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Executive Summary

This deliverable represents the final version of the Worker's Training Platform (WTP) of the STAR project. This report, categorized as OTH type, accompanies the web platform, for skill gap analysis and worker training, that has been developed and deployed for public use and validation.

In this document we consider the initial version (Deliverable 5.9) and the original plans, detailing how the functionalities have been implemented and where the main focus has been placed, for the development of an anonymous, privacy centric Workers Training Platform.

This platform is focused on three main ideas: skill gap assessments and recommendations, training materials, and tool and component profiles. In order to cover them, we have developed a Virtual Interviewer and a chatbot for conversations related to occupations. These two functionalities have been deployed to a web platform together a training course recommendation engine and a collection of training assets, and a virtual demo showroom where the human centric developments of STAR are detailed.

In this deliverable we also present the materials on human centricity training developed by the University of Groningen. These training assets cover different factors related to human centricity and provide suggestions for different professional profiles: from workers to developers and managers.

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1.0	30/06/2023	INTRA	Final Version

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Definitions, Acronyms and Abbreviations

Acronym/ Abbreviation	Title
AI	Artificial Intelligence
API	Application Programming Interface
AWS	Amazon Web Services
CMS	Content Management System
CV	Curriculum Vitae
ESCO	European Skills, Competences, and Occupations
HDT	Human Digital Twin
HR	Human Resources
HTTPS	Hypertext Transfer Protocol Secure
ICT	Internet and Communication Technology
IT	Information Technology
JSON	JavaScript Object Notation
NLP	Natural Language Processing
OECD	Organisation for Economic Cooperation and Development
PDF	Portable Document Format
REST	Representational State Transfer
SME	Small Medium Enterprise
SSL	Secure Sockets Layer
STAR	Safe and Trusted Human Centric Artificial Intelligence in Future Manufacturing Lines
TLS	Transport Layer Security
UI	User Interface
UML	Unified Modelling Language
VPS	Virtual private server
WP	Work Package
WTP	Workers’ Training Platform

1 Introduction

1.1 Scope and objectives

The use of AI in manufacturing requires not only appropriate tools and innovative ideas, such as those being studied and developed in the project, it also requires making available to workers and even managers knowledge about the entire ecosystem related to AI and IT technologies, such as security, privacy, or robotics. Moreover, for the employee to be able to apply these technologies, it is also necessary to know how occupations evolve and to be able to assess and decide where she/he wants to evolve and how she/he wants to train herself/himself.

Based on these two ideas, the task "*T5.5 Workers' Training and Continuous Learning*" was born. In June 2023 we delivered the first version of this document, the deliverable called "D5.9 Workers' Training Platform-Initial version" in which we presented some scenarios and requirements and detailed our approach towards a workers' training platform. This deliverable is available together with other deliverables under <https://star-ai.eu/deliverables>.

In this second version, we present the steps we followed for delivering the platform, including some technical decisions we took and how we cover the scenarios and requirements. The objectives remain: First, to create a workers' training and continuous learning system (WTP), which would allow workers to assess their current skills and detect training needs, for their current occupation or even for similar occupations that SMEs are starting to need. Second, to link to training materials in multi-media format, including video, images, animations, and presentations generated in the project, training catalogues provided by partners, or even external course recommendations. Third, encourage in some way that workers and managers interested in AI in the manufacturing sector can access some tools, simulation environments, or simply informative profiles of several innovations generated in the STAR project. The approaches have been updated slightly to accommodate new innovations like NLP and the more and more common conversational agents, but the essence and the objective remains the same.

This deliverable not only presents the platform. During the development process, the interest in creating materials on human centricity was identified. This is a key topic in STAR and has a significant impact on workers and Industry 5.0. For this reason, this deliverable is complemented by an annex including the materials generated by the University of Groningen.

1.2 Outline

The deliverable at hand is divided as follows: first we introduce the topic and present the reasoning behind the WTP. After that, we provide information relative to the scenarios and requirements and how we cover them. We present later the architecture and the design of the system together all the efforts related to the implementation and integration. Next, we introduce the human centricity materials. Finally, we draw the conclusion and present future activities.

2 Data sources, scenarios, and requirements

In this section, we will detail the coverage we did to the original scenarios, requirements and data sources. In the case of the former two, we will maintain the templates we presented in the initial version of this document under which we will provide details of how they have been approached and whether they have been met or whether an alternative implementation has been chosen in the end.

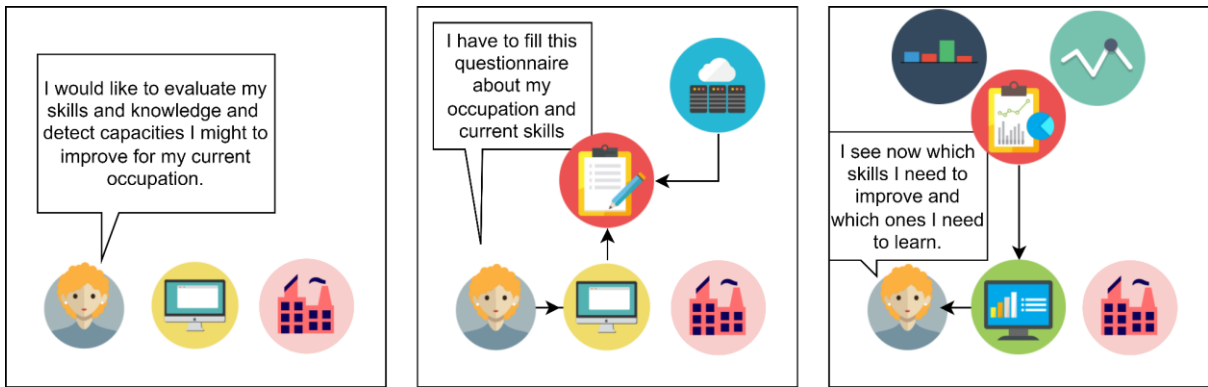
2.1 Scenarios

In the initial document we started from the scenarios as a starting point for requirements discovery. The 4 main scenarios we detailed were:

- The worker self-evaluates her/his skills and knowledge.
- The worker gets training recommendations based on her/his occupation and skills.
- The worker is linked to STAR related training assets, gets information about STAR results and simulation systems.
- The worker investigates which roles best fit her/his knowledge.

Below we present them again and indicate some details of the support we provide for these scenarios.

Table 1: Scenario #1

#1 - The worker self-evaluates her/his skills and knowledge	
	
<p>Purpose: Allow the users to self-assess their competencies and provide them with the skills, knowledge they can gain, improve, or maintain</p>	
<p>User: Bertha</p>	<p>Equipment: Computer, Mobile device</p>
<p>Starting Point: Bertha accesses the Worker Training Platform</p>	
<p>Scenario:</p> <ol style="list-style-type: none"> 1. Bertha accesses the Workers’ Training subsite of the STAR Platform 2. Bertha is asked about her current occupation 3. Bertha is provided with a list of skills relevant to her occupation 4. Bertha indicates her level in each of the skills 	

5. Bertha obtains for each of the skills related to her job, which ones she could improve, maintain, or gain.

This scenario (Table 1) has been fulfilled and is supported within the platform. The objective was for Bertha to self-assess her skills and competencies. Initially we considered that a questionnaire was the best option and developed a proof-of-concept dynamic questionnaire that required the user to enter their level for certain factors. This questionnaire was dynamic, as the list of factors (skills, knowledge) to be answered was different for each occupation and was generated automatically. The following image (Figure 1) shows the questionnaire. As can be seen, we tried to provide support for analysing not only the skills and knowledge, but also the tasks, abilities and work activities, in order to give an adequate result on the status of the worker with respect to the baseline offered by the occupational databases.

Search for a job:

Select the job:

- Manufactured Building and Mobile Home Installers
- Manufacturing Engineers
- Potters, Manufacturing
- Sales Representatives, Wholesale and Manufacturing, Except Technical and Scientific Products
- Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products

Please select your level on the following elements:

▶ Abilities:

▶ Knowledge:

▶ Skills:

▶ Work Activities:

▼ Tasks:

Apply continuous improvement methods such as lean manufacturing to enhance manufacturing quality, reliability, or cost-effectiveness.

none
 little
 medium
 good
 excellent

Design layout of equipment or workspaces to achieve maximum efficiency.

none
 little
 medium
 good
 excellent

Communicate manufacturing capabilities, production schedules, or other information to facilitate production processes.

none
 little
 medium
 good
 excellent

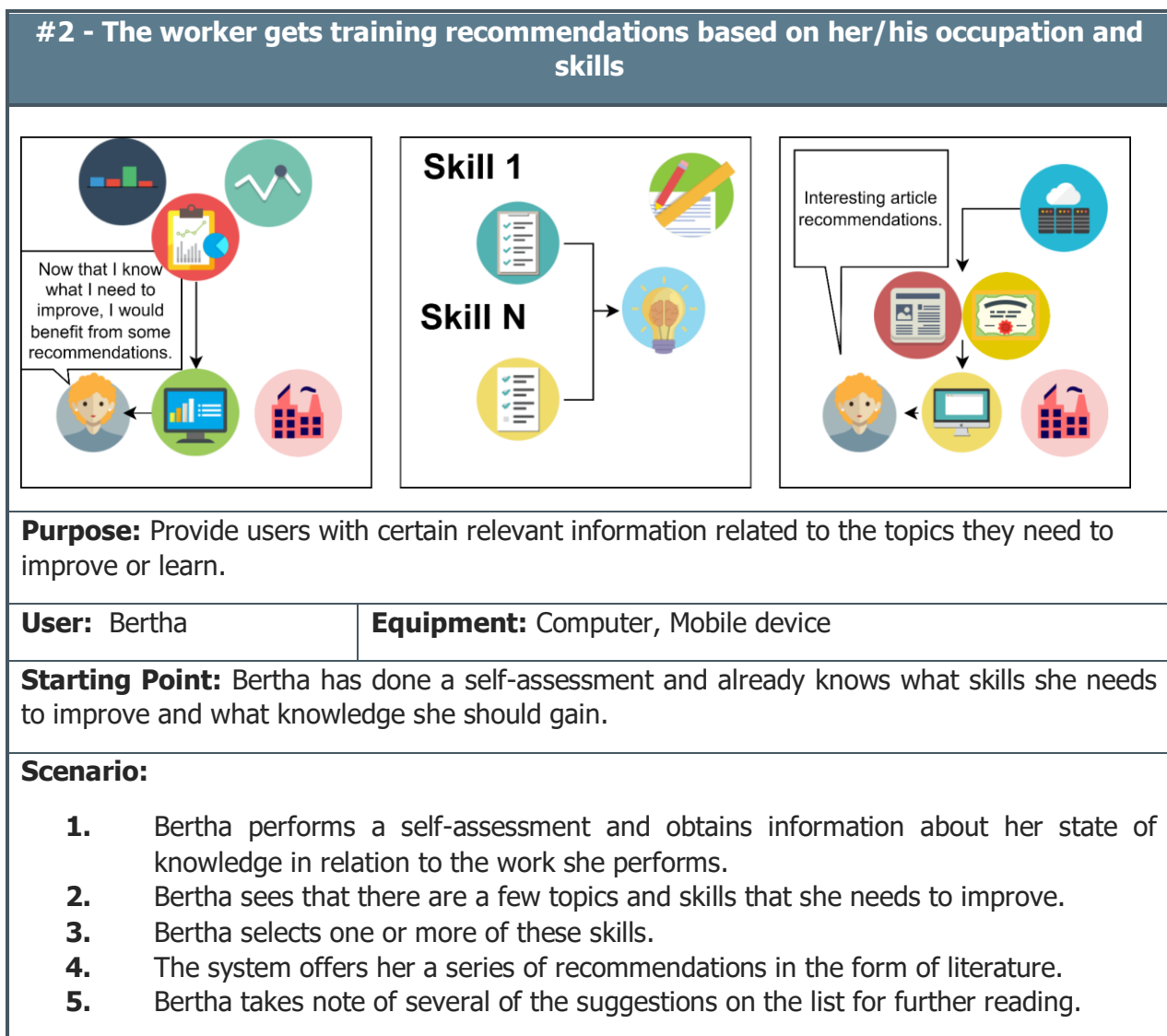
Figure 1: Scenario 1 - Self Assessment PoC

The biggest problem when presenting the self-assessment as a questionnaire is that the number of questions the user had to answer and the amount of time she/he had to dedicate were high (there were professions with more than 100 questions), so the potential engagement was lower.

Therefore, and benefiting from the research in other work packages of the project (especially WP4), we considered adapting the user interface to be a multimodal interface, integrating a conversational agent that asks a series of questions on which we extract certain information. These questions can be completed with the addition of a CV to provide more contextual information. We have called this solution the virtual STAR interviewer and its operation is detailed in subsequent sections.

The functionality and the objective of this scenario is totally covered by the virtual STAR interviewer, and the questionnaire based self-assessment still remains as potential solution for specific cases.

Table 2: Scenario #2



This scenario (Table 2) is also covered in the platform. Once the user completes the assessment (both in questionnaire and virtual interviewer versions) he/she receives information on how he/she stands with respect to the baseline. As mentioned above and in the previous deliverable this baseline uses the O*NET data to establish the reference.

As shown in the image below (Figure 2), the user receives a global eligibility percentage and several partial ones. All of them take as reference the occupation the user has selected and the O*NET baseline. The partial percentages are related to different capacities: tasks, knowledge, skills, etc., and the global one is an aggregation of them. This approach is interesting for gap detection, since in some cases it can detect that the missing eligibility is due to a low score in a group and can enable the user to train on it, or simply to discover that although the score is high overall there are some tasks on which he/she has no training and which he/she needs to learn.

Analysis results:



Missing knowledge or skills by which you can raise your score

Tech Skills:



- ▶ Adobe Systems Adobe Acrobat
 - ▶ Adobe Systems Adobe Illustrator
 - ▶ Adobe Systems Adobe Photoshop
 - ▶ Advanced business application programming ABAP
 - ▶ AJAX
- [more...](#)

Skills:



- ▶ Quality Control Analysis
 - ▶ Reading Comprehension
 - ▶ Systems Analysis
 - ▶ Judgment and Decision Making
 - ▶ Speaking
- [more...](#)

Knowledge:

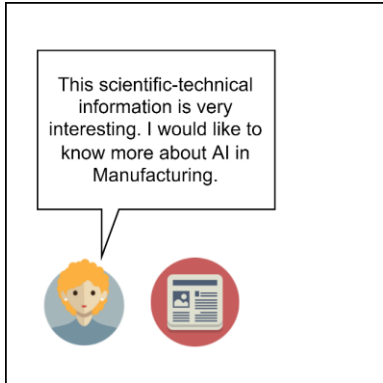
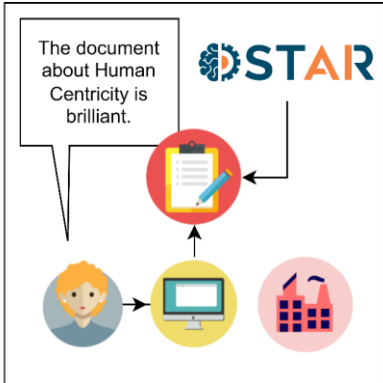
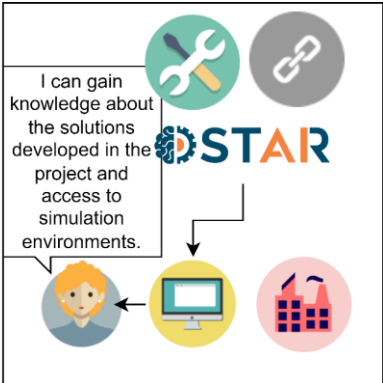


Figure 2: Assessment results

For each capability, a list of items that would improve the user's score for that capability is displayed, along with a checkbox. The score or eligibility is dynamic, it adapts to new user interactions. This allows the user to add capabilities if he/she has forgotten them and immediately see the score improve. It also allows the user to decide on training plans, selecting some of the skills and seeing the impact they might have globally.

Table 3: Scenario #3

#3 - The worker is linked to STAR related training assets, gets information about STAR results and simulation systems

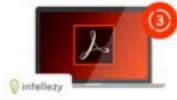
		
<p>Purpose: To provide users with assets and materials generated in the project, which can be used to improve their knowledge in the main topics of STAR, such as manufacturing, security, and artificial intelligence.</p>		
<p>User: Bertha</p>	<p>Equipment: Computer, Mobile device</p>	
<p>Starting Point: Bertha believes she could use knowledge related to AI in Manufacturing and accesses STAR to obtain this information.</p>		
<p>Scenario:</p> <ol style="list-style-type: none"> 1. Bertha enters the Workers’ Training Platform and gets some training suggestions, some of these references are project materials. 2. Bertha accesses the blog posts, books, and various documents and articles generated in the project. 3. Bertha discovers that several of the project solutions have an informative page with the profile of these solutions and that some of them link directly to tools or solutions developed by project partners that she can download or simulations that she can observe. 4. Bertha studies one of them as it may be of interest to her and to implement it in the company where she works. 		

This scenario (Table 3) is about training. This has been addressed in 3 ways to cover all points.

On the one hand, both the virtual interviewer and the informational chatbot (which we will detail later) have been trained with a collection of courses related to the project topics, carefully selected by the project partner Netcompany-Intrasoft (INTRA). In this way, when the user is presented with the skills, he/she needs to improve, he/she is also offered potential courses that would improve those skills. The image below (Figure 3) shows one of the recommended courses for the tech skills: Adobe Acrobat. As mentioned above, by clicking on the checkbox related to the skill set, the user can see how his or her score would be impacted if he or she were to gain knowledge in that course.

▼ Adobe Systems Adobe Acrobat

Udemy course recommended:



[Adobe Acrobat DC Pro Advanced](#)

- ▶ Adobe Systems Adobe Illustrator
 - ▶ Adobe Systems Adobe Photoshop
 - ▶ Advanced business application programming ABAP
 - ▶ AJAX
- [more...](#)

Figure 3: Training recommendations

The second point is related to training materials and project components, applications or simulators. These materials, for more impact and visibility, are published on the project homepage and of course on the marketplace (<https://www.market.star-ai.eu/>). For this reason, in this training platform, we include the fundamental information of these (both materials and components) and we link each of them to the main marketplace. This has the advantage that we can increase the traffic of the marketplace, by involving users who come to the WTP to do the assessments.

The last point is about specific training. One of the key points of the project and of the platform is to put the worker at the centre of the production where his or her well-being and knowledge are prioritised. Therefore, as part of this task we have worked on materials on human centricity which will be added to the project materials and are also included in the training platform for employees. These materials are also detailed below.

Table 4: Scenario #4

#4 - The worker investigates which roles best fit her/his knowledge		
<p>Maybe the platform can analyse my skills and tell me interesting occupations for me.</p>		<p>Now I know, that if I improve this skill a little bit, I could become...</p>
<p>Purpose: Offer suggestions on potential career changes or plans to qualify for another occupation.</p>		
<p>User: Bertha</p>	<p>Equipment: Computer, Mobile device</p>	
<p>Starting Point: Bertha analyses her skills</p>		
<p>Scenario:</p>		

1. Bertha accesses the platform.
2. Bertha fills in a questionnaire about the skills and knowledge she has.
3. The system analyses these skills and knowledge and compares them with a collection of occupations, both like her current ones and completely different ones.
4. The system offers a list of roles close to Bertha's knowledge.
5. The system informs about the training needed to reach those roles.

The last scenario (Table 4) was related to helping the worker to find alternative occupations. To do so, we developed a self-assessment covering all the capabilities available in the database and compared the results to provide the user with a ranking of the 5 most suitable occupations for that skill set. This functionality can be seen in the image below (Figure 4).

The main drawback was similar to some of the previous scenarios, as it required the user to answer hundreds of questions in order to have concrete and correct information. For this reason, it has been decided to present this information in a different way. Specifically, it is in the chatbot detailed below where the user can search for related occupations or ask for occupations that have specific tasks or skills in common. This makes interaction simpler while providing relevant information for alternative occupations.

Find out which job you are best suited for

Please select your level on the following elements:

▶ Abilities:

▶ Knowledge:

▶ Skills:

▶ Work Activities:

Get Results
Restart

Suggested job categories

1. Model Makers, Wood
2. Cutters and Trimmers, Hand
3. Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic
4. Foundry Mold and Coremakers
5. Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic

Figure 4: Alternative Occupations

2.2 Requirements

In this section we will follow a similar approach to the one we adopted for the scenarios, although this time we will go through the requirements and give some brief details on how we have approached and covered each one.

2.2.1 Functional Requirements

Table 5: Functional requirement #1

#F1 - Self-assess worker skills	
Description: The solution should allow the user to assess themselves on the skills and knowledge related to their occupation.	
Rationale: The main objective of the platform is that the user is presented with a set of knowledge, skills or activities related to their work and can self-assess themselves. This information will be processed by an engine in the backend to provide useful information to the user.	
Priority: 1	Conflict: -
Acceptance criteria: The user can select an occupation, obtain the skills/knowledge related to this occupation and submit their ratings for these skills.	
Notes: The main interface for obtaining user information is through questionnaires.	

#F1 - Self-assess worker skills was a fundamental requirement, as its priority indicates. As we have mentioned above both in the self-assessment concept tests and with the Curriculum Vitae processing, as well as with the virtual interviewer we fulfilled this requirement, and offer the functionality on the platform.

Table 6: Functional requirement #2

#F2 - Profile STAR Tools	
Description: The platform should present, integrate content, and provide access simulation systems from other STAR tasks.	
Rationale: As part of WP5 of the project, several ideas and solutions will be developed. Some of them may be interesting for future implementation in workplaces. Therefore, it would be interesting for each of these solutions to have a page or profile on the platform: informing about the idea, the contact person and showing images, videos, or documents about the solution. If the solution is downloadable (e.g., in a virtual machine), deployable in the cloud, or its code is available to build it, the profile page should provide access or links to these.	
Priority: 2	Conflict: -
Acceptance criteria: There are profile pages on the platform showing WP5 developments.	

Notes: It may be of interest that the profiles we develop can be compatible with the main platform of the project or even eventually be transferred there.

#F2 - Profile STAR Tools is a requirement related to the exposure of the components related to work package 5 of the project. As mentioned before, the project main page includes a marketplace where the information of all commercially exploitable components is displayed. In the workers training platform, we have chosen to build on this marketplace and link to it. In this way each component of WP5 has a descriptive profile in the WTP that links to the marketplace and its component within the marketplace if it has one. This way we avoid confusing users with two marketplaces and transfer traffic to the main marketplace.

Table 7: Functional requirement #3

#F3 - Compare workers skills	
Description: The solution must have an engine to compare the data sent by the user with a baseline for their occupation.	
Rationale: It is necessary to have an engine that processes the data entered by the user and compares them against references for that occupation stored in the database.	
Priority: 1	Conflict: -
Acceptance criteria: The engine can receive user data and compare it with the reference in the database.	
Notes: -	

#F3 - Compare workers skills is another of the fundamental requirements and therefore another one that was addressed from the very beginning. The engine of our platform relies on an O*NET database with which we offer the possibility to compare user input with reference information. The chatbot also offers functionalities to compare skills. For example, it can provide a match between the tasks shared by a robotic welding equipment operator and a robotic operator, and it will search for the closest occupations (using Transformers) and provide the task information.

Table 8: Functional requirement #4

#F4 - Recommended actions and plans	
Description: The platform should recommend actions, plans to improve skills and knowledge.	
Rationale: As a result of the user's self-assessment of skills and knowledge, it is necessary to inform the user about which skills and knowledge they should keep, which they should improve and which of them, which they currently do not have, would be interesting for their current occupation.	
Priority: 2	Conflict: -

<p>Acceptance criteria: As a result of the assessment, the worker is presented, for each skill, what needs he/she has in each skill.</p>
<p>Notes: -</p>

#F4 - Recommended actions and plans is another of the functionalities implemented in the platform. Specifically, as we have mentioned in the scenarios, we inform the user about the capabilities that he/she has to improve and can even observe how a potential eligibility would vary if he/she had this knowledge or ability.

Table 9: Functional requirement #5

#F5 - External learning materials	
<p>Description: The platform should suggest materials and programs related to skills.</p>	
<p>Rationale: It would be interesting if the system could recommend some readings related to the skills, knowledge, and technologies that the user needs to improve. In the absence of better databases, databases of scientific articles could be used, on which to search for relevant terms, evaluate the citations/recommendations and present a top five of relevant articles.</p>	
<p>Priority: 2</p>	<p>Conflict: -</p>
<p>Acceptance criteria: The user is provided with a list of reading materials related to the skills they need to improve.</p>	
<p>Notes: -</p>	

#F5 - External learning materials are covered in two ways. On the one hand, the project partner INTRA manually selected a number of relevant courses related to manufacturing and associated them to occupations. This selection of courses is used as the main recommendation when users have a gap related to one of the subjects covered in the project. For cases where there is no specific training in the database of selected courses, we use the API of the online learning platform Udemy and after having processed the terms for similarity, we make requests for training materials related to those terms.

Table 10: Functional requirement #6

#F6 - STAR Related learning materials and assets	
<p>Description: The platform should suggest materials and assets created in STAR.</p>	
<p>Rationale: The project has authored a book, published several articles and dozens of technical posts. WP5 will also create specific documentation on certain topics of interest for AI in manufacturing, such as Human Centricity. It is interesting that these articles also appear in the recommendations.</p>	
<p>Priority: 2</p>	<p>Conflict: -</p>

Acceptance criteria: The user is provided with a list of reading materials related to the skills they need to improve. Some of these materials are materials developed as part of the STAR project

Notes: Some of these materials will be part of the materials to be produced in WP7 and included in the main project platform, and vice versa. Some of the materials developed ad-hoc for the WP5 task, in which the Workers’ Training Platform is included, can be transferred to the global platform.

#F6 - STAR Related learning materials and assets has been included in the current version of the platform. On the one hand, the system recommends not only the materials of the functional requirement #F5, but it is also based on a database of courses related to the STAR project, manually selected by the company INTRASOFT.

In addition, during the development of the workers training platform, the University of Groningen has elaborated a tutorial course on Human Centricity, which will be included in the list of project assets.

Table 11: Functional requirement #7

#F7 - Integration API	
Description: The platform must have an API for integration.	
Rationale: The most critical part of the Workers’ Training Platform is the backend that collects the data and performs the analysis. The front end could be offered in one of the project's applications (such as Human Digital Twin) or even be implemented as a series of specific pages in the project's main CMS. For these reasons it is important to provide an API rest for the integration of at least the part related to the analysis and recommendations.	
Priority: 1	Conflict: -
Acceptance criteria: A REST API is available.	
Notes: Is worth providing support for OpenAPI and JSON Schema to simplify the integration.	

#F7 The platform must have an API for integration has also been covered. Initial integration tests with SUPSI's HDT required the generation of several REST endpoints that allowed skills analysis from external platforms. To do this we took advantage of the capabilities of the FastAPI Python library to generate these endpoints and to provide also a playground where the functionality could be tested. The following image shows the WTP integration playground.

avt-api ^{0.0.1} OAS3

/openapi.json

Worker Training Platform - skill assessment

R2M - Website

Authorize 






Default Default operations	^
GET / Root	▼
Occupations Operations related to worker occupations	^
GET /occupations/{keyword} Occupations	▼ 
Skills Operations related to worker skills	^
GET /skills/all Skills All	▼ 
GET /skills/{occupation} Skills	▼ 
POST /skills/{occupation} Skill Suggestions	▼ 
Career Operations related to career path discovery and career changes	^
POST /career/skills Find Occupations Matching Skills	▼ 

Figure 5: API and endpoints

Table 12: Functional requirement #8

#F8 - User Interface	
Description: The solution should provide a User Interface to facilitate the interaction with the operators.	
Rationale: The solution would benefit from offering an intuitive and simple interface so that the user can self-assess and obtain the results.	
Priority: 3	Conflict: #F7 (Low impact) As mentioned in the #F7 the user interface might be finally included in the project platform or one of the tools.
Acceptance criteria: There is a user interface, and it is accessible to workers.	
Notes: For cohesion and homogeneity the UI of the solution could eventually be integrated as part of the main project platform. For this reason, it is of interest to keep the look and feel of the main platform.	

To meet **#F8 - User Interface**, a user interface has been developed to facilitate the use of the application. This interface is based on modern web technologies and follows the same colour scheme and structure as the main web of the project. We wanted the design to be as readable as possible and for the worker to be able to find the content easily. In later sections you can see the final result of this look-and-feel.

Table 13: Functional requirement #9

#F9 - Career Suggestions	
Description: The solution could offer recommendations related to changes of position.	
Rationale: Once the user has submitted data related to his or her skills and knowledge, the system could try to search for a few relevant jobs related to the user's skills.	
Priority: 3	Conflict: -
Acceptance criteria: The user is offered an ordered list of five relevant roles, occupations, or jobs.	
Notes: -	

As part of **#F9 - Career Suggestions** and as mentioned earlier in the scenarios and as can be seen in Figure 4: Alternative Occupations, we provide career growth or activity change recommendations based on user feedback and the comparison of these with the baseline provided by the occupational databases.

Table 14: Functional requirement #10

#F10 - Visual Results	
Description: The solution could deliver results in visual form.	
Rationale: Sometimes it can be interesting for the user to receive the information in a slightly more visual format. For that reason, it can be worth to present radar charts and other similar graphics.	
Priority: 4	Conflict: -
Acceptance criteria: The user is offered various graphs related to their skills and how far or close they are to the baseline.	
Notes: Depending on the final form of the UI, it could be interesting to generate a PDF document with the visual summary of the information.	

For requirement **#F10 - Visual Results**, and not being a key priority requirement, we have followed a different strategy. As mentioned above, we have tried to facilitate the interaction by means of conversational agents, so the output results have been more adapted to this environment: simple messages as a multimodal response, or result trees that allow the user to check immediately the results of the query.

Table 15: Functional requirement #11

#F11 - Public Data Sources	
Description: The system engine must be based on public information.	
Rationale: There are several widely used and well-known databases such as ESCO and O*NET. For the credibility of the results, it is interesting that the system is based on one or	

both. There is also Open Data from the OECD and from various workers' offices, which can allow us to complete the data.	
Priority: 1	Conflict: -
Acceptance criteria: The engine relies on Open Data or in well-known public databases.	
Notes:	

#F11 - Public Data Sources have been our main data source. As previously mentioned, several occupational databases and especially O*NET have been our reference for the calculations made in the engine and for a large part of the suggestions.

2.2.2 Non-Functional

Apart from the functional requirements, there are few non-functional requirements we must consider from the very beginning of the product development. These requirements are detailed in the tables below.

Table 16: Non-functional requirement #1

#NF1 - Secure API	
Description: APIs must support HTTPS and require authentication.	
Rationale: While the platform does not have high security requirements, it is important that at least the traffic is encrypted, and the use of the API is controlled by at least basic authentication.	
Priority: 2	Conflict: -
Acceptance criteria: HTTPS and authentication support.	
Notes:	

#NF1 - Secure API was accomplished in two ways. On the one hand, certificates were added using Let's Encrypt, to support encrypted communication with the platform. On the other hand, access to the API required the client user to be authenticated in order to use the endpoints. In our initial case for the integration with the HDT we used basic authentication as HTTP authentication schema.

Table 17: Non-functional requirement #2

#NF2 - Privacy first	
Description: The solution should take care of the privacy of the workers.	
Rationale: The platform is using personal data about the knowledge of the workers. To avoid privacy problems or this data being used to profile workers, the project's worker training platform should not require authentication, or at least authentication that can relate	

the platform user to the worker. In addition, the data of the workers or the self-assessment will not be saved.	
Priority: 2	Conflict: -
Acceptance criteria: The self-assessment data is not saved in the database of the working training platform.	
Notes: In the case of third-party integration, where the Workers’ Training Platform is only the calculation and recommendation engine, we can guarantee privacy within the training platform, but not in third-party applications, since these are the ones that collect the data.	

For **#NF2 - Privacy first**, although initially it was thought of adding a user registration system and user control of the content generated by each one, a solution more compatible with privacy was immediately chosen. No user data is stored in the proofs of concept or on the web platform. As discussed in the requirement notes, despite not storing data on the platform, it is possible for applications that integrate with the WTP to make use of the data, although the WTP cannot control this.

Table 18: Non-functional requirement #3

#NF3 - Multiplatform, multi device	
Description: The solution should be universal and depend as little as possible on the device.	
Rationale: The REST API already offers a certain universality. In the case of the user UI, it is necessary that it can be used from computers or mobile devices.	
Priority: 3	Conflict: -
Acceptance criteria: The solution works on mobiles, tablets, and computers.	
Notes: -	

#NF3 - Multiplatform, multi device has been fulfilled by the realisation of a multi-device compatible website. Any modern browser, even any mobile browser, can make use of the system's capabilities. Multimodal voice interaction is supported only for those modern browsers that implement it (e.g. Chrome). In any case the user can always interact with the system by text input.

Table 19: Non-functional requirement #4

#NF4 - Containerised and deployable anywhere	
Description: The platform should be containerized and facilitate deployment and integration.	
Rationale: With the objective that the platform does not depend on third-party cloud services and that at the same time integration with the main platform of the project is	

facilitated, it is interesting that Docker and Docker-compose be supported as means of composing and containerising the platform.	
Priority: 3	Conflict: -
Acceptance criteria: Dockerfiles are available, and the solution runs on top of docker.	
Notes: -	

We have finally decided not to dockerize the solution, at least for the moment. The deployment is done by pulling the information from the version control system (git) and deploying it on the server that manages the application. This requirement will be re-evaluated in the future to adapt the platform to scalability needs.

2.3 Data sources

Among the data sources mentioned in the initial document, O*NET has been the one finally chosen and the most used. It includes major part of the necessary information and is updated on a quarterly basis. ESCO is also of great interest due to its suitability for the European market, several tests have been carried out and it is proposed as a complement to provide the system with more data. Finally, occupational databases have also been evaluated in Canada and even in several Asian countries. In the new STAR book "Artificial Intelligence in Manufacturing: Enabling Intelligent, Flexible and Cost-Effective Production Through AI" there is a chapter called "Integrating Knowledge into Conversational Agents for Worker Upskilling" where part of these databases that we have evaluated are detailed.

3 Final Version Architecture Development

In this section we will present the overall image of the architecture to go into the details about the backend and the interface presented to the user. The next picture (Figure 6) shows the overall architecture, with some components, specifically in the backend grouped in functionalities.

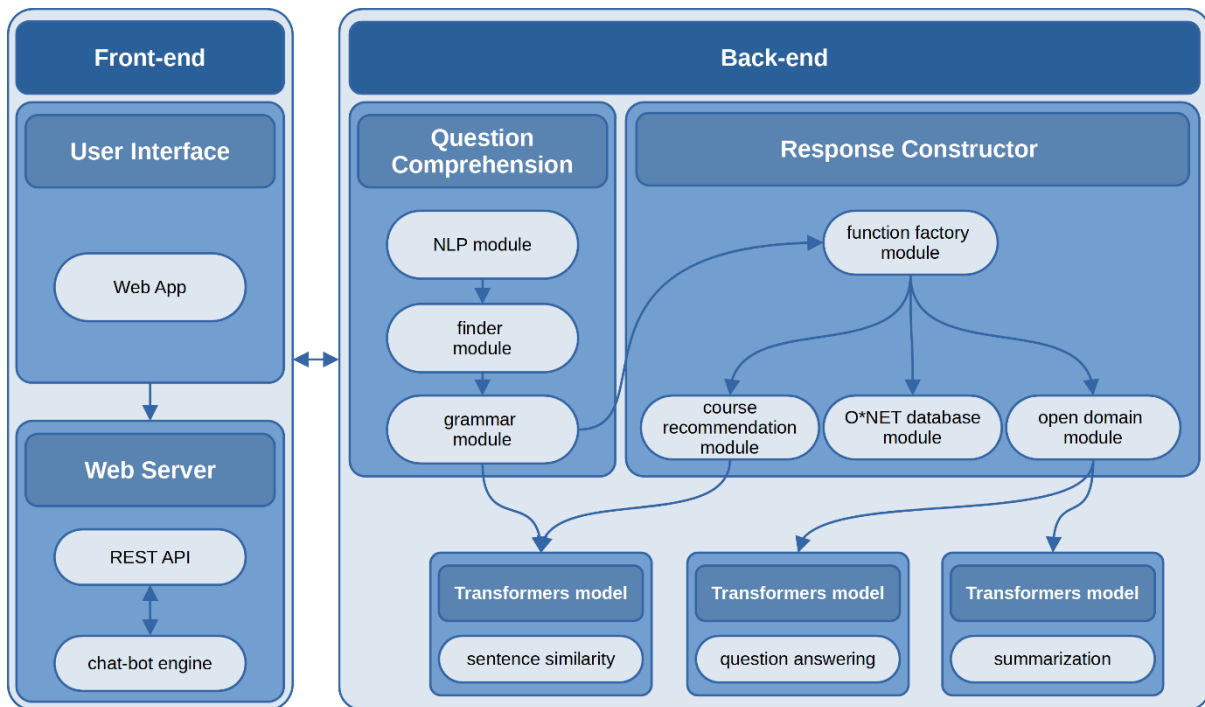


Figure 6: Architecture

The overall functionality, as far as the chatbot engine module is concerned, receives the input text from the REST API module and sequentially queries the NLP, and grammar modules of the Question Comprehension block. Specifically, it sends the text received as input to the NLP module and receives the elements extracted from it. Then it sends those items to the grammar module and gets the list of questions built on them. Once it has collected the list of questions built on the extracted elements, it submits the questions and the user input to the sentence similarity module of the Transformers model to select the question with the highest similarity to the user input. Finally, it compares the similarity score, returned by the Transformers model for that question, with an empirically chosen threshold. Once this process has finished it calls a different function of the function factory module based on the result of this comparison and on the type of the question itself. Each function of the module retrieves the information necessary for one of the recognized question types, constructs the response in natural language, and returns it to the calling module.

3.1 Backend development

For the backend, starting with the server, we have used a collection of virtual private servers (VPS) under the control of R2M. This configuration will be maintained during the project, while monitoring the functionality and correcting errors. Depending on different scalability and performance needs, not only depending on the user but also on the complexity of the transformers for the information search, we will consider the deployment on in computing service providers like AWS or Google Cloud. We also consider the possibility of using dedicated

servers with graphics processing units, to increase the performance of the artificial intelligence models.

These servers run a Linux system based on Debian GNU/Linux running a MariaDB database containing the complete O*NET database. The development has been based on the use of Python and several of its libraries for the development of web applications in Python and for the use of machine learning and AI.

As far as the web part is concerned, we have used Flask, a minimalist framework for creating web applications. On top of this we have assembled a Jinja2 template system, to display the information to the user. These templates use JavaScript and CSS, taking advantage of a theme for the selection of the appropriate colours and structure.

Among the most representative AI libraries we can mention Pytorch and sentence-transformers. Pytorch is a well-known library for deep learning based on tensors and neural networks. Sentence-transformers is a library for sentence and text embeddings and calculating sentences with a similar meaning.

This entire system makes use of a NGINX web server together with a Python web server gateway interface HTTP server, to handle user requests and return information to them.

3.1.1 Security and Privacy

As mentioned earlier in the requirements, we have implemented Basic authentication in the APIs. Finally, as we have discarded the idea of user registration, in order to keep the privacy of the workers and not to store any data, we have not needed specific authentication or authorisation solutions in the web interface.

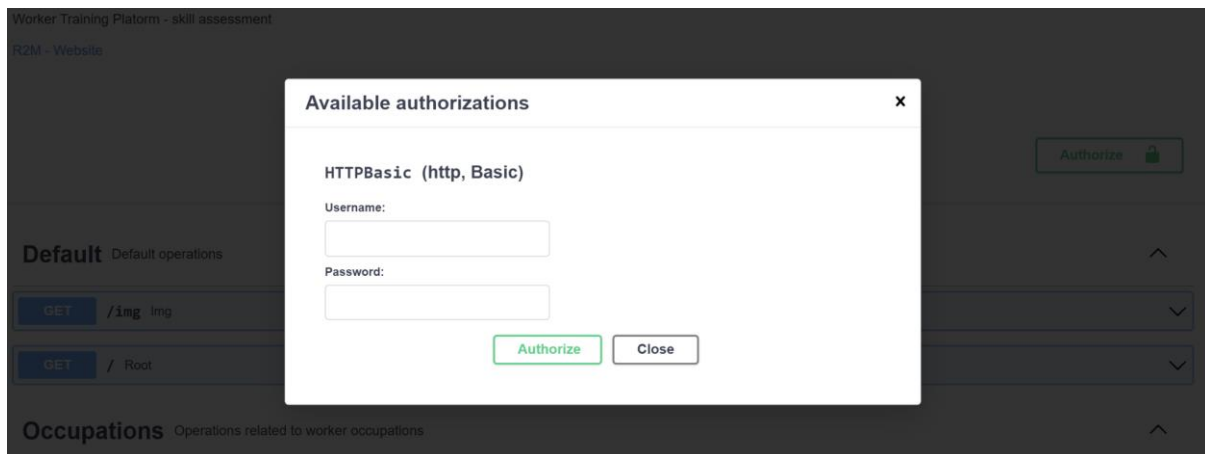


Figure 7: API authentication

We have used TLS/SSL certificates for two reasons. First and foremost, to encrypt the data transferred to the platform. The second is because of the requirement of certain browsers that the platform must have valid certificates in order for speech recognition to work. Finally, and as an added security measure, the data, especially those received through the API, are validated using the Pydantic Data validation framework.

3.2 Desing and Interfaces

If in the first version of this document we included the mock-ups. Here we include the final version of the designs used in the platform. As a reminder, it should be noted that the main

objective was to develop a platform for workers where they could not only discover training needs but could also access certain training materials and be informed of certain solutions and relevant simulators developed in the project.

The following image (Figure 8) shows the landing page. As mentioned above, it uses the colours and a top menu structure similar to the main STAR website. Also, the backgrounds are based on those used on the project page. At the top there is a horizontal menu, which gives access to the main functionalities. These functionalities, in line with the objectives of the platform are: i) Virtual interviewer and chatbot to allow the worker to discover training needs and get more information about his job position; ii) Collection of training assets, aligned with the project assets; and iii) Information about the platforms and tools developed in the work package 5 of the project.



Figure 8: Landing page

The first feature is the Virtual STAR interviewer. On this page (Figure 9) there is a chatbot at the bottom of the page which allows by means of a conversation to automatically fill in the required information in the "Input CV" field in the middle of the page. This information will be the one that after the selection of the occupation, in "Select the job", will be evaluated by our gap detection and recommendation generation engine. In the event that the user does not want to use the conversational chatbot or that their device does not support it, they can upload their CV both in PDF and in text format, so that it can be processed and sent directly to the gap detection engine and recommendations.

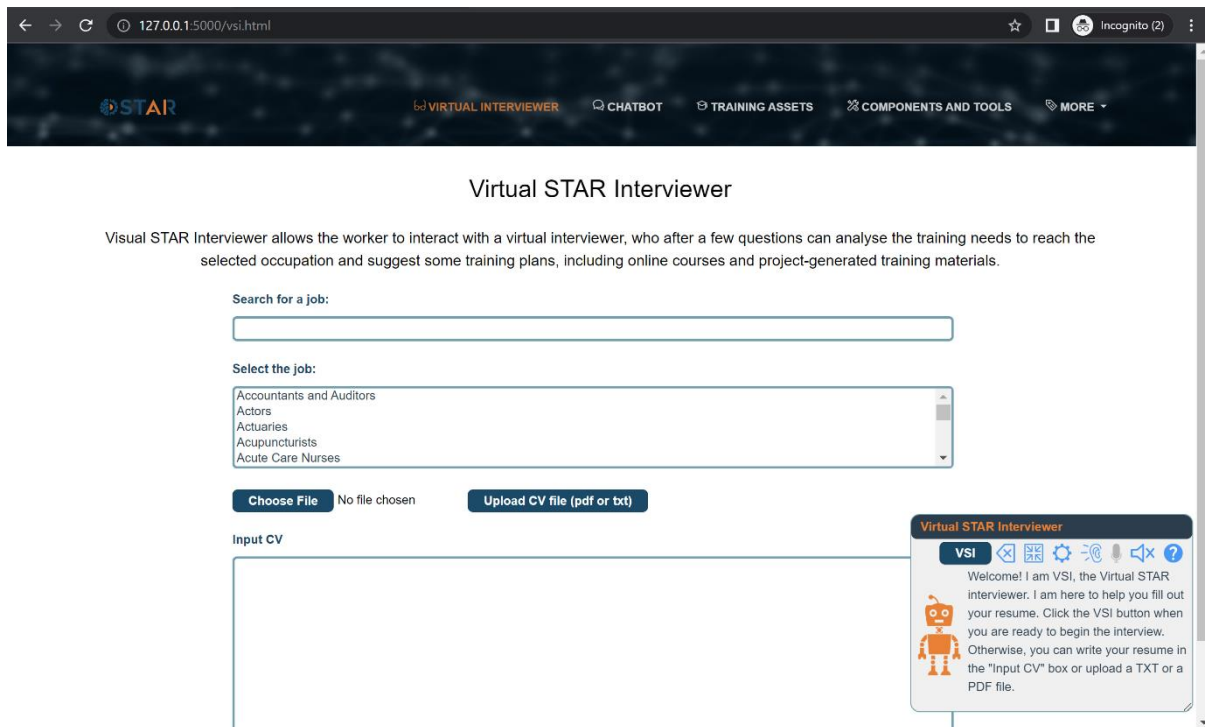


Figure 9: Virtual STAR interviewer

The following screen (Figure 10) shows what we have called chatbot, a system for the worker to consult information about occupations and discover similarities to their current profession or know what they should improve to change their position.

As in the Virtual STAR Interviewer, in the lower right part the multimodal chatbot is shown, with which the user can interact by voice and text. In the centre of the screen the structure of the questions that can be asked together with several generic demonstrative examples is shown.

The main query types are:

- Alternate names of jobs.
- [Abilities | Knowledge | Skills | Tasks | Tech-Skills | Tools used | Work activities] that are important or necessary in any job.
- Description of a job.
- The similarities between a couple of jobs.
- Which jobs require a specific [Ability | Knowledge | Skill | Task | Tech-Skill | Tool | Work activity].
- Recommendations on how to improve one [Ability | Knowledge | Skill | Task | Tech-Skill | Tool | Work activity].

The list below shows a collection of example queries:

- List alternate names for taxi drivers.
- Tell me other designations for developers.
- List tools for programmers.
- List some skills that actors need.

- Tell me some work activities performed by actors.
- Describe the work of a taxi driver.
- Describe the work of the actors.
- Compare the jobs of pilots and actors.
- What are the similarities between surgeons and nurses?
- What job requires servers?
- Which professions require medical masks?
- Can you teach me something about python?
- How can I improve my speech clarity?

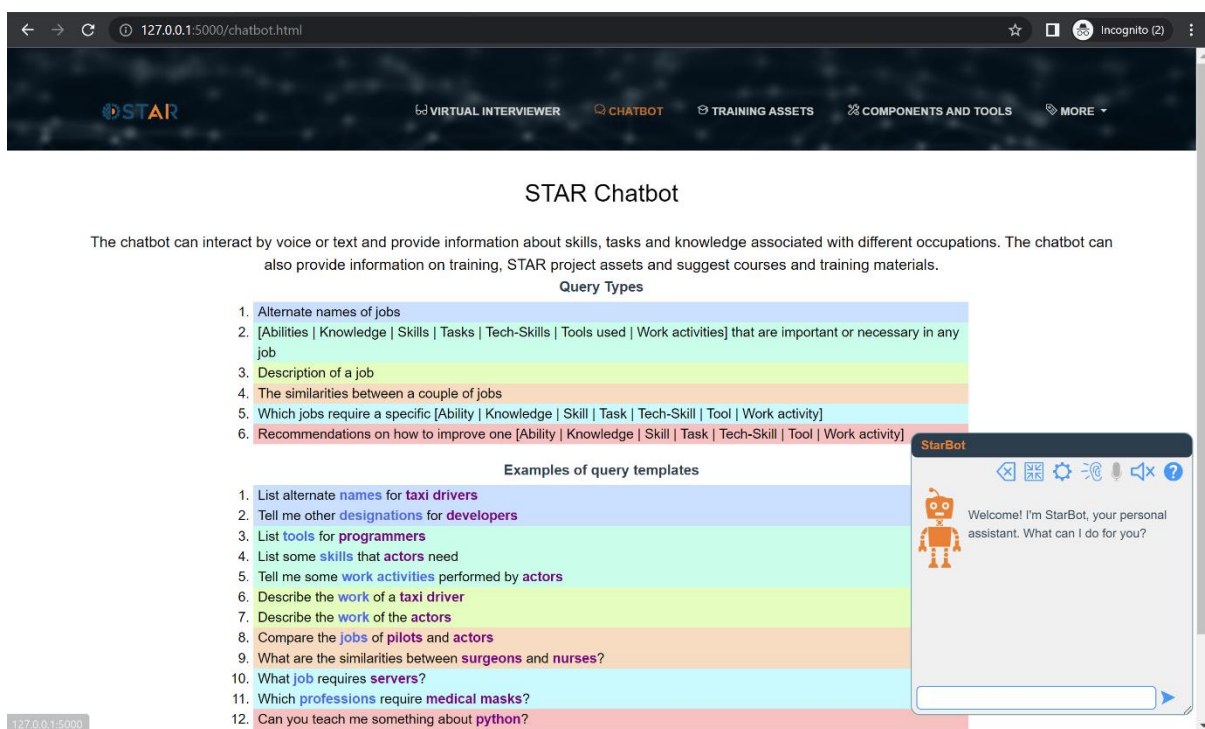


Figure 10: Chatbot

The following screen (Figure 11) shows the catalogue of training assets and didactic materials of the project. These materials are in line with the materials displayed on the main website of the STAR project. Not only that, but they are linked to them so that once clicked, the user will access the project website and can consult them.

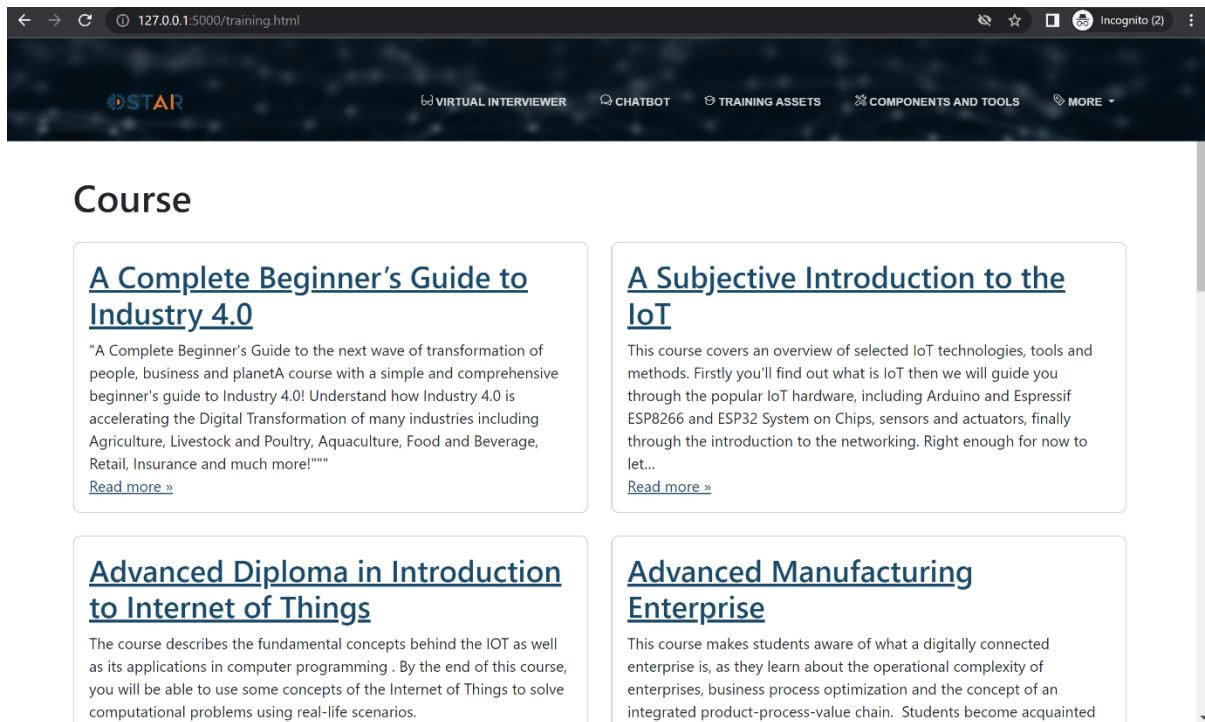
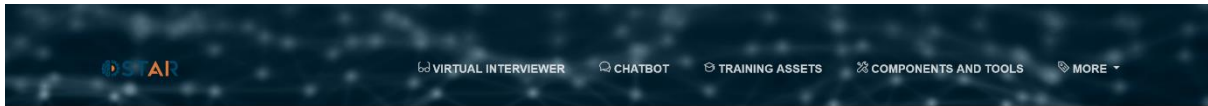


Figure 11: Training Assets

Finally, the tools and solutions section are shown. In this section (Figure 12) we wanted to inform about some of the Human Centred solutions developed in the project and offer the visitor the possibility of contacting the developer to carry out a simulation or demo, or access to the code. As can be seen, several cards are shown in which a descriptive image of the tool is shown, together with the responsible organisation and the name or theme of the solution.



Components and Tools

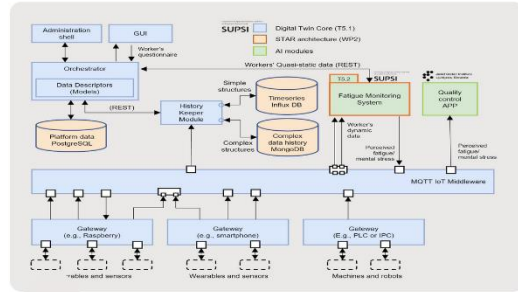
Find below some Human Centred Simulation and Digital Twins for Safe & Secure AI tools, components and simulation system developed in STAR.
For the full Marketplace of STAR components, visit [Marketplace by STAR](#)



SUPSI

Human-Centred Digital Models for AI Systems and Processes

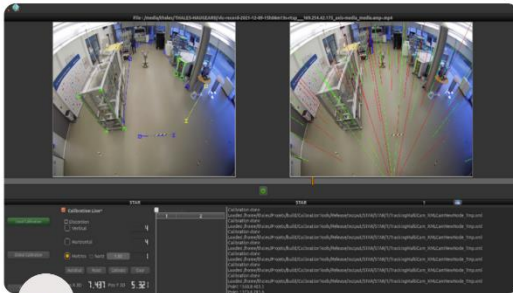
SUPSI



SUPSI

Digital Twins for Worker Safety

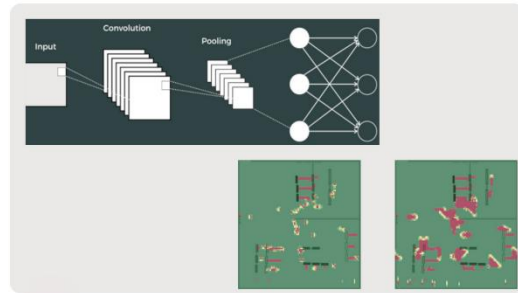
SUPSI



THALES

Visual Analytics for Safety Zones Detection

Thales



THALES

Simulation and Reinforcement Learning for AMR

Thales

Figure 12: Components and tools

Once one of the cards is clicked, the complete detail of the solution is shown (Figure 13). Including contact person, website, link to the STAR project marketplace, along with a description of the technology and organisation. Finally, an image carousel is shown with details of the tool or solution.



Human-Centred Digital Models for AI Systems and Processes

Contact Person: [Elias Montini](#)

[WEB SITE](#)

[MARKET LINK](#)

Technology

The Human Digital Twin Core Infrastructure is divided into three main technological layers (Sensor Layer, Middleware and Digital Twin Architecture) and consists of different components: Agents and Gateways that enable data collection from workers and operational units; IIoT Middleware that supports M2M connectivity and data flows; Data Storage and Time Series Data Storage that support the storage of data flowing to the IIoT Middleware as time series or (quasi-)static data; Orchestrator that is responsible for the management of all the entities in the HDT; Administration Shell that enables the management and configuration of the HDT; GUI which recaps and offers a nice and understandable way to visualize the data flowing in the HDT; Functional Modules (Digital Twin Core - Data processing, analysis and decision modules) aimed at recognizing human states and conditions and computing complex features that enable human and machine decision makers to take human factors into account in their execution and control logics.

Organisation

SUPSI offers more than 30 bachelor's and master's degree courses, characterized by cutting edge education which merges classical theoretical-scientific instruction with practical orientation. Great focus is given to research, carried out in key domains for EU competitiveness, and funded on acquired projects within European or National frameworks. Within SUPSI, the Institute of System and Technologies for Sustainable Production (ISTePS) will participate to the project. The mission of the Institute is the innovation of products, manufacturing processes and business models in order to accompany companies in facing the challenges of globalization under the economic, environmental and social aspects. The fulfilment of the mission is achieved through the development of human capital and the innovation of production systems and technologies by means of education activities at bachelor, master and employment levels, as well as through research, development and technology transfer activities with reference to the life cycle of products and industrial processes, in the fields of design, automation and management of production systems and the relative value chains. Key research areas are: Sustainability and Personalization; Human in the Loop; Simulation Technologies; Automation and Control.

Technology showroom

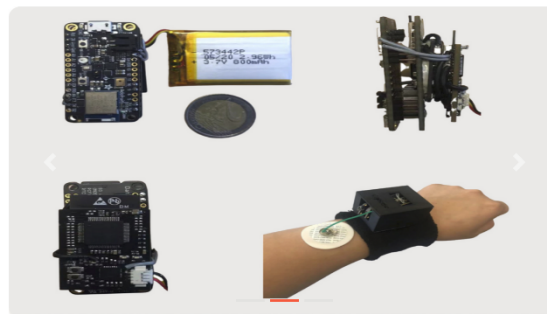


Figure 13: Solution Details

4 Human Centricity Training Assets

The “T5.5 Workers' Training and Continuous Learning” task is not only focused on the platform. As part of it, and given the growing interest in the concept of Human Centricity, the partner RUG has developed training materials detailing the concept and each of the factors that constitute it. In addition to information on each factor, general considerations for assessment are added for each of the factors, along with different points of consideration for the different roles.

The factors analysed are as follows:

- Accountability
- Transparency, Explainability, and Interpretability
- Fairness, Inclusivity, and Non-discrimination
- Safety and Security
- Privacy and Data Agency
- Well-being
- Human Agency and Oversight
- Task and Skill Variety
- Ergonomics and Physical Demand
- Other Considerations for Human-centricity (Problem Solving, Information Processing, Interdependence, Feedback from job/Others, and Ease of Use)



Figure 14: Cover Page of the training

The intended audience is:

- System Developers
- Front-line workers
- Operations Managers
- Team Leaders
- Organisations themselves

And the objectives of the course are to:

- Educate participants on the elements and implications of human-centricity.
- Enable participants to effectively assess the human-centricity of AI systems in their workplace by providing guidance and tools for evaluation.
- Equip participants with the knowledge and practices to create and maintain ethical AI systems that align with human interests and values.

This course is included as an annex to this deliverable and will be promoted both in the project's training assets and on the Workers' Training Platform.

5 Conclusions, current and future activities

During this document, we have presented the second version of the Workers' Training Platform. As in the previous version we have outlined the three main ideas of content that we expect it to contain: assessments and recommendations, training materials and tool and component profiles.

Regarding the former, we have introduced our Virtual STAR Interviewer together with an occupational information chatbot. Regarding the second, the integration with the training materials of the STAR project and the recommendation system that makes use of a database generated specifically for the project. Regarding the third point we have presented a virtual showroom of the technologies and components related to human centricity and we have created profiles so that visitors and users can obtain information, contact the responsible organisation or even access the STAR marketplace.

To do all this we have started from the initial scenarios and requirements, which we have gone through one by one indicating how we have covered them. In addition to this, we have presented the training material generated by University of Groningen, which will be useful not only for employees, but also for developers and managers.

This platform for workers will be integrated with the main platform of the project <https://star-ai.eu/> in which a link will allow access to the functionalities presented above. The training materials will also be accessible in the STAR project library.

Discussions have also taken place, with WP7, Unparallel and Netcompany-Intrasoft on content, catalogues of recommendations, the integration of profiles in the marketplace and the management and generation of training assets.

In the short term, the main activity is the coordination with WP7 and WP8 packages for the integration of the platform and presentation of all the content in a coherent and homogeneous way. In the medium term, new developments related to the WTP are being considered, among them the possibility of applying a similar approach in another format and moving from the web to more immersive formats such as virtual 3D worlds, representing information about the factory while allowing workers to obtain information about the company's activities.

Annex 1: Human Centricity Training Manual

ASSESSMENT FACTORS FOR HUMAN-CENTRIC ARTIFICIAL INTELLIGENCE

Helping Manufacturing Organisations and their employees assess the human-centricity of their systems

A.1 Introduction

As artificial intelligence (AI) continues to revolutionize how we live and work, it is imperative for the manufacturing industry to prioritize human-centricity when developing and implementing AI-enabled systems. This comprehensive training manual serves as a valuable resource for professionals in the manufacturing industry with the knowledge and skills necessary to assess and prioritize human-centricity when developing, deploying, and operating AI-enabled systems. By understanding and addressing fundamental considerations such as accountability, transparency, and well-being, among others, we can create a better working environment that optimizes human and machine capabilities.

The rapid advancement of AI technologies has introduced new opportunities and challenges in the manufacturing industry. While AI systems have the potential to enhance productivity and efficiency, it is crucial to ensure that they align with human interests, values, and needs. The goal is to develop systems that empower workers, promote their well-being, and augment their capabilities by enabling them to engage in activities of higher added value that require more advanced human cognitive capabilities.

The training manual adopts a comprehensive and cohesive approach, ensuring a thorough understanding of human-centric AI systems' principles, implications, and practical application. Through this training, our goal is to empower participants to assess the human-centricity of AI systems in their workplace and make informed decisions that prioritize the well-being and autonomy of employees. Additionally, we recognize the importance of considering the overall impact on the organisation, including the optimisation of machine capabilities, to achieve a harmonious and productive human-machine collaboration. This training manual consists of ten modules encompassing the essential aspects of human-centricity in AI systems, derived from analysing various guidelines and research articles. These modules are:

- Accountability
- Transparency, Explainability, and Interpretability
- Fairness, Inclusivity, and Non-discrimination
- Safety and Security
- Privacy and Data Agency
- Well-being
- Human Agency and Oversight
- Task and Skill Variety
- Ergonomics and Physical Demand
- Other Considerations for Human-centricity (Problem Solving, Information Processing, Interdependence, Feedback from job/Others, and Ease of Use)

A.1.1 Course Objectives

The objectives of this course are to:

- Educate participants on the elements and implications of human-centricity.
- Enable participants to effectively assess the human-centricity of AI systems in their workplace by providing guidance and tools for evaluation.
- Equip participants with the knowledge and practices to create and maintain ethical AI systems that align with human interests and values.

A.1.2 Course Intended Audience

This course is for professionals in the manufacturing industries who interact with AI-enabled systems or are involved in developing and managing AI-enabled technologies for such industries. These can be:

- System Developers
- Front-line workers
- Operations Managers
- Team Leaders
- Organisations themselves

A.1.3 Course Learning Outcomes

Upon completion of this course, as a part of a team, you should be able to contribute towards:

- Develop a solid understanding of the principles of human-centric AI and their significance in the development and deployment of AI systems in manufacturing.
- Identify potential ethical risks and pitfalls associated with AI-enabled systems, such as bias, discrimination, and privacy concerns.
- Apply effective methods to assess the human-centricity of AI systems in their organisation, including evaluating accountability, transparency, fairness, safety, privacy, and well-being.
- Implement best practices for creating and maintaining ethical AI systems that align with human interests, values, and regulatory requirements.

We start by defining what human-centricity is. Human-centricity is an approach that places humans at the center of design, development, and operation processes of technology and systems (IBM, n.d). It emphasizes the consideration and prioritisation of human needs, values, and well-being throughout the entire lifecycle of a system or technology. Human-centricity involves incorporating human factors, ergonomics, and usability knowledge to create systems that are user-friendly, accessible, and aligned with human values (ISO, 2010).

Building upon the concept of human-centricity, the following modules delve into specific aspects that contribute to the development of responsible and trustworthy AI systems.

A.2 Accountability

The module of accountability is closely related to risk management, transparency, explainability, auditability, human agency, oversight, and responsibility. Accountability for AI involves determining the level of trust in AI systems and assigning responsibility for any

mistakes or harm caused by their outcomes (Liu et al., 2021). As per the ISO standards (2022), accountability involves allocated responsibility, which enables the tracing of actions back to the responsible entity. In most cases, the accountability can fall on the system designer, the systems engineer, and even the operator working with the AI depending on the circumstances. Many AI-based systems are "black-boxes" due to the lack of explainability and transparency. The increasing complexity and involvement of numerous vital components, such as input data, algorithm theory, implementation details, real-time human control, etc., complicates the determination of accountability for the actions of the AI (Liu et al., 2021).

Issues also arise when considering self-learning neural networks. In such cases, the decisions made by the AI system may deviate significantly from the original design, making it difficult for the developer and operator to predict the AI's future behavior. Consequently, holding the operator legally or morally responsible for the AI's actions becomes challenging (Bird et al., 2020). For this reason, there should be a remedy by which it is possible to reconsider the decision of the AI itself before it is enacted, which can give some control to humans leading to rectifying the consequences.

One way of ensuring accountability is by *Auditability*. Auditing an AI system involves assessing the system against a set of regulations from various perspectives conducted by internal or external auditors (EU Commission, 2021a). Different manufacturing organisations adhere to different sets of regulations, typically adopted from multiple frameworks developed by regulatory bodies. Most of the regulations from the various AI systems regulatory bodies follow similar aspects.

Liu et al. (2021) divide audits into two categories:

- **Internal Audits** conducted by the individuals within the system designer or operator groups are crucial as they can access the internal data used for training and model implementation., These audits are conducted before the system's deployment and can identify potential harm and prevent setbacks. However, internal auditors may struggle to provide an objective audit report due to shared interests as the people they are auditing.
- **External Audits** involve third-party evaluators independent of the system designers and operators. As they share no interests with the internal workers, these auditors can provide more novel perspectives and objective audit reports. However, external audits have some disadvantages. First, external auditors cannot access the internal data, such as the training data and the model implementation details, making auditing difficult. Second, external audits occur after the system deployment, making adjustments to the systems costly, and most times, the system may already have done harm.

The content for the following two sections was analysed from the studies of IEEE Ethically Aligned Design First Edition, EU Commission's Ethics by Design, and Ethics of Use Approaches for Artificial Intelligence, Liu et al. (2021), Bird et al. (2020), Fjeld et al. (2020).

General Considerations for Assessment of Accountability

It is necessary to create steps to create accountability for the system.

- Identify potential risks and consequences: Assess the potential risks and unintended consequences of AI-enabled systems, including bias, discrimination, and privacy breaches.
- Ensure the adequate implementation of accountability mechanisms: Check if there are transparent processes for reporting, investigating, and mitigating AI-related issues. There should be clear channels for workers to report AI-related concerns and provide feedback on system performance.
- Is it possible to do monitoring and continuous improvement: It should be possible to monitor AI system performance and implement improvements to address identified issues. Use the learnings from evaluations to feed back into the system and ensure continuous improvement.
- Training and awareness: Educating employees on their accountability responsibilities and the ethical implications of AI. Encourage employees to take ownership of their roles in the AI system lifecycle, fostering a culture of accountability and ensuring workers consider the ethical implications of their actions and decisions when working with AI-enabled systems.

Accountability Considerations for the Different Roles

Operators:

- Adherence to established accountability policies and guidelines issued by IEEE, European Commission or other AI system regulatory bodies.
- Reporting any AI-related concerns or incidents.
- Monitoring performance of AI-enabled system and providing feedback.
- Determine if the AI system sends alerts and warnings to stop mistakes and risky behavior so that users may take responsibility for their activities. Operators can learn from these notifications and improve their task-taking responsibility by obtaining the proper instructions.
- Provide comments on how well the notifications and instructions worked, as well as ideas for enhancements to the system's accountability-supporting capabilities.

System Developers:

- Designing AI Systems with accountability in mind.
- Implementing mechanisms for monitoring and auditing system performance.
- Ensuring compliance with relevant accountability regulations and standards issued by the IEEE, European Commission or other AI system regulatory bodies.
- Developing user interfaces that promote accountability awareness and transparency.
- AI systems must be created to permit human monitoring and control over decision cycles and operations, unless strong grounds indicate differently.
- Justifications for the lack of human oversight should be explicit in how people will be able to comprehend the judgments made by the system and how humans will be able to override those decisions.

- Independent third parties should be able to audit AI systems, and there should be policies and resources in place to make this auditability possible.
- Resolve difficulties and enhance the efficiency of AI systems.
- The design of AI systems should incorporate mechanisms for recording and documenting the system's decisions, enabling human review and accountability.
- Mechanisms for capturing and documenting AI system choices should be incorporated into the architecture in order to facilitate human scrutiny and accountability.
- Where feasible and appropriate, AI systems should have the capacity to report internal operations purely for human oversight, external audit, and accountability.
- Evaluating the ethical implications of AI system features and functionality.

Operations Manager:

- Developing and enforcing organisation-wide accountability policies.
- Overseeing AI system risk assessment and mitigation strategies.
- Monitor how the production system is currently set up and make sure it contains the elements required to encourage staff to perform responsibly.
- Collect employee input on how well the system supports accountability, and then make changes as necessary to keep a human-centric approach.
- Ensuring compliance with relevant accountability regulations and standards issued by the IEEE, European Commission or other AI system regulatory bodies.

A.3 Transparency, Explainability, and Interpretability

This module is closely related to the modules of Accountability, Safety and Security, Human Agency, and Privacy. These three criteria are grouped in this section as they are complementary.

According to the EU Commission's Ethics By Design and Ethics of Use Approaches for Artificial Intelligence, the transparency of an AI system requires stakeholders to know and understand the purpose, inputs, and operations of AI programs. Since transparency spans from the purpose of the system (designing) to the operations of the system (deployment), it must be maintained throughout the life of the AI system. This necessitates a culture of openness from design and development to deployment (Fjeld et al.,2020), ensuring the stakeholders using or affected by the system comprehend the main concepts. Without transparency, people cannot grasp or challenge the decisions made by the AI systems making it impossible to identify incorrect decisions or training data errors that could lead to unintended consequences (IEEE, 2017). The EU Commission (2021a) emphasizes the importance of AI system traceability, highlighting the need to log and document both the decisions made by the system and the entire process (including data gathering and labeling descriptions and the algorithm used) that led to those decisions.

Explainability refers to the ability of an AI system to provide reasoning behind its decisions and predictions in a way that humans understand. The significance of explainability grew as

deep learning models emerged. These models are known as black boxes due to the lack of explanation of the underlying mechanism behind their prediction. This lack of transparency hinders trust and limits the use of these models in critical applications. As a result, the concept of XAI emerged, aiming to create AI systems that offer intuitive understanding.

Interpretability is the concept of making AI model output and predictions understandable and relatable. Researchers often use explainability and interpretability interchangeably, but there are differences. An AI model is interpretable if humans can understand the model itself on its predictions. A human can understand an interpretable AI model's prediction by examining its parameters or summary, as it demonstrates the decision-making process, even when input data or algorithm parameters change (Liu et al., 2021). As a result, these models are not considered "black boxes. An explainable model implies that additional explanations are used to assist humans in understanding why it made certain predictions/decisions that it did. However, the model is still black-box and opaque (Liu et al., 2021).

The role of employees in assessing transparent, explainable, and interpretable AI deployment and operation

The prominent employee roles identified that can contribute towards Transparent and explainable systems are operations managers, system developers, and operators. These roles have the basic understanding of whether or not the AI system's decision-making process can classify the decisions correctly or not. They can hence maintain ethical behavior and adhere to relevant regulations.

- System performance: the Operations managers first give their requirements on transparency to the system designers, who must then translate it for the system developers. The system developers will construct the system according to the requirements and must audit this before deploying. Operators must evaluate AI system performance during the assessment, identifying potential issues or improvement areas. This helps ensure that the AI system operates efficiently and effectively. The system developers can then work on the concerns and feedback provided by the operators to improve the system.
- Ethical behavior and compliance with regulations: the Operations manager and the systems developers should clearly understand the ethical criteria the system they are trying to build must comply with. These should be conveyed to operators to operate the system with these in mind. The operators can then assess if the system upholds ethical standards, including respecting colleagues and other stakeholders, maintaining confidentiality, and ensuring the AI system's decision-making process does not lead to unfair or discriminatory outcomes. By prioritising ethical behavior, workers contribute to a positive work environment and uphold the organisation's reputation.

Transparency, Explainability, and Interpretability Considerations for the Different Roles

After analysing the studies of Bird et al. (2020), the EU Commission's Ethics by Design, and Ethics of Use Approaches for Artificial Intelligence, the following considerations were made for each role.

Operators

- Understanding the AI system's decision-making process and outputs.

- Actively seeking clarification on AI-related actions and decisions.
- Communicating AI system performance and issues to relevant stakeholders.

System Developers

- Developing AI systems with transparency, explainability, and interpretability considerations.
- Implementing mechanisms to monitor and audit these elements in AI systems.
- Working together with other stakeholders ensures that the AI system's outputs and decision-making process are clear and easy to grasp.
- Whenever feasible, provide justifications for particular decisions so that users and stakeholders may understand the reasoning behind them.
- Mechanisms should be in place to explain the decision made and the information or criteria that went into it. Particularly crucial for systems that have the potential to harm people considerably, interfere with their rights, or adversely influence their interests individually or as a group.
- Create methods and use tools that make it possible to document the development processes in a way that people can understand and assess. The documentation should be able to explain the system's judgments, and the methods that allow humans to override them.
- Take precautions to prevent or reduce the likelihood that the system may provide people with inaccurate or misleading information. To reduce the danger of disinformation, documentation, functionality, or other measures should be put in place, especially as this risk could rise after the system is up and running.
- Determine whether the system has the potential to distort data or make judgments that humans cannot trace or comprehend. If so, design specifications should be introduced to make data operations as transparent as feasible.
- In case data activities cannot be audited, Formal justifications should be produced to state the reasons why.

Operations Managers

- Overseeing AI system risk assessment and mitigation strategies related to transparency, explainability, and interpretability.
- Ensuring compliance with relevant regulations and standards issued by the IEEE, European Commission or other AI system regulatory bodies.
- Ensure that the AI system allows for traceability and transparency, making it clear who is responsible for specific actions and identifying areas for improvement.

A.4 Fairness, Inclusivity, and Non-discrimination

This module is closely related to the modules Accountability, Transparency, Explainability, and Interpretability. Biases, incompleteness, and poor governance models in the data sets used for AI system training and operation can lead to discrimination. To establish trust in an AI

system, it is crucial to ensure that its decisions are unbiased and non-discriminatory, which requires transparency and explainability.

A trustworthy AI system must prevent discriminatory behaviors in human-machine interaction and ensure fair decision-making for individuals or groups. For this reason, it is necessary to assume that the data gathered for training is biased, skewed, or incomplete unless proven otherwise (Bird et al., 2020). Data from human activities may reflect societal biases, so it is crucial to demonstrate the data's accuracy, representativeness, or neutrality (Bird et al., 2020). Addressing ethical issues during data preparation can prevent new biases or ethical concerns. Liu et al. (2021) identify three kinds of bias: productive, erroneous, and discriminatory. Productive bias is essential for machine learning algorithms to function effectively, as it favors specific distributions or functions to improve performance in solving certain problems. Erroneous bias can result from systematic error caused by faulty assumptions, leading to undesirable test data performance. Discriminatory bias reflects the algorithm's unfair behavior towards a particular group or individual.

Fairness ensures that everyone has equal access to fundamental rights and opportunities without discrimination based on their identity (EU Commission, 2021b). Achieving this requires the integration of inclusion and diversity throughout the AI lifecycle. However, algorithms based on neural networks can still learn biases from data during training (Bird et al., 2020). For instance, the COMPAS algorithm designed to assess the likelihood of someone committing a violent crime discriminated against black people, even though it wasn't given race as an input; instead, it inferred race from sensitive data such as addresses (Uclalaw, 2019).

Microsoft's AI principles define inclusivity as when the AI systems empower and engage everyone. To ensure that AI technologies benefit and empower all, they must address various human needs and experiences. Inclusive design practices will help system developers identify and address potential barriers in a product or environment that could unintentionally exclude people (Fjeld et al., 2020). Consequently, AI systems should be designed to comprehend users' context, needs, and expectations.

Employee role in assessing Fairness, Inclusivity, and Non-discrimination

After analyzing the studies of STAR deliverable 2.9 “Report on Co-Design Workshops and Focus Groups-Initial version”, IEEE Ethically Aligned Design First Edition, EU Commission's Ethics By Design, and Ethics of Use Approaches for Artificial Intelligence, Liu et al.(2021), Bird et al.(2020), Fjeld et al.(2020), the most prominent roles in evaluating the criteria of Fairness, Inclusivity, and Non-discrimination as a part of the human centrality of the system are the system developers and the operators. Both these roles share some common responsibilities:

- Continuous monitoring of AI system performance to identify and mitigate any potential fairness, inclusivity, or non-discrimination issues.
- Participating in training sessions and workshops about fairness, inclusivity, and non-discrimination to enhance their understanding and contribute to prioritising these values.

Operators

- Provide feedback on AI-enabled system performance related to fairness, inclusivity, and non-discrimination.

- Conduct regular audits and reviews of the AI system performance to ensure compliance with standards.

System Developers

System developers can assess this criterion by:

- Recognising any discriminatory effects and biases that could be produced by the data used to train the AI system.
- Working carefully to eradicate prejudice and discrimination in AI systems by making sure that the algorithms, input data, and system architecture are unbiased and inclusive. Pre-processing, in-processing, and post-processing techniques might all be used to accomplish this.
 - a) Pre-processing is the process of eliminating bias from training data to make sure an algorithm is fair from the start. This may entail resampling, reweighting, or data transformation to produce a dataset that is more evenly distributed and representative.
 - b) In-processing: Eliminates bias during the model-training phase in order to address bias at the algorithmic level. Techniques include utilising adversarial training, reweighting, regularisation, bandits, and fairness restrictions in the learning process.
 - c) Directly alters model outputs to guarantee impartial results. This may entail modifying decision thresholds, employing calibration strategies, or utilising decision optimisation approaches to take fairness goals into account.
- Working with diverse teams during the development of AI systems to make sure that a variety of viewpoints and experiences are taken into account, which may assist in discovering potential biases and enhance fairness.
- By maintaining transparency throughout the AI development process, it becomes simpler for others to comprehend and evaluate the system's elements of fairness, inclusiveness, and non-discrimination. This can entail thorough documenting of the information, formulas, and design choices incorporated into the AI system.
- Developing guidelines and best practices to encourage fairness, inclusion, and non-discrimination within the company. This may entail developing procedures, assessment measures, or checklists to assist in making sure these requirements are constantly taken into account throughout the lifespan of an AI system. These guidelines can also be passed down to operators when assessing fairness, auditing, or testing the system.

A.5 Safety and Security

Safety and security are paramount in any AI system, especially in manufacturing, where AI can significantly influence the operation and performance of machinery and equipment. Safety pertains to the AI system's ability to operate without posing an unacceptable risk of physical injury or damage to people and the environment (Fjeld et al., 2020). At the same time, security tackles the external threats to the system and its capacity to protect sensitive information (Fjeld et al., 2020). This theme is connected to Accountability, Privacy, and Well-being.

Designers and operators should emphasize safety and security when developing and operating AI systems, ensuring they do not pose undue risk to humans, equipment or environment. They must consider safety measures before and after AI system deployment (Fjeld et al., 2020). During development, AI systems must undergo testing to prevent possible risks of harm and potential human rights violation. Testing scenarios should cover both likely and unexpected scenarios. The system's developers must also ensure that the systems do not evolve in unforeseen ways.

Since machine learning and neural networks continue to learn and evolve based on the new input it receives, ongoing testing and monitoring of these systems are essential after deployment to ensure adherence to safety standards and prevent significant deviations from original designs (Fjeld et al., 2020). Designers and operators must consider that AI systems might be used in contexts they were not designed for. Thus, systems should be inherently designed to make "safe decisions" regardless of context (Bird et al., 2020). However, developers and operators of the AI system cannot always predict the risks associated with such machines; therefore, safety mechanisms should be integrated into the system as a fail-safe, allowing the system to shut down safely in case of problems.

AI system security must be robust to withstand external attacks (EU Commission, 2021a). Regular testing before and after deployment is necessary to prevent security measure degradation over time. Assessments should address information sharing on vulnerabilities, cyberattacks, and protecting personal data privacy and confidentiality. Anonymisation, de-identification, and encryption can help achieve data security (Fjeld et al., 2020). System developers must go beyond assuming the system will function when developing systems that may have an influence on human safety and well-being. They must be aware of, evaluate, and take mitigating measures for the ethical hazards posed by black box software. IEEE's Ethically Aligned Design gives four possible strategies for risk prevention and mitigation -

1. **Anticipate Evaluation:** To enable evaluation and pinpoint areas for improvement, define assessment criteria and metrics throughout the deployment phase, taking into account technical, user-level, and community-level aspects.
2. **Systematic Risk Analysis:** Adopt a risk analysis and management method to prevent future failures by proactively identifying them and creating plans to lessen their effects, allowing for iterative improvements based on observed behavior.
3. **Incorporate Fail-Safe Components:** Integrate fail-safe techniques to address unexpected norm breaches in the system architecture. Establish stringent regulations that are tailored to tasks and communities, continually check operations for violations, and take the necessary precautions to reduce hazards.
4. **Publicly Accessible Database:** Create a database that is open to the public that records any unintended consequences brought on by certain AI systems. Include thorough explanations of problems, detecting techniques, background knowledge, and solutions, encouraging openness and collaboration.

By implementing these strategies, engineers can address ethical risks, enhance accountability, and foster the responsible development and deployment of AI systems.

Employee Role in Assessing Safety and Security

After analyzing the STAR deliverable 2.9 "Report on Co-Design Workshops and Focus Groups-Initial version", IEEE Ethically Aligned Design First Edition, EU Commission's Ethics by Design, and Ethics of Use Approaches for Artificial Intelligence, the EU Commission's The Ethics of artificial intelligence: Issues and Initiatives, the following considerations were made for each role. The prominent employee roles that should ensure the safety and security of the AI systems involve the system developers, team leaders, and operators. Their responsibilities, in general, involve:

- Understanding the potential risks and threats associated with the system.
- Applying best AI safety and security practices during AI systems' design, development, deployment, and operation.
- Regularly monitoring AI system performances to identify and mitigate safety and security issues.
- Participating in safety and security training to keep up with the latest threats and mitigation strategies.

Operators

Operators are often the first line of defense in safety and security after deploying the system. So they should be:

- Receive training to identify anomalies or safety concerns in AI systems' operation. By being aware of safety protocols and actively participating in training, operators contribute to a secure work environment.
- Perform regular system checks and maintenance audits to continuously test the system's safety and security. Any concerns picked up during the tests and audits should be reported to the team leaders or system developers for further investigation.
- Collaborate with system developers to install necessary security updates.

Team Leaders

- They must ensure their team members are adequately trained and aware of the safety and security protocols.
- They should establish communication channels between operators and system developers to report and resolve safety and security issues.

System Developers

- Determine if the system has the potential to harm people, property, or the environment physically. If so, incorporate fail-safe procedures for safe system shutdown in the event of unanticipated issues and design features to reduce risk or severity.
- Put in place procedures to safeguard the integrity and quality of data, such as procedures to confirm that datasets are secure and unhacked.
- Create procedures to identify continuing data quality deterioration before the system makes use of the data, avoiding external corruption and reducing low-level data corruption.
- Ensure that AI algorithms are safe to use and robust against any cyber-attacks.

- Comprehensive threat models and risk assessments should be carried out throughout the design process to find any possible safety and security weaknesses.
- Include security components in AI design, such as data encryption, access controls, and intrusion detection systems.

Operations Manager

- Use the Key Performance Indicators to track and measure the effectiveness of safety and security measures.
- Collaborate with external stakeholders, such as regulatory bodies and industry partners, to share best practices and stay informed about threats and trends in AI safety and security.
- Enforce compliance with relevant safety and security regulations and standards.
- Oversee risk assessment and mitigation strategies related to safety and security.
- Foster a culture that prioritizes employee safety and satisfaction. This includes ensuring that employees feel safe working with AI-enabled systems.
- Regular safety audits and reviews should be conducted to ensure compliance with safety standards and to identify areas for improvement.

A.6 Privacy and Data Agency

This module closely ties safety and security, Transparency, Explainability, and Interpretability. Respecting the fundamental rights to privacy and data protection is crucial in all industries, including manufacturing. Regulatory bodies like the European Union and the GDPR have established frameworks and regulations to uphold these rights. Breaching these regulations or misusing data can result in severe reputational damage, loss of customer trust, legal and financial consequences, and negative impacts on employee morale. Thus, finding a balance between privacy protection and leveraging data for innovation is essential for AI-enabled systems in manufacturing, maximising both efficiency and compliance.

The main privacy principles include Consent, Control over the Use of Data, Right to Rectification, Right to Erasure, and Privacy by Design (Fjeld et al., 2020). Consent requires obtaining permission from individuals before using their information. Informed consent further necessitates informing individuals of the risks, benefits, and alternatives of sharing their data. Control over the Use of Data allows individuals to influence how and why their information is used. The Right to Rectification permits individuals to amend or modify their information if it needs to be corrected or completed. The Right to Erasure grants individuals the enforceable right to remove personal data held by a third-party entity.

When considering privacy in a manufacturing context, it is essential to understand the types of data collected and stored within the AI system. This helps identify potential privacy risks, such as unauthorized access to data or data leakage. Storing only the minimum amount of data necessary for the intended purposes and ensuring data usage is limited to those purposes is crucial (EU Commission Ethics By Design and Ethics of Use Approaches for Artificial Intelligence). This is particularly important in machine learning, where algorithms can extract information from data, discover new patterns, and transform seemingly harmless data into sensitive personal data (Bird et al., 2020). Embedding the principles of data minimisation and data protection by design is critical when building AI systems. However, this may seem

contradictory since AI-based machine learning requires access to extensive data for training. Finding the right tradeoff for efficient AI use is essential.

In manufacturing industries, AI can streamline processes and enhance productivity, but it also raises critical questions about data privacy for workers. AI systems often collect, store, and analyse various types of employee data to optimize operations, such as personal information, work performance metrics, biometric data, or health-related information. Such extensive data collection can inadvertently compromise employee privacy rights if not properly managed.

Several challenges are associated with ensuring data privacy in AI-driven manufacturing systems:

1. Identifying and protecting sensitive employee information can be difficult due to the sheer volume and variety of data collected.
2. AI algorithms may inadvertently identify individuals from anonymized data or infer sensitive information, even when such data is not explicitly provided.
3. The lack of transparency in AI-driven systems, often called "black-box" algorithms, can make it challenging for employees to understand how their data is being used and processed.

Protecting data privacy requires robust data governance mechanisms. These mechanisms should ensure compliance with data protection laws, restrict unauthorized access, and guarantee that data is used only for its intended purposes. Data privacy should be integral to AI design and deployment, not an afterthought. By addressing these privacy concerns, organisations can foster a more secure and transparent environment for their employees and the public and maintain compliance with data protection regulations.

Employee role in assessing Privacy and Data Agency

After analysing the STAR deliverable 2.9 "Report on Co-Design Workshops and Focus Groups-Initial version", IEEE Ethically Aligned Design First Edition, EU Commission's Ethics by Design, and Ethics of Use Approaches for Artificial Intelligence, EU Commission's The Ethics of artificial intelligence: Issues and Initiatives, and the article by Liu et al. (2021), the following considerations were made for each role.

Operators

- Actively report any privacy-related concerns or incidents.
- Understand and comply with their organisation's privacy regulations and guidelines and the specific AI systems in use.
- Gain knowledge of the data flow within the AI system, including data collection, storage, and access.
- Regularly monitor and audit AI systems for potential privacy risks, taking corrective actions when necessary.

System Developers

- Include privacy considerations in the AI system from the start of the development process, adhering to the principles of privacy-by-design.

- Set up appropriate authentication procedures and access controls to restrict access to sensitive data.
- Make that the development methods, procedures, and tools respect people's fundamental rights while supporting ethical criteria for privacy, personal data protection, and data governance.
- Use data minimisation techniques by gathering and storing just essential data.
- Examine any potential ethical or data protection violations in each process's activities.
- Make sure no unnecessary personal information is gathered, and if it is, put in place safeguards to protect data subjects.
- Treat mixed databases containing both personal and non-personal data as personal data, and make sure embedded systems let individuals access, delete, and make corrections to their data while safeguarding the privacy of others.
- Review and update the system's privacy controls on a regular basis to address new risks and weaknesses.
- When possible, safeguard data using anonymisation or pseudonymisation procedures.
- Work together with legal teams to comprehend and properly apply privacy legislation.
- Encourage and include privacy-enhancing technologies (PETs) in system design.
- Perform Privacy Impact Analyses (PIAs) at the beginning of the system design process.
- Create mechanisms that let users exercise their data rights, including the ability to view, correct, or delete their data.

A.7 Well-being

Employee well-being encompasses various aspects, including satisfaction, stress reduction, positive social interactions, and many others. According to IEEE's ethically aligned design, well-being refers to evaluating an individual's overall quality of life and external circumstances. A well-being assessment takes into account important aspects of a person's life, including happiness, achieving objectives, and generally operating well in their surroundings. However, there must be a way to define and measure the benefits we want to increase. However, system developers must define and measure the benefits they want to increase. Frameworks like the OECD Guidelines on Measuring Subjective Well-being and the OECD Better Life Index can serve this purpose. Although numerous well-being measures exist with different indicators, they do not reflect all well-being aspects. Therefore, system developers should explore other frameworks and select relevant ones for their systems.

AI systems can significantly enhance collaboration, cooperation, and communication among employees in a manufacturing context. For example, AI-powered communication tools can facilitate more effective information sharing and collaboration by providing real-time data, recommendations, and insights that help employees make better decisions and solve problems collaboratively.

Moreover, AI systems can be designed to promote social interaction and support by connecting employees with shared interests, goals, or challenges, fostering a sense of community and camaraderie. AI systems can also help to identify and address potential sources of conflict or miscommunication, promoting a more harmonious and supportive work environment.

There are different aspects to consider, and three kinds of indicators can measure this; - Subjective, Objective, and Composite. Subjective indicators, such as the World Happiness Report and the European Social Survey, help better understand psychological well-being within a country's population. Objective indicators, like the Better Life Index and the Sustainable Development Goals Indicators, typically measure income, health, consumption, crime, and more. Composite indicators, such as the UN's Human Development Index and the Social Progress Index, combine subjective and objective measures to produce a single measure reflecting both indicators.

Although AI technologies can be developed legally, profitably, and safely, they may not always contribute positively to human and environmental well-being. This means that technology created with the best intentions can still negatively affect people's mental health, emotions, sense of self, and other well-being dimensions. System developers should ensure that their stakeholders know well-being concepts and metrics as possible determinants for developing, deploying, marketing, and monitoring their technology.

AI systems provide a fantastic possibility for societal improvement on all fronts. However, they may cause damage unwittingly or on purpose. It is essential to weigh potential advantages, drawbacks, and trade-offs, yet it might be difficult to predict every relevant direct and indirect effect. However, it is advisable to look at case studies of related items and their effects on health, as well as any consequences that could be relevant.

Employee Role in Assessing Well-being

After analyzing the STAR deliverable 2.9 "Report on Co-Design Workshops and Focus Groups-Initial version"⁹, IEEE Ethically Aligned Design First Edition, EU Commission's Ethics by Design, and Ethics of Use Approaches for Artificial Intelligence, EU Commission's the following considerations were made for each role.

Operators

- They may gauge well-being by seeing how the system affects their own and their co-workers' well-being.
- Take part in wellness activities and offer candid comments to assist the programs in improving.
- Seize the chance to express worries or ideas about their contentment, tension, or general well-being.
- Seek support from teammates and team leaders in managing their workload and stress levels.
- Take part in social gatherings and team-building exercises to create a positive work atmosphere and enhance general wellbeing.
- Operators can also report any problems with work-life balance, workload, or the usability of the system that may be having an adverse effect on their general wellbeing.

- Determine whether having access to clear and well-defined processes helps employees feel less stressed, more satisfied with their jobs, and more secure in their careers.

Team Leaders

- Actively communicate with their team members to understand their well-being, concerns, and needs.
- Conduct regular check-ins, provide support and resources to address work-related stress, and promote a healthy work environment.
- Ensure that the system is designed and deployed in a way that prioritizes the well-being of the operators and promotes a positive work experience.

System Developers

- Measure well-being by including elements that encourage positive user support and social connections. For instance, they can create channels for communication, instruments for cooperation, and systems for providing feedback which encourages productive teamwork and promotes a feeling of community.
- Take into account how the system could affect users' well-being and prioritize good user experiences while making design decisions.
- Modify their current development, marketing, and assessment cycles to include health-related issues at every stage of their operations.

Operations Managers

- Monitor key performance indicators for operator satisfaction, stress levels, and social interactions to gauge well-being. Identify whether the data is useful in shedding light on employee wellbeing and bringing up potential improvement areas.
- Examine trends and patterns relating to mental and physical stress using the information and KPIs that have been gathered. This evaluation can aid in the identification of possible problems and serve as a guide for the creation of strategies and actions to enhance procedures and advance employee wellbeing.
- Conduct surveys and anonymous feedback sessions often to evaluate employee happiness and well-being and to pinpoint areas for development.
- Implement programs that enhance employee well-being, such as flexible work hours, wellness initiatives, or team-building social activities.
- Monitor how well employees are performing and make sure their workloads are appropriate and balanced to avoid burnout.
- Create an environment where employees feel comfortable sharing their worries or ideas for improving their happiness and well-being.
- Ensure that the system is developed and implemented in a way that prioritizes the operators' well-being and fosters a satisfying working environment.
- Avoid isolating certain individuals in a way that makes it impossible for them to communicate socially or professionally.

A.8 Human Agency and Oversight

IEEE's Ethically Aligned Design defines human agency as the ability of individuals to make decisions and take actions based on their values, goals, and preferences. It is essential to preserve human agency in a manufacturing environment to ensure that employees use AI systems as tools to enhance their capabilities rather than being controlled or replaced by these technologies (Liu et al., 2021). This theme relates to safety and security, transparency, explainability and interpretability, and well-being.

The Asilomar AI principles, the guidelines for responsible AI development, emphasize that humans should choose how and whether to delegate decisions to AI systems to achieve human-chosen objectives (AI Principles, 2017). To better understand how AI helps retain the user's autonomy over their work, autonomy can be divided into scheduling autonomy, decision-making autonomy, and methods autonomy (Morgeson & Humphrey, 2006).

1) Scheduling autonomy refers to the extent to which an AI system allows employees to decide how to schedule their work (STAR D6.11 "Techno-Economic and Socio-Economic Evaluation-Initial version"). Employees can gain more control over their work schedules by leveraging AI-based tools, such as smart scheduling systems and automated prioritisation. Moreover, AI systems can learn from individual preferences and work patterns to optimize schedules, increasing flexibility and adaptability.

2) Decision-making Autonomy refers to how an AI system allows employees to make autonomous decisions (STAR D6.11 "Techno-Economic and Socio-Economic Evaluation-Initial version"). AI-driven analytics and insights can empower employees to make informed decisions based on data and expert recommendations. AI systems should be designed to provide support and recommendations rather than dictating decisions, ensuring that employees maintain control over their choices.

3) Methods Autonomy refers to the extent to which an AI system enables employees to have considerable independence and freedom in performing their work (STAR D6.11). AI systems can offer a range of tools, options, and techniques for completing tasks, allowing employees to choose the best approach based on their expertise, skills, and preferences.

Maximising the benefits of AI systems in the workplace requires finding a balance between AI assistance and preserving human autonomy. This balance ensures the employees maintain control over their work and contribute to their overall job satisfaction.

Technology Misuse

As said by IEEE's ethically aligned design first edition, as AI systems become more sophisticated and complex, the potential for misuse also grows, posing risks such as privacy violations, biased decision-making, and safety hazards. Preserving human agency allows employees to maintain control over AI systems and make informed decisions based on their expertise and judgment. Human oversight is needed to enable humans to oversee AI systems. These can be achieved through a human-in-the-loop (HITL) governance strategy. HITL enables humans to identify misbehavior by autonomous systems and take corrective actions, providing accountability and promoting trust in AI systems (Bird & al., 2020). Additionally, implementing a "kill switch" allows human operators to interrupt or divert a system to prevent the system from escaping outside control and causing harm (Bird & al., 2020).

Employee Role in Assessing Human Agency

The IEEE's ethically aligned design first edition and the EU Commission's Ethics By Design and Ethics of Use Approaches for Artificial Intelligence were analysed for the following assessment considerations.

Operators

Operators play a crucial role in preserving human agency when using AI systems. They should be trained to use AI systems responsibly and be aware of potential misuse. By providing feedback on the system's performance and usability, operators can help to ensure that AI systems support human agency and do not undermine employee autonomy.

System developers

- System developers are responsible for designing AI systems that protect the human agency and allow end users and those affected by the AI system to maintain control over basic decisions about their work.
- Developers should ensure that AI applications do not autonomously make decisions about fundamental personal issues without human oversight and options for redress, which humans typically decide through free personal choices.
- It is imperative that system designers create tools that do not subjugate, force, mislead, manipulate, objectify, or dehumanize workers.
- Developers should tell operators and other individuals impacted by the AI system about the logic underlying the AI's decision-making process in order to foster openness and trust.
- System designers must consider possible abuse and create solutions that reduce the likelihood of such events.
- Create safe systems with strong access controls, encryption, and other security measures to thwart unwanted access while maintaining control of the system's operations by human operators.
- Use monitoring and logging tools to keep tabs on user behavior and system performance. This will help you spot possible problems or misuse right away.
- Identify the requirements and concerns of operators, team leaders, and operations managers in order to make that the AI system is built to enable human agency and supervision.

A.9 Task and Skill Variety

Task variety refers to the range of different tasks that employees perform within their job roles, while skill variety refers to the range of skills and abilities employees utilize to complete these tasks (Morgeson & Humphrey 2006). In manufacturing, task and skill variety are essential for employee engagement, job satisfaction, and overall performance. Therefore, this topic is linked to the theme of well-being.

AI-enabled systems offer significant potential for enhancing manufacturing task variety and skill variety. These technologies can automate repetitive tasks, allowing employees to focus on more complex and varied tasks that require problem-solving, creativity, and human

intuition. Additionally, AI systems can provide real-time data, insights, and recommendations that empower employees to make more informed decisions, broadening their skill sets and enhancing their expertise.

However, integrating AI systems also presents challenges for task and skill variety. There is a risk that the automation of certain tasks may lead to reduced skill development opportunities and the erosion of employee autonomy (Parker & Grote, 2022). Thus, AI systems should be designed to support a variety of tasks and skill development opportunities for employees. This can be achieved by creating systems adapted to different tasks and facilitating collaboration, enabling employees to learn from each other and develop new skills.

Employee Role in Assessing Task and Skill Variety

The STAR Deliverable D2.9 “Report on Co-Design Workshops and Focus Groups - Initial version” was analysed to bring out the following assessment considerations.

Operators

- Provide feedback on job preferences, aspirations, and opportunities for skill development in the context of AI system deployment.
- Participate in training programs designed to enhance skills and adapt to new technologies.
- Engage in task rotation, leveraging AI systems to diversify tasks and reduce monotony.

System Developers

- Design AI systems that enable task rotation and skill variety, considering employees' preferences and aspirations.
- Develop recommender systems that provide personalized training paths based on current skills, experience, and desired skillset.
- Ensure AI systems facilitate skill development and job enrichment by supporting diverse tasks and learning opportunities.
- Design AI systems that consider workers' historical performance and skills for task assignments.

Team Leaders

- Analyse team members' historical performance and skills to facilitate appropriate task assignments.
- Promote task rotation to ensure that employees can learn new skills and improve existing ones.
- Collaborate with system developers to ensure AI systems support diverse tasks and skill development opportunities.

Operations Manager

- Implement policies that promote task rotation and skill variety within the organisation.
- Allocate resources for continuous training and skill development, considering both current and future needs.

- Collaborate with system developers to ensure AI systems are designed and deployed to support diverse tasks and skill development by considering the future needs of the organisation, including technological advancements and market fluctuations.

A.10 Ergonomics and Physical Demand

In a manufacturing context, ergonomics and physical demands are essential factors to consider for the well-being of employees. According to The International Ergonomics Association, ergonomics is the field that studies how people interact with other system components and the profession that uses theory, principles, information, and design techniques to enhance both human well-being and system performance. On the other hand, physical demands refer to the level of physical effort required to perform tasks within a work environment (Morgeson & Humphrey 2006).

With many tasks in manufacturing involving repetitive motions, heavy lifting, and extended periods of standing or sitting, ensuring that workstations and equipment are designed with human well-being in mind is crucial. By considering body dimensions, posture, muscular strength, and movement in a workstation design, the risk of injury can be reduced, fatigue minimized, and overall worker satisfaction enhanced (ISO, 2016). Employees should be able to alternate their posture for prolonged tasks, such as switching between sitting and standing (ISO, 2016).

By incorporating ergonomics into the design process, companies can create work environments that reduce the likelihood of work-related injuries, such as musculoskeletal disorders (Hignett, Wilson & Morris 2005), common in manufacturing settings. Furthermore, ergonomically designed workspaces and equipment can improve worker efficiency, reduce errors, and increase productivity.

Poor ergonomics and high physical demands can severely affect employee well-being and job satisfaction. Employees exposed to inadequate ergonomic conditions are more likely to experience discomfort and fatigue and develop chronic injuries or illnesses. This affects the individual and can lead to increased absenteeism, decreased productivity, and higher worker turnover in the organisation (Laitinen, Saari, Kivistö & Rasa 1998).

In designing AI systems for manufacturing, it is essential to consider ergonomic principles and physical demands. This includes creating user interfaces that are intuitive and easy to navigate, developing comfortable and safe hardware, and designing software that reduces the cognitive load on operators.

Developing AI systems that support and enhance employee well-being is a priority. By minimising physical strain and repetitive tasks, AI systems can help alleviate the burden on workers in manufacturing and reduce the risk of injury. For example, AI-powered collaborative robots (cobots) can work alongside human operators to perform repetitive or physically demanding tasks, allowing employees to focus on more complex and engaging activities.

Deploying and operating AI systems that optimize workstation design, layout, and workflows can significantly reduce physical demands and promote ergonomic best practices. AI systems can monitor employee movements and provide real-time feedback on proper ergonomic practices, helping to reduce the risk of injury and improving overall well-being.

Employee Role in Assessing Ergonomics and Physical Demands

The ISO standards ISO 2016, 2018, and STAR Deliverable D2.9 "Report on Co-Design Workshops and Focus Groups - Initial version" were analysed to bring out the following considerations

Team Leader

- Evaluate the variety in tasks assigned to employees and the balance between repetitive and diverse activities.
- Assess the effectiveness of break schedules in reducing fatigue and maintaining employee well-being.
- Gather employee feedback about their satisfaction with task variety and the overall work environment.

System Developer

- Examine how workstations, tools, and controls are made to make sure that they reduce the possibility of human mistakes and take into account worker physical traits.
- Evaluate the controls' usability and suitability for the tasks carried out by personnel.
- Gather input from the staff on the ergonomics and usability of the tools and workstations.
- Evaluate the accessibility and functionality of tools that require little setup. Consider if the equipment on hand make it possible for employees to complete their responsibilities quickly and effectively, reducing physical demands and fostering a pleasant work environment.
- Collect feedback on how well the tools fulfill physical and ergonomic needs from operators and operations managers. Examine if the equipment makes the workplace safer and more comfortable, lowering the likelihood of accidents and enhancing general well-being.

Operations Manager

- Analyse workload distribution to ensure employees are neither overloaded nor underloaded and identify areas where adjustments are necessary.
- Evaluate the effectiveness of task rotation and changes in activities in maintaining employee engagement and well-being.
- Monitor employee feedback on the overall work environment, including workload, task variety, and the job's physical demands.
- Measure staff engagement levels and how they relate to objectives for job growth or improvement. Higher involvement and dedication to the business may result from a more diversified and difficult work environment.
- Examine how job enlargement or enrichment affects the performance of the person and the team. Efficiency and productivity should rise as a result of a well-executed enlargement or enrichment plan without endangering worker wellbeing.

A.11 Other Considerations for Human-centricity (Problem Solving, Information Processing, Interdependence, Feedback from job/Others, and Ease of Use)

Enhancing worker satisfaction, productivity, and overall efficiency in manufacturing requires focusing on key factors such as problem-solving, information processing, interdependence, ease of use, and feedback. These factors are further amplified with the integration of artificial intelligence (AI) in manufacturing environments.

The basis of industrial operations is problem-solving, which involves coming up with original ideas and solutions, identifying and fixing nonroutine issues, and avoiding or correcting mistakes. (Jackson et al., 1993; Wall, Corbett, Clegg, Jackson, & Martin, 1990). Efficient information processing is crucial due to the large volume of data in manufacturing processes, enabling meaningful insights for decision-making. Interdependence among roles and departments ensures smooth coordination and workflow. Interdependence measures how much a task depends on other people and how others rely on it to get the job done. (Kiggundu, 1981). The ease of use of systems and tools impacts their adoption and effective utilisation.

Feedback is an essential part of problem-solving, providing valuable information about operations' effectiveness and areas for improvement. It can come from the job or others in the organisation (Hackman & Lawler, 1971). These factors collectively influence worker satisfaction and productivity, as effective problem-solving tools, constructive feedback, and user-friendly systems contribute to job satisfaction and productivity. Moreover, efficient information processing and a high degree of interdependence among different roles contribute to the overall efficiency of manufacturing operations.

AI plays a significant role in enhancing these elements in manufacturing. AI systems assist in troubleshooting and problem-solving by offering relevant data, predictive analysis, and actionable insights for faster and more accurate decisions. Real-time feedback on job performance, process efficiency, and system status promotes continuous learning and improvement. AI systems process complex data swiftly and accurately, presenting it in a user-friendly manner to aid decision-making. AI technologies like collaborative robots and AI-driven communication tools can significantly enhance interdependence in the workplace. The ease of use of AI systems is crucial for seamless integration. Intuitive, user-friendly, and easily accessible AI systems minimize the learning curve and resistance to adoption, facilitating their integration into daily operations.

In developing AI systems for manufacturing industries, system developers must consider the potential negative impacts of over-dependence on technology. The excessive use of technology can lead to feelings of stress and overwhelm among employees, resulting from constant connectivity, a wide range of applications to navigate, multitasking, information overload, uncertainty, and technical issues (Chala et al., 2018; Coupe, 2019). These factors, known as job demands, can contribute to the increased mental and psychological effort required to cope with the technology-driven work environment.

System developers should prioritize employees' well-being and mental health by designing AI systems that balance automation and human control. They should aim to reduce unnecessary complexity, streamline processes, and provide adequate support to ensure the technology is

user-friendly and easy to comprehend. By addressing these concerns, system developers can alleviate the stress associated with technology use and promote a healthier work environment.

Employee Role in Assessing Other Considerations of Human-centricity

The articles of Baker and Zuech (2022), Laker (2022), Makarius, Mukherjee, Fox & Fox (2020), Tong, Jia, Luo & Fang (2021), and STAR Deliverable D2.9 "Report on Co-Design Workshops and Focus Groups - Initial version" were used as starting points to bring out the following assessment considerations.

Operators:

- Evaluate the usefulness of the resources and tools the AI system offers for problem-solving. Examine if the system provides useful data for troubleshooting and problem-solving, including predictive analysis and actionable insights.
- Provide feedback about the system's capacity to provide real-time feedback on job performance, process effectiveness, and system status. Examine if the provided feedback is timely, informative, and contributes to ongoing development.
- Assess the system's ease of use, taking into account its accessibility, intuitiveness, and user-friendliness. Provide feedback on any difficulties you may have had using the system and make suggestions for enhancements to make it easier to use.
- Assess whether simulation tools that can adjust to real-time changes in the manufacturing process are readily available. Analyse if using these technologies enables operators to model various scenarios and modify their actions accordingly, improving their capacity for problem-solving and lowering stress.

Team Leaders:

- Assess the impact of AI systems on problem-solving within the team. Evaluate whether the system supports team members in diagnosing and solving nonroutine problems and encourages generating innovative solutions.
- Gather feedback from team members regarding the effectiveness of feedback received from the AI system and its contribution to individual and team performance improvement.
- Evaluate the level of interdependence facilitated by the AI system. Assess whether the system promotes collaboration, coordination, and effective communication among team members and departments.

System Developers:

- Assess the AI system's capacity for accurate and timely processing of complicated data. Examine the system's ability to manage vast amounts of data, analyse it well, and present it in a way that facilitates decision-making.
- Examine the system's ease of use from a technological standpoint. Analyse how well the system integrates with the existing infrastructure and how simple it is to configure and maintain.

- Include characteristics and capacities for problem-solving in the design of the AI system. Make that the system offers pertinent information, analytical tools, and decision assistance to help people solve problems successfully.
- Collect feedback from system engineers, team leaders, and operators to better understand their individual feedback requirements. Make sure the system supports the gathering, analysis, and efficient delivery of feedback to improve the performance of individuals and teams.
- Develop the system with an emphasis on information processing requirements, making sure it can handle and process complicated data effectively and present it in an understandable and straightforward manner.

Operations Managers:

- Assess the impact of AI systems on problem-solving across the organisation. Evaluate how the system supports problem-solving at different levels, from operators to team leaders and beyond.
- Determine the extent to which the AI system has enabled interdependency throughout the company. Analyse if the system encourages coordination, cooperation, and good communication across various roles and departments, contributing to the success of the company as a whole.
- Evaluate the availability of historical data on the output system's performance. Consider if the system offers operations managers insightful information about the system's historical performance, enabling them to make data-driven decisions to increase efficiency and well-being.

A.12 Annex Conclusion

By fostering a human-centric approach to AI system development, deployment, and operation, we can harness the full potential of these technologies while ensuring the well-being, autonomy, and skill development of workers. This training manual will equip you with the necessary tools and knowledge to create a harmonious integration of AI systems in manufacturing, where human needs and values are at the forefront.

By prioritising human needs and values, we can create a future where AI and human collaboration thrive. The success of AI-driven systems lies not only in their technological capabilities but also in their ability to enhance human experiences, promote a healthier work environment, and foster skill development. With the knowledge gained from this training manual, professionals in the manufacturing industry can lead the way in creating AI systems that truly prioritize human-centricity and contribute to a better and more sustainable future.

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