEFF workshop

2.4.1 Preparatory phase

The workshop took place on 5/7/2021. In preparation for the workshop IBER-OLEFF and RuG organised a bilateral meeting and collaborated to prepare the proposed agenda and an initial setup for the MIRO collaboration boards. Microsoft Teams was employed in parallel for shared presentations and the discussion.

2.4.2 Workshop Agenda

Opening - 15h00-15h10

As-Is Scenario - 15h10-15h15

To-Be Scenario - 15h15-15h20

IBER Use Cases - 15h20-15h25

Introduction to Workshop - 15h25-15h30

Workshop UC1 - 15h30-16h00

Break - 16h00-16h10

Workshop UC2 - 16h10-16h40

Workshop UC3 - 16h40-17h10

Break - 17h10-17h20

Collaboration Scenarios - 17h20-17h50

Evaluation - 17:50 – 18:00

2.4.3 Virtual collaboration board setup

A virtual collaboration board was set up, following the structure described in section 3.2, similar to the structure of the PCL workshop.

2.4.4 Workshop execution

The workshop had a duration of 3h and 18 participants from the STAR project partners contributed to it. IBER-OLEFF opened the workshop presenting the use cases and their requirements.

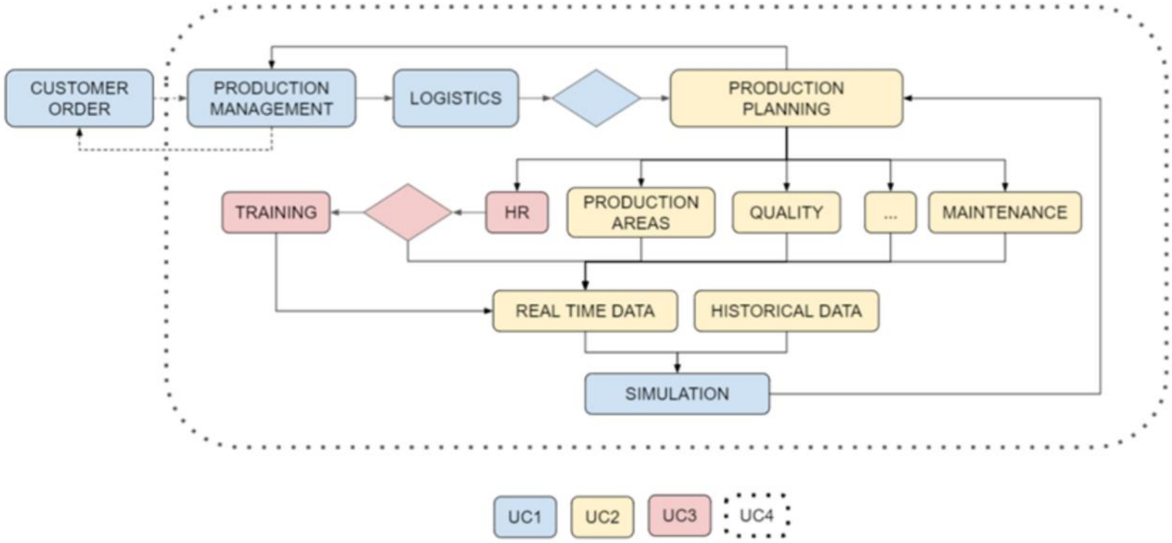


Figure 13: IBER-OLEFF presenting the pilot case and its use cases

RuG described the process to be followed, using the MIRO collaboration boards. Following the agenda, the participants joined the workshop co-creation activities to define user stores, components and the linkage between components and user stories.

2.4.5 Workshop outcomes

The final MIRO collaboration board after the intense co-creation activity can be seen in Figure 14.

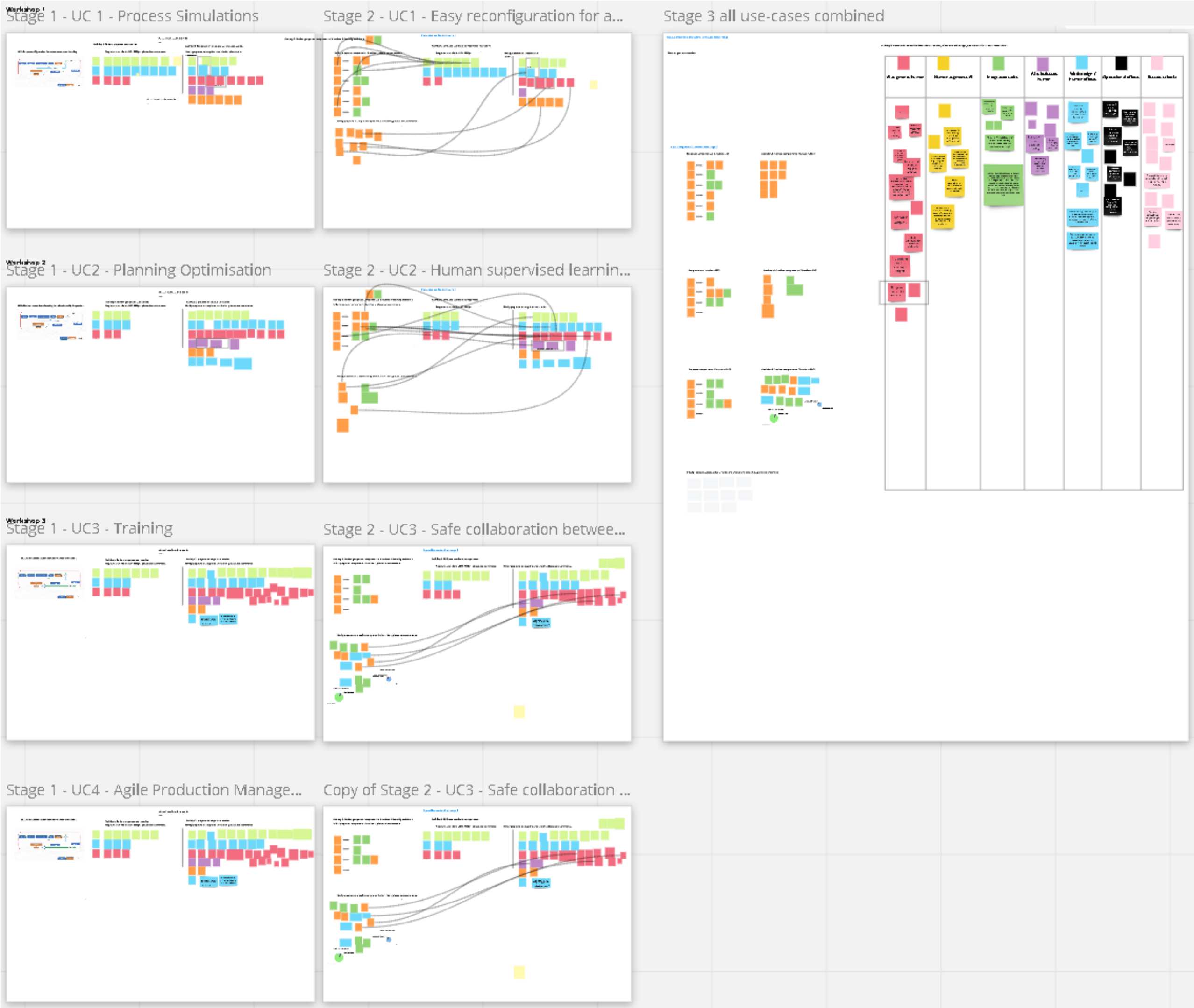


Figure 14: Final collaboration board from the IBER-OLEFF co-creation workshops

The final outcomes are presented next.

2.4.5.1 Use Case 1 – Process Simulations for Accelerated Decisions and Safe Processes

The use case is relevant to performing production process simulation to drive decisions and reconfigure production as a result.

User Stories

Organisational User

I want to take right decisions regarding production system in order to accommodate customer orders
I want to be able to simulate different scenarios of production system in order to select the adequate one
I want to have real-time insights into the performance of the production system
I want to have access to historical data regarding the performance of the production system

Technical User

I want to be able to fast and easily reconfigure production system in order to be flexible
I want to be able to prepare reconfiguration of the production system in virtual domain in order to not affect the productivity
I want to be able to monitor the current configuration of the production system
I would like the simulation to adapt to real-time changes in the production process (also the operational user)
I want to have tools plug and play and/or with minimal setup
I want to receive notifications if there is something that needs immediate attention
I want to be able to fast and easily reconfigure production system in order to be flexible
I want to define validation criteria and intercomponent hard and soft dependencies
I want to have only validated configurations deployed in operational environment

Operational User

I want to have real-time insights of warehouses stocks (finished products & unfinished parts)
I would like to monitor the whole process and current status.
I would like the simulation to adapt to real-time changes in the production process

I want to have information about when and how simulation is inaccurate
I would like to be aware of new tools in line. (to be safe for example)

Technology Provider

As a technology provider delivering an AI component for resources planning	I need access to the monitored parameters and the production

Components

Accelerate decisions at production management level

Configuration simulator

Virtual simulation module

Configuration simulator

Validation of developed configuration

Performance data collection system

Dashboarding of real-time information

Various components for the above

Component that feeds real time data to simulator

PLCs and sensors in work centres for data acquisition

Interface with IBER-OLEFF software (PHC, ProSes, CAQ)

Universal adapters for tools

Database to store datasets

Component to monitor the human activity (IMU, Wearable glass, etc)

Various functionalities for the above

Comparison of simulated outcomes with real ones

Project Information Security (non-functional)

2.4.5.2 Use Case 2 - Production Planning Optimisation

The use case is about producing optimised production planning aiming in parallel at zero-defect production.

Organisational User

I want maximisation of productivity
I want to have clear insights into the performance
I want to have a monitoring system of manufacturing processes
I want to consider workers historical performance and skills in order to assign jobs and tasks

Technical User

I want to receive notifications whenever an abnormality of defects is detected by monitoring system
I want to be able to quickly & easily reconfigure production system
I want to spend as little time as possible setting up and training operational users
I want to consider workers historical performance and skills in order to assign jobs and tasks

Operational User

I want to be safe when performing my work
I want to have clear procedures to follow
I want to be assigned to the jobs and tasks that I prefer, that fit my aspirations and that can allow me to increase my skills.
I want to be informed about any problem in the line and the procedure to resolve that.

Technology Provider

Researcher

I want to have access to the data from production line. (Training testing)

Components

Monitoring system of production processes (hardware + software)
Visualisation System (software)

HR Training System (software, with access to "knowledge repository")
Human digital twin (software)
Data collecting system (with sensors, cameras etc, feeding into a "Knowledge repository)
AI resource planning and assignment component (with Configuration Validation

2.4.5.3 Use Case 3 - Training

The use case is about managing appropriate user training for preventing operator errors.

Organisational User

I want to provide a safe and healthy working environment for all employees
I would like that my employees will be trained based on current but also future needs (e.g., technologies, market fluctuations, etc.)
I want to combine the best of both human and machine

Technical User

I want to be safe when I am working close to a robot
I want to spend as little time as possible training operational users
I don't want the digital system to be prone to attacks that might disrupt its functions
I want a recommender system to provide a training path based on current skills and experience, and desired skillset.

Operational User

I want to work in a safe environment
I don't want to be burned out by my work
I would like to receive clear and easy-accessible instructions on tasks if needed
I would like to know clear safety measures
I want to receive alarm/notification to prevent me making an error (or warn me that I made an error) or an unsafe action; and receive appropriate instructions
I want to follow training to improve my job profile, increase my skills and pursue my aspirations.
As an operational user I would like to get trained in a virtual reality to be safe

As an operational user I want to follow training that allows me to improve my job profile, increase my skills and follow my aspirations.

Technology Provider

I need to have training content for operators to include in a content management system

Researcher

I want to have access to user profiles, their skillset, and available training options (short characterisation, e.g., course, time required, cost, etc) so that a recommender system for employee training can be developed. Any external information on managers' criteria for employee eligibility is welcome too.

Components

Shared space safety system (for example to deliver prevention of human-machine collisions)
Digital safety system (for example to prevent evasion & poisoning attacks)
Mental health monitoring services system (with fatigue / emotion detection module)
Content management systems for tasks - instructions - required skills - guidelines - common mistakes (Skills matrix management functionality included)

2.4.6 Proposed Human-AI synergy outcomes

2.4.6.1 Categorisation of Human-AI collaboration activities

AI augments humans

Co-creation workshop addition
Operator receives task instructions
Human decision makers are supported by AI in production planning and job assignment.
AI recommender system to suggest employee training paths for skills acquisition
Error reduction
Fast and accurate training
AI recommender system for decision making options
Training HR's monitored by AI to identify accuracy of operational methods

Human augments AI

Co-creation workshop addition
Human configurator of AI edits CMS to feed into recommended actions for tasks
Selection of training data cases for human activity / fatigue recognition
Human returns validated or rejected reconfiguration cases (to be used for AI training)
Recording of prototype correct actions for AI-delivered human training

Integrated Human and AI tasks

Co-creation workshop addition
Human validation of AI derived reconfiguration
Joint human-machine tasks for assembly
Human validation of AI derived reconfiguration
Joint human-machine tasks for assembly

AI substitutes human

Co-creation workshop addition
event detection (for alerts etc)
Detect defects
Monitoring and maintenance action recommendation

Expected outcomes on human and work design effects

Co-creation workshop addition
Job enrichment and avoidance of over-specialisation
Cognitive support of operators with context-relevant recommendations
Safer jobs + workplace

Expected outcomes on operational performance

Co-creation workshop addition
Flattening of resources allocation peaks

Reliability

Success criteria

Co-creation workshop addition	**Analysis – how to measure?**
Human Safety	Recording of incidents / Survey
Improved performance	Part of the evaluation methodology
Improved flexibility (training and task assignment are performed to increase skills, extending the assignment options)	Successful reconfiguration cases / survey / part of the evaluation methodology
Security	Successful reconfiguration cases / survey
Agility of production system	Successful reconfiguration cases / part of the evaluation methodology
Usability	User survey

2.4.7 Workshop evaluation

The workshop was evaluated by means of a survey distributed at the end of the workshop. A total of 6 workshop participants executed the survey. The survey included closed questions (Q2-Q8; Q10), as well as open questions (Q9, Q11). A 5-point Likert scale was adopted ranging from poor to excellent (Q2), and from strongly disagree to strongly agree (Q3-8, Q10). An overview of the questions and the responses are shown in Table 12.

Overall, the workshop was positively evaluated as indicated by an overall score of the workshop. The objective, which was clearly stated, was also met. The workshop was well organised and perceived as useful and relevant. Respondents agreed that they had sufficient opportunity to contribute to the workshop. Instructions were clear and finally, the workshop met respondents' expectations. Respondents found most useful that they had the opportunity to add comments to clarify all ideas mentioned, the co-creation and collaboration process, and the Miro board (i.e. digital work). Respondents suggested conducting a physical workshop as soon as this is possible.

Table 12: Evaluation of IBER-OLEFF pilot co-creation workshop

Question	**Mean response** 1 strongly disagree -5 strongly agree
Q2 - Overall, how would you rate this workshop?	4.22
Q3 - The objectives of the workshop were clearly stated.	4.67

Q4 - The objectives of the workshop were met.	4.44
Q5 - The workshop was well organised.	4.33
Q6 - The workshop was useful and relevant.	4.67
Q7 - I had sufficient opportunity to contribute to this workshop.	4.89
Q8 - The instructions were clear.	4.56
Q10 - The workshop met my expectations.	4.67
Q9 - What do you like best or find most useful in this workshop?	The opportunity to add comments to clarify all ideas mentioned.
	The collaborative digital work
	Co-creation process
	Miro
Q11 - Do you have any ideas or suggestions for the improvement of future co-creation workshops?	It would be nice to have a physical meeting to do this exercise but of course due to the pandemic this was not possible
	Not a particular one. That was a successful workshop for me!
	Keep going
	Add "to-do" for MIRO boards

2.5 Overall workshop conclusions

This report outlined the activities that have taken place during the Design Phase co-creation workshops at each pilot case and the key outcomes from these workshops. It also includes output of a survey distributed among project participants with the aim to collect preparatory information to prepare content for the online workshop executed via MIRO online visual collaboration platform.

The key challenge during this project activity was the COVID-19 overall situation, which prevented the project from conducting co-creation workshops with physical presence of participants in a common room for collaboration. Therefore, the mitigation action that was taken opted instead to employ a virtual collaboration tool, namely MIRO.

To better prepare for the co-creation sessions, a STAR project partners survey was designed, distributed, filled-in and analysed, aimed at influencing the structure and the initial "seeding" content of the workshops. This was deemed important, as the lack of physical presence was expected to hamper the collaboration efforts, and therefore initial 'seeding' of concepts and ideas acted as sufficient stimulus to initiate a very lively collaborative co-creation activity in each workshop.

During the workshops, the participants, coming from different perspectives, as represented by the different stakeholder roles of the project partners, worked jointly to co-create key concepts and ideas, bringing together design motivation and requirements, system components that could be relevant to them, bringing in perspectives from different categories of users, in the form of user stories. Importantly, the participants worked to link the user stories and the envisaged components and their expected functionality with potential outcomes and effects / success criteria for the human-centric AI solutions to be developed in the STAR project. The workshops were positively evaluated at the end, marking a very successful co-creation activity during the time of the pandemic restrictions. It was further concluded that the project partners would consequently be expected to take stock of the co-creation activities outcomes when designing and implementing their parts within the overall STAR portfolio of solutions. As the co-creation activities outcomes by their nature are of conceptual and rather abstract nature, the next step would be for them to be more concretely taken into account in the STAR components design, development and testing. It is highly relevant that this is done in a way that examines also both the consistency and feasibility of the derived outcomes, given the project aims, targets, and available resources. Furthermore, the co-creation activities outcomes will be taken particularly into account in the evaluation methodology for the project outcomes in deliverables D6.11 and D6.12. The most important outcome arising from the activities reported in this deliverable is that they offered the partners the opportunity to act as a collaborative co-creation team, triggering the composition of ideas and design requirements and concepts, especially at a time that such a collaboration was particularly restricted due to the pandemic.

3 Early Development and Testing Phase Workshop

3.1 Workshop preparation

A one-day co-creation workshop was held for the early development and testing phase, consisting of three individual workshops focused on each pilot site. The co-creation workshop was scheduled to take place July 6th 2022 (M19) in Athens, Greece. The preparation of the workshop included several meetings with pilot partners to discuss the objective of the workshop and specify relevant workshop activities. Pilot partners specified the importance of discussing their individual updated use cases and related requirements with the technical partners as to make sure that it is well understood how the 'system' should work (be implemented) in the factory to achieve defined success criteria (i.e., socio-technical performance outcomes).

3.1.1 Proposed workshop objective

The overall objective of the (co-creation-) workshop is to focus on reconciling the **updated** requirements of the updated use cases in terms of how the system should work in the factory with the technical components developed in the individual work packages 3, 4 and 5. This includes linking the updated use cases with STAR components and discuss further courses of actions per technical partner.

3.1.2 Workshop input and structure

Based on the proposed objective, the following workshop format was tentatively proposed and listed in Table 13. Workshops were structured per pilot case (IBER, DFKI and Philips), amounting to three '2-hour' workshops. Table 13 proposes a list of different workshop topics addressed per use case, the methods and tools deployed to facilitate the discussion, the input needed for the workshop, the desired outcomes of each activity and the facilitator of each activity.

The pilot workshop starts off with a short presentation of the updated use cases by the pilot leads thereby focusing on **highlighting** the main and realistic changes compared to earlier use case versions. Then, activities 2 and 3 were conducted per use case: the user stories will be elicited, followed by evaluating how the STAR technical components fulfil/enable the specified functionality in the user stories, including a possible demonstration provided by partners through e.g., prototypes. Finally, pilot partners provided input regarding relevant success criteria, followed by the evaluation of the workshop.

Table 13: Structure and format workshop 2

	Workshop topics	How?	Input required	Format /tools	Desired outcomes	Facilitators
1	Present **updated** use cases and specific process scenarios	Presentation	Updated uses cases and process scenarios (provided by pilot partners)	PowerPoint presentation	All partners prepared for discussion of feasibility of use cases	Pilot leads (DFKI, Philips, IBER)

	(**highlighting the changes**) 1. As IS 2. To Be = STAR Use cases					
2	**Per use case**: Elicitate (discuss, refine and update) user stories per updated use case	Plenary discussions with all participants	Updated use cases and user stories	1. Prepare PowerPoint slides (Pilot leads) 2. Prepare flipchart posters with pre-defined user stories for discussion (RuG)	Updated and realistic user stories	Pilot leads (DFKI, Philips, IBER)
3	**Per use case:** Evaluate STAR technical components and adherence to user stories requirements	Plenary discussions with all participants: link technical components to user stories	- List of components Prototypes/demonstrators (provided by technical partners)	Flipchart posters with numbered technical components	All user stories linked to STAR technical components	Technical partners
4	**Overall pilot system:** Identify **updated** success criteria (i.e., socio-technical performance criteria) defined for the pilot case	Plenary discussion based on a number of pre-formulated statements to assess adherence	List of evaluation criteria from workshop 1 and updates from pilot partners	List of criteria	Validated criteria as input for socio-technical evaluation	RuG
5	**Evaluation workshop**	Short plenary discussion			Feedback	RuG

3.1.3 Workshop agenda

Table 14 presents the agenda of the workshop.

Table 14: Agenda Workshop 2

Time	Activity	Content	Responsible
09:30-09:45	Arrival & Welcome Coffee		
09:45-10:00	Opening of the workshop	Welcome the participants; Introduction to the objectives of the co-creation workshops	RuG
10:00-12:00	Workshop IBER • Present updated use cases (5 min) • Use case 1 • Use case 2 • Use case 3 • Use case 4	Discuss updated user stories and linked technical components	IBER together with RuG
12:00-13:00	Workshop Philips (Part 1) Use case 2 • Current status / ideas of pilot • User stories of pilot • Mapping of STAR components • User stories technical partners • Final view/ conclusion/next steps	Discuss updated user stories and linked technical components	Philips together with RuG
13:00-14:00	Lunch break		
14:00-15:00	Workshop Philips (Part 2) Use case 1 • See outline above	See above	Philips together with RuG
15:00-15:15	Short Coffee break		
15:15-17:15	Workshop: DFKI • Present updated use cases (5 min) • Use case 1 • Use case 2 • Use case 3	Discuss updated user stories, linked technical components and socio-technical performance criteria	DFKI together with RuG
17:20-18:00	Debrief & evaluation workshop	Summarise main points and evaluate the	RuG

		workshop	

3.2 Workshop outcomes

The workshop outcomes are structured per pilot case.

3.2.1 Workshop IBER

The following sub-sections present the outcomes of the workshop discussions per use cases, and concludes with the mapping of STAR technical components to use cases and identified success criteria for evaluating the success of the ai-enabled systems implemented at the pilot cases.

Each (updated) use case was presented by the task leader, followed by a plenary discussion and mapping how the use cases link to the individual STAR components.

3.2.1.1 Use case 1: Production process simulation

The use case was not significantly modified compared to earlier described versions. The main identified issue relating to this use case is its unclear link to the STAR components. The following ideas were discussed:

- The possibility to merge this use case with use case 2 should be further investigated
- The possibility to adjust the use case to meet the STAR components, e.g., human digital twin,
- Narrow down the addressed problem to a smaller scope to increase the feasibility,
- Q-lector/JSI Unipi are interested and will investigate further opportunities for cooperation while seeking a link to existing tasks.

3.2.1.2 Use case 2: Production planning optimisation

The use case was not significantly modified compared to earlier described versions. The main identified issue relating to this use case is its unclear link to the STAR components. The following ideas were discussed:

- Similar to use case 1, the possibility to link it to the same STAR components as use case 1 will be investigated.

3.2.1.3 Use case 3: Employee Training for Reduction of Human Errors

The use case was not significantly modified compared to earlier versions. The main identified issue relating to this use case is its unclear link to the STAR components. The following ideas were discussed:

- Overall, this use case is not yet clear to STAR partners and hence the link to existing STAR component is also not clear,
- IBER is to provide an example of data and content which might form a basis for any diagnoses and decision,
- Another possibility is the potential link to the knowledge platform of task 5.5; this should be further investigated.

3.2.1.4 Use case 4: Agile Production Management System Data Integrity and Reliability

The use case was not significantly modified compared to earlier versions. The main identified issue relating to this use case is its unclear link to the STAR components. The following ideas were discussed:

- This use case can clearly be linked to the STAR components developed in WP3, including the AI cyber-defence tool and blockchain,
- For the implementation of the use cases, IBER must provide access to relevant servers,
- The collected data can be stored on a central repository for training purposes,
- Scenarios for security threats and incidents must be identified based on use case 3.

3.2.1.5 Mapping STAR components to use cases

The following Table 15 summarises the mapping of use cases to STAR components as specified in the objectives of the workshop.

Table 15: IBER Mapping use cases and STAR components

Use case	Link STAR component
Use case 1: "*Production Processes Simulations for Accelerated Decisions and Safe Processes*"	• To be determined
Use-case2: "*Production Planning Optimisation*"	• To be determined
Use-case 3: "*Employee Training for Reduction of Human Errors*"	• Fatigue monitoring system • Natural language processing • Feedback module
Use case 4: *"Agile Production Management System Data Integrity and Reliability"*	• Distributed Ledger Services for Data Reliability • Runtime monitoring system • Risk Assessment and Mitigation Engine • Security Policies Manager • AI Cyber-Defence Strategies

3.2.2 Workshop PLC

Similar to the previous section 2.2.1, the following sub-sections present the outcomes of the workshop discussions per use cases, and concludes with the mapping of STAR technical components to use cases and identified success criteria for evaluating the success of the ai-enabled systems implemented at the pilot cases.

3.2.2.1 Use case 1: Easy reconfiguration for automated part handling

- The classification of data was identified as a challenge because the data set currently consists of image data: can this be linked to active learning,

- AI training for part identification can be based on image data and labels,
- Philips will provide a data-set: can data of localisation be used to identify the product?
- Necessary to explore the feasibility because of other data type requirements regarding new model, configuration and training: possible to use photos instead?
- The link to WP3 need to be discussed further.

3.2.2.2 Use-case 2: Human supervised learning for visual quality inspections

The discussion regarding this use case as primarily concerned with the mapping of the STAR components to the user stories.

- Identification of defects: potential link to active AI,
- Acquire feedback from operator: link to 'Feedback module (Explainable AI)',
- To learn links to 'Active AI',
- To understand why the AI does things links to 'Explainable AI',
- To ensure the mental well-being links to 'Fatigue monitoring system',
- To ensure quality of decision-making links to 'Fatigue monitoring system',
- To avoid disengagement links to 'Fatigue monitoring system,'
- To learn a new quality inspection links to 'active learning' (to be explored),
- Provide a safe system links to WP3 and needs to be further explored.

3.2.2.3 Use-case 3: Safe collaboration between human and machine

The previous feedback given in section 3.2.2.2 also applies to this use case.

3.2.2.4 General feedback

In addition to the discussions per use case and the mapping of the technical components, the PLC task leader asked the following questions:

- What is unclear regarding use cases?
    - WP3 need more detail for scenario formulation including a process flow: possibly define a new use case (use case 4) for WP3?
- How should we move forward?
    - Discuss data sharing between Philips and partners and gain access to environment,
    - Define the complete flow of the pilot; define different scenarios and process flows and identify relevant data,
    - Gather pilot feedback to specify what is critical to pilot partners for implementation,
    - Identify critical assets for WP3,
    - Define next steps and uncertainties about integration of STAR components on Philips premises,
    - Define where the demo will be deployed: on Philips premises or in a separate server- Also consider the Blockchain as a service, outside local premises.

3.2.2.5 Mapping STAR components to use cases

The following Table 16 summarises the mapping of use cases to STAR components as specified in the objectives of the workshop.

Table 16: PLCs Mapping use cases and STAR components

Use case	STAR component
Use case 1: *Easy reconfiguration for automated part handling*	Mainly focusses on implementing technologies developed within WP4 aiming to provide a system that can detect different parts and is able to react to these observations. • XAI library • Simulated reality • Active learning
Use-case 2 - *"Human supervised learning for visual quality inspections"*	Also focusses on the implementation of technologies developed in WP4 aiming to provide an automated quality control system that can be easily setup and reconfigured. • XAI library • Simulated reality • Active learning
Use-case 3 - *"Safe collaboration between human and machine"*	Focuses on the development and implementation of technologies from WP5 aiming to leverage the best of both human and machine while ensuring employee mental and physical safety. • Human centred digital twin core infrastructure • Fatigue monitoring system
Use-case 4 - *"AI Cyber-defence and decentralised reliability for industrial data"*	Focuses on the development and integration of the components in WP3 aiming to provide a secure system. • Distributed ledger services for data reliability • Runtime monitoring system • AI Cyber Defence strategies • Risk assessment and mitigation engine • Securities policies manager

3.2.2.6 Overall specified success criteria

The following success criteria in Table 17 were identified during the workshop by pilot partners to be included in the socio-technical evaluation.

They are specified into technical, operational and social criteria to be addressed.

Table 17: PLC – Identified success criteria

Technical criteria	Operational criteria	Social criteria
• Security • Accuracy • Reliability • Robustness • Explainability • Low latency	• Labour productivity • Machine set-up time • Process reliability • Process flexibility • Performance	• Mental health • Satisfaction/well-being • Motivation • Task feedback • Trust • Transparency

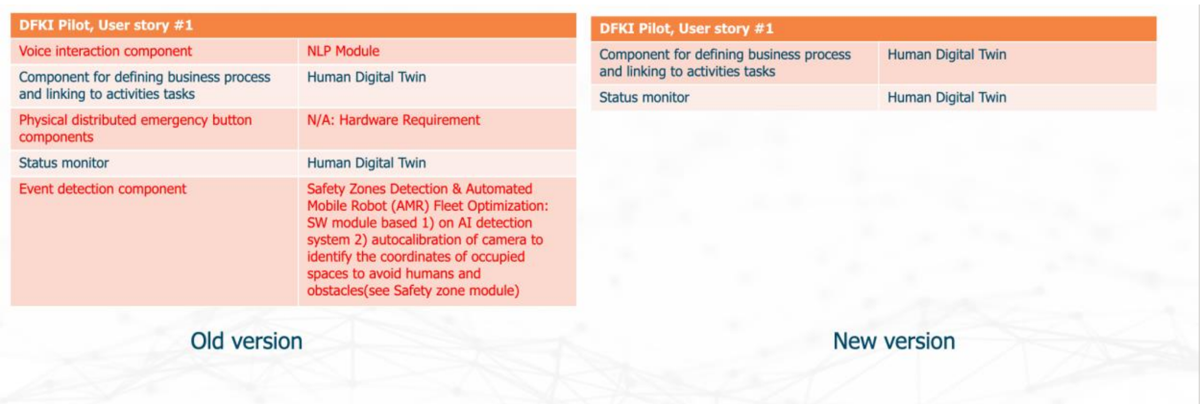
3.2.3 Workshop DFKI

Similar to the previous section 3.2.3, the following sub-sections present the outcomes of the workshop discussions per use cases, and concludes with the mapping of STAR technical components to use cases and identified success criteria for evaluating the success of the ai-enabled systems implemented at the pilot cases.

3.2.3.1 Use case 1: Human Intention Recognition

Table 18 presents the old user stories and updated user stories as presented and discussed in the workshop.

Table 18: Updated user stories of use case 1 – DFKI



DFKI Pilot, User story #1	
Voice interaction component	NLP Module
Component for defining business process and linking to activities tasks	Human Digital Twin
Physical distributed emergency button components	N/A: Hardware Requirement
Status monitor	Human Digital Twin
Event detection component	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimization: SW module based 1) on AI detection system 2) autocalibration of camera to identify the coordinates of occupied spaces to avoid humans and obstacles(see Safety zone module)

Old version

DFKI Pilot, User story #1	
Component for defining business process and linking to activities tasks	Human Digital Twin
Status monitor	Human Digital Twin

New version

Comments regarding updated user stories

- The user stories regarding 'voice interaction component, 'physical distributed emergency button components' and 'event detection component' are moved to use case 2.

3.2.3.2 Use case 2: Robot reconfiguration based on the dynamic layout

Table 19 presents the old user stories, and Table 20 presents the updated user stories as presented in the workshop.

Table 19: Old user stories of use case 2 – DFKI

DFKI Pilot, User story #2	
Robotino's laser scanner	N/A: Hardware requirement
Visualisation components	Human Machine Interface
Plans a route avoiding obstacles	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation
Collision detection	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation
Determine the positions of the modules with AI	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation: SW module based 1) on AI detection system 2) autocalibration of camera to identify the coordinates of occupied spaces to avoid
Creates an online heatmap of the area	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation: SW module based 1) on AI detection system 2) autocalibration of camera to identify the coordinates of occupied spaces to avoid (see Safety zone module)
Navigation Simulation	Automated Mobile Robot Fleet Optimisation
Initiate robot connection	N/A: Out of prototype scope
Send the commands to the Robot	HDT – MQTT publisher- subscribers to send non-static object heatmaps to the AMR path planificator
Emergency stop	N/A: Embedded in robot
Physical stop button components	N/A: Hardware requirement
Auto-configuration for fast setup	Safety zone detection: autocalibration of camera to identify the coordinates of occupied spaces to avoid
Status monitor	AMR Fleet Optimisation
Human feedback to robot	Human Machine Interface
Voice interface	NLP Module
Distribution over obstacle detection instead of single detection.	Safety zone detection definition trough Heatmaps
Event detection component	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation: SW module based 1) on AI detection system 2) autocalibration of camera to identify the coordinates of occupied spaces to avoid (see Safety zone module)
Business process, activity, task definition / configuration component	Human Digital Twin
Component to link event logs to states	Human Digital Twin

Table 20: Updated user stories of use case 2 – DFKI

DFKI Pilot, User story #2	
Robotino's laser scanner	N/A: Hardware requirement
Visualisation components	Human Machine Interface
Plans a route avoiding obstacles	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation

Collision detection	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation
Determine the positions of the modules with AI	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation: SW module based 1) on AI detection system 2) autocalibration of camera to identify the coordinates of occupied spaces to avoid
Creates an online heatmap of the area	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation: SW module based 1) on AI detection system 2) autocalibration of camera to identify the coordinates of occupied spaces to avoid Human and Obsticles (see Safety zone module)
Navigation Simulation	Automated Mobile Robot Fleet Optimisation
Initiate robot connection	N/A: Out of prototype scope
Send the commands to the Robot	HDT – MQTT publisher- subscribers to send non-static object heatmaps to the AMR path planificator
Emergency stop	N/A: Embedded in robot
Physical stop button components	N/A: Hardware requirement
Auto-configuration for fast setup	Safety zone detection: autocalibration of camera to identify the coordinates of occupied spaces to avoid
Status monitor	AMR Fleet Optimisation
Human feedback to robot	Human Machine Interface
Distribution over obstacle detection instead of single detection.	Safety zone detection definition trough Heatmaps
Business process, activity, task definition / configuration component	Human Digital Twin
Component to link event logs to states	Human Digital Twin

Comments regarding updated user stories

- Investigate possibility to create an online heatmap of the area and discuss option to integrate into User story 3,
- Regarding user story 'Navigation Simulation' resembles a digital twin of DFKI pilot for THALES: need to discuss possibility what it can be and how it can be implemented,
- Regarding user story 'send the commandos to the Robot': no voice interface integrated yet,
- Regarding user story 'Distribution over obstacle detection instead of single detection' it is not clear yet what this implies; needs to be discussed.

3.2.3.3 Use case 3: Dynamic path planning using both first and second use cases

Table 21 presents the new user stories related to use case 3. No earlier user story was defined.

Table 21: New user stories of use case 3 – DFKI

DFKI Pilot, User story #3	
Event detection component	Safety Zones Detection & Automated Mobile Robot (AMR) Fleet Optimisation: SW module based 1) on AI detection system 2) autocalibration of camera to identify the coordinates of occupied spaces to avoid

	humans and obstacles(see Safety zone module)

3.2.3.4 Identified issues and questions to be addressed

Using Robotino's own navigation algorithm.

- Possible until time-out period but after time-out, the error must be reset or STAR algorithms must be used: to be investigated,
- If possible, collision in red area is detected by Robotino's sensors.

Dynamic safety zones

- The zones must be redefined based on robot speed, human speed and must move together with robot.

Detecting human's (next) activity

- Use cameras and/or inertial measurement unit (IMU) sensor.

Open questions to be addressed:

Should we send the map of the environment to THALES?

1. How about the dynamic environment?
2. How about Labelling the Modules?
3. How about using 3D environment from 2-ceiling cameras and label modules?

3.2.3.5 Mapping STAR components to use cases

The following Table 22 summarises the mapping of use cases to STAR components as specified in the objectives of the workshop.

Table 22: DFKI Mapping use cases and STAR components

Use case	STAR component
Use case 1: "*Human Intention Recognition*"	The component for detecting human activities and predict the intention of the worker based on the wearable sensors on two wrists are developed and provided from WP5 • Human centred digital • Worker activity recognition
Use-case 2: "*Robot reconfiguration based on the dynamic layout*"	This module, Safety Zone Detection, is also provided from WP5. Human Centred Digital twin provide the data transferring pipeline and provide the simulation of the layout considering the location of the AMR as well as workers. • Safety zones detection & automated mobile robot (AMR) fleet optimisation • Simulated reality • Active learning

	• Explainable AI
Use-case 3 - "*Dynamic path planning using both first and second use cases*"	This use case is referring to the combination of the two first use cases. Here we fuse the detection of the human intentions from first use case with the path planning module from second use case to have the safe and reliable environment for the human robot interaction. This is mainly referred to WP5 tasks and the combination will happen in the Human Centred Digital Twin component.

3.2.3.6 Overall specified success criteria

The following success criteria presented in Table 23 were identified during the workshop by pilot partners to be included in the socio-technical evaluation.

They are specified into technical, operational and social criteria to be addressed.

Table 23: DFKI Identified success criteria

Technical criteria	Operational criteria	Social criteria
• Security • Accuracy • Reliability • Robustness • General safety • System resilience • Explainability • Low latency • Scalability • Privacy • Data protection	• OEE (machine productivity) • Run times (availability) • Machine set-up time • Process reliability • Machine availability • Machine flexibility • Process flexibility • Performance	• Mental health • Task feedback • Trust • Transparency • Usability • Human safety

3.3 Overall workshop conclusions

The three workshops conducted for each pilot case successfully managed to update all pilot partners on the use cases, including updating requirements. It thereby created a mapping of how use cases are linked to STAR components, identifying a number of gaps which need to be addressed by pilot and technical partners. Furthermore, it identified a number of technical issues which also require attention in the further development of STAR components. Finally, important success criteria were identified, which need to be streamlined with criteria addressed and measured during the socio-technical evaluation of STAR components (as specified in D6.11 and reported on in D6.12 of Work package 6.

4 Final Development and Testing Phase Workshop

The workshops held for the final development and testing phase included an internal and an external workshop. The internal workshop included STAR partners, whereas the external workshop was co-organised by the STAR partners, Philips and the University of Groningen, as well as the Innovation Cluster Drachten and the AI Hub North Netherlands. The two workshops were held on April 5th at PLC (Philips) in Drachten. In the following section, the preparations and outcomes are presented for the internal workshop (Section 4.1) and the external workshop (Section 4.2).

4.1 Internal STAR co-creation workshop

4.1.1 Proposed workshop objective

The internal workshop was focused on discussing potential updates regarding pilot's use cases with STAR technical partners, and further validation of the key performance indicators defined for the socio-technical evaluation by pilot partners. This includes identifying any updates to key performance indicators and preliminary discussion on potential data collection methods and tools.

4.1.2 Workshop input and structure

The workshop involved representatives of different functions and roles relevant to designing an AI-enabled solution for manufacturing lines, as expressed within the consortium partnership, including different roles within the manufacturing stakeholders, technology providers, research organisations, as well as legal and ethics experts. Based on the proposed objective, the following workshop structure presented in Table 24 was developed. It proposes a list of different workshop topics addressed per use case, the methods and tools deployed to facilitate the discussion, the input needed for the workshop, the desired outcomes of each activity and the facilitator of each activity. The workshop was run for every pilot partner individually, and the outcomes are presented in Section 4.1.4.

Table 24: Workshop 3 structure

	Workshop topics	How?	Input required	Format /tools	Desired outcomes	Facilitators
1	What is demonstrated in which use case of the pilot: Update uses cases including technical discussion: what is demonstrated in which use case of the pilot	Presentation followed by interactive discussion	Updated use cases	PowerPoint presentation	List of (technical) issues to be addressed	Pilot leads (DFKI, PLC, IBER)
2	How success is assessed and measured: updates and discussion of key performance indicators (i.e.,	Interactive discussion	List of pre-defined key performance indicators per use cases and overview of socio-technical criteria defined	PowerPoint presentation, flip-charts	Updated list of key performance indicators including indicators for measurement	RuG

	success criteria) of each pilot case		in D6.6			

4.1.3 Workshop agenda

The agenda of the workshop is presented in the table below

Table 25: Agenda Workshop 3 – internal

Date and Time	Activity	Content	Facilitators
April 4th: 15:00 -17:15	Workshop IBER	15:00-16:00 Updates use cases and open (technical) issues 16:00-17:00 Discussion of updated key-performance indicators	RuG
April 5th: 09:15 - 11:15	Workshop DFKI	09:15-10:15 Updates use cases and open (technical) issues 10:15- 11:15Discussion of updated key-performance indicators	RuG
April 5th: 11:15 - 13:15	Workshop PLC	11:15-12:15 Updates use cases and open (technical) issues 12:15-13:15 Discussion of updated key-performance indicators	RuG
April 5th: 13:15 – 14:00	Lunch	-	-

4.1.4 Internal Workshop outcomes

4.1.4.1 Workshop IBER

- Discussion and feedback of key performance indicators per use case

The following Table 26 presents overall feedback collected regarding the objectives of the use cases and related key performance indicators. In addition, feedback collected on emerging discussion points are presented.

Table 26: Feedback key performance indicator - IBER

Use case objective	Defined KPI and specification	Feedback and action
Use case 1: Accelerate plant management decisions supported by real-time information and production process	• 1. Number of right decisions due to the use of Artificial Intelligence platform as support (Units: %) Baseline: N/A Target: 50 % • 2. Confidence in the system related to the production system simulations resulting from the use of artificial intelligence platform, (Units: %)	• Key Performance Indicators still valid but need to be evaluated further when use case is developed by technical partners: IBER scheduled a meeting with Q-Lector to discuss potential involvement in use case. • Important to consider how the technology will impact the work of planners in terms of broader socio-

simulations	Baseline: N/A Target: 80 %	technical evaluation criteria: this has to be defined prior to the socio-technical evaluation: consider wider unit of analysis than operators on the floor but all potential users throughout the life-cycle of a technology.
Use case 2 Improved production planning / productivity maximisation	• 10 % increase by of production linearity (Units %), Baseline: 20 production peaks Target: 20 production peaks • 25 % extra work hours reduction Units: %), Baseline: 160 extra work hours / year Target 120 extra work hours / year • 10 % down time reduction (Units %), Baseline: 10 times / year Targe: 9 times year	• Key performance indicators still valid but need to be evaluated further when use case is developed by technical partner: IBER scheduled a meeting with Q-Lector to discuss potential involvement in use case • Concept of production linearity in context of use case not clear yet and needs to be investigated and specified for evaluation • Important to consider how the technology will impact the work of planners and operators in terms of broader socio-technical evaluation criteria: this has to be defined prior to socio-technical evaluation
Use case 3: Flexible Human Resource Training	• 10 % reduction in human errors associated with incomplete / inappropriate training (operative methods on the production line) (Units: %), Baseline 10 Target: 9 • 10 % reduction in human errors due to overspecialisation related to performing the same functions in the same workplaces over a given period of time (Units: %), Baseline 10 Target: 9	• Key performance indicators still valid • Explore possibility of fatigue detection for use cases: explore how sensors benefit the worker • Explore possibility to include assessment of worker satisfaction due to the implementation of STAR component
Use case 4: Ensure the confidentiality, integrity, availability, non-repudiation and authenticity of data transmitted, stored and processed in components of the Agile Production Management System	• Detect data poisoning (Units: %), Baseline: 0 % Target: 90 % • Ensure data integrity (Units: %), Baseline: 0 % Target: 90 %	• IBER needs to define relevant scenarios and provide data for Work Package 3 leaders
Other emerging discussion points	• Economic criteria not yet included as key performance indicator and in socio-technical evaluation • Performance criteria very techno-focused	• Schedule meeting to scan assessment criteria defined in socio-technical evaluation methodology addressing social and trust aspects, operational, technical and economic criteria • No economic criteria defined yet for IBER: define standard criteria for all pilot cases to assess economic and financial

		benefits: • Costs versus benefits/estimation of expected benefits: make reasonable assumptions • Explore inclusion of additional social and trust criteria in evaluation

4.1.4.2 Workshop DFKI

○ Discussion of use case objective and key performance indicators

The following section presents overall feedback collected regarding the use cases and key performance indicators, which are defined per use case and per corresponding overall objective in Table 27. In addition, feedback collected on emerging discussion points are presented.

Table 27: Feedback key performance indicator - DFKI

Use case objective	Defined KPI and specification	Feedback and action
UC1: Human intention recognition	• Demonstrate application adequate accuracy, typically 95%. ○ 70 % accuracy ○ 60 % F1-score ○ 90 % for walking activity class	• KPI's still valid; no further update is needed
UC2: Robot reconfiguration based on the dynamic layout	• Comparison of the online and offline route planning algorithms in dynamic and uncertain environments. • Relevant statistical comparison of algorithms on a realistic dataset	• KPI regarding comparison of online and offline route planning needs to be more carefully defined and further specified: potential performance dimensions may include: ○ Time required to build the map ○ Improvement of accuracy ○ Complexity?
UC3: Dynamic path planning using both first and second use cases	• Easier reconfiguration of robots when factory layout changes. • Around 25% efficiency improvement.	• KPI's still valid • Further specify a measurement target for 'easier reconfiguration'
Other emerging discussion points	• Potential KPI's to consider: 1. Safety performance 2. Economic criteria not included as KPI 3. No KPI's defined for Work Package 3 yet	1. Potential measure: distance to humans (TBD) 2. Economic criteria may include costs saved through potential benefits e.g. efficiency improvements, costs of sensors (TBD) 3. Use case and KPI's needs to be defined for addressing WP3

		○ Goal is to identify abnormal behaviour; Define thresholds in asset movements ○ DFKI: Define scenarios and provide data to WP3 partners

4.1.4.3 Workshop PLC

Discussion of use case objective and key performance indicators

The following section presents overall feedback collected regarding the use cases and key performance indicators, which are defined per use case and corresponding overall objective in Table 28. In addition, feedback collected on emerging discussion points are presented.

Table 28: Feedback key performance indicator - PLC

Use case objective	Defined KPI and specification	Feedback and action
Use case 1: Easy reconfiguration for automated part handling	• Reconfiguration time to adapt the part handling system to new parts: <= 30min; • Reconfiguration effort to adapt the quality inspection by vision system to new parts <=50 cycles (currently there is a baseline of 1000+ cycles). •	• Listed KPI's still valid • Regarding measurement, an experiment could be designed to compare new and historical data and simulate performances
Use-case 2: Human supervised learning for visual quality inspections	• Cycle time per part: <=1.6 seconds per part; • False positives: ~ 0% of parts; • False negatives: <= 0.01% of parts.	• Listed KPI's still valid
Use-case 3: Safe collaboration between human and machine	• Ease of use during operation: suitable for users with secondary education; • Ease of use during reconfiguration: suitable for users in Intermediate vocational education.	• Listed KPI's still valid • Additional KPI's may be relevant to include (TBD): Mental fatigue included in use case: identify if KPI's need to be defined;
Use-case 4: AI Cyber-defence and decentralised reliability for industrial data	• X% of evasion/poisoning attacks identified and/or resolved • Increased Satisfaction / Safety Feeling: >=30% (measured in user studies). (link to social criteria?)	• KPI's still valid
Other emerging discussion points and resulting considerations:	Pilot 1 replaced by a new pilot includes some important changes: • No direct operator/A.I. comparison possible • Data labelling more demanding (12 failure modes) • Increased importance of the quality check	• Economic criteria need to be defined for pilot case; consider standard criteria for all pilot cases • Discuss social and trust criteria for Q-engineers and involvement of other potential users

	• AI decides about product quality autonomously, as opposed to an operator being supported in decision-making by the AI (pilot 1 • A Quality Engineer is responsible for system output on batch level • A challenge includes how to ease the cognitive load of work activities like the data labelling to enable AI to both perform better, and expand its 'knowledge' to new cases • How to learn to trust the A.I. quality judgment in such an important quality check • Important to ensure that the entirety of this system is protected for threats like cyber-attacks using WP3 components	

4.1.5 Overall internal workshops conclusions

The workshop successfully met his defined objective, namely updating technical partners about any updates regarding the use cases, including any potential discussions on open technical issues. Furthermore, previously defined KPI's were assessed for comprehensiveness, and the potential inclusion of additional criteria addressing social, technical, operational and economic criteria was discussed. It was found that for all pilot partners, economic (including financial) criteria needs to be identified. Furthermore, it is essential to more closely evaluate the impact of STAR components on human work, including the inclusion of criteria focused on social and trust criteria, including work design. The workshop therefore provided a significant number of follow-up discussions to further steer the development of human-centric, safe and trusted technologies at pilot partners.

4.2 External co-creation workshop

The external workshop was a three-hour interactive workshop organised with external stakeholders, including STAR partners, Philips, the Innovation Cluster Drachten and the AI Hub North Netherlands. Of the approximately 40 participants, 35 % were researcher/academics, 38 % developer/integrator of digital technologies/AI, 15 % industry representatives, 4 % legal experts, 4 % government representatives, and 4 % consultants.

4.2.1 Proposed workshop objective

The overall objective of the (co-creation) workshop was to discuss demonstrate and exhibit key findings and insights of the STAR project to external stakeholders.

4.2.2 Workshop structure and content

Table 29 summarises the structure and content of the workshop, divided into three main activities. The workshop's first session focused presented STAR's insight regarding trusted and human-centric AI in manufacturing with industrial cases, including what STAR delivers, what was learnt from STAR and some hands-on tips on how to deliver human-centric AI including examples. The following section focused on providing practical tips, interactive use and demonstration of STAR AI tools in manufacturing use cases. A demonstration exhibition was set up with 5 stands presenting tools developed in STAR (Quality inspection and Active Learning, STAR Risk Assessment Engine and Security Manager, Video Analytics and Reinforcement Learning for AMR's, Workers Training Platform for continuous training and Human Digital Twins in Collaborative Robotics Applications) where interested participants could see demos and discuss with the STAR partners about the specific functionalities. The workshop wrapped up with a session on the assessment of human-centric AI systems in manufacturing, introducing participants to the hands-on evaluation methodology as developed and applied in the project. The workshop concluded with a final evaluation of the workshop.

Table 29: Workshop structure and content – external STAR workshop

Workshop topics	How?	Format /tools	Facilitators
Trusted and Human-Centric AI in Manufacturing with Industrial Cases Opening and 'logistics of workshop' • What STAR delivers and how! • What we learned from STAR and … • Tips on how to deliver human-centric AI (steps/tips with examples) • Description of the demo stands	Presentation including interactive polls	Presentation	RuG, Intrasoft
How to involve the Human in the Loop: practical tips, interactive use and demonstration of STAR AI tools in manufacturing uses cases • Quality inspection (WP4): JSI and RuG (demo+interaction) • WP3 tools: demo and presentation • WP5: Thales (demo and presentation?) • Human digital twin: videos and presentation • R2M: demonstration (Workers Training Platform)	Demonstration stands	Demo/interactive experiment	STAR partners
How to approach the assessment of human-centric AI systems in manufacturing: active discussion and evaluation • How to assess human-centric systems: what are the criteria? • Assessment: What are the top 3 socio-technical criteria (per category) • Evaluate what you have seen on stands (15 mins)	Presentation including polls, wordcloud)		RuG

4.2.3 Workshop agenda

The agenda of the workshop is presented in the following table

Table 30: Agenda workshop 2 - external

Time	Activity
13.45 – 14:00	Arrival
14:00 - 14:40	Trusted and Human-Centric AI in Manufacturing with Industrial Cases
14:40 – 15:40	How to involve the Human in the Loop: practical tips, interactive use and demonstration of STAR AI tools in manufacturing uses cases
15:45-16:30	How to approach the assessment of human-centric AI systems in manufacturing: active discussion and evaluation
16:30-17:00	Participants mix-up and drinks

4.3 Workshop outcomes

The workshop included a number of interactive polls where participants were asked about different relevant subjects, including the perception of the concept of human-centricity and the importance of different criteria to assess the performance and success of human-centric AI. The outcomes of the three polls are presented in section 4.3.1. Moreover, a survey was distributed at the end of the workshop for evaluation purposes of the workshop but also to gauge participants view on how human-centric AI applications in the production sector can be evaluated in terms of the different criteria presented as relevant for the evaluation. The outcome of the survey will be fully synthesised and integrated in deliverable 6.12 of task 6.6 (i.e. socio-technical evaluation and stakeholder's feedback). The responses of the survey questions are also presented in section 4.3.2.

4.3.1 Outcomes poll questions presented during workshop

How do participants perceive the concept of human-centricity?

Figure 15 presents the responses of participants regarding their perception of the concept of human-centricity. The figure illustrates a wide diversity of answers from respondents, including important outcomes of human-centric design such as safety, trustworthiness, sustainability. It also refers to the need to focus on human needs, interaction and diversity. The outcome of the poll certainly shows that the concept of human-centricity is not yet clearly defined.

Figure 15: Outcomes Wordcloud poll: what is human-centricity?

List up to 5 ethics and trust criteria which you find most relevant for measuring the success of human-centric AI?

Figure 16 summarises the respondents' answers regarding which of the provided ethics and trust criteria are found most relevant for measuring the success of human-centric AI. Of the 17 criteria, human safety (17 %), reliability (11 %), accountability (9%), transparency (9%) were the most highly rated criteria, closely followed by criteria such as fairness and non-discrimination (8 %), accuracy (7 %), Similar to the concept of human-centricity, the responses demonstrate a wide diversity of which ethics and trust criteria is most relevant to assess the success of human-centric AI.

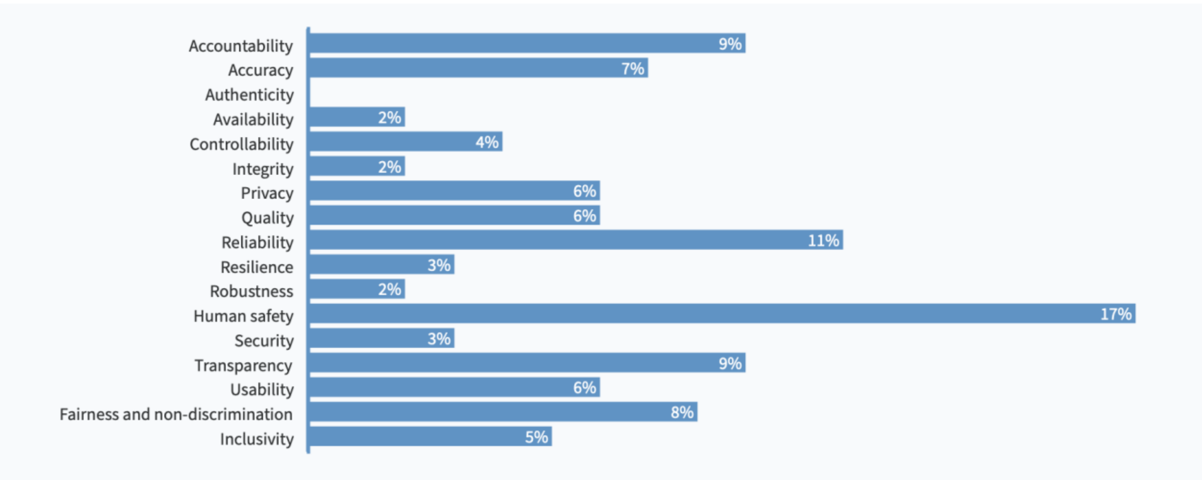


Figure 16: Outcomes rating importance of ethics- and trust criteria

List up to 5 motivational and well-being criteria which you find most relevant for measuring the success of human-centric AI?

Figure 17 summarises the respondents' answers regarding which of the provided motivational and well-being criteria are found most relevant for measuring the success of human-centric AI. Of the criteria, satisfaction (15 %), decision-making autonomy (13%), usability (12 %), and well-being (9%) were rated the highest, closely followed by cognitive ergonomics (8 %), work performance (7 %) and mental fatigue (7 %).

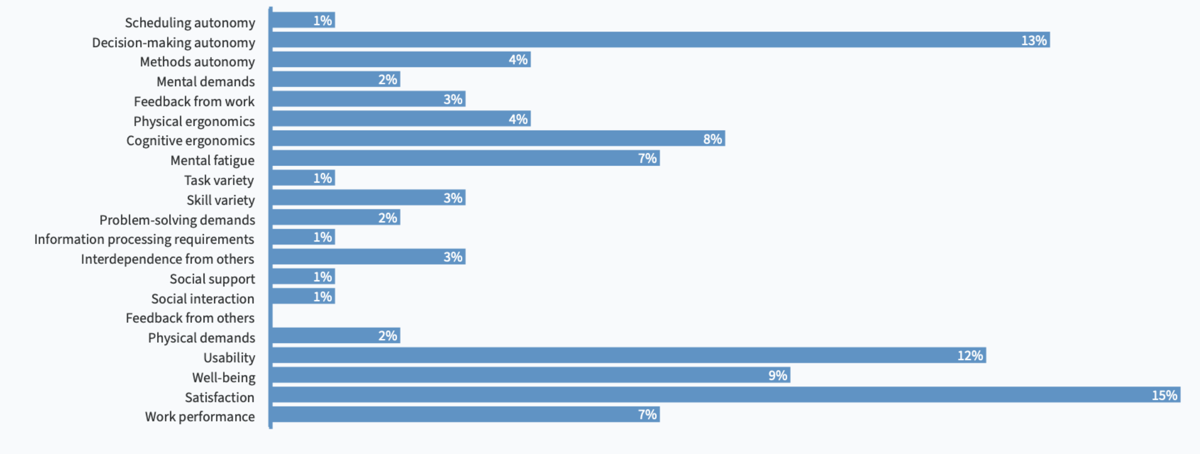


Figure 17: Outcomes rating importance of motivational and well-being criteria

4.3.2 Outcomes survey external workshop

Table 31 summarises the outcomes of the survey distributed to participants at the end of the workshop. Its goal was to gauge participants view on how human-centric AI applications in the production sector can be evaluated in terms of the different criteria presented as relevant for the evaluation.

Table 31: External workshop survey outcomes

Question	Mean response	Question	Mean response
In at least one of the workshop presented cases, human-AI collaboration enhances efficiency.	4.21	In my work experience/environment, I recognise that human-AI collaboration may indeed lead to increased efficiency (response irrespective of whether we already apply such collaboration).	4.29
In at least one of the workshop presented cases, human-AI collaboration contributes to improving effectiveness.	4.46	In my work experience/environment, I recognise that human-AI collaboration may indeed lead to increased effectiveness (response irrespective of whether we already apply such collaboration).	4.04
In at least one of the workshop presented cases, human-AI collaboration leads to improved organisational freedom from risk.	4.04	In my work experience/environment, I recognise that human-AI collaboration may lead to increased freedom from risk.	3.48
In at least one of the workshop presented cases, human-AI collaboration leads to improved freedom for risk for humans.	3.88	Trust is a multi-faceted concept. Characteristics of trustworthiness include, accountability, accuracy, authenticity, availability, controllability, integrity, privacy, quality, reliability, resilience, robustness, safety, security, transparency and usability. In at least one of the workshop presented cases, human-AI collaboration leads to improved system trust (tick the following characteristics of trust for which you think this is applicable).	See Figure 18
In my work experience/environment, I recognise that human-AI collaboration may lead to increased usefulness. (tick the	See Figure 19	/	

following characteristics of trust for which you think this is applicable)			
In at least one of the workshop presented cases, without explainability added on AI it is harder to achieve the same level of trust or accountability.	4.17	In my work experience/environment, I recognise that explainability added in AI-driven outcomes may indeed lead to enhanced trust or accountability (response irrespective of whether we already apply such collaboration).	4.43
In at least one of the workshop presented cases, human-AI collaboration enhances adaptability	4.00	In my work experience/environment, I recognise that human-AI collaboration may lead to increased scalability (response irrespective of whether we already apply such collaboration)	3.74
In at least one of the workshop presented cases, without human-AI collaboration it is harder to achieve the same level of creativity.	3.35	In my work experience/environment, I recognise that human-AI collaboration may lead to increased enhanced creativity. (Response irrespective of whether we already apply such collaboration).	3.57
In at least one of the workshop presented cases, without human-AI collaboration it is harder to take into account at the same level relevant ethical considerations.	3.86	In my work experience/environment, I recognise that without human-AI collaboration it is harder to take into account the same level relevant ethical considerations (response irrespective of whether we already apply such collaboration).	3.91
In at least one of the workshop presented cases, without Human-AI collaboration it is not possible to achieve the same success (complementarity)	4.05	In my work experience/environment, I recognise that joint human-AI complementarity may improve either AI or human capabilities (or both). (response irrespective of whether we already apply such joint human-AI decision making).	4.27
In at least one of the workshop presented cases, without joint human-AI decision making synergy it is not possible to achieve the same success.	4.18	In my work experience/environment, I recognise that joint human-AI decision making may indeed lead to better decisions (response irrespective of whether we already apply such joint human-AI decision making).	4.32

Figure 18 summarises responses which characteristics of trust the participants rate applicable for improved trust during human-AI collaboration in at least one of the workshops' presented use cases. Safety (n=16), security (n=14), and accuracy (n=13) were identified as the most applicable characteristics for improved trust, followed closely by accuracy (n=13), quality (n=12) and usability (n=11).

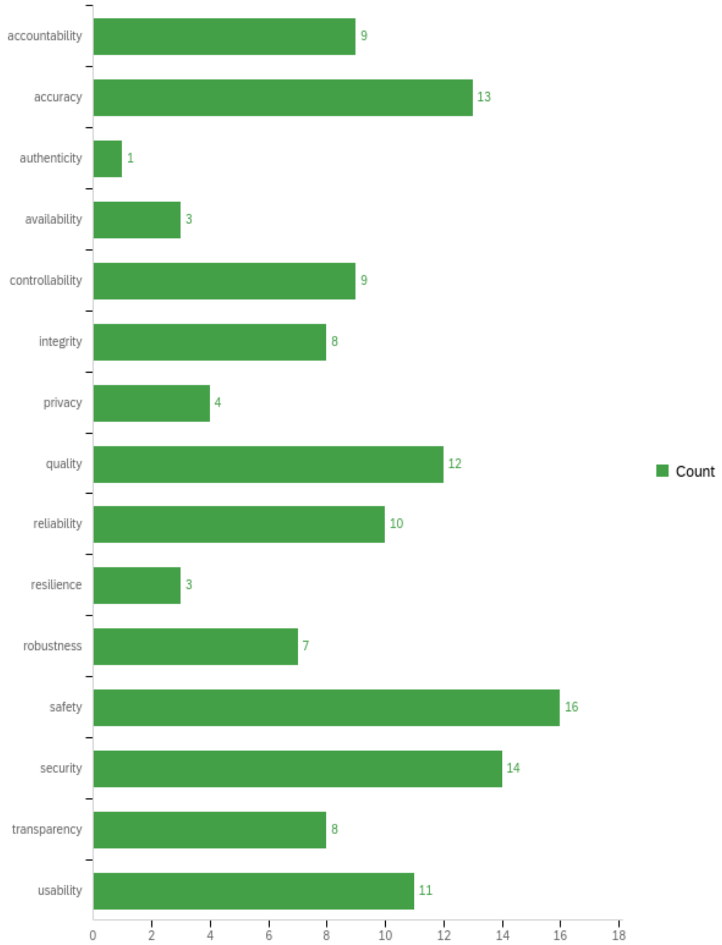


Figure 18: Applicable characteristics of trust at workshop's demonstrated use cases

Figure 19 summarises the participants responses regarding trust characteristics applicable to their own work environment and the potential use of AI. Specifically, quality, robustness and safety top the responses (n=14) with accuracy coming closely next (n=13). Of high importance (n=11) are also controllability, reliability, security and usability.

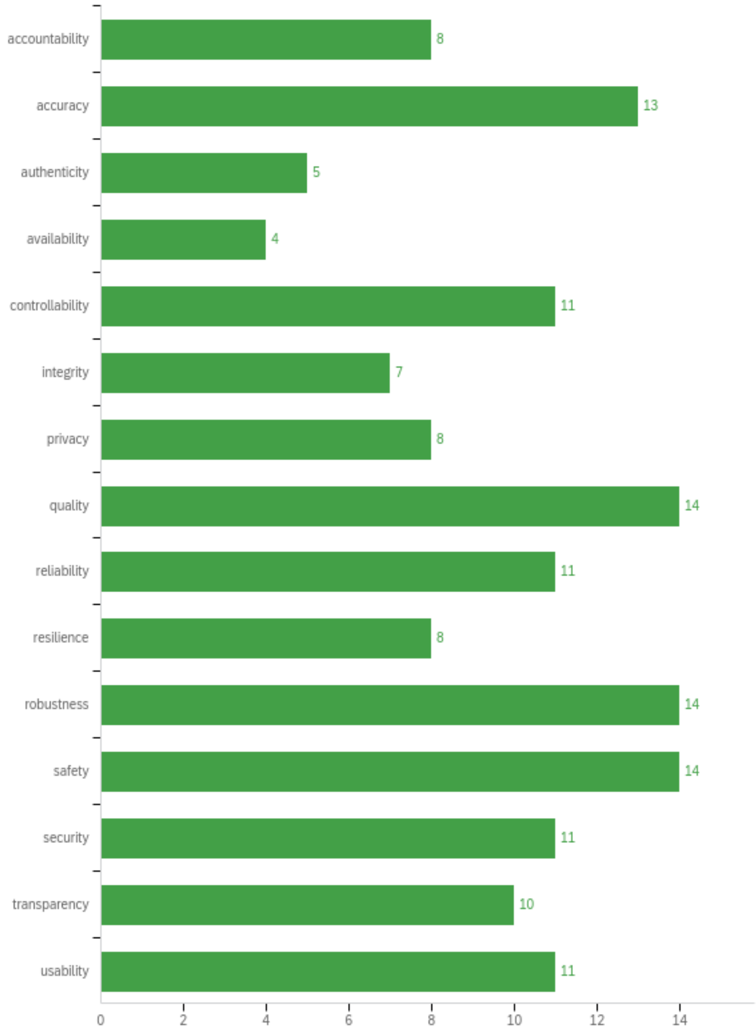


Figure 19: Applicable characteristics of trust for increased usefulness due to human-AI collaboration

4.4 Workshop evaluation

The following questions addressed the evaluation of the workshop. Questions were asked on a 5-point Likert scale ranging from 'not at all useful' (1) to 'extremely useful' (5). 22 respondents filled in the survey. Overall, the responses indicate that participants found the workshop useful in terms of the information and tips provided on human-centric AI and the evaluation of these systems as well as the tools demonstrated. Table 31 presents the function of all respondents, and Table 32 provides the outcome of the evaluation questions posed to respondents.

Table 32: Background of respondents

Background respondent	Count
Industry	4
Research / Academia	8
Legal & Ethics expert	1

Developer/integrator of digital technologies & AI	7
Government representative	1
Consultant	1
Total	22

Table 33: Outcomes workshop evaluation

Evaluation questions	**Average response**
The overall information and tips provided on Human-Centric AI in manufacturing were useful	4.09
The STAR AI tools and cases which were demonstrated are useful.	4.05
The Evaluation approach for Human-Centric AI was useful.	4.09
Overall, I am satisfied with the workshop activities and I feel there are useful takeaways for me	4.27

5 Overall conclusions

This deliverable provides an overview of the Co-Design and feedback Workshops which have been specified, organised, and conducted during the whole course of the STAR project. Three comprehensive set of co-creation workshops were organised throughout the different phases of the project, namely the 'definition and design' phase, the 'early development and testing' phase, and the 'final development and testing' phase. Each workshop objective was successfully met, providing important input to steer the future development of the STAR component in each respective project phase. Partners had the opportunity to discuss and co-create on important aspects including specifying and further validating the pilot use cases, requirements, and success criteria in the early phases of the project, and linking and reconciling these further with the developed STAR components in the later stage of the project, including a thorough discussion and update of the relevant key performance objectives to measure the success of human-centric AI in manufacturing lines.

Workshops held during the 'Definition and Design' phase of the project, specifically focused on bringing together different stakeholder roles of the project partners, worked jointly to co-create key concepts and ideas, bringing together design motivation and requirements, system components that could be relevant to them, bringing in perspectives from different categories of users, in the form of user stories. Importantly, the participants worked to link the user stories and the envisaged components and their expected functionality with potential outcomes and effects / success criteria for the human-centric AI solutions to be developed in the STAR project. The workshops were positively evaluated at the end, marking a very successful co-creation activity during the time of the pandemic restrictions. It was further concluded that the project partners would consequently be expected to take stock of the co-creation activities outcomes when designing and implementing their parts within the overall STAR portfolio of solutions.

Workshops held during the 'Early Development and Testing' phase of the project successfully managed to update all pilot partners on the use cases, including updating requirements. It thereby created a mapping of how use cases are linked to STAR components, identifying a number of gaps which need to be addressed by pilot and technical partners. Furthermore, it identified a number of technical issues which also require attention in the further development of STAR components. Finally, important success criteria were identified, which need to be streamlined with criteria addressed and measured during the socio-technical evaluation of STAR components.

Workshops held during the 'Final Development and Testing' phase successfully updated technical partners about any updates regarding the use cases, including any potential discussions on open technical issues. Furthermore, previously defined KPI's were assessed for comprehensiveness, and the potential inclusion of additional criteria addressing social, technical, operational and economic criteria was discussed. It was found that for all pilot partners, economic (including financial) criteria needs to be identified. Furthermore, it was found to be essential to more closely evaluate the impact of STAR components on human work, including the inclusion of criteria focused on social and trust criteria, including work design. The workshop therefore provided a significant number of follow-up discussions to further steer the development of human-centric, safe and trusted technologies at pilot partners.

During the external workshop, participants e.g., from industry, academia and AI developer and integrator were enthusiastic about the accumulated knowledge and technologies of the project. Survey data was collected about participants view on relevant criteria to measure the performance human-centric AI-enabled systems, reflecting important input for the socio-technical evaluation of D6.12.

The overall outcome of the workshops successfully helped steering the development and implementation of STAR components towards human-centric, safe and trusted AI, as envisioned overall by the project.

References

Reference	Name of document
[REF-01]	STAR. D2.8: User Studies and Co-Design for Human-Centred AI. 2021-02-28
[REF-02]	STAR D6.11 Socio-technical evaluation methodology
[REF-03]	Morgeson, F. P., & Humphrey, S. E. (2006). The Work Design Questionnaire (WDQ): developing and validating a comprehensive measure for assessing job design and the nature of work. *Journal of applied psychology*, *91*(6), 1321.

Appendix

Preparatory survey for workshops

Part 0

What is your role in the STAR project?

- Use case representative/employee
  - PCL
  - Iber
  - DFKI

- Scientific institution/researcher
- Technology developer
- Expert ________
- Other ________

Please indicate the targeted AI system addressed in this survey:

- PCL
- Iber
- DFKI

- AI technology in general

Part 1 Task scenarios between AI and humans

We identify four different task scenarios that are relevant in the context of AI and which are important to consider during the design and development phase. Per scenario, please provide concrete and relevant examples of future tasks at the selected use case that fall within these categories.

AI substitutes humans
AI arguments humans
Human augments AI in tasks
Integrated AI & human perform tasks collaboratively

Part 2 Human and job effects

The next questions will focus on rating the importance of considering a number of human and job effects during the design, development and deployment of the selected use case with the corresponding AI solution. Table ? provides an overview of relevant effects.

Questions 2.1.

2.1.1. Please rate what you expect the impact of deploying the AI solution will be on the future _______ of the user?

2.1.2. Would you rate this impact to be a positive or negative outcome?

2.1.3. Please rate the importance of considering the following human and job effects during the design, development and deployment of the AI system.

Work design related effects (Ref 3)	**Human (factor) effects**
Job autonomy (work scheduling, decision-making and work methods	Physical demands
Task variety	Well-being
Feedback from the job	Safety
Job complexity	Fatigue
Specialisation	Mental workload
Problem solving	Trust
Information processing	System usability
Variety of skills	Situation awareness
Interdependence (initiated and received)	Explainability
Feedback (from others)	Job satisfaction
Social support	Motivation
Interaction of users outside the organisation	Intrusiveness
	Ergonomics

Question 2.2.

Can you identify human or job-related factors not previously mentioned and that you consider important to measure the success of the AI system?

Part 3 Operational effects of AI

In this section, you are asked to rate the importance of considering a number of operational factors during the design, development and deployment of an AI system in manufacturing.

Questions 3.1.

Please rate the importance of considering the following operational effects during the design, development and deployment of the AI system.

Operational effects

Productivity
Process quality
Process efficiency
Process flexibility
Costs
Speed/lead-time

Question 3.2.

Can you identify operational factors not previously mentioned and that you consider important to measure the success of the system?

Part 4 Success criteria to guide the design, development and deployment

In this section, you are asked to rate the importance of success criteria to guide successful design, development and deployment of the AI technology.

Success criteria are generic and can guide the system designers to jointly pay attention to different contributing factors (human, technical and operational) early on in the design process. They are derived from the envisioned human, technical and operational effects examined in part 3 and 4 of the survey.

Please rate the importance of the following criteria for the successful design, development and deployment of the AI system.

(Strongly disagree to strongly agree)

4.1. Reliability

The ability of the socio-technical system to perform as required for a given time period and for given conditions, without failure.

4.2. Performance

The ability of the socio-technical system to deliver specified performance targets.

4.3. Safety

Human Safety: The ability of the socio-technical system to exhibit freedom from risk of harm to persons

Technical Safety: The ability of the socio-technical system to exhibit freedom from risk of damage / loss to technical assets.

Environmental Safety: The ability of the socio-technical system to exhibit freedom from risk of damage to the environment.

4.4. Security

The ability of the socio-technical system to resist an attack.

4.5. Usability

Usability can be described as the capacity of a system to provide conditions for its users to perform the tasks safely, effectively, and efficiently while enjoying the experience.

4.6. Job enrichment

Job enrichment is a type of job 'redesign' (see Job Design). It refers to building into jobs "greater scope for personal achievement and its recognition, more challenging and responsible work, and more opportunity for individual advancement and growth.

4.7. Physical support

Optimal design of the physical elements, interactions and activities

4.8. Cognitive support

Optimal design of the mental requirements, interactions and activities

4.9. Social support

Optimal design which allows for sufficient social interaction.

4.10. Can you identify additional success criteria not previously mentioned and that you consider important to guide successful design, development and deployment of AI technology?