



MOTIVATEXR

Maintenance, Support & Operation Training using Immersive Virtual and Augmented Technology for Efficiency with XR

D3.3 INDUSTRIAL USER REQUIREMENTS AND USE-CASE SCENARIOS

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Abstract	This report outlines the process and outcomes of a task aimed at defining, prioritizing, and updating user requirements, as well as developing use-case scenarios for various categories of end-users, including authors, trainers, support teams, and technicians across different industrial sectors. The task involved exploring these user requirements to extract specific operational needs and define pilot scenarios, alongside an evaluation framework to assess the system's efficiency and adaptability to diverse industrial contexts.
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EXECUTIVE SUMMARY

This deliverable represents the first release of the work aimed at investigating and defining user requirements and Use-Case scenarios within the MotivateXR project. The objective of this work is to define, prioritize, and continually update the user requirements for various industrial scenarios outlined in the project.

To begin, a series of online meetings were conducted with each Pilot owner to better define their respective use-case scenarios. Based on the insights gained, a questionnaire was drafted to gather User Needs. This process involved all technical partners before submitting the questionnaire to the Pilot owners. The information collected was summarized and aligned with the description of each use-case scenario. A user-centered approach was adopted, beginning with the definition of user needs and evolving toward the determination of both user and system requirements. Stakeholders (technology and pilot owners) were engaged throughout the process from the early stages.

To prioritize user needs for each use-case, the Analytic Hierarchy Process (AHP) approach was implemented. During dedicated workshops, semi-structured interviews were conducted to rank user needs. A preliminary list of system requirements was developed and organized based on the importance rankings provided by the Pilot owners. While some initial conclusions regarding system requirements have been drawn, further work is necessary to finalize both the requirements and their prioritization for each Use-Case scenario in the MotivateXR project.

The approach proved valuable not only for the Pilot partners but also for all technical partners involved. It provided an opportunity to refine Use-Case definitions and facilitated discussions with technicians, operators, and end-users, helping to identify common issues in adopting XR technology in production environments.

The goal of defining "Industrial End-user Requirements and Use-case Scenarios" has been achieved, resulting in a complete list of system requirements, which is presented in this document. These findings revealed that most system requirements are common across the different Pilots, irrespective of the industrial sector. These common requirements primarily pertain to content creation and usage, with typical XR applications allowing interaction with text, files, media, and 3D models. For training purposes, animations and basic interactions are considered essential. Additionally, XR systems should facilitate on-site understanding of step-by-step procedures and provide access to official documentation. However, certain system requirements are specific to individual industrial applications.

For example, both the home appliance and aluminum industries exhibit similar applications, where XR systems are intended for training and on-site access to technical documentation. However, while the assembly processes for white goods are complex, windows and frames involve less complexity.

While many Use-Cases emphasize the benefits of augmented reality (AR) solutions, one is likely to focus more on virtual reality (VR) solutions, particularly for training, multi-user applications, and troubleshooting simulations. Across all Pilots, there is a general demand for simplified solutions that

allow for easy document and file interaction, with hands-free gestures being highly desirable. It is also important to ensure offline functionality and support for both indoor and outdoor procedures.

Additionally, most Pilots have expressed the need for recording and monitoring procedure progress. However, this requirement may raise social, ethical, and legal concerns, which will need to be carefully analyzed.

In the coming months, several activities will be carried out to finalize the User and System requirements, as well as the Use-Case scenarios:

- All technical partners will review the preliminary User and System requirements to provide feedback on prioritization and descriptions.
- Technical workshops will be organized to review the distribution of User Needs and Requirements within the technical tools, ensuring interoperability within the MotivateXR framework.
- A detailed methodology for validating System requirements will be developed to establish a clear process for demonstrating the achievement of project goals.
- Social, ethical, and legal analysis outcomes will be considered in a second release of the user and system requirements list, where risks will be addressed, and countermeasures defined.
- So far, the analysis has been high-level, avoiding detailed exploration of specific XR tool functionalities required by each Use-Case. In the next phase, technical workshops will delve deeper into the System Requirements already identified, refining them or adding new ones where necessary to meet project objectives.
- Finally, Use-Case scenarios will be further detailed to map each step of the operations and the users involved, providing a step-by-step description of the expected tasks for the operators.

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ABBREVIATIONS

AAA	Architectural Aluminum Academy
AMM	Aircraft Maintenance Manual
AMR	Autonomous Mobile Robots
AR	Augmented Reality
ATA	Specific part of the airplane subjected of maintenance
BIR	Bi-Rex
DMU	Digital Mock-Up
HGE	Hisense Gorenje Europe
MRO	Maintenance and Repair Operations
SPL	Spare Part List
SR	System Requirements
TSM	Trouble Shooting Manual
UN	User Needs
UR	User Requirements
UX	User Experience
VR	Virtual Reality
XR	eXtended Reality

INTRODUCTION

This report is the first release (Month 4th) of the work done in order to investigate and define user-requirements and Use-Case scenarios of MotivateXR project. The goal was to define, rank by priority, and keep updated the user-requirements for all the various industrial scenarios defined within the project. A second release, more exhaustive and updated, will be released on Month 19th (D3.4). All instruments, forms, excel files and dashboard annexed to this report, are available in the MotivateXR SharePoint and will be updated during the entire project execution.

The following section reports a description of the document structure that helps to understand all the steps of the process designed and implemented to extract specific functional and non-functional requirements for all Pilots. Firstly, a set of online meetings were organized to interview each Pilot owner to better define the relevant use case scenario. Starting from the best understanding of each Pilot, a specific questionnaire was drafted to collect user needs and finalized involving all technical partners, before submitting to the Pilot owners. All the collected information was then reported in a short summary together with the description of each Use-Case scenario. A user centered approach was used to identify User Requirements, starting from User Needs definition [1] involving, since the beginning and in the whole process, all the stakeholders (Technology owner and Pilot owner). The AHP (Analytic Hierarchy Process) [2] approach was implemented to help prioritize User Needs per each Use-Case scenario, as better explained in the following sections. A preliminary list of System Requirements has been drafted and organized in hierarchical order of importance based on Pilot owner ranking of User Needs. Some conclusions on the preliminary System Requirements have been already outlined, but further work will be done to finalize them, as well as their priority per each Use-Case Scenario envisaged in the MotivateXR project.

STRUCTURE OF THE DOCUMENT

In this section, a description of the report structure is provided. Main contents have been organized in three main sections and two Appendixes. More details on sections' content are reported below.

Section 1 – Materials and Methods: Within this section materials and methods used to better define Use-Case Scenario and extrapolate related user requirements are reported. Details on the process implemented for user needs identification up to analysis and translation into functional and non-functional system requirements are provided, as well as on the tools specifically developed and used for the MotivateXR project. Materials and methods used have been selected, keeping in mind that partners will continue to apply them and continuously review user requirements, to ensure that the solutions developed in the MotivateXR project fully meet user needs and stay at the forefront.

Section 2 – Results and Pilots analysis: The section is organized in five separate sub-sections, one per Pilot, where details about the Use-Case scenarios are provided and results of the implementation of the methodology and tools previously selected are reported.

Each Pilot subsection includes:

- A short textual description of the Scenario, with some pictures to help better understand the environment, the user and the activity to be performed.
- Answers to the online questionnaire.
- A list of the identified User Needs uniquely coded and sorted by priority. User Needs hierarchy and matrix filling criteria are provided to help understand the results given.
- A list of User functional and non-functional Requirements and System Requirements.

The section ends with a short recap of the most important information collected, giving an overall vision of all Use-Case scenarios.

Section 3 - Discussion and conclusion: Where final analysis, draw sums and summary tables of all Use-Case scenarios are provided together with a preliminary overall reading of the results.

Appendix A: Which includes the document prepared to help collect and prioritize User Needs, User Requirements and System requirements during the dedicated workshops.

Appendix B: Which includes tables with User Needs AHP matrices for each Pilot.

1 MATERIALS AND METHODS

User requirements represent the specific needs, expectations, and desires that users have for a product/service. To properly identify and analyze them is critical to developing a successful, user-friendly and application-appropriate product/service. Indeed, if a product or service meets the needs of the target audience, it is more likely to be successful in the market [3].

Identifying and analyzing user requirements can be done in various ways, such as surveys and interviews with potential users, market research to identify trends and needs of the target audience, observation and analysis of user behavior and needs when using similar products or services, user feedback and reviews of existing products or services, workshops and focus groups to discuss the needs and expectations of users, depending on the specific situation.

Within this section materials and methods used to better define Use-Case Scenarios and extrapolate related user requirements are reported. Details on the process implemented for user needs identification up to analysis and translation into functional and non-functional system requirements are provided, as well as on the tools specifically developed and used for the MotivateXR project.

Materials and methods used have been selected, keeping in mind that partners will continue to apply them and continuously review user requirements, to ensure that the solutions developed in the MotivateXR project fully meet user needs and stay at the forefront.

1.1 PILOT SURVEY

To precisely outline each Use-Case scenario of the MotivateXR project, a set of virtual meetings have been organized at the very beginning of the project, opened to all partners. Each Pilot owner was asked to provide a brief description of the company and the products and/or production workflow that could be positively affected by the MotivateXR project results, providing some hints on expectations, needs and desires.

Starting from the outputs of the meetings, a dedicated questionnaire was designed containing around 30 questions aimed at collecting most of the so-called “directly got” and “predictable” user needs for each specific use case.

Multiple choice questions have been chosen as the preferred way to collect information in a clear and easy-to-answer way, except in cases where this type of response was too reductive and open-ended questions were preferred. Questions were focused on aspects of interaction, usability, safety and technical requirements in general. The goal of the questionnaire was also to push Pilot owner into a deeper analysis of their Use-Case and the intended users, selecting the most valuable applications for MotivateXR technologies.

The complete list of submitted questions is reported below.

PILOT SURVEY – COMPLETE LIST OF QUESTIONS

- 1. Name and Surname**
- 2. Email**
- 3. Pilot: End User Company Name**
- 4. How long does the Task last:**
 - 1 to 10 minutes
 - 10 minutes to 1 hour
 - 1 to 4 hours, half shift
 - Typically, the whole shift, 8 hours
- 5. How long should the XR device information last:**
 - 1 to 10 minutes
 - 10 minutes to 1 hour
 - 1 to 4 hours, half shift
 - Typically, the whole shift, 8 hours
- 6. Does the operator need to have hands free during task execution?**
 - Yes
 - No
- 7. Does the operator need to wear PPE (Personal Protective Equipment) during task execution? If so, please select all those needed and, if not listed, report them**
 - PPE Gloves
 - Protective goggles
 - Helmet
 - Protective headphones Earphones and/or radio communication systems
 - Other.... Please specify which PPE is not listed
- 8. Does the operator need to use tools or machinery in task execution? If so, which ones?**
 - No tools

- Yes, the following tools (Specify)
- 9. Tools or Machinery used, short description**
- 10. The task is performed**
- Lying down
 - Knee position
 - Sitting Standing
 - On ladder or another challenging surface
 - Other
- 11. When performing the task, the operator**
- Always remains in the same position
 - Needs to move by walking and/or changing position
- 12. Is it possible to slightly reduce the operator's field of vision and/or to cover eyes sometimes and/or reducing the resolution of real environment (see through) during task execution?**
- Yes, most of the time
 - Yes, but only at certain times necessary for information retrieval
 - No, never
- 13. Are interactions with displays and/or LED lighting systems foreseen during the execution of the task? (we can have flickering and backlighting problem within XR)**
- Yes
 - No
- 14. It is possible to use voice commands to guide the operator**
- Yes
 - No
- 15. It is possible to send or receive data from operator's location (connectivity)**
- Yes
 - No
- 16. Is more than one person involved in the process?**
- Yes
 - No
- 17. Are tasks sequential and involve more than one operator, with specific specialization, please specify?**
- 18. Are task activities personal and linked to the individual operator, i.e. each operator must have his own viewer and work plan**
- Yes, several operators can complete a single task
 - Yes, the individual operator resumes on the next shift but must remember where he/she arrived
 - No, individual operator completes the task using different tools to remember progress
- 19. Could an unfinished task be completed later (personally or by a subsequent operator)? If so, should the task progress be recorded?**
- Yes
 - No
- 20. Credentials or authentication systems are required to access certain information useful in task execution**
- Yes
 - No
- 21. Is it necessary to track parts and objects interactions in the task execution?**
- Yes

- No
- 22. Is it necessary to track tools in the task execution?**
 - Yes
 - No
- 23. Are objects/products 3D complete models available?**
 - Yes, always
 - Yes, but only of certain products
 - No, we only have 2D documentation and paper documentation
- 24. The machinery in production is sensorised and provides data to the outside world**
 - Yes
 - No
- 25. The actual machinery has a graphic interface**
 - Yes
 - No
- 26. Are there any standards applied within your facilities and operational?**
 - Yes (List standards if available)
 - No
- 27. Are there any security rules applied within your facilities and operational?**
 - Yes (List security rules if necessary)
 - No
- 28. Which stakeholders are expected to be involved with the XR besides the main user (e.g. IT maintenance department, internal content supervisor)**
 - Only main user
 - Others (Specify)
- 29. Please specify both existing roles and new responsibilities**

The form was digitalized and submitted to Pilot owners as a link to a Microsoft SharePoint form (<https://forms.office.com/e/VYpfKKzMAf?origin=lprLink>).

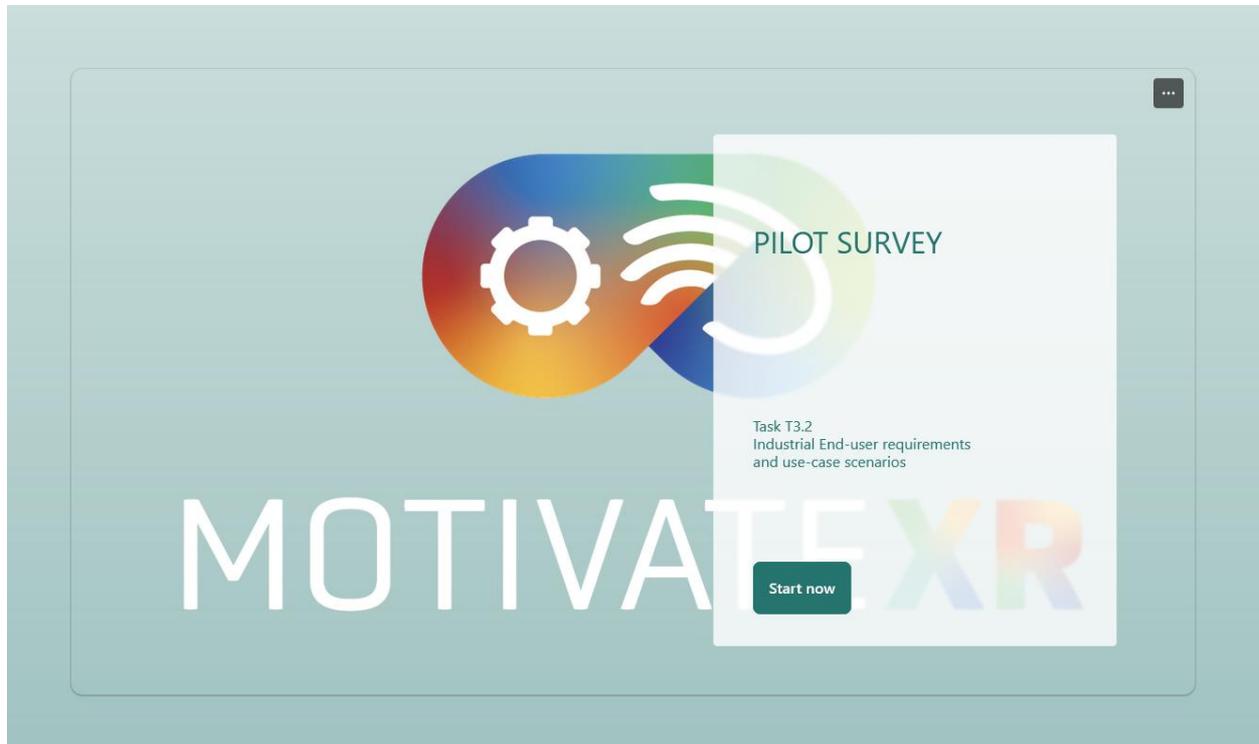


FIGURE 1: PILOT SURVEY FRONT PAGE LAYOUT.

In addition to the questionnaire, a short template to collect general information on the pilots has been produced and uploaded in the MotivateXR SharePoint platform ([PILOT SHORT SUMMUARY_v02.docx](#)). Pilot owners have been requested to provide a short description of the use case together with some representative pictures/images to help clearly outline the working environment as well as the intended end-users during the execution of the tasks selected.

To collect “unexpressed” and “unpredictable” user needs, an in-depth interview has been organized for each Pilot owner, where the participation of all the project partners has been highly recommended. The meeting was intended to gather qualitative insights on experiences, motivations, and detailed feedback, to check all answers, correct any misunderstanding or missing information, and compare them with the main scenario description. The approach used was a semi-structured interview [4]. All collected information is reported in Section 2 “Results and Pilots analysis”, in the relevant sub-section where Pilots details are provided.

Outputs of this preliminary analysis have been used to properly identify User Needs following the methodology described in the next subsection. Supplementary worksheets on Use-Case scenarios and specific user groups will be prepared in the upcoming months of the MotivateXR project. They would probably include a list of actions within tasks execution to better describe how final users are involved and identify every single phase where MotivateXR tool(s) could be effectively used to help the worker while performing his activity.

1.2 USER NEEDS IDENTIFICATION AND PRIORITIZATION

A comprehensive user needs analysis can help make data-driven decisions for product design and development as well as validating ideas for new features and enhancements, thus resulting in a product that delivers value to users and makes their jobs easier.

User needs analysis offers several benefits such as:

- Understand users pain points, so as to develop solutions that help users overcome them.
- Create data-driven product strategies to implement specific functions or features that will resonate with the end-users avoiding relying on intuition to make product-related decisions.
- Increase user satisfaction, so as to develop solutions that meet users' expectations and help them realize their goals thus reducing the risk of early abandonment of use.
- Get a clear idea of what challenges users could face when using the new product under development thus helping to pinpoint areas of friction in the user experience (UX) and devise ways to make the user journey more seamless.

In order to properly and uniquely classify User Needs a codification criterion has been defined. A unique code in the form of "UN-XXXX-PX" has been assigned to each User Need, where:

- "UN" is the acronym for Use Need.
- "XXXX" are four digits, starting from 0100, to enumerate the needs, leaving room for insertion of other needs in the future.
- "PX" is the acronym for Pilot number, where X varies from 1 to 5, providing a direct reference to the relevant Pilot.

An excel worksheet has been prepared to help identify and track the User Needs. Tables have been organized as shown in Figure 2, including per each User Need code (UN ID) also a description of the need (What do I want the XR system to do?) and the identification of the source of the need (Who is the person who expressed this need? Who benefits?).

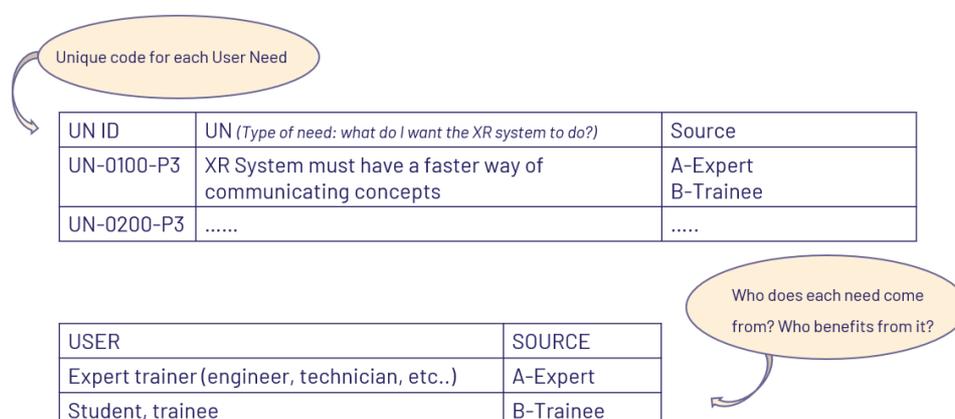


FIGURE 2: EXAMPLE OF USER NEEDS IDENTIFICATION TABLE.

Moreover, a categorization on the type of user needs has been also implemented using a color code. Four main areas have been identified as reported below (Table 1).

	Technical-functional specifications
	Manufacturing specifications & cost
	Safety specifications
	Aesthetic specifications

TABLE 1: COLOR CODE FOR USER NEEDS TYPE.

A preliminary list of User Needs (UN) has been drafted by CETMA for each Pilot, starting from the information gathered through the surveys and the in-depth interviews. Then the drafted excel files have been shared with Pilot owners, which reviewed and integrated the contents.

To go through a proper ranking of User Needs, the Analytic Hierarchy Process (AHP)¹ has been used. The AHP is one of the most popular and widely employed multicriteria methods. It is a structured group decision making technique for organizing and analyzing complex decisions. Using a specially designed format, each member of the team uses the process of a forced choice paired comparison to rate the relative importance of each pair of items, in this case the user needs.

Five focus groups have been defined, one per each Use-Case scenario, to go through the User Needs ranking process. Each group was composed by CETMA and the relevant Pilot owner and was asked to systematically evaluate the various User Needs by comparing them to each other two at a time. In making the paired comparisons, actual data could be used if available, otherwise subjective judgments about the user needs' relative importance in the specific scenario were suggested.

To help go through the AHP process, an excel worksheet has been prepared for each Pilot where all the identified user needs were reported in rows and columns using the same order as shown in Figure 3. A dedicated workshop has been organized for each Pilot to fill the matrix and participants have been guided through the process working row by row, asking whether the row element (i.e. UN-0100-P1) was less, equal or more important than the column element (UN-0200-P2).

A scale of 0-3, with the following definitions, has been used:

¹ https://en.wikipedia.org/wiki/Analytic_hierarchy_process

- **0** points = if the row element is **less important** than the column element.
- **1** point = if row element and column element have the **same importance**.
- **3** points = if the row element is **more important** than the column element.

Obviously where the row and column elements are the same, the value assigned was 1.

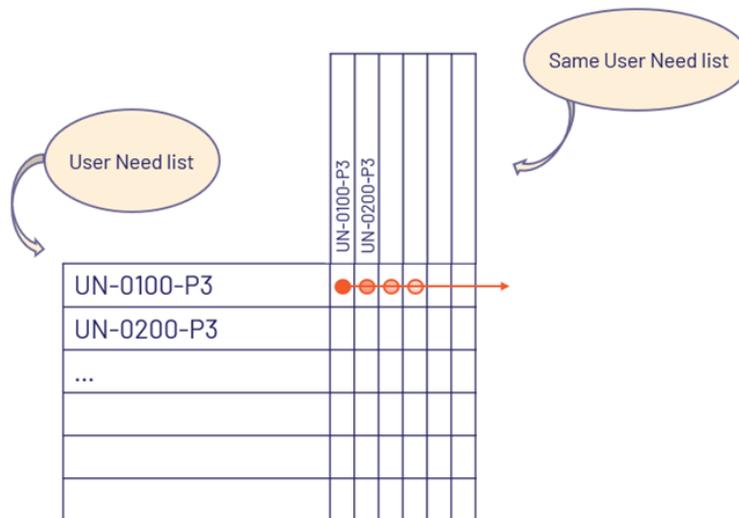


FIGURE 3: AHP MATRIX.

Here follows a short example of the quick guide provided to the participant of the workshops, which can be consulted in Appendix A.

Compilation example

I read row UN-0100-P3 and compare it (one by one) with the user needs in the columns. As I compare (one by one) I assign a value according to the following map:

Number meaning
3 = the row element is more important than the column element
1 = row element and column element have the same importance
0 = the row element is less important than the column element

In the example I indicated that, **for me user**, UN-0100-P3 is:

- More important than UN-0200-P3;
- Less important than UN-0300-P3;
- Less important than UN-0400-P3;
- It is as important as UN-0500-P3.

	UN-0100-P3 - Aluminum information	UN-0200-P3 - Gripping points information	UN-0300-P3 - Required PPE	UN-0400-P3 - Equipment guidance	UN-0500-P3 - Expert support request	UN-0600-P3 - Step by step guidance	UN-0700-P3 - Clear visibility of the procedure	UN-0800-P3 - Time coherence	UN-0900-P3 - Correct tool handling	UN-1000-P3 - Assembly process	UN-1100-P3 - Documentation access
UN-0100-P3 - Aluminum information	1	3	0	0	1						
UN-0200-P3 - Gripping points information		1									
UN-0300-P3 - Required PPE			1								
UN-0400-P3 - Equipment guidance				1							

FIGURE 4: AHP MATRIX SCORING EXAMPLE.

A final column reporting the sum of the scores given for each row has been added. These values have been normalized on a scale from 0 to 5, where 5 has been applied to the maximum value reachable by one User Need if it is assumed to be the most important among the others (max value = $3 * (\text{Total number of user need identified} - 1) + 1$).

A relative score in percentage has been calculated by dividing each normalized value by the sum of the normalized values and used to sort UNs accordingly.

To view the individual tables, please refer to Section 2 where the complete lists with the scoring are reported while the matrix developed for every single pilot is available in Appendix B.

1.3 USER REQUIREMENTS DEFINITION

Once the User Needs (UN) have been identified, User Requirements “UR” have been determined with the goal of giving visibility of the strategies expected and integrated into the system so that the user needs expressed for each pilot are accommodated.

In order to properly and uniquely classify User Requirements as already done for User Needs, a codification criterion has been defined. A unique code in the form of “UR-AAAA-XXXX-PX” has been assigned to each User Requirements, where:

- “UR” is the acronym for Use Requirement.
- “AAAA” is the acronym to discriminate between functional and non-functional requirements:
 - FUNC for Functional requirement: these requirements relate to the specific functions and features that a product or service should offer to meet the needs of the users;
 - NFUN for Non-functional requirement: these requirements relate to aspects such as usability, performance, security, and reliability, which are important for the success of a product or service but are not directly related to the actual functions and features.
- “XXXX” are four digits, starting from 0100, to enumerate the requirements, leaving room for insertion of other requirements in the future release of the deliverable.
- “PX” is the acronym for Pilot number, where Y varies from 1 to 5, providing a direct reference to the relevant Pilot.

UR ID	UR (<i>HOW do I accommodate the user?</i>)	DESCRIPTION	NOTES	UN REFERENCE
UR-FUNC-0100-P3	XR procedure	Guided visualization of the procedure		UN3-0100-P3
UR-NFUN-0200-P3	Easy to use	The system needs to be usable by non-experts	The end user does not have to worry about their students' level of technological knowledge

FIGURE 5: EXAMPLE OF USER REQUIREMENTS TABLE.

As shown in the figure above, an excel worksheet has been prepared and circulated to help define User Requirements, where a short title is provided for each UR, together with a description of the requirement, and the possibility to add notes if necessary. The “UN reference” column reports the user needs that underlie each requirement.

User Requirements have been then prioritized, based on the importance of the UNs to which they refer, reporting the level of priority also in the definition of System Requirements, as described in the next sub-section. Prioritization of URs ensures that the most important User Needs are met and resources used effectively. Obviously, a regular review of URs is envisaged to ensure they remain relevant and up to date as User Needs could change or be refined during the project execution.

1.4 SYSTEM REQUIREMENTS DEFINITION AND PRIORITIZATION

In order to be able to provide all the technical elements necessary for the development of the XR system, System Requirements are finally identified and listed.

As in the previous descriptions of UN and UR, system requirements follow a unique code structured in the same way: they are identified by the acronym “SR”, followed by the usual four digits “XXXX”. Finally, the reference to the specific pilot is given through the acronym “PX” or, if the system requirement is requested by all Pilots with the acronym “AP” (All Pilots).

SR ID	SR (<i>WHAT the system must have/do to achieve URs?</i>)	DESCRIPTION	VERIFICATION METHOD*	UR REF.	PRIORITY
SR-0100-P3	3D Models	File extension compatible with the XR player	D	UR-FUNC-0100	M
SR-0200-P3	

FIGURE 6: EXAMPLE OF SYSTEM REQUIREMENTS TABLE.

As for URs and UNs, an excel worksheet has been prepared and circulated by CETMA. In addition to the unique code associated with each SR, a brief title, a description of the requirement, and a column containing the URs to which each SR refers is given. Two additional columns have been inserted:

- Verification Method (VM): contains suggested ways to verify the execution of the functions described and then integrated into the XR system. Table 2 shows the description for each verification method.

VM	
Inspection (I)	Visual verification (UI, Shapes, layouts, etc.)
Analysis (A)	When other methods are not appropriate or too cumbersome. Based on judgments
Demonstration (D)	Verification of system behavior also through images or screen captures.
Test (T)	Measuring product performance and functions under representative environments.

TABLE 2: VERIFICATION METHODS.

- Priority: indicates the priority of integrating the described functions within the XR system, taking advantage of the MoSCoW methodology [4]. MoSCoW analysis is a method for clustering items into four primary groups: *Must Have*, *Should Have*, *Could Have*, and *Wish to Have*. It was created by Dai Clegg and is used in many Agile frameworks. Priority groups are further detailed below:
 - Must have (**M**): items that are vital and must be implemented into the system. Without them the project becomes useless.
 - Should have (**S**): items that are important to the project, but not mandatory. These items support core functionality but may wait until a second increment of development.
 - Could have (**C**): items that are not essential for reaching the project objective, but nice to have. They have a small impact if left out.
 - Wish to have (**W**): items that don't present enough value and can be deprioritized and considered for future phases of the project.

An explicative diagram of the interrelation between User Needs, User Requirements, and System Requirements is shown in Figure 7.

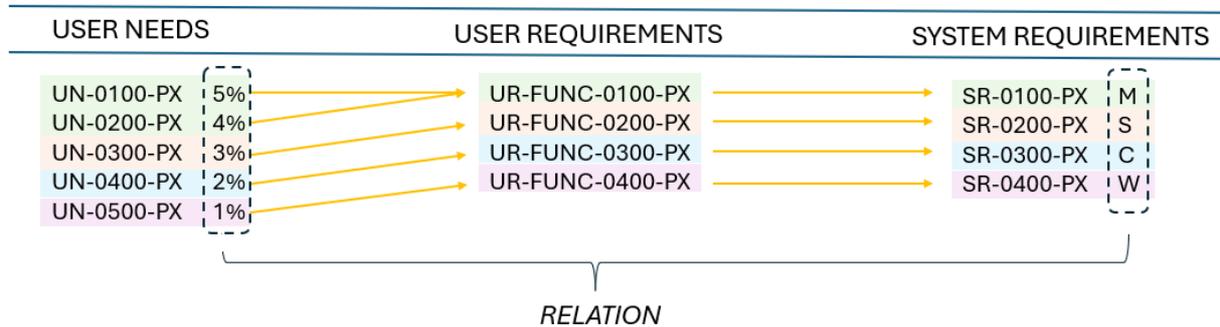


FIGURE 7: UN, UR AND SR RELATION SCHEME.

A generalized ranking criterion has been adopted to correlate User Needs priorities expressed in relative score to the MoSCoW priority groups, as reported below:

- For UN-XXXX-PX relative scores higher than 3.5%, the relevant SR-XXXX-PX can be classified as “Must Have (M)”.
- For UN-XXXX-PX relative scores ranging from 2.5% to 3.5%, the relevant SR-XXXX-PX can be classified as “Should Have (S)”.
- For UN-XXXX-PX relative scores ranging from 1% to 2.5%, the relevant SR-XXXX-PX can be classified as “Could Have (C)”.
- For UN-XXXX-PX relative scores ranging from 0 to 1%, the relevant SR-XXXX-PX can be classified as “Whish to Have (W)”.

In cases where a UR was linked to more than one UN, the priority level of the related SR has been evaluated on the average of the UNs scores or based on the projected needs and priorities expressed by the Pilot owner.

Within the same MoScoW priority group SRs have been further prioritized based on the relative score of the relevant User Need.

2 RESULTS AND PILOTS ANALYSIS

This section is focused on the definition of Use-Case Scenarios and on the results obtained from the application of the previously described methodology to define User Needs, User Requirements and System Requirements. For simplicity one sub-section per Pilot has been created using the following nomenclature:

- Pilot 1 - Aerospace Industry.
- Pilot 2 - Home appliance Industry.
- Pilot 3 - Aluminum Industry.

- Pilot 4 - Electric Distribution Industry.
- Pilot 5 - Robot-human hybrid manufacturing.

Some pictures have been included to facilitate the understanding of real-working environment for each application. In the next release of this deliverable (D3.4 expected at Month 19th) a new set of pictures with more details on each step of the task/procedure performed in every industrial application considered within the MotivateXR project will be included.

2.1 PILOT 1 – AEROSPACE INDUSTRY

The Aeronautical Pilot will be centered on technician Training for maintenance and repair operations (MRO). This activity is currently performed using both Theoretical and Practical courses using conventional environment for training. The main goal within the Motivate XR project is to implement XR tools to simplify training activities while improving access to documentation and new scenarios simulation.

2.1.1 SCENARIO DESCRIPTION AND QUESTIONNAIRE RESULTS

Aerospace Valley is the leading European competitiveness cluster in the aerospace sector serving 3 strategic sectors in Occitanie/Pyrénées-Méditerranée & Nouvelle-Aquitaine regions. It contributes to the development and competitiveness of its 830 members through innovation by promoting collaborative research and development projects. With its diverse ecosystem of leading groups, start-ups, SMEs, research laboratories, public actors, academic institutions and training organizations, Aerospace Valley is the only community in the world that brings together all the actors in the value chain from all segments of the aeronautics and space sector.

As already mentioned, the Aeronautical Pilot will be centered on technician Training for maintenance and repair operations (MRO). The actual procedure for training activities has been provided by Aerocampus Aquitaine during the in-depth interviews conducted by CETMA, in which the contents of the short summary and questionnaire results have been analyzed.

Actual training rooms for theoretical courses are based on PC and screen and desktop interaction. Future applications could be entirely managed only in a Virtual Reality environment.

This use case scenario will be specifically focused on practical courses. In real-world practice, students have at their disposal the aircraft, and all the tools necessary for the part they will work on. They also have technical documentation on the airplane parts and sub-parts including Aircraft Maintenance Manual (AMM), which is the most used, and the Trouble Shooting Manual (TSM). The AMM is dedicated to scheduled maintenance and the TSM is used in case a problem is found.

The maintenance is usually performed on a specific part of the airplane, called ATA. Each ATA has its own specific operations, which are detailed in the ATA Chapter of the AMM. For these operations, the manual details the part involved in the maintenance, the tools needed, and the sub-operations to be performed.



FIGURE 8: ACTUAL TRAINING CLASSROOM.



FIGURE 9: AIRPLANE DIGITAL TWIN

VR training should follow the same approach, with the advantage that could be performed everywhere without the necessity to immobilize real aircrafts for a long time. Main difference is that trainees would interact with a Digital Mock-Up (DMU) of the airplane while wearing VR headset or while working on desktop computer in their classroom. Trainees would be able to go through the AMM and interact with the DMU, but restrained to the specific scenario developed by the trainer. Only a few interactions could be performed with the entire airplane.

Actually, trainees are always supported by trainers which help, guide and orient them to improve the efficacy of the training giving them feedback and instructions in real time. The possibility to provide this level of expert support is highly demanded also in VR training.

Moreover, in the actual practical training working groups are fostered to help increase the capability of trainees to work as a team. Groups are typically made of two - three people working on the same task and usually two groups could be working on different tasks at the same time in the same scenario and environment. This level of collaboration is required in VR training in order to enable more than one trainee to work in parallel on the same task and more than one group of trainees working in the same scenario but on different tasks. Simulation of radio is not mandatory, but in real-environment could happen.

Further information has been gathered from answers provided to the questionnaire submitted, which are reported in Table 3.

QUESTIONS	ANSWERS
How long does the Task last:	1 to 4 hours, half shift;
How long should the XR device information last:	1 to 4 hours, half shift;

Does the operator need to have his hands free during task execution?	Yes
Does the operator need to wear PPE (Personal Protective Equipment) during task execution?	No PPE
Does the operator need to use tools or machinery in task execution? If so, which ones?	Yes; In virtual mode, trainees need to have common and specific tool depending the tasks in scenarios.
The task is performed	Standing; some task needs Knee position and Sitting.
When performing the task, the operator	Always remains in the same position
Is it possible to slightly reduce the operator's field of vision and/or to cover eyes sometimes and/or reduce the resolution of real environment (see through) during task execution?	Yes, most of the time
Are interactions with displays and/or LED lighting systems foreseen during the execution of the task? (we can have flickering and backlighting problems within XR)	No
Is it possible to use voice commands to guide the operator?	Yes
It is possible to send or receive data from operator's location (connectivity)	No
Is more than one person involved in the process?	Yes
Are tasks sequential and involve more than one operator, with specific specialization, please specify?	Yes
Are task activities personal and linked to the individual operator, i.e. each operator must have his own viewer and work plan	Yes
Could an unfinished task be completed later (personally or by a subsequent operator)? If so, should the task progress be recorded?	Yes, several operators can complete a single task
Credentials or authentication systems are required to access certain information useful in task execution	No
Is it necessary to track parts and objects interactions in the task execution?	Yes
Is it necessary to track tools in the task execution?	Yes
Are objects/products 3D complete models available?	No, we only have 2D documentation and paper documentation. The entire aircraft is digitalized ("complete" digital twin most of the time),

The machinery in production is sensorised and provides data to the outside world	No
The actual machinery has a graphic interface	No
Are there any standards applied within your facilities and operational?	Yes; Standard applied to computer in cybersecurity
Are there any security rules applied within your facilities and operational?	Yes;
Which stakeholders are expected to be involved with the XR besides the main user (e.g. IT maintenance department, internal content supervisor)?	Yes; IT maintenance department.

TABLE 3: PILOT 1 QUESTIONNAIRE ANSWERS.

Main important highlights from questionnaire answers and interviews are listed below:

- Operator needs to have his hands-free during task execution and they will use controller to navigate and interact with 3D models.
- No Personal Protective Equipment (PPE) is required while performing VR training, but some users need to wear personal eyewear.
- All training activities are performed in an indoor environment and tools and machinery could be simulated.
- 3D models of the entire airplane usually exist, while in most cases digital mock-ups and digital twins still need to be created
- As previously mentioned, this scenario includes the interaction and cooperation of groups of up to 4 people.
- Trouble Shooting, Maintenance and Repairs are the main tasks/procedures performed.
- Courses are usually managed up to 4 hours and some tasks/exercises could be completed in more than one day.
- Data privacy and Cyber security of all information related to the airplane, have some important restrictions to be kept in mind. The same consideration should be done for external internet connections.

2.1.2 USER NEEDS

In consideration of the details described in the scenario, and according to the response of the questionnaire filled out within the Pilot, the needs expressed by the Pilot were organized into a table (Table 4) and sorted according to importance values (and consequently implementation priorities), please refer to Table 1 for color codification.

The degree of importance is shown in value of relative percentage to total percentage weight, as explained in Section 1.2.

UN ID	USER NEEDS	IMPORTANCE [%]
UN-1000-P1	XR System must show the correct ways to perform the operations	5.3
UN-2000-P1	XR System must allow for well-defined element visibility	5.3
UN-0700-P1	XR System must display procedures in a highly visible way	5.0
UN-1700-P1	XR System must offer comfortable user experience	5.0
UN-1900-P1	XR System must have a clear and defined layout	4.9
UN-0600-P1	XR System must show the steps of the process operations step by step	4.8
UN-1500-P1	XR System must allow stable and secure wearability	4.3
UN-1600-P1	XR System must allow adaptable wearability for different users	4.3
UN-3200-P1	XR System must guarantee an easy creation/modification of the scenario	4.3
UN-1400-P1	XR System must allow the user to be able to run an entire process without restricting the user's hands	4.2
UN-3000-P1	XR System must offer the possibility to let more than one trainee to work at the same time in the same environment	3.7
UN-2200-P1	XR System must enable well-defined visibility of elements in indoor environment	3.4
UN-2100-P1	XR System must make searching for information in the trouble shooting manual and maintenance manual	3.2
UN-0400-P1	XR System must provide guidance on the equipment to be used in the training course	3.1
UN-0200-P1	XR System must be able to suggest the intervention points for maintenance operations	3.1
UN-3100-P1	XR System could be used offline ore on a local network (intranet) for confidentiality and security reasons	3.0
UN-0500-P1	XR System must be able to allow requests for support from an experienced operator	2.9
UN-1100-P1	XR System must be able to provide access to view manuals and/or other documentation useful to the process	2.9
UN-3300-P1	XR system must guarantee an easy review on exercise execution	2.8
UN-2600-P1	XR system should guarantee an easy desktop preview of the built exercise	2.8

UN-0300-P1	XR System must provide guidance on required tools	2.8
UN-2800-P1	XR System must provide feedback on the use of correct tools	2.8
UN-2300-P1	XR System must provide a runtime of at least 4 hours	2.4
UN-2900-P1	XR System must make searching for information on the manual intuitive, quick and accurate	2.4
UN-0900-P1	XR System must show the correct ways to handle the tools needed for the operation	2.1
UN-2700-P1	XR System must allow the identification of a safety work area	1.6
UN-3400-P1	XR System must provide virtual storage to manage removed and spare parts	1.4
UN-2500-P1	XR System must allow saving of executed steps and steps not yet executed	1.3
UN-0100-P1	XR System must enable the transmission of basic knowledge about the airplane model	1.
UN-1800-P1	XR System must have a distinctive layout	1.0
UN-0800-P1	XR System must guide the trainee at times coherent with the exercise	0.8
UN-1300-P1	XR System must have a non-prohibitive cost	0.8
UN-2400-P1	XR System must provide audio feedback (equipment sounds)	0.7
UN-1200-P1	XR System must be able to provide guidance in different languages	0.4

TABLE 4: PILOT 1 USER NEEDS.

User Needs hierarchization has been performed using the AHP matrix, applying the methodology described in Section 1.2. The AHP matrix for Pilot 1 is available in Appendix B.

Normalization of the scores obtained in the matrix has been done according to the methodology described in Section 1.2. and in accordance with the needs of the Pilot owner.

2.1.3 USER REQUIREMENTS AND SYSTEM REQUIREMENTS

Following the definition of the UNs described in the previous paragraph, **User Requirements (URs)** were determined so that they would collect the necessary information to provide guidance on how the needs expressed by the Pilot owner could be realized. URs list is reported in Table 5.

It is important to highlight that a single UR can meet several needs at once. Such correlation is reported in the last column of the table "UN Reference".

Finally, **System Requirements (SR)** have been defined, starting from functional URs, considering what the XR system must have to do to achieve the User Requirements listed before.

As described in Section 1.3, Table 6 contains details and descriptions for each SR, showing also useful information on verification methodologies - VM (to be performed to achieve requirements) and details on the degree of implementation priority within the XR system.

System Requirements falling under priority W (Wish to have) have no verification methods provided.

UR-ID	USER REQUIREMENT	DESCRIPTION	UN REF
UR-FUNC-0100-P1	XR process	Guided visualization of the process steps	UN-0200-P1 UN-0600-P1 UN-0900-P1 UN-1000-P1
UR-FUNC-0200-P1	XR textual information	Virtual spaces containing useful written details	UN-0100-P1 UN-0600-P1 UN-2100-P1 UN-2800-P1 UN-3300-P1
UR-FUNC-0300-P1	3D models	Visualization of 3D elements useful for the exercise fruition	UN-0900-P1 UN-2000-P1 UN-3400-P1
UR-FUNC-0400-P1	2D/3D animations	Guided process through the presence of virtual elements	UN-0200-P1 UN-0600-P1 UN-0800-P1 UN-0900-P1 UN-1000-P1 UN-2800-P1
UR-NFUN-0500-P1	Easy to use	The system needs to be usable by non-experts	UN-1200-P1 UN-1700-P1 UN-1900-P1 UN-2900-P1 UN-3200-P1 UN-3300-P1 UN-3500-P1
UR-FUNC-0600-P1	Back/Forward instructions	Process step execution flow aligned with actual operator progress	UN-0600-P1 UN-0800-P1 UN-1900-P1 UN-2500-P1 UN-3200-P1 UN-3300-P1 UN-3500-P1
UR-FUNC-0700-P1	Homepage	Possibility to return to homepage at any time	UN-1700-P1 UN-1900-P1
UR-FUNC-0800-P1	Intranet connection	XR device local networking	UN-3100-P1

UR-FUNC-0900-P1	Data storage	Local/Offline storage of instruction manuals, videos or other documentation	UN-0100-P1 UN-1100-P1 UN-3400-P1
UR-FUNC-1000-P1	Data Input/Output	Audio instruction and remote interaction with experienced users (through audio, images, video streaming)	UN-0500-P1 UN-2400-P1
UR-NFUN-1100-P1	Wearability	Comfortable and adjustable wearability for all different types of users	UN-1500-P1 UN-1600-P1
UR-FUNC-1200-P1	Instructions language	Opportunity to see instructions in different languages	UN-1200-P1
UR-NFUN-1300-P1	Battery	Battery system to power the wearable device	UN-2300-P1
UR-NFUN-1400-P1	Price	Estimated cost of the XR device - TBD	UN-1300-P1
UR-FUNC-1500-P1	Saving steps	Opportunity to continue the process at different times since the last save of the executed operations	UN-2500-P1
UR-FUNC-1600-P1	Quality of virtual elements	Visibility of instructions and virtual elements present in process instructions	UN-0700-P1 UN-1700-P1 UN-2000-P1 UN-2200-P1
UR-FUNC-1700-P1	Recognizable layout	Identification of an effective element display system and distinctive elements	UN-1700-P1 UN-1800-P1
UR-FUNC-1800-P1	Spare parts storage	Management of removed and replacement components	UN-3400-P1
UR-FUNC-1900-P1	Remote viewing	Desktop preview of the completed exercise	UN-2600-P1
UR-FUNC-2000-P1	Safety information	Provide the operator safety instruction (i.e. Recommend which PPE should be used for the selected process)	UN-0400-P1
UR-FUNC-2100-P1	Tools information	Illustration of the equipment needed for the process	UN-0300-P1 UN-0900-P1 UN-2800-P1
UR-FUNC-2200-P1	Gesture controls	Interaction with operator without controllers	UN-1400-P1
UR-FUNC-2300-P1	Searching info system	Quick search mode for files and words contained in documents	UN-2100-P1 UN-2900-P1
UR-FUNC-2400-P1	Customizable panels	Textures, specific images or background colors to text panels or buttons	UN-1800-P1 UN-1900-P1
UR-FUNC-2500-P1	Exercise review	Easy review of the steps conducted by the trainee during the exercise	UN-3300-P1

UR-FUNC-2600-P1	Working area	Visualization of the boundary at the working area	UN-2700-P1
UR-FUNC-2700-P1	Multi player	The system needs to be used by more than one trainee sharing the same training environment and time	UN-3000-P1

TABLE 5: PILOT 1 USER REQUIREMENTS.

SR-ID	SYSTEM REQUIREMENTS	DESCRIPTION	VM	UR REF	PRIORITY
SR-0100-AP	Independent scenes	Different independent scenes and then connected together according to the order of the process to be performed	D	UR-FUNC-0100-P1	M
SR-0200-AP	Static text box	Insertion of text and ability to change its size, font, color and background	D	UR-FUNC-0200-P1	M
SR-0300-AP	3D text box	Visualization of 3D text useful for the exercise fruition	D	UR-FUNC-0200-P1 UR-FUNC-0300-P1	M
SR-0400-AP	Dynamic text box	Insertion of text on elements that are "clickable" or have dynamic functionality within scenes	T	UR-FUNC-0200-P1	M
SR-0500-AP	3D models format	Define the format of the 3D files that can be introduced into the scene to be realized	D	UR-FUNC-0300-P1	M
SR-0600-AP	3D models scale	Definition of a function to change the scale of 3D models	D	UR-FUNC-0300-P1	M
SR-0700-AP	Buttons	Presence of dynamic elements that regulate scene change or introduction/deletion of elements within the scene	T	UR-FUNC-0600-P1 UR-FUNC-0700-P1	M
SR-0800-AP	Storage space	Dedicated internal memory for uploading manuals or documents that can be viewed offline	D	UR-FUNC-0900-P1	M
SR-1000-AP	Text files	Uploading text files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P1	M

SR-1100-AP	Video files	Uploading video files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P1	M
SR-1200-AP	Images files	Uploading image files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-2400-P1	M
SR-1400-AP	Adjustable contrast	Changing contrast levels between virtual elements and scene background	T	UR-FUNC-1600-P1	M
SR-1500-AP	Adjustable brightness	Changing the brightness levels of scenes displayed in XR mode	T	UR-FUNC-1600-P1	M
SR-1600-AP	Layout positioning	Positioning in the space of virtual elements	I	UR-FUNC-1700-P1	M
SR-1700-AP	Elements animations	Management of motion in space of virtual elements; management of motion time frame	T	UR-FUNC-0400-P1	M
SR-0100-P1	Intranet	Local network connection between XR using devices in the process	T	UR-FUNC-0800-P1	M
SR-0200-P1	Gesture inputs	Definition of interaction using user hand gestures	T	UR-FUNC-2200-P1	M
SR-0300-P1	Multi-trainee	Collaboration of multiple trainees in the same environment	T	UR-FUNC-2700-P1	M
SR-2000-AP	Tools details	Diagrams, charts, graphs, or animations for the proper use of the necessary equipment	D	UR-FUNC-2100-P1	S
SR-0400-P1	Exercise comparison	Comparison of current exercise with correct process; feedback on correct execution	T	UR-FUNC-2500-P1	S
SR-0500-P1	Mirroring	Desktop preview of the finished exercise done during the training course	D	UR-FUNC-1900-P1	S
SR-0600-P1	Safety	Working area and equipment current use information	D	UR-FUNC-2000-P1	S
SR-0900-AP	Audio files	Uploading audio files, retrieving, and defining format specifications of files to be introduced into the XR process	D	UR-FUNC-1000-P1	C
SR-1800-AP	Virtual keyboard	Entering characters useful for search functions or word entry	D	UR-FUNC-2300-P1	C
SR-1900-AP	Saving mode	Implementation of a collection of scene saves (progress storage)	D	UR-FUNC-0900-P1	C

				UR-FUNC-1500-P1	
SR-0700-P1	Word/Info search bar	Search panel for information within an open document	T	UR-FUNC-2300-P1	C
SR-0800-P1	Part list	Mode of displaying components to be used during the exercise	D	UR-FUNC-1800-P1	C
SR-0900-P1	Boundary area	Netting or virtual alarm boundary in case the operator accidentally crosses it	T	UR-FUNC-2600-P1	C
SR-1300-AP	Languages	Management of scene selection translated into different languages depending on the initial choice of preferred language	-	UR-FUNC-1200-P1	W

TABLE 6: PILOT 1 SYSTEM REQUIREMENTS.

2.2 PILOT 2 – HOME APPLIANCE INDUSTRY

The Home Appliance Industry Pilot will be focused on Training activities of technicians and assistance during maintenance operations onsite. Actually, maintenance of whitegoods is performed by trained technicians. Maintenance interventions are typically pre-planned, indeed specific spare parts are ordered in advance and manuals are consulted by reviewing exactly the procedures relating to the specific product that will be the object of the maintenance.

Onsite troubleshooting and access to technical documentation is essential to correctly perform the task. MotivateXR tools could provide simplification and significant improvement with respect to the access to technical documentation. A simplified scenario will also include usage of MotivateXR tools for direct intervention executed by untrained customers.

2.2.1 SCENARIO DESCRIPTION AND QUESTIONNAIRE RESULTS

Hisense Gorenje Europe (HGE) is the company in charge of all supporting functions of Gorenje, like after sales, IT sales, marketing and accounting. The company has a strong presence in the European market for home appliances, where it sells a range of household appliances such as washing machines, tumble driers, ovens, cook hobs, refrigerator, freezer, dishwashers, etc. The company in total produces 3.5 million large home appliances per year.

As already mentioned, the Home Appliance Pilot will be centered on technician Training for maintenance operations and remote support onsite. The actual procedure for training activities and maintenance tasks has been provided by HiSense Gorenje during the in-depth interviews conducted by CETMA where the contents of the short summary and questionnaire results have been analyzed.

In real maintenance tasks, the technician follows a sort of preparation protocol before actually going to the customer: first of all, the Call for maintenance is checked and spare parts that are expected to be changed are ordered from the Spare Part List (SPL) where 2D drawings of the part can be consulted. This procedure is usually performed on a desktop PC (almost 10 minutes of duration). Once finished, the technician reviews maintenance procedures from the manuals that are relevant for the specific product being maintained. Most of the HGE service manuals are provided in soft and hard copy but are also available on a mobile application and the official website. Two different kinds of manuals are accessible for technicians (using personal credentials) and one for final users with free guest access. In some cases, manuals are also in the form of video, provided through a YouTube channel with limited access to certified technicians and service managers.

In this Pilot the application of MotivateXR tools should simplify all maintenance procedures. The already existing workflow and materials would be followed, while new features would be added such as spare parts identification, visualization, interaction and ordering, and the fruition of advanced information (such as videos of replacement procedure which includes complex workflows of troubleshooting).

Such kind of advancement, not only requires to implement the MotivateXR tools but also to upgrade the actual SPL from 2D to 3D interactive SPL, where parts could be rotated, isolated, hidden, zoomed in/out and interactive data examined (code, price, video manuals, dimensions, weight, version ...) before adding the part to the shopping cart.

The creation of advanced manuals using XR tools is fostered. The tool will help technical support to speed-up/simplify education and or training process of service managers and technicians. At the same time, the tool could also be beneficial for everyday use of service technicians, to update their knowledge (repair, refurbishment). Starting from January the 1st 2025, in order to be compliant with the New Eco Directive, manuals for dish washer should be provided also for customers.



FIGURE 10: WASHING MACHINE MAINTENANCE.



FIGURE 11: VIDEO GUIDE ON YT PRIVATE LINK.

Further information has been gathered from answers provided to the questionnaire submitted, which are reported in Table 7.

QUESTIONS	ANSWERS
How long does the Task last:	1 to 4 hours, half shift;
How long should the XR device information last:	1 to 10 minutes;
Does the operator need to have his hands free during task execution?	Yes
Does the operator need to wear PPE (Personal Protective Equipment) during task execution?	Gloves, Protective shoes.
Does the operator need to use tools or machinery in task execution? If so, which ones?	Yes; Standard tools (power drill, screwdriver, wrench ...) Every technician has his personal equipment
The task is performed	Sitting while ordering the parts. While repairing also on knee, lay down and sitting.
When performing the task, the operator	Needs to move by walking and/or changing position
Is it possible to slightly reduce the operator's field of vision and/or to cover eyes sometimes and/or reduce the resolution of real environment (see through) during task execution?	Yes, but only at certain times necessary for information retrieval
Are interactions with displays and/or LED lighting systems foreseen during the execution of the task? (we can have flickering and backlighting problems within XR)	Yes. Quick interaction with display only for short time and troubleshooting.
Is it possible to use voice commands to guide the operator?	Yes
It is possible to send or receive data from operator's location (connectivity)	Yes
Is more than one person involved in the process?	No
Are tasks sequential and involve more than one operator, with specific specialization, please specify?	No
Are task activities personal and linked to the individual operator, i.e. each operator must have his own viewer and work plan	Yes
Could an unfinished task be completed later (personally or by a subsequent operator)? If so, should the task progress be recorded?	Yes, several operators can complete a single task d

Credentials or authentication systems are required to access certain information useful in task execution	Yes
Is it necessary to track parts and objects interactions in the task execution?	No
Is it necessary to track tools in the task execution?	No
Are objects/products 3D complete models available?	Yes, but only of certain products
The machinery in production is sensorised and provides data to the outside world	No
The actual machinery has a graphic interface	Yes
Are there any standards applied within your facilities and operational?	No
Are there any security rules applied within your facilities and operational?	Yes, Standard security rules. Important also to high lights when parts are under current or high voltage, presence of sharp edge etc.
Which stakeholders are expected to be involved with the XR besides the main user (e.g. IT maintenance department, internal content supervisor)?	Others: IT, Technical support, call center

TABLE 7: PILOT 2 QUESTIONNAIRE ANSWERS.

Main important highlights from the questionnaire and interviews are reported below:

- The intervention, which can last a maximum of 2 hours, is performed close to the whitegoods (seated, knee or laydown position).
- Only gloves and protective shoes are required. Manuals should highlight warnings such as sharp edges, powered elements or electrical risk.
- During maintenance procedure technician can access manuals and video.
- They also have a tablet and a personal mobile to call in case of special needs.
- On-site troubleshooting is sometime needed, and a few other parts must be ordered (part number should be identified). The intervention will then be completed in the following days.
- Some easy maintenance procedures could be performed directly by the final customer.
- A more realistic 3D video could help while explaining those kinds of procedures.
- Logs of the intervention are saved and available for up to 4 years.

2.2.2 USER NEEDS

As with Pilot 1, a list of User Needs (UN) was described for this Pilot based on the information collected by CETMA through the questionnaire, the meetings and jointly organized workshops. The UNs follow the same nomenclature rules as in the previous (and subsequent) cases and again are ordered by hierarchy, confided to and shared with the Pilot owner.

Here following the UNs list, please refer to Table 1 for color codification:

UN ID	USER NEEDS	IMPORTANCE [%]
UN-1700-P2	XR System must offer comfortable user experience	5.9
UN-1400-P2	XR System must allow the user to be able to run an entire process without restricting the user's hands	5.4
UN-2200-P2	XR System must enable well-defined visibility of elements in indoor environment	5.4
UN-0600-P2	XR System must show the steps of the process operations step by step	5.1
UN-1900-P2	XR System must have a clear and defined layout	5.0
UN-2000-P2	XR System must allow for well-defined element visibility	4.9
UN-0700-P2	XR System must display procedures in a highly visible way	4.7
UN-1500-P2	XR System must allow stable and secure wearability	4.7
UN-2800-P2	XR System must have a stable internet connection	4.6
UN-1600-P2	XR System must allow adaptable wearability for different users	4.5
UN-2900-P2	XR System must be able to manage the display of elements in "exploded" mode	4.2
UN-2600-P2	XR System must provide the operator with the safety conditions	4.1
UN-2300-P2	XR System must provide a runtime of at least 2 hours	4.0
UN-3000-P2	XR System must allow saving of executed interventions	3.9
UN-2500-P2	XR System must be able to show product codes	3.6
UN-1000-P2	XR System must provide access with credentials	3.5
UN-0200-P2	XR System must be able to suggest the intervention points for maintenance operations	3.3
UN-2700-P2	XR System needs to display 3D elements of the spare part list	3.3
UN-0400-P2	XR System must provide guidance on required PPE	3.0

UN-0500-P2	XR System must be able to allow requests for support from an experienced operator	2.9
UN-1100-P2	XR System must be able to provide offline access to view manuals and/or video useful to the process	2.9
UN-0300-P2	XR System must guide the operator to use the necessary tools	2.4
UN-2100-P2	XR System must make searching for information on the manual intuitive, quick and accurate	2.2
UN-1300-P2	XR System must have a non-prohibitive cost	1.5
UN-0800-P2	XR System must guide the trainee at times coherent with the exercise (animations speed, screwing speed, etc.)	1.0
UN-0100-P2	XR System must enable the transmission of basic knowledge about the machines models	1.0
UN-0900-P2	XR System must show the correct ways to handle the tools needed for the operation	0.9
UN-2400-P2	XR System must be able to provide audio indications	0.9
UN-1800-P2	XR System must have a distinctive layout	0.8
UN-1200-P2	XR System must be able to provide guidance in different languages	0.5

TABLE 8: PILOT 2 USER NEEDS.

It is important to highlight how the individual UNs contain the reference to the Pilot (UN - XXXX - **P2**).

For User Needs prioritization rules, please refer to the methodology described in Section 1.2. The AHP matrix for this Pilot is available in Appendix B.

Normalization of the scores obtained in the matrix has been done according to the methodology described in Section 1.2. and in accordance with the needs of the Pilot owner.

2.2.3 USER REQUIREMENTS AND SYSTEM REQUIREMENTS

Following the definition of the UNs described in the previous paragraph, **User Requirements (URs)** were determined as reported in Table 9.

Finally, **System Requirements (SR)** have been defined, starting from functional URs, considering what the XR system must have or do to achieve the User Requirements listed before (Table 10).

As for Pilot 1 System Requirements falling under priority W (Wish to have) have no verification methods provided.

UR ID	USER REQUIREMENT	DESCRIPTION	UN REF
UR-FUNC-0100-P2	XR process	Guided visualization of the process steps	UN-0200-P2 UN-0300-P2 UN-0600-P2 UN-0900-P2
UR-FUNC-0200-P2	XR textual information	Virtual spaces containing useful written details	UN-0100-P2 UN-0600-P2 UN-2500-P2
UR-FUNC-0300-P2	3D models	Visualization of 3D elements useful for the exercise fruition	UN-2000-P2 UN-2700-P2 UN-2900-P2
UR-FUNC-0400-P2	2D/3D animations	Guided process through the presence of virtual elements	UN-0200-P2 UN-0600-P2 UN-0800-P2 UN-0900-P2
UR-NFUN-0500-P2	Easy to use	The system needs to be usable by non-experts	UN-1200-P2 UN-1700-P2 UN-1900-P2 UN-2100-P2
UR-FUNC-0600-P2	Back/Forward instructions	Process step execution flow aligned with actual operator progress	UN-0600-P2 UN-0800-P2 UN-1900-P2 UN-3000-P2
UR-FUNC-0700-P2	Homepage	Possibility to return to homepage at any time	UN-1700-P2 UN-1900-P2
UR-FUNC-0800-P2	Wi-fi connection	XR device networking	UN-2800-P2
UR-FUNC-0900-P2	Data storage	Local/Offline storage of instruction manuals, videos or other documentation (flag)	UN-0100-P2 UN-1100-P2
UR-FUNC-1000-P2	Data Input/Output	Audio instruction and remote interaction with experienced users (through audio, images, video streaming)	UN-0500-P2 UN-2400-P2
UR-NFUN-1100-P2	Wearability	Comfortable and adjustable wearability for all different types of users	UN-1500-P2 UN-1600-P2
UR-FUNC-1200-P2	Instructions language	Opportunity to see instructions in different languages	UN-1200-P2
UR-NFUN-1300-P2	Battery	Battery system to power the wearable device	UN-2300-P2
UR-NFUN-1400-P2	Price	Estimated cost of the XR device - TBD	UN-1300-P2

UR-FUNC-1500-P2	Saving steps	Opportunity to continue the process at different times since the last save of the executed operations	UN-3000-P2
UR-FUNC-1600-P2	Quality of virtual elements	Visibility of instructions and virtual elements present in process instructions	UN-0700-P2 UN-1700-P2 UN-2000-P2 UN-2200-P2
UR-FUNC-1700-P2	Recognizable layout	Identification of an effective element display system and distinctive elements	UN-1700-P2 UN-1800-P2
UR-FUNC-1800-P2	Spare parts storage	Viewing and “adding to cart” of spare parts required to complete maintenance tasks	UN-2500-P2 UN-2700-P2
UR-FUNC-1900-P2	See-through system	AR visualization of virtual elements in the scene	UN-0200-P2 UN-1400-P2 UN-2200-P2 UN-2600-P2
UR-FUNC-2000-P2	Safety information	Provide the operator safety instruction (i.e. Recommend which PPE should be used for the selected process)	UN-0400-P2 UN-2600-P2
UR-FUNC-2100-P2	Tools information	Illustration of the equipment needed for the process	UN-0300-P2 UN-0900-P2
UR-FUNC-2200-P2	Gesture controls	Interaction with operator without controllers	UN-1400-P2
UR-FUNC-2300-P2	Searching info system	Quick search mode for files and words contained in documents	UN-2100-P2
UR-FUNC-2400-P2	Customizable panels	Textures, specific images or background colors to text panels or buttons	UN-1800-P2 UN-1900-P2
UR-FUNC-2500-P2	Login/Logout	Credential access to a specific process manual	UN-1000-P2
UR-FUNC-2600-P2	Voice recognition	Speech to text function	UN-0500-P2 UN-2400-P2

TABLE 9: PILOT 2 USER REQUIREMENTS.

SR ID	SYSTEM REQUIREMENT	DESCRIPTION	VM	UR REF	PRIORITY
SR-0100-AP	Independent scenes	Different independent scenes and then connected together according to the order of the process to be performed	D	UR-FUNC-0100-P2	M

SR-0200-AP	Static text box	Insertion of text and ability to change its size, font, color and background	D	UR-FUNC-0200-P2	M
SR-0300-AP	3D text box	Visualization of 3D text useful for the exercise fruition	D	UR-FUNC-0200-P2 UR-FUNC-0300-P2	M
SR-0400-AP	Dynamic text box	Insertion of text on elements that are “clickable” or have dynamic functionality within scenes	T	UR-FUNC-0200-P2	M
SR-0500-AP	3D models format	Define the format of the 3D files that can be introduced into the scene to be realized	D	UR-FUNC-0300-P2	M
SR-0600-AP	3D models scale	Definition of a function to change the scale of 3D models	D	UR-FUNC-0300-P2	M
SR-0700-AP	Buttons	Presence of dynamic elements that regulate scene change or introduction/deletion of elements within the scene	T	UR-FUNC-0600-P2 UR-FUNC-0700-P2	M
SR-0800-AP	Storage space	Dedicated internal memory for uploading manuals or documents that can be viewed offline	D	UR-FUNC-0900-P2	M
SR-1000-AP	Text files	Uploading text files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P2	M
SR-1100-AP	Video files	Uploading video files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P2	M
SR-1400-AP	Adjustable contrast	Changing contrast levels between virtual elements and scene background	T	UR-FUNC-1600-P2	M
SR-1500-AP	Adjustable brightness	Changing the brightness levels of scenes displayed in XR mode	T	UR-FUNC-1600-P2	M
SR-1700-AP	Elements animations	Management of motion in space of virtual elements; management of motion time frame	T	UR-FUNC-0400-P2	M
SR-1900-AP	Saving mode	Implementation of a collection of scene saves (progress storage)	D	UR-FUNC-0900-P2 UR-FUNC-1500-P2	M
SR-0400-P2	Wi-fi connection	Local network connection mode with access and signal display capability	T	UR-FUNC-0800-P2	M
SR-0500-P2	Login function	Credential entry panel	T	UR-FUNC-2500-P2	M
SR-0600-P2	See-through scene	Managing transparency and clarity levels when displaying virtual elements in AR mode	D	UR-FUNC-1600-P2	M

				UR-FUNC-1900-P2	
SR-0800-P2	Gesture inputs	Definition of interaction using user hand gestures	T	UR-FUNC-2200-P2	M
SR-0300-P2	Speech to text/Text to speech	Voice recognition modes for the fruition of specific steps in the process	T	UR-FUNC-2600-P2	S
SR-0700-P2	PPE	Icons and directions for using them in the correct way	D	UR-FUNC-2000-P2	S
SR-0900-P2	Part list	Mode of displaying products in the store	D	UR-FUNC-1800-P2	S
SR-0900-AP	Audio files	Uploading audio files, retrieving, and defining format specifications of files to be introduced into the XR process	D	UR-FUNC-1000-P2	C
SR-1200-AP	Images files	Uploading image files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-2400-P2	C
SR-1600-AP	Layout positioning	Positioning in the space of virtual elements	I	UR-FUNC-1700-P2	C
SR-1800-AP	Virtual keyboard	Entering characters useful for search functions or word entry	D	UR-FUNC-2300-P2	C
SR-2000-AP	Tools details	Diagrams, charts, graphs, or animations for the proper use of the necessary equipment	D	UR-FUNC-2100-P2	C
SR-0100-P2	Remote call	Support calls management	T	UR-FUNC-1000-P2	C
SR-0200-P2	Word/Info search bar	Search panel for information within an open document	T	UR-FUNC-2300-P2	C
SR-1300-AP	Languages	Management of scene selection translated into different languages depending on the initial choice of preferred language	D	UR-FUNC-1200-P2	W

TABLE 10: PILOT 2 SYSTEM REQUIREMENTS.

2.3 PILOT 3 – ALUMINUM INDUSTRY

The Aluminum Industry Pilot will be focused on Training activities and Onsite assistance. Architectural Aluminum Academy typically provides different levels of training, guidance and remote support. Training is usually performed through classroom sessions, practical hands-on workshops, and demonstrations by experienced trainers within the Academy. Onsite assistance is performed through assembly guidance that includes access to step-by-step instructions and remote support from supervisors or senior technicians of the Academy. Motivate XR tools could be used in order to

simplify training activities, but also while performing onsite assembling to improve access to technical documentation.

2.3.1 SCENARIO DESCRIPTION AND QUESTIONNAIRE RESULTS

Architectural Aluminum Academy (AAA) is an Innovation and Skills Development Center in the sector of Architectural Aluminum Systems, with premises in Athens and Thessaloniki. It was created on the initiative of ALUMIL and the partnership with two of the greatest universities in the country (Aristotle University of Thessaloniki & University of Macedonia). AAA fosters the advancement of the construction industry by prioritizing the continual training and development of its professionals, using XR technologies.

Architectural Aluminum Academy training activities are performed using traditional methods as detailed hereafter.

- Training is conducted through classroom sessions, practical hands-on workshops, and demonstrations by experienced trainers. The training sessions cover various aspects of aluminum architecture, including material handling, cutting, assembly, and installation techniques. This process is typically time-consuming and requires the involvement of a specific number of participants to ensure that everyone can follow the session and become proficient in hands-on tasks. In some case training can be conducted also in the factory.
- Assembly Guidance refers to the support required after training and during the assembly process. Fabricators and technicians rely on detailed manuals and printed guides that provide step-by-step instructions for various tasks. During assembly, fabricators often require remote support from supervisors or senior technicians of the Academy.
- Remote Support is provided via phone calls and video conferencing tools. Expert fabricators guide the on-site personnel through various tasks by sharing screens and providing verbal instructions.

	
<p>FIGURE 12: TYPICAL TRAINING SESSION.</p>	<p>FIGURE 13: ASSEMBLING PROCEDURE.</p>

The working environment at the Architectural Aluminum Academy includes wide areas equipped with all necessary tools and machinery for handling, cutting, assembling, and installing aluminum structures. Workstations are organized to facilitate efficient workflow and safety. There are also storage areas with designated zones for storing raw materials, tools, and finished products, managed through inventory systems to ensure proper organization and access.

Within the academy there are also dedicated spaces for classroom training sessions, equipped with projectors, whiteboards, and seating arrangements for trainees.

Further information has been gathered from answers provided to the questionnaire submitted, which are reported in Table 11.

QUESTIONS	ANSWERS
How long does the Task last:	1 to 4 hours, half shift;
How long should the XR device information last:	10 minutes to 1 hour;
Does the operator need to have his hands free during task execution?	Yes
Does the operator need to wear PPE (Personal Protective Equipment) during task execution?	Gloves, Protective goggles, Helmet, Protective headphones;
Does the operator need to use tools or machinery in task execution? If so, which ones?	Yes, Drill Driver & Impact Driver, Sealant gun, Deburring tool handle, screw drivers, allen keys, metal hammer, rubber mallet, cutter knife, measure tape, digital caliper, cobalt drill, gasket shear, brush, plastic glazing paddle, pencil)
The task is performed	Standing
When performing the task, the operator	Needs to move by walking and/or changing position
Is it possible to slightly reduce the operator's field of vision and/or to cover eyes sometimes and/or reduce the resolution of real environment (see through) during task execution?	Yes, but only at certain times necessary for information retrieval
Are interactions with displays and/or LED lighting systems foreseen during the execution of the task? (we can have flickering and backlighting problems within XR)	No

Is it possible to use voice commands to guide the operator?	Yes
It is possible to send or receive data from operator's location (connectivity)	Yes
Is more than one person involved in the process?	Yes
Are tasks sequential and involve more than one operator, with specific specialization, please specify?	Yes
Are task activities personal and linked to the individual operator, i.e. each operator must have his own viewer and work plan	No
Could an unfinished task be completed later (personally or by a subsequent operator)? If so, should the task progress be recorded?	Yes, the individual operator resumes on the next shift but must remember where he/she arrived
Credentials or authentication systems are required to access certain information useful in task execution	No
Is it necessary to track parts and objects interactions in the task execution?	Yes
Is it necessary to track tools in the task execution?	Yes
Are objects/products 3D complete models available?	Yes, but only of certain products
The machinery in production is sensorised and provides data to the outside world	No
The actual machinery has a graphic interface	No
Are there any standards applied within your facilities and operational?	Yes, Use of PPE, ergonomic training area, adequate ventilation and lighting, industrial flooring
Are there any security rules applied within your facilities and operational?	Yes, Electromechanical equipment must comply with all standards The premises must comply with all standards
Which stakeholders are expected to be involved with the XR besides the main user (e.g. IT maintenance department, internal content supervisor)?	Trainer – supervisor – remote expert

TABLE 11: PILOT 3 QUESTIONNAIRE ANSWERS.

Main important highlights from the questionnaire and interviews are reported below:

- MotivateXR tools should be used on the Academy premises and on-site, for training, guidance and remote support.
- When training is performed in the academy, tools can be easily marked and tracked. Onsite tools could not be tracked.
- Different kinds of information can be provided during training and support, depending on the task performed (Text, video, 3D animations, audio).
- This scenario will focus on correct assembly and mounting of aluminum frame. Users of the XR tools can be both experts (trainers) and non-experts (trainees, technicians, etc.).
- Task lasts a maximum of 4 hours, while XR content will be used for less than 1 hour.
- The operator needs to have his hands free during task execution and they will use PPE such as gloves, protective goggles, helmet and sometimes also protective headphones.
- Most of the tasks are performed in a standing position with few movement/walking into the surroundings of execution.
- Challenges include miscommunication or misunderstanding of written/oral communication, especially while access to expertise is not available.
- Real-time access to expert guidance can be limited, particularly in situations where senior technicians are occupied with other tasks or not immediately available. A complete list of tools is available in the attachments.

2.3.2 USER NEEDS

A list of User Needs (UN, Table 12) was defined for this Pilot based on the information collected by CETMA through the questionnaire, the meetings and jointly organized workshops. The UNs follow the same nomenclature rules as in previous cases and again are ordered by hierarchy, confided to and shared with the Pilot owner. Please refer to Table 1 for color codification.

UN ID	USER NEEDS	IMPORTANCE [%]
UN-1000-P3	XR System must show the correct ways to perform assembly operations	6.5
UN-2600-P3	XR System must be able to track elements on the workstation	6.0
UN-2000-P3	XR System must allow for well-defined element visibility	5.8
UN-0700-P3	XR System must display procedures in a highly visible way	5.5
UN-2100-P3	XR System must have a stable internet connection	5.4

UN-0600-P3	XR System must show the steps of the process operations step by step	5.4
UN-1400-P3	XR System must allow the user to be able to run an entire process without restricting the user's hands	5.3
UN-2300-P3	XR System must provide a runtime of at least 4 hours	4.7
UN-1700-P3	XR System must offer comfortable user experience	4.6
UN-0300-P3	XR System must provide guidance on required PPE	4.3
UN-1900-P3	XR System must have a clear and defined layout	4.1
UN-1500-P3	XR System must allow stable and secure wearability	3.6
UN-1600-P3	XR System must allow adaptable wearability for different users	3.5
UN-2200-P3	XR System must enable well-defined visibility of elements in indoor environment	3.5
UN-0400-P3	XR System must provide guidance on the equipment to be used in the training course	3.3
UN-0500-P3	XR System must be able to allow requests for support from an experienced operator	3.2
UN-2500-P3	XR System must allow saving of executed steps and steps not yet executed	3.0
UN-1100-P3	XR System must be able to provide access to view manuals and/or other documentation useful to the process	2.9
UN-0900-P3	XR System must show the correct ways to handle the tools needed for assembly	2.8
UN-2800-P3	XR System must provide feedback on the use of correct tools	2.8
UN-1300-P3	XR System must have a non-prohibitive cost	2.6
UN-2400-P3	XR System must be able to provide audio indications	2.6
UN-2900-P3	XR System must make searching for information on the manual intuitive, quick and accurate	2.2
UN-0200-P3	XR System must be able to suggest the gripping points of Aluminum modules	2.1
UN-0800-P3	XR System must guide the trainee at times coherent with the exercise (animations speed, screwing speed, etc.)	1.6
UN-0100-P3	XR System must enable the transmission of basic knowledge about the material Aluminum	0.9
UN-1200-P3	XR System must be able to provide guidance in different languages	0.7
UN-2700-P3	XR System must allow the identification of a safety work area	0.6
UN-1800-P3	XR System must have a distinctive layout	0.5

TABLE 12: PILOT 3 USER NEEDS.

For User Needs prioritization, please refer to the methodology described in Section 1.2. The AHP matrix for this Pilot is available in Appendix B.

Normalization of the scores obtained in the matrix has been done according to the methodology described in Section 1.2. and in accordance with the needs of the Pilot owner.

2.3.3 USER REQUIREMENTS AND SYSTEM REQUIREMENTS

Having established all the User Needs, User Requirements (URs, Table 13) and System Requirements (SRs, Table 14) were determined to identify the expected core functionalities for the XR ecosystem.

UR ID	USER REQUIREMENT	DESCRIPTION	UN REF
UR-FUNC-0100-P3	XR process	Guided visualization of the process steps	UN-0200-P3 UN-0600-P3 UN-0900-P3 UN-1000-P3
UR-FUNC-0200-P3	XR textual information	Virtual spaces containing useful written details	UN-0100-P3 UN-0600-P3
UR-FUNC-0300-P3	3D models	Visualization of 3D elements useful for the exercise fruition	UN-0900-P3 UN-2000-P3
UR-FUNC-0400-P3	2D/3D animations	Guided process through the presence of virtual elements	UN-0200-P3 UN-0600-P3 UN-0800-P3 UN-0900-P3 UN-1000-P3 UN-2700-P3 UN-2800-P3
UR-NFUN-0500-P3	Easy to use	The system needs to be usable by non-experts	UN-1200-P3 UN-1700-P3 UN-1900-P3 UN-2900-P3
UR-FUNC-0600-P3	Back/Forward instructions	Process step execution flow aligned with actual operator progress	UN-0600-P3 UN-0800-P3 UN-1900-P3 UN-2500-P3
UR-FUNC-0700-P3	Homepage	Possibility to return to homepage at any time	UN-1700-P3 UN-1900-P3
UR-FUNC-0800-P3	Wi-fi connection	XR device networking	UN-2100-P3
UR-FUNC-0900-P3	Data storage	Local/Offline storage of instruction manuals, videos or other documentation (flag)	UN-0100-P3 UN-1100-P3

UR-FUNC-1000-P3	Data Input/Output	Audio instruction and remote interaction with experienced users (audio/image/video streaming)	UN-0500-P3 UN-2400-P3
UR-NFUN-1100-P3	Wearability	Comfortable and adjustable wearability for all different types of users	UN-1500-P3 UN-1600-P3
UR-FUNC-1200-P3	Instructions language	Opportunity to see instructions in different languages	UN-1200-P3
UR-NFUN-1300-P3	Battery	Battery system to power the wearable device	UN-2300-P3
UR-NFUN-1400-P3	Price	Estimated cost of the XR device - TBD	UN-1300-P3
UR-FUNC-1500-P3	Saving steps	Opportunity to continue the process at different times since the last save of the executed operations	UN-2500-P3
UR-FUNC-1600-P3	Quality of virtual elements	Visibility of instructions and virtual elements present in process instructions	UN-0700-P3 UN-1700-P3 UN-2000-P3 UN-2200-P3
UR-FUNC-1700-P3	Recognizable layout	Identification of an effective element display system and distinctive elements	UN-1700-P3 UN-1800-P3
UR-FUNC-1800-P3	Tracking	Real element identification system for correct alignment of virtual elements in the working scene	UN-2600-P3
UR-FUNC-1900-P3	See-through system	AR visualization of virtual elements in the scene	UN-0200-P3 UN-1400-P3 UN-2200-P3 UN-2600-P3
UR-FUNC-2000-P3	Safety information	Provide the operator safety instruction (i.e. Recommend which PPE should be used for the selected process)	UN-0300-P3
UR-FUNC-2100-P3	Tools information	Illustration of the equipment needed for the process	UN-0400-P3
UR-FUNC-2200-P3	Working area	Visualization of the boundary at the working area	UN-2700-P3
UR-FUNC-2300-P3	Searching info system	Quick search mode for files and words contained in documents	UN-2900-P3
UR-FUNC-2400-P3	Customizable panels	Textures, specific images or background colors to text panels or buttons	UN-1800-P3 UN-1900-P3
UR-FUNC-2500-P3	Gesture controls	Interaction with operators without controllers	UN-1400-P3
UR-FUNC-2600-P3	Voice recognition	Speech to text function	UN-0500-P3 UN-2400-P3

TABLE 13: PILOT 3 USER REQUIREMENTS.

SR ID	SYSTEM REQUIREMENT	DESCRIPTION	VM	UR REF	PRIORITY
SR-0100-AP	Independent scenes	Different independent scenes and then connected together according to the order of the process to be performed	D	UR-FUNC-0100-P3	M
SR-0200-AP	Static text box	Insertion of text and ability to change its size, font, color and background	D	UR-FUNC-0200-P3	M
SR-0300-AP	3D text box	Visualization of 3D text useful for the exercise fruition	D	UR-FUNC-0200-P3	M
SR-0400-AP	Dynamic text box	Insertion of text on elements that are "clickable" or have dynamic functionality within scenes	T	UR-FUNC-0200-P3	M
SR-0500-AP	3D models format	Define the format of the 3D files that can be introduced into the scene to be realized	D	UR-FUNC-0300-P3	M
SR-0600-AP	3D models scale	Definition of a function to change the scale of 3D models	D	UR-FUNC-0300-P3	M
SR-0700-AP	Buttons	Presence of dynamic elements that regulate scene change or introduction/deletion of elements within the scene	T	UR-FUNC-0600-P3 UR-FUNC-0700-P3	M
SR-1200-AP	Images files	Uploading image files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-2400-P3	M
SR-1400-AP	Adjustable contrast	Changing contrast levels between virtual elements and scene background	T	UR-FUNC-1600-P3	M
SR-1500-AP	Adjustable brightness	Changing the brightness levels of scenes displayed in XR mode	T	UR-FUNC-1600-P3	M
SR-1700-AP	Elements animations	Management of motion in space of virtual elements; management of motion time frame	T	UR-FUNC-0400-P3	M
SR-1800-AP	Virtual keyboard	Entering characters useful for search functions or word entry	D	UR-FUNC-2300-P3	M
SR-0100-P3	Remote call	Support calls management	T	UR-FUNC-0800-P3	M
SR-0500-P3	Wi-fi connection	Local/global network connection mode with access and signal display capability	T	UR-FUNC-0800-P3	M
SR-0600-P3	Image/element recognition	Recognition of images or elements on which to track other elements within the scene	T	UR-FUNC-1800-P3	M

SR-0700-P3	See-through scene	Managing transparency and clarity levels when displaying virtual elements in AR mode	D	UR-FUNC-1600-P3 UR-FUNC-1900-P3	M
SR-0800-P3	PPE	Icons and directions for using them in the correct way	D	UR-FUNC-2000-P3	M
SR-01000-P3	Gesture inputs	Definition of interaction using user hand gestures	T	UR-FUNC-2500-P3	M
SR-0800-AP	Storage space	Dedicated internal memory for uploading manuals or documents that can be viewed offline	D	UR-FUNC-0900-P3	S
SR-0900-AP	Audio files	Uploading audio files, retrieving, and defining format specifications of files to be introduced into the XR process	D	UR-FUNC-1000-P3	S
SR-1600-AP	Layout positioning	Positioning in the space of virtual elements	I	UR-FUNC-1700-P3	S
SR-1900-AP	Saving mode	Implementation of a collection of scene saves (progress storage)	D	UR-FUNC-0900-P3 UR-FUNC-1500-P3	S
SR-2000-AP	Tools details	Diagrams, charts, graphs, or animations for the proper use of the necessary equipment	D	UR-FUNC-2100-P3	S
SR-0400-P3	Speech to text/Text to speech	Voice recognition modes for the fruition of specific steps in the process	T	UR-FUNC-2600-P3	S
SR-1000-AP	Text files	Uploading text files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P3	C
SR-1100-AP	Video files	Uploading video files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P3	C
SR-0200-P3	Manuals search bar	Search panel for information within the storage space	T	UR-FUNC-2300-P3	C
SR-0300-P3	Word/Info search bar	Search panel for information within an open document	T	UR-FUNC-2300-P3	C
SR-1300-AP	Languages	Management of scene selection translated into different languages depending on the initial choice of preferred language	D	UR-FUNC-1200-P3	W
SR-0900-P3	Boundary area	Netting or virtual alarm boundary in case the operator accidentally crosses it	D	UR-FUNC-2200-P3	W

TABLE 14: PILOT 3 SYSTEM REQUIREMENTS.

2.4 PILOT 4 – ELECTRIC DISTRIBUTION INDUSTRY

The Electric Distribution Industry Pilot will be focused on Training activities and Onsite assistance during inspections and maintenance of wooden poles of electricity distribution network. It could be disruptive to provide real time information to guide technicians into pole characterization processes, whose results define the nature of the next activity (maintenance, replacement or reinforcement). MotivateXR tools could be used while the technician is performing onsite intervention, improving access to technical documentation. Training and remote support are both actions that could be improved thanks to XR tools.

2.4.1 SCENARIO DESCRIPTION AND QUESTIONNAIRE RESULTS

HEDNO S.A. (Hellenic Electricity Distribution Network Operator S.A.) conduct operation, maintenance and development of the power distribution network in Greece, as well as the assurance of a transparent and impartial access of consumers and of all network users in general.

The tasks related to the Motivate XR project for HEDNO is the maintenance and inspection of wooden poles in the distribution network. Both for the maintenance task and the inspection task of wooden poles, HEDNO carries out multi-day trainings for the involved personnel. Technicians acquire both a theoretical and a practical background in the field and are examined in order to obtain the necessary HEDNO certification.

The first pole maintenance must take place 15 years after its initial installation and, if performed correctly, can prevent its rotting for at least 10 years. After the first maintenance, it must be repeated every 10 years.



FIGURE 14: POLE INSPECTION WITH RESISTOGRAPH.



FIGURE 15: POLE MANTAINANCE.

First, HEDNO technicians determine the group of poles to be maintained, which are then visually inspected and a 45 cm deep hole below the ground surface is dug. Pole selection is made using electrical drawings rather than ID number of the pole, which happens to miss in some cases (a metal label). The pole is then inspected using hammers and drills. The damaged parts of the pole are located and removed and, if possible, the remaining strength of the pole is estimated. This evaluation is based on relevant criteria and technicians characterize it as suitable for maintenance / to be replaced / to be reinforced using an algorithm based on written guidelines (around 15 pages). Technicians then proceed with pole maintenance procedures that include hole refilling and mark of the year and maintenance method on the pole. Details are then recorded on special forms, the Wooden Pole Inspection and Maintenance Report.

Pole inspection could also be performed with a specific tool, named resistograph. The procedure includes the following steps. First, Visual inspection and Sound inspection with hammer are performed. Then, the pole is checked by drilling the pole at different heights and angles, including drilling below the soil surface. If the result of the resistograph inspection is unsuccessful (FAILED), the pole should be replaced. If the result of the resistograph inspection is successful (ACCEPTABLE) and there is no internal pocket, then the pole will remain in the distribution network. If the result of the inspection with the resistograph is successful, but the pole has an internal pocket, then we follow the maintenance procedure we described above. The resistograph inspection data are stored in the device's memory and transferred to a PC for further analysis.

Further information has been gathered from answers provided to the questionnaire submitted, which are reported in Table 15.

QUESTIONS	ANSWERS
How long does the Task last:	1 to 4 hours, half shift;
How long should the XR device information last:	1 to 4 hours, half shift;
Does the operator need to have his hands free during task execution?	Yes
Does the operator need to wear PPE (Personal Protective Equipment) during task execution?	Gloves; Protective goggles; Helmet; Work boots, reflective vest.
Does the operator need to use tools or machinery in task execution? If so, which ones?	Yes, the following tools: Hammer (1/2 kg), Hoe, Shovel, Impact drill (battery powered), Graduated metal rod (in cm), Scraper, Brush, Portable pump with nozzle, Stapler, Metal measuring tape (2m), Resistograph, Computer (in the office)
The task is performed	Knee position
When performing the task, the operator	Needs to move by walking and/or changing position

Is it possible to slightly reduce the operator's field of vision and/or to cover eyes sometimes and/or reduce the resolution of real environment (see through) during task execution?	Yes, most of the time
Are interactions with displays and/or LED lighting systems foreseen during the execution of the task? (we can have flickering and backlighting problems within XR)	No
Is it possible to use voice commands to guide the operator?	Yes
It is possible to send or receive data from operator's location (connectivity)	Yes
Is more than one person involved in the process?	Yes
Are tasks sequential and involve more than one operator, with specific specialization, please specify?	No
Are task activities personal and linked to the individual operator, i.e. each operator must have his own viewer and work plan	Yes
Could an unfinished task be completed later (personally or by a subsequent operator)? If so, should the task progress be recorded?	Yes, the individual operator resumes on the next shift but must remember where he/she arrived
Credentials or authentication systems are required to access certain information useful in task execution	Yes
Is it necessary to track parts and objects interactions in the task execution?	Yes
Is it necessary to track tools in the task execution?	Yes
Are objects/products 3D complete models available?	No, we only have 2D documentation and paper documentation
The machinery in production is sensorised and provides data to the outside world	No
The actual machinery has a graphic interface	Yes
Are there any standards applied within your facilities and operational?	Yes; Internal HEDNO Guideline No 11, Safety Plan Instructions for the specific task.

Are there any security rules applied within your facilities and operational?	Yes; Internal HEDNO Guideline No 15
Which stakeholders are expected to be involved with the XR besides the main user (e.g. IT maintenance department, internal content supervisor)?	Health & Safety Department

TABLE 15: PILOT 4 QUESTIONNAIRE ANSWERS.

Main important highlights from the questionnaire and interviews are reported below:

- It has been highlighted that workers need to work under direct sunlight, using different kinds of tools and some of them, like the resistograph, already have a display on it.
- While performing the task workers must move in nature and part of the job is walking to the next site/pole.
- Tasks are performed by a group composed of a trained technician (certified pole inspector trained for using a resistograph) and other assistant workers (2 or 3).
- It will be essential to provide the workers with further information in real-time to guide them in the characterization process.
- A solution to simplify and accelerate the process of taking notes would be helpful.
- Members of the wooden pole maintenance crew should wear the following PPE: Work uniform including work boots, Nitrile gloves or protective gloves and special protective goggles especially when handling chemical substances.
- Training on-site and remote support are the principal applications, so it is necessary to guarantee a stable connection in areas far from cities.
- The report is not very analytic but more related to the entire job performed.
- Technicians could use MotivateXR tools also to take notes or maybe someone in the office could take notes for him.
- Daily Reports are provided and filled. Retrieving names or drawings from the office could help in the procedure.

2.4.2 USER NEEDS

Below is the table containing the list of User Needs identified for Pilot 4, see Table 16. The strategy adopted remains the same as in the previous pilots, and the identified needs ranked on the basis of importance obtained from the methodology used and discussed above. Please refer to Table 1 for color codification.

UN ID	USER NEEDS	IMPORTANCE [%]
UN-1800-P4	XR System must allow stable and secure wearability	5.4
UN-1900-P4	XR System must allow adaptable wearability for different users	5.4
UN-1300-P4	XR System must enable well-defined visibility of elements in outdoor environment	5.3
UN-1700-P4	XR System must allow the user to be able to run an entire process without restricting the user's hands	5.3
UN-0900-P4	XR System must show the steps of the process operations step by step	5.0
UN-1100-P4	XR System must be able to track elements on the workstation	4.8
UN-0400-P4	XR System must suggest actions to be taken in the maintenance process	4.6
UN-2100-P4	XR System must allow for well-defined element visibility	4.6
UN-2000-P4	XR System must offer comfortable user experience	4.4
UN-1000-P4	XR System must provide the operator with the safety conditions for the maintenance training	4.4
UN-0800-P4	XR System must show the correct ways to perform maintenance operations	4.0
UN-0600-P4	XR System must have a clear and defined layout	3.7
UN-0100-P4	XR System must provide the option for the user to register the pole	3.3
UN-2200-P4	XR System must have a stable internet connection	3.2
UN-2500-P4	XR System must be able to save the process, and the pole location executed	3.2
UN-2400-P4	XR System must be able to upgrade data from a previously registered process done	2.8
UN-3200-P4	XR System must retrieve onsite some technical data from company database	2.7
UN-3100-P4	XR System must be able to provide access to view semantic information for contextual assistance	2.6
UN-2900-P4	XR System must provide an evaluation of the process carried out	2.6
UN-3000-P4	XR System must be able to project the result of the evaluation	2.6
UN-0200-P4	XR System must be able to provide the option to select the type of action to be performed by the operator	2.5
UN-0700-P4	XR System must show the correct ways to perform inspection operations	2.4
UN-1200-P4	XR System must provide access with credentials	2.4

UN-2800-P4	XR System must be able to input data through the operator's input in order to fill in the inspection data	2.3
UN-1500-P4	XR System must be able to provide access to view manuals and/or other documentation useful for the onsite training	2.0
UN-2700-P4	XR System must allow saving of executed steps and steps not yet executed	2.0
UN-0500-P4	XR System must guide the operator to use the necessary tools in the maintenance process	1.5
UN-0300-P4	XR System must provide guidance on required PPE	1.3
UN-2600-P4	XR System must provide a runtime of at least 8 hours	1.1
UN-2300-P4	XR System must be able to provide audio feedback	1.0
UN-3300-P4	XR System must allow easy solutions to upload and create process documentation	0.8
UN-1400-P4	XR System must have a non-prohibitive cost	0.7
UN-1600-P4	XR System must be able to provide guidance in different languages	0.4

TABLE 16: PILOT 4 USER NEEDS.

For User Needs prioritization, please refer to the methodology described in Section 1.2. The AHP matrix for this Pilot is available in Appendix B.

Normalization of the scores obtained in the matrix has been done according to the methodology described in Section 1.2. and in accordance with the needs of the Pilot owner.

2.4.3 USER REQUIREMENTS AND SYSTEM REQUIREMENTS

Following the definition of the UNs described in the previous paragraph, **User Requirements (URs)** were determined as reported in Table 17.

Finally, **System Requirements (SR)** have been defined, starting from functional URs, considering what the XR system must have or do to achieve the User Requirements listed before (Table 18).

As for Pilot 1 System Requirements falling under priority W (Wish to have) have no verification methods provided.

UR ID	USER REQUIREMENT	DESCRIPTION	UN REF
UR-FUNC-0100-P4	XR process	Guided visualization of the process steps	UN-0200-P4 UN-0400-P4 UN-0700-P4 UN-0800-P4 UN-0900-P4
UR-FUNC-0200-P4	XR textual information	Virtual spaces containing useful written details	UN-0900-P4 UN-1200-P4 UN-3100-P4
UR-FUNC-0300-P4	3D models	Visualization of 3D elements useful for the exercise fruition	UN-0500-P4 UN-2100-P4
UR-FUNC-0400-P4	2D/3D animations	Guided process through the presence of virtual elements	UN-0300-P4 UN-0900-P4
UR-NFUN-0500-P4	Easy to use	The system needs to be usable by non-experts	UN-1600-P4 UN-2000-P4 UN-3300-P4 UN-0600-P4
UR-FUNC-0600-P4	Back/Forward instructions	Process step execution flow aligned with actual operator progress	UN-0900-P4 UN-2000-P4 UN-2700-P4 UN-0600-P4
UR-FUNC-0700-P4	Homepage	Possibility to return to homepage at any time	UN-2000-P4 UN-0600-P4
UR-FUNC-0800-P4	Wi-fi connection	XR device networking	UN-2200-P4
UR-FUNC-0900-P4	Data storage	Local/Offline storage of instruction manuals, videos or other documentation (flag)	UN-1500-P4 UN-3200-P4 UN-3300-P4
UR-FUNC-1000-P4	Data Input/Output	Audio instruction and interaction with useful data	UN-2300-P4 UN-2800-P4
UR-NFUN-1100-P4	Wearability	Comfortable and adjustable wearability for all different types of users	UN-1800-P4 UN-1900-P4
UR-FUNC-1200-P4	Instructions language	Opportunity to see instructions in different languages	UN-1600-P4
UR-NFUN-1300-P4	Battery	Battery system to power the wearable device	UN-2600-P4
UR-NFUN-1400-P4	Price	Estimated cost of the XR device - TBD	UN-1400-P4

UR-FUNC-1500-P4	Saving steps	Opportunity to continue the process at different times since the last save of the executed operations	UN-2400-P4 UN-2500-P4 UN-2700-P4
UR-FUNC-1600-P4	Quality of virtual elements	Visibility of instructions and virtual elements present in process instructions	UN-1300-P4 UN-2000-P4 UN-2100-P4
UR-FUNC-1700-P4	Recognizable layout	Identification of an effective element display system and distinctive elements	UN-2000-P3 UN-0600-P3
UR-FUNC-1800-P4	Tracking	Real element identification system for correct alignment of virtual elements in the working scene	UN-1100-P4
UR-FUNC-1900-P4	See-through system	AR visualization of virtual elements in the scene	UN-1100-P4 UN-1300-P4 UN-1700-P4
UR-FUNC-2000-P4	Safety information	Provide the operator safety instruction (i.e. Recommend which PPE should be used for the selected process)	UN-0300-P4 UN-1000-P4
UR-FUNC-2100-P4	Tools information	Illustration of the equipment needed for the process	UN-0500-P4
UR-FUNC-2200-P4	Working area	Collection of information about the intervention location	UN-0100-P4 UN-2400-P4 UN-2500-P4
UR-FUNC-2300-P4	Evaluation feedback	Easy review of the steps conducted and evaluation display mode	UN-2900-P4 UN-3000-P4
UR-FUNC-2400-P4	Customizable panels	Textures, specific images or background colors to text panels or buttons	UN-2100-P4 UN-0600-P4
UR-FUNC-2500-P4	Gesture controls	Interaction with operators without controllers	UN-1700-P4
UR-FUNC-2600-P4	Retrieve company's data	Access to DB for useful data	UN-3200-P4
UR-FUNC-2700-P4	Login/Logout	Credential access to a specific process manual	UN-1200-P4

TABLE 17: PILOT 4 USER REQUIREMENTS.

SR ID	SYSTEM REQUIREMENT	DESCRIPTION	VM	UR REF	PRIORITY
SR-0100-AP	Independent scenes	Different independent scenes and then connected together according to the order of the process to be performed	D	UR-FUNC-0100-P4	M
SR-0200-AP	Static text box	Insertion of text and ability to change its size, font, color and background	D	UR-FUNC-0200-P4	M
SR-0300-AP	3D text box	Visualization of 3D elements useful for the exercise fruition	D	UR-FUNC-0200-P4	M
SR-0400-AP	Dynamic text box	Insertion of text on elements that are “clickable” or have dynamic functionality within scenes	T	UR-FUNC-0200-P4	M
SR-0500-AP	3D models format	Define the format of the 3D files that can be introduced into the scene to be realized	D	UR-FUNC-0300-P4	M
SR-0600-AP	3D models scale	Definition of a function to change the scale of 3D models	D	UR-FUNC-0300-P4	M
SR-0700-AP	Buttons	Presence of dynamic elements that regulate scene change or introduction/deletion of elements within the scene	T	UR-FUNC-0600-P4 UR-FUNC-0700-P4	M
SR-1200-AP	Images files	Insertion of images or photos within the scene	D	UR-FUNC-2400-P4	M
SR-1400-AP	Adjustable contrast	Changing contrast levels between virtual elements and scene background	T	UR-FUNC-1600-P4	M
SR-1500-AP	Adjustable brightness	Changing the brightness levels of scenes displayed in XR mode	T	UR-FUNC-1600-P4	M
SR-1600-AP	Layout positioning	Positioning in the space of virtual elements	I	UR-FUNC-1700-P4	M
SR-1700-AP	Elements animations	Management of motion in space of virtual elements; management of motion time frame	T	UR-FUNC-0400-P4	M
SR-0100-P4	Wi-fi connection	Local network connection mode with access and signal display capability	T	UR-FUNC-0800-P4	M
SR-0200-P4	Image/element recognition	Recognition of images or elements on which to track other elements within the scene	T	UR-FUNC-1800-P4 UR-FUNC-2200-P4	M

SR-0300-P4	See-through scene	Managing transparency and clarity levels when displaying virtual elements in AR mode	D	UR-FUNC-1600-P4 UR-FUNC-1900-P4 UR-FUNC-2200-P4	M
SR-0400-P4	Gesture inputs	Definition of interaction using user hand gestures	T	UR-FUNC-2500-P4	M
SR-0800-AP	Storage space	Dedicated internal memory for uploading manuals or documents that can be viewed offline	D	UR-FUNC-0900-P4	S
SR-0900-AP	Audio files	Uploading audio files, retrieving, and defining format specifications of files to be introduced into the XR process	D	UR-FUNC-1000-P4	S
SR-1800-AP	Virtual keyboard	Entering characters useful for search functions or word entry	D	UR-FUNC-2700-P4	S
SR-1900-AP	Saving mode	Implementation of a collection of scene saves (progress storage)	D	UR-FUNC-0900-P4 UR-FUNC-1500-P4	S
SR-0500-P4	PPE	Icons and directions for using them in the correct way	D	UR-FUNC-2000-P4	S
SR-0600-P4	Access to DB information	Communication with the company's database for access to useful data for the exercise	T	UR-FUNC-1000-P4 UR-FUNC-2600-P4	S
SR-0700-P4	Geotracking	Built-in GPS system to detect the intervention location and then save it locally	D	UR-FUNC-2200-P4	S
SR-1000-AP	Text files	Uploading text files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P4	C
SR-1100-AP	Video files	Uploading video files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P4	C
SR-2000-AP	Tools details	Diagrams, charts, graphs, or animations for the proper use of the necessary equipment	D	UR-FUNC-2100-P4	C
SR-0800-P4	Evaluation	Verification of the process performed in accordance with the guidelines provided by the company (display AI outcome)	D	UR-FUNC-2300-P4	C

SR-0900-P4	Login function	Credential entry panel	T	UR-FUNC-2700-P4	C
SR-1300-AP	Languages	Management of scene selection translated into different languages depending on the initial choice of preferred language	-	UR-FUNC-1200-P4	W

TABLE 18: PILOT 4 SYSTEM REQUIREMENTS.

2.5 PILOT 5 – ROBOT – HUMAN HYBRID MANUFACTURING

Robot-human hybrid manufacturing industry scenario will be focused on a real production environment where assembly procedures are conducted by an experienced operator usually supported by printed manuals or, at best, explanatory videos. This scenario is quite far from the one of the Smart Digital Factory that Bi-Rex aims to simulate and promote, so MotivateXR tools would be useful to work in this direction. Indeed, the main focus of this Pilot will be on simplifying assembly procedures by introducing a Collaborative Robot (cobot) in the assembly station and providing the operator mixed reality instructions for an effective collaboration with the Robot.

2.5.1 SCENARIO DESCRIPTION AND QUESTIONNAIRE RESULTS

BI-REX is one of the 8 Italian Competence Centers funded by the Italian Ministry of the Economic Development, within the Industry 4.0 National Plan.

Its public-private Consortium, born in 2018, with headquarter in Bologna (Italy), gathers in partnership 61 players among Universities, Research Centers and Companies of excellence, to support companies in their digitization, sustainability and innovation processes and in the adoption of enabling technologies with a view to Industry 4.0 framework, BI-REX offers a complete Pilot Plant.

The BI-REX pilot line simulates a production line, with machines and equipment, as usually happens in the places where Collaborative Robots are installed. Usually, these environments are characterized by shelving, storage areas, areas where machinery is present, warehouses and more. The floor is often marked with lanes, walkways, prohibited areas, etc.

Currently, at the stations, assembly is carried out by experienced operators, supported by a printed manual or, at best, an explanatory video. The collaborative robot will have to be intuitively and efficiently programmed to ensure the correct picking of components: once picked, the components can be precisely positioned within the work plan of the assembly station.

The operator will take care of:

- Loading components: The operator will be responsible for replenishing trays or automatic magazines with the necessary components.

- Final quality control: The operator will carry out a final visual check of the completed assembly, verifying compliance with quality requirements.
- Anomaly management: In the event of problems or malfunctions, the operator will intervene to resolve the situation and restart the process.
- Programming and supervision: the operator will be responsible for the initial programming of the cobot and general supervision of the assembly process.

In order to make operations simpler and more easily adaptable in a smart digital factory context, the new scenario developed within the MotivateXR project will simplify assembly by smoothly implementing the various operational steps (the collaborative robot hands the operator the parts to be assembled), supported by mixed reality instructions illustrating how to perform the various operations.

The objective of the application is to make the procedure more flexible, adaptable and simple, using mixed reality technologies and leaving the dexterity tasks to the operator. Rather than just provide instructions for assembly steps, MotivateXR tools should provide also safety-related instructions, (i.e. suggesting when to start assembly operations in a safe way). To support this, a collaboration interaction between collaborative robot and user should be defined.

In order to simplify the assembly process, it will be necessary to:

- Define a clear and logical assembly sequence, minimizing unnecessary movements of the cobot and the operator. In addition, the cobot will deliver the components in the correct assembly sequence and ensure that they are adhered to. Using mixed (surely augmented) reality software, once the cobot has picked up the component to be assembled, it deposits it on the work surface and instructs the operator how to assemble it, waiting for the signal to retrieve the next part. Use intuitive, simple and clear tool to simplify and anticipate cobot outreaches.
- Clearly define the work areas of the cobot and the operators.
-



FIGURE 16: ASSEMBLY OF GEARBOX COMPONENTS.



FIGURE 17: HUMAN-MACHINE INTERFACE FOR ASSEMBLY.

Further information has been gathered from answers provided to the questionnaire submitted, which are reported in Table 19.

QUESTIONS	ANSWERS
How long does the Task last:	1 to 15 minutes
How long should the XR device information last:	1 to 15 minutes
Does the operator need to have his hands free during task execution?	Yes
Does the operator need to wear PPE (Personal Protective Equipment) during task execution?	Gloves, safety shoes
Does the operator need to use tools or machinery in task execution? If so, which ones?	Screwdriver
The task is performed	Standing
When performing the task, the operator	Needs to stay close to the working desk
Is it possible to slightly reduce the operator's field of vision and/or to cover eyes sometimes and/or reduce the resolution of real environment (see through) during task execution?	Yes, but only at certain times necessary for information retrieval
Are interactions with displays and/or LED lighting systems foreseen during the execution of the task? (we can have flickering and backlighting problems within XR)	Yes
Is it possible to use voice commands to guide the operator?	Yes
It is possible to send or receive data from operator's location (connectivity)	Yes
Is more than one person involved in the process?	No
Are tasks sequential and involve more than one operator, with specific specialization, please specify?	No
Are task activities personal and linked to the individual operator, i.e. each operator must have his own viewer and work plan	Yes
Could an unfinished task be completed later (personally or by a subsequent operator)? If so, should the task progress be recorded?	Yes, the individual operator resumes on the next shift but must remember where he/she arrived

Credentials or authentication systems are required to access certain information useful in task execution	No
Is it necessary to track parts and objects interactions in the task execution?	Yes
Is it necessary to track tools in the task execution?	No
Are objects/products 3D complete models available?	Yes, but only of certain products
The machinery in production is sensorised and provides data to the outside world	No
The actual machinery has a graphic interface	No
Are there any standards applied within your facilities and operational?	No
Are there any security rules applied within your facilities and operational?	No
Which stakeholders are expected to be involved with the XR besides the main user (e.g. IT maintenance department, internal content supervisor)?	Only main user

TABLE 19: PILOT 5 QUESTIONNAIRE ANSWERS.

Main important highlights from questionnaire and interviews are the followings:

- This use case scenario will be applied to an indoor production site.
- Task could be performed by not specifically skilled people such as Technician and Operator inside the facility.
- The application is for single person usage.
- Total duration of the task is limited to a few hours or less.

2.5.2 USER NEEDS

Table 20 reports the User Needs (UNs) that emerged for the specific Pilot case. As with previous Pilots, the UNs have been sorted on the basis of relative percent importance. Please refer to Table 1 for color codification.

UN ID	USER NEEDS	IMPORTANCE [%]
UN-1000-P5	XR System must show the correct ways to perform assembly operations	6.5
UN-2600-P5	XR System must be able to track elements on the workstation	6.0
UN-2000-P5	XR System must allow for well-defined element visibility	5.8
UN-0700-P5	XR System must display procedures in a highly visible way	5.5
UN-2100-P5	XR System must have a stable internet connection	5.4
UN-0600-P5	XR System must show the steps of the process operations step by step	5.4
UN-1400-P5	XR System must allow the user to be able to run an entire process without restricting the user's hands	5.3
UN-2300-P5	XR System must provide a runtime of at least 4 hours	4.7
UN-1700-P5	XR System must offer comfortable user experience	4.6
UN-0300-P5	XR System must provide guidance on required PPE	4.3
UN-1900-P5	XR System must have a clear and defined layout	4.1
UN-1500-P5	XR System must allow stable and secure wearability	3.6
UN-1600-P5	XR System must allow adaptable wearability for different users	3.5
UN-2200-P5	XR System must enable well-defined visibility of elements in indoor environment	3.5
UN-0400-P5	XR System must enable the possibility to take picture of the executed steps	3.3
UN-0500-P5	XR System must be able to allow requests for support from an experienced operator	3.2
UN-2500-P5	XR System must allow saving of executed steps and steps not yet executed	3.0
UN-1100-P5	XR System must be able to provide access to view manuals and/or other documentation useful to the process	2.9
UN-0900-P5	XR System must show the correct ways to handle the tools needed for assembly	2.8
UN-2800-P5	XR System must provide feedback on the use of correct tools	2.8
UN-1300-P5	XR System must have a non-prohibitive cost	2.6
UN-2400-P5	XR System must be able to provide audio indications	2.6
UN-0200-P5	XR System must be able to suggest the gripping points of components	2.1
UN-0800-P5	XR System must guide the trainee at times coherent with the exercise (animations speed, screwing speed, etc.)	1.6
UN-0100-P5	XR System must enable the transmission of basic knowledge about the robot	0.9
UN-1200-P5	XR System must be able to provide guidance in different languages	0.7
UN-2700-P5	XR System must allow the identification of a safety work area	0.6
UN-1800-P5	XR System must have a distinctive layout	0.5

TABLE 20: PILOT 5 USER NEEDS.

For User Needs prioritization, please refer to the methodology described in Section 1.2. The AHP matrix for this Pilot is available in Appendix B.

Normalization of the scores obtained in the matrix has been done according to the methodology described in Section 1.2. and in accordance with the needs of the Pilot owner.

2.5.3 USER REQUIREMENTS AND SYSTEM REQUIREMENTS

Following the definition of the UNs described in the previous paragraph, **User Requirements (URs)** were determined as reported in Table 21.

Finally, **System Requirements (SR)** have been defined, starting from functional URs, considering what the XR system must have or do to achieve the User Requirements listed before (Table 22).

UR ID	USER REQUIREMENT	DESCRIPTION	UN REF
UR-FUNC-0100-P5	XR process	Guided visualization of the process steps	UN-0200-P5 UN-0600-P5 UN-0900-P5 UN-1000-P5
UR-FUNC-0200-P5	XR textual information	Virtual spaces containing useful written details	UN-0100-P5 UN-0600-P5
UR-FUNC-0300-P5	3D models	Visualization of 3D elements useful for the exercise fruition	UN-0900-P5 UN-2000-P5
UR-FUNC-0400-P5	2D/3D animations	Guided process through the presence of virtual elements	UN-0200-P5 UN-0600-P5 UN-0800-P5 UN-0900-P5 UN-1000-P5 UN-2700-P5 UN-2800-P5
UR-NFUN-0500-P5	Easy to use	The system needs to be usable by non-experts	UN-1200-P5 UN-1700-P5 UN-1900-P5 UN-2900-P5
UR-FUNC-0600-P5	Back/Forward instructions	Process step execution flow aligned with actual operator progress	UN-0600-P5 UN-0800-P5 UN-1900-P5 UN-2500-P5
UR-FUNC-0700-P5	Homepage	Possibility to return to homepage at any time	UN-1700-P5 UN-1900-P5
UR-FUNC-0800-P5	Wi-fi connection	XR device networking	UN-2100-P5

UR-FUNC-0900-P5	Data storage	Local/Offline storage of instruction manuals, videos or other documentation (flag)	UN-0100-P5 UN-1100-P5
UR-FUNC-1000-P5	Data Input/Output	Audio instruction and remote interaction with experienced users (audio/image/video streaming)	UN-0500-P5 UN-2400-P5
UR-NFUN-1100-P5	Wearability	Comfortable and adjustable wearability for all different types of users	UN-1500-P5 UN-1600-P5
UR-FUNC-1200-P5	Instructions language	Opportunity to see instructions in different languages	UN-1200-P5
UR-NFUN-1300-P5	Battery	Battery system to power the wearable device	UN-2300-P5
UR-NFUN-1400-P5	Price	Estimated cost of the XR device - TBD	UN-1300-P5
UR-FUNC-1500-P5	Saving steps	Opportunity to continue the process at different times since the last save of the executed operations	UN-2500-P5
UR-FUNC-1600-P5	Quality of virtual elements	Visibility of instructions and virtual elements present in process instructions	UN-0700-P5 UN-1700-P5 UN-2000-P5 UN-2200-P5
UR-FUNC-1700-P5	Recognizable layout	Identification of an effective element display system and distinctive elements	UN-1700-P5 UN-1800-P5
UR-FUNC-1800-P5	Tracking	Real element identification system for correct alignment of virtual elements in the working scene	UN-2600-P5
UR-FUNC-1900-P5	See-through system	AR visualization of virtual elements in the scene	UN-0200-P5 UN-1400-P5 UN-2200-P5 UN-2600-P5
UR-FUNC-2000-P5	Safety information	Provide the operator safety instruction (i.e. Recommend which PPE should be used for the selected process)	UN-0300-P5
UR-FUNC-2100-P5	Operator's point of view	Photo of the operator actual view	UN-0400-P5
UR-FUNC-2200-P5	Working area	Visualization of the boundary at the working area	UN-2700-P5
UR-FUNC-2300-P5	Customizable panels	Textures, specific images or background colors to text panels or buttons	UN-1800-P5 UN-1900-P5
UR-FUNC-2400-P5	Gesture controls	Interaction with operators without controllers	UN-1400-P5
UR-FUNC-2500-P5	Voice recognition	Speech to text function	UN-0500-P5 UN-2400-P5

TABLE 21: PILOT 5 USER REQUIREMENTS.

SR ID	SYSTEM REQUIREMENT	DESCRIPTION	VM	UR REFERENCE	PRIORITY
SR-0100-AP	Independent scenes	Different independent scenes and then connected together according to the order of the process to be performed	D	UR-FUNC-0100-P5	M
SR-0200-AP	Static text box	Insertion of text and ability to change its size, font, color and background	D	UR-FUNC-0200-P5	M
SR-0300-AP	3D text box	Visualization of 3D text useful for the exercise fruition	D	UR-FUNC-0200-P5	M
SR-0400-AP	Dynamic text box	Insertion of text on elements that are "clickable" or have dynamic functionality within scenes	T	UR-FUNC-0200-P5	M
SR-0500-AP	3D models format	Define the format of the 3D files that can be introduced into the scene to be realized	D	UR-FUNC-0300-P5	M
SR-0600-AP	3D models scale	Definition of a function to change the scale of 3D models	D	UR-FUNC-0300-P5	M
SR-0700-AP	Buttons	Presence of dynamic elements that regulate scene change or introduction/deletion of elements within the scene	T	UR-FUNC-0600-P5 UR-FUNC-0700-P5	M
SR-1200-AP	Images files	Uploading image files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-2300-P5	M
SR-1400-AP	Adjustable contrast	Changing contrast levels between virtual elements and scene background	T	UR-FUNC-1600-P5	M
SR-1500-AP	Adjustable brightness	Changing the brightness levels of scenes displayed in XR mode	T	UR-FUNC-1600-P5	M
SR-1700-AP	Elements animations	Management of motion in space of virtual elements; management of motion time frame	T	UR-FUNC-0400-P5	M
SR-1800-AP	Virtual keyboard	Entering characters useful for search functions or word entry	D	UR-FUNC-2200-P5	M
SR-0100-P5	Remote call	Support calls management	T	UR-FUNC-0800-P5	M
SR-0200-P5	Wi-fi connection	Local/global network connection mode with access and signal display capability	T	UR-FUNC-0800-P5	M
SR-0300-P5	Image/element recognition	Recognition of images or elements on which to track other elements within the scene	T	UR-FUNC-1800-P5	M

SR-0400-P5	See-through scene	Managing transparency and clarity levels when displaying virtual elements in AR mode	D	UR-FUNC-1600-P5 UR-FUNC-1900-P5	M
SR-0500-P5	PPE	Icons and directions for using them in the correct way	D	UR-FUNC-2000-P5	M
SR-0700-P5	Gesture inputs	Definition of interaction using user hand gestures	T	UR-FUNC-2400-P5	M
SR-0800-AP	Storage space	Dedicated internal memory for uploading manuals or documents that can be viewed offline	D	UR-FUNC-0900-P5	S
SR-0900-AP	Audio files	Uploading audio files, retrieving, and defining format specifications of files to be introduced into the XR process	D	UR-FUNC-1000-P5	S
SR-1600-AP	Layout positioning	Positioning in the space of virtual elements	I	UR-FUNC-1700-P5	S
SR-1900-AP	Saving mode	Implementation of a collection of scene saves (progress storage)	D	UR-FUNC-0900-P5 UR-FUNC-1500-P5	S
SR-2000-AP	Tools details	Diagrams, charts, graphs, or animations for the proper use of the necessary equipment	D	UR-FUNC-2100-P5	S
SR-0800-P5	Speech to text/Text to speech	Voice recognition modes for the fruition of specific steps in the process	T	UR-FUNC-2500-P5	S
SR-0900-P5	Image files creation	Operator point of view picture from an external camera	T	UR-FUNC-2100-P5	S
SR-1000-AP	Text files	Uploading text files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P5	C
SR-1100-AP	Video files	Uploading video files, retrieving, and defining format specifications of the files to be introduced into scenes	D	UR-FUNC-0900-P5	C
SR-1300-AP	Languages	Management of scene selection translated into different languages depending on the initial choice of preferred language	D	UR-FUNC-1200-P5	W
SR-0600-P5	Boundary area	Netting or virtual alarm boundary in case the operator accidentally crosses it	D	UR-FUNC-2200-P5	W

TABLE 22: PILOT 5 SYSTEM REQUIREMENTS.

3 CONCLUSIONS

This report is the first release (Month 4th) of the work done in order to investigate and define user-requirements and Use-Case scenarios of the MotivateXR project. A second release (D3.4), more exhaustive and updated, will be released on Month 19th.

The user-centered approach implemented to define User Requirements involving all the stakeholders of the MotivateXR Project (Technology providers and End-Users) in the process since the beginning has been highly appreciated and led to effective results. Use-Case Scenarios have been deeply discussed and the most interesting and challenging application selected thanks to the contributions both from Pilot owners and technical partners helping delineate each Scenario.

The chance to discuss with technicians, operators and final users helped also to highlight the most important pain points, which means typical problems related to the adoption of XR technologies in real industrial environments.

The goal of task T3.2 “Industrial End-user requirements and use-case scenarios” has been reached, resulting in a preliminary list of User Requirements and System Requirements per Pilot, as reported in Sections 2.1.3, 2.2.3, 2.3.3, 2.4.3 and 2.5.3. Obviously, a regular review of User and System Requirements is envisaged to ensure they remain relevant and up to date as User Needs could change or be refined during the project execution, for this reason a second release of this report is expected at M19 (D3.4).

From the analysis of the System Requirements identified some conclusions can be drawn.

Notwithstanding the industrial sector, a significant amount of System Requirements is common among Pilots, being them quite general, as shown in Table 23.

SR ID	SYSTEM REQUIREMENT	DESCRIPTION
SR-0100-AP	Independent scenes	Different independent scenes and then connected together according to the order of the process to be performed
SR-0200-AP	Static text box	Insertion of text and ability to change its size, font, color and background
SR-0300-AP	3D text box	Visualization of 3D text useful for the exercise fruition
SR-0400-AP	Dynamic text box	Insertion of text on elements that are “clickable” or have dynamic functionality within scenes
SR-0500-AP	3D models format	Define the format of the 3D files that can be introduced into the scene to be realized
SR-0600-AP	3D models scale	Definition of a function to change the scale of 3D models
SR-0700-AP	Buttons	Presence of dynamic elements that regulate scene change or introduction/deletion of elements within the scene
SR-0800-AP	Storage space	Dedicated internal memory for uploading manuals or documents that can be viewed offline

SR-0900-AP	Audio files	Uploading audio files, retrieving, and defining format specifications of files to be introduced into the XR process
SR-1000-AP	Text files	Uploading text files, retrieving, and defining format specifications of the files to be introduced into scenes
SR-1100-AP	Video files	Uploading video files, retrieving, and defining format specifications of the files to be introduced into scenes
SR-1200-AP	Images files	Uploading image files, retrieving, and defining format specifications of the files to be introduced into scenes
SR-1300-AP	Languages	Management of scene selection translated into different languages depending on the initial choice of preferred language
SR-1400-AP	Adjustable contrast	Changing contrast levels between virtual elements and scene background
SR-1500-AP	Adjustable brightness	Changing the brightness levels of scenes displayed in XR mode
SR-1600-AP	Layout positioning	Positioning in the space of virtual elements
SR-1700-AP	Elements animations	Management of motion in space of virtual elements; management of motion time frame
SR-1800-AP	Virtual keyboard	Entering characters useful for search functions or word entry
SR-1900-AP	Saving mode	Implementation of a collection of scene saves (progress storage)
SR-2000-AP	Tools detail	Diagrams, charts, graphs, or animations for the proper use of the necessary equipment

TABLE 23: SYSTEM REQUIREMENTS COMMON TO ALL PILOTS.

These common requirements mainly address content creation and fruition, indeed XR applications are mainly requested to allow interaction with text, files, media contents and 3D files. Scenarios where training and onsite maintenance activities are foreseen usually require animations and basic interaction to be provided, as well as the possibility to avail users of step-by-step procedures and access to official documentation. Simplified solutions to allow easy interaction with documents and files and hands-free gestures are requirements highly requested in all Use-Case Scenarios.

On the other hand, some System Requirements are quite specific for the single industrial application, as the procedures/workflows currently in use impose limits in the use of XR technologies that must necessarily be taken into consideration.

Home appliance Industry and Aluminum Industry have a lot of elements in common in terms of application. They both expect XR System usage for training purposes and to allow technical documentation access while performing onsite activities. The main difference between those applications is that whitegoods are very complex assembly with respect to windows and frames which are typically less complex.

The application of Electric Distribution Industry is, in some way, very specific. The possibility to work in a wide environment, with complex backgrounds, and specific requirements to walk around the working environment, with position tracking requests are potentially highly demanding.

The Robot – Human Hybrid Manufacturing Scenario even if quite similar to maintenance activities foreseen in the Home Appliance and Aluminum Industries, also requires the possibility to preview cobot movements and to save pictures of the procedures from the operator point of view.

While most of the Use-Case Scenario highlighted the opportunity to use augmented reality solutions, the Aerospace Industry would probably focus mainly on virtual reality solutions. Because this Pilot is focused on training activities, they expect to have multi-user applications and troubleshooting simulations without working on real airplanes.

Specific precautions must be taken to allow also offline usage of XR technology and to permit both indoor and outdoor procedures. In addition, most of the pilots express the need to record and monitor procedure advancements. This specific request, but also others could conflict with some social, ethical and legal challenges and further analysis will be conducted in the next months of the project and included in D3.4.

In the next month the following activities will be conducted to finalize User and System Requirements as well as Use-Case Scenarios:

- All technical partners will be asked to analyze in detail the preliminary URs and SRs defined so far and provide any further feedback on prioritization and description.
- Specific technical workshops will be organized in order to review User Needs and User Requirements distribution within technical tools in order to analyze the required interoperability within the MotivateXR framework.
- Methodology to conduct the validation of System Requirements will be further detailed in order to define a clear way to demonstrate reached goals.
- Social, ethical and legal analysis outcomes will be considered, and a second release of User and System Requirements list will be provided, where concerns/risks are taken into account and countermeasures to overcome them defined.
- The analysis done so far is of a high level and aims not to go too deep into the details of the XR tools' functionalities demanded by the single Use-Case. In the next months, technical workshops will be organized to dig into the single System Requirement already identified and refine their definition or add those still missing but essential to reach the goals.
- Finally, Use-Case scenarios will be further detailed in order to map each single step of the operations to be performed and the Users involved so as to provide a description by Step of what is expected to be performed by the operators".

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APPENDIX A

Guidance slides on the methodology applied to define User Needs and the implementation of a hierarchy scale are provided within this section.

CETMA has prepared a mini guide for pilot owners in order to provide all the information necessary to the pilot owner to modify or integrate the information already prepared by CETMA.

One-to-one workshops were organized with all project Pilots so as to clarify the method and comment on the material produced and previously shared with them.

Within the guide, the main steps are given in order to enable pilot owners to be able to act independently, having already provided the initial analysis set up by CETMA. Additional workshops were then held where any further changes or additions were made together, to better be aligned and avoid typos or misunderstanding errors.

It is important to highlight how the user was put at the center of the System Requirements identification strategy, starting with a thorough analysis of each Pilot's needs.

The document made explicit here in images was sent to all pilots in a pdf document available in the SharePoint of MotivateXR Project ([User_Needs_Methodology_Manual.pdf](#)).

Below is the detailed information from the mini guide sent to the pilots:

User Needs description

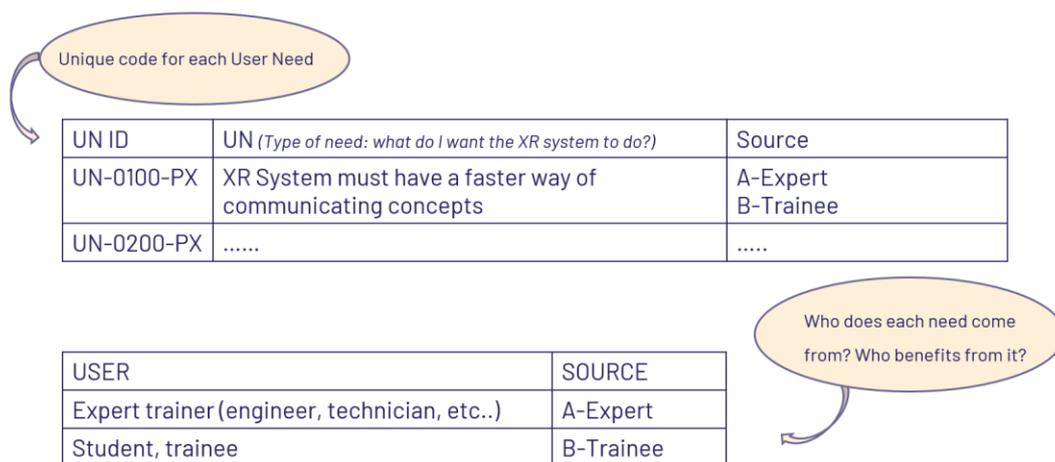


FIGURE 18: USER NEEDS STRUCTURE.

Figure 18 shows the structure of User Needs, making the following explanatory:

- SOURCE: indicates the closely related user and beneficiary of each User Need presented in the list.
- UN ID: each User Needs consists of four digits of which the first digits are in sequential order of collection of individual needs (e.g. 01, 02, etc.) while the last two digits will allow in the second release any additions closely related to the currently listed needs (e.g. needs closely related to UN 0500 can be added in this way: UN 0510, UN 0520, etc., then leaving the last digit to report additional related needs). Figure 19 makes this information clear.

User Needs description



UN-1100	XR System must be able to provide access to view manuals and/or other documentation useful to the process	A-Expert; B-Trainee
UN-1200	XR System must be able to provide the guidance in different languages	A-Expert
UN-1300	XR System must have a non-prohibitive cost	B-Trainee
UN-1400	XR System must allow the user to be able to run an entire process without restricting the user's hands	B-Trainee
UN-1500	XR System must allow stable and secure wearability	B-Trainee
UN-1600	XR System must allow adjustable visibility for different tasks	B-Trainee
UN-1700	XR System must offer a comfortable user experience	B-Trainee
UN-1800	XR System must have a distinctive layout	A-Expert; B-Trainee
UN-1900	XR System must have a clear and defined layout	B-Trainee
UN-2000	XR System must allow for well-defined element visibility	B-Trainee
UN-2100	XR System must have a stable internet connection	A-Expert; B-Trainee
UN-2200	XR System must enable well-defined visibility of elements in indoor environment	B-Trainee
UN-2300	XR System must provide a runtime of at least 4 hours	A-Expert
UN-2400	XR System must be able to provide audio indications	A-Expert; B-Trainee
UN-2500	XR System must allow saving of executed steps and steps not yet executed	B-Trainee
UN-2600	XR System must be able to recognize markers placed on the workstation	A-Expert
UN-2700	XR System must allow the identification of a safety work area	A-Expert
UN-2800	XR System must provide feedback on the use of correct tools	B-Trainee
UN-2900	XR System must make searching for information on the manual intuitive, quick and accurate	B-Trainee

If I want to add some user needs not yet considered?

I CAN:

1. Add an intermediate need (if strictly related to one already on the list): e.g., UN-1610;
2. Directly insert a new UN, e.g. UN-3000;
3. Replace a user need with a new one, simply overwriting it if I see appropriate.

FIGURE 19: EXPLANATION OF UN MODIFICATION.

In Figure 20 and Figure 21 the explanation of information needed to know the method of compiling a UN - UN correlation matrix is provided. The matrix considers a one-to-one comparison of the identified needs, thus obtaining (through the algebraic sum of the values on each row) a score for each need, which will then be normalized and used to make a hierarchy of importance of the UNs provided for each Pilot.

The figures are then shown:

User Needs Matrix

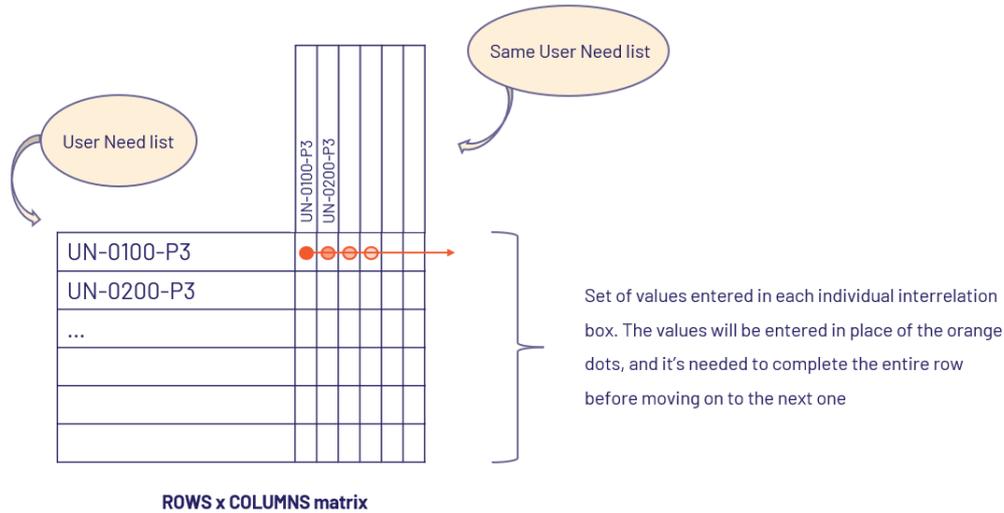


FIGURE 20: MATRIX EXPLANATION.

User Needs Matrix

Compilation example

I read row UN-0100-P3 and compare it (one by one) with the user needs in the columns. As I compare (one by one) I assign a value according to the following map:

Number meaning
3 = the row element is more important than the column element
1 = row element and column element have the same importance
0 = the row element is less important than the column element

In the example I indicated that, **for me user**, UN-0100-P3 is:

- More important than UN-0200-P3;
- Less important than UN-0300-P3;
- Less important than UN-0400-P3;
- It is as important as UN-0500-P3.

	UN-0100-P3 - Aluminum information	UN-0200-P3 - Gripping points information	UN-0300-P3 - Required PPE	UN-0400-P3 - Equipment guidance	UN-0500-P3 - Expert support request	UN-0600-P3 - Step by step guidance	UN-0700-P3 - Clear visibility of the procedure	UN-0800-P3 - Time coherence	UN-0900-P3 - Correct tool handling	UN-1000-P3 - Assembly process	UN-1100-P3 - Documentation access
UN-0100-P3 - Aluminum information	1	3	0	0	1						
UN-0200-P3 - Gripping points information		1									
UN-0300-P3 - Required PPE			1								
UN-0400-P3 - Equipment guidance				1							

FIGURE 21: MATRIX COMPILATION METHOD.

Figure 21 then shows the legend of values to be assigned to each box in the matrix, which will allow for unique results for each need. The completed matrices for each Pilot are given in Appendix B.

APPENDIX B

This Appendix contains the UN - UN correlation matrices created, modified, and discussed with individual Pilots in order to obtain a set of needs, sorted by hierarchy of importance, realized through a focused comparison of individual needs.

Analytic Hierarchy Process (AHP) method was applied here and adapted to the case study. The matrices were set up by CETMA, making the correct configuration and precompiling all the fields provided to obtain an index of importance for each need.

Within Appendix B, for ease of reading and displaying the values obtained, screenshots of the Excel file sheets compiled and shared with all pilot owners are shown. They have been integrated into the Appendix in ascending order (numerical reference assigned to each Pilot within the project).

The matrices shown are composed as follows:

- Each line contains the ID code for each User Need and an identifying title that recalls the description in the list of UNs. The name has been reduced to a few words so as to increase the readability of the file and to make it easier to read when compiling the matrix.
- In the Excel file, the name of each UN is the same as in the individual rows and columns (top of the matrix), accompanied by its UN ID; the screens included within this Appendix omit the entire description (UN name) in the columns, allowing for a more readable file.
- The diagonal highlighted in blue indicates the intersection points between each UN (present in the row) and itself (present in the column), thus presenting a value of 1 as they surely share the same importance.
- The "Total" column indicates the value obtained from the sum of each row.
- The "Normalized value" column contains the value (described in Section XX) used to obtain the final hierarchy value for each UN.
- The "Relative %" column contains the ratio between the normalized value (corresponding for each UN) and the sum of the normalized values present in the "Normalized value" column, as described in Section XX.

The matrices prepared for the different Pilots then follow, on the basis of which the hierarchies of importance of the User Needs have been identified, information which is then useful for defining the priority level present in the list of System Requirements present for each Pilot.

	UN-0100-P1	UN-0200-P1	UN-0300-P1	UN-0400-P1	UN-0500-P1	UN-0600-P1	UN-0700-P1	UN-0800-P1	UN-0900-P1	UN-1000-P1	UN-1100-P1	UN-1200-P1	UN-1300-P1	UN-1400-P1	UN-1500-P1	UN-1600-P1	UN-1700-P1	UN-1800-P1	UN-1900-P1	UN-2000-P1	UN-2100-P1	UN-2200-P1	UN-2300-P1	UN-2400-P1	UN-2500-P1	UN-2600-P1	UN-2700-P1	UN-2800-P1	UN-2900-P1	UN-3000-P1	UN-3100-P1	UN-3200-P1	UN-3300-P1	UN-3400-P1	TOTAL	Normalized value	Relative %	
UN-0100-P1 - Airplane model	1	1	0	0	0	0	0	1	3	0	1	3	3	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	1	0	0	0	1	0	19	1,0	1%	
UN-0200-P1 - Intervention points information	1	1	1	1	0	1	1	1	3	1	3	3	3	1	1	1	1	3	0	0	1	1	3	3	0	1	3	1	1	1	3	1	0	47	2,4	3%		
UN-0300-P1 - Required Tools	3	1	1	1	1	0	0	3	3	0	1	3	3	3	1	1	0	3	0	0	0	1	1	3	1	1	1	1	1	1	1	0	1	42	2,1	3%		
UN-0400-P1 - Equipment guidance	3	1	1	1	1	0	0	3	1	0	1	3	3	1	1	0	3	0	0	1	1	0	3	3	1	3	1	1	0	3	1	1	3	47	2,4	3%		
UN-0500-P1 - Expert support request	3	3	1	1	1	0	0	3	1	0	0	3	3	1	1	1	0	3	0	0	1	1	1	3	3	1	1	1	1	0	1	1	3	44	2,2	3%		
UN-0600-P1 - Step by step guidance	3	1	3	1	3	1	1	3	3	1	1	3	3	3	1	1	1	3	1	0	1	1	3	3	3	1	3	3	3	3	3	3	3	73	3,7	5%		
UN-0700-P1 - Clear visibility of the procedure	3	1	3	3	3	1	1	3	3	1	1	3	3	3	1	1	1	3	1	1	3	1	3	3	3	1	3	3	1	3	3	3	3	76	3,8	5%		
UN-0800-P1 - Time coherence	1	1	0	0	0	0	0	1	0	0	0	3	1	0	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	12	0,6	1%		
UN-0900-P1 - Correct tool handling	0	0	0	1	1	0	0	3	1	1	0	3	3	1	0	0	0	0	0	0	1	1	1	3	3	0	1	0	1	1	1	1	1	3	32	1,6	2%	
UN-1000-P1 - Procedure	3	1	3	3	3	1	1	3	1	1	1	3	3	3	3	3	1	3	1	1	3	1	3	3	3	3	3	1	3	3	3	3	3	80	4,0	5%		
UN-1100-P1 - Documentation access	1	0	1	1	3	1	1	3	3	1	1	3	1	1	1	0	3	0	0	1	0	1	3	3	3	1	0	0	1	1	0	1	3	44	2,2	3%		
UN-1200-P1 - Different languages	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	6	0,3	0%		
UN-1300-P1 - Low cost	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	1	3	1	1	0	0	0	0	0	0	1	12	0,6	1%		
UN-1400-P1 - User hands free	3	1	0	1	1	0	0	3	1	0	1	3	3	1	1	1	1	3	3	1	3	1	3	3	3	1	3	3	3	1	3	3	64	3,2	4%			
UN-1500-P1 - Stable wearability	3	1	1	1	1	1	1	3	3	0	1	3	3	1	1	1	1	3	3	3	3	0	1	3	3	3	3	1	3	1	3	1	3	66	3,3	4%		
UN-1600-P1 - Adaptable wearability	3	1	1	1	1	1	1	3	3	0	1	3	3	1	1	1	1	3	3	3	3	0	1	3	3	3	3	1	3	1	3	1	3	66	3,3	4%		
UN-1700-P1 - Comfortable UX	3	1	3	3	3	1	1	3	3	1	3	3	3	1	1	1	1	3	1	1	3	1	3	3	3	3	3	3	3	1	3	1	3	76	3,8	5%		
UN-1800-P1 - Distinctive layout	1	0	0	0	0	0	0	1	3	0	0	1	1	0	0	0	0	1	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1	15	0,8	1%		
UN-1900-P1 - Clear and defined layout	3	3	3	3	1	1	3	3	1	3	3	3	0	0	0	1	3	1	1	3	1	3	3	3	3	3	3	3	1	3	3	75	3,8	5%				
UN-2000-P1 - Well defined elements visibility	3	3	3	3	3	3	1	3	3	1	3	3	3	1	0	0	1	3	1	1	3	1	3	3	3	3	3	3	3	3	1	3	3	80	4,0	5%		
UN-2100-P1 - Information searching	3	1	3	1	1	1	0	3	1	0	1	3	3	0	0	0	0	3	0	0	1	1	3	3	3	1	3	1	1	3	1	0	1	3	49	2,5	3%	
UN-2200-P1 - Indoor environment	3	1	1	1	1	1	1	3	1	1	3	3	3	1	3	3	1	3	1	1	1	1	0	0	3	1	0	3	3	3	0	0	1	52	2,6	3%		
UN-2300-P1 - N.4 hours runtime	3	1	3	1	0	0	1	1	0	1	3	1	0	1	1	0	1	0	1	0	0	3	1	3	1	0	3	1	1	3	1	0	0	1	37	1,9	2%	
UN-2400-P1 - Audio indications	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	3	0	1	0	0	1	1	0	0	0	0	0	10	0,5	1%		
UN-2500-P1 - Saving steps mode	1	0	1	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1	3	1	1	3	1	1	0	0	0	1	19	1,0	1%		
UN-2600-P1 - Desktop preview	3	3	1	1	1	1	1	3	3	0	0	3	1	0	0	0	0	1	0	0	1	1	3	3	1	1	3	0	3	0	0	0	1	3	42	2,1	3%	
UN-2700-P1 - Work area identification	3	1	1	0	1	0	0	3	1	0	1	3	3	1	0	0	0	1	0	0	0	3	0	1	0	0	1	0	0	0	0	0	0	24	1,2	2%		
UN-2800-P1 - Feedback on using correct tools	1	0	1	1	1	0	0	3	3	1	3	3	3	0	1	1	0	3	0	0	1	0	1	1	1	3	3	1	1	0	1	0	1	3	42	2,1	3%	
UN-2900-P1 - Searching info on the manuals	1	1	1	1	1	0	1	3	1	0	3	3	3	0	0	0	0	3	0	0	1	0	1	3	1	0	3	1	1	0	0	0	0	3	36	1,8	2%	
UN-3000-P1 - Multi-trainee session available	3	1	1	3	3	0	0	3	1	0	1	3	3	0	1	1	1	3	1	0	0	0	0	3	1	3	3	3	3	1	3	1	3	56	2,8	4%		
UN-3100-P1 - Offline/local network	3	1	1	0	1	0	0	3	1	0	1	3	3	0	0	0	0	3	0	0	1	3	1	3	3	3	3	1	3	0	1	0	1	3	46	2,3	3%	
UN-3200-P1 - Easy creation/modification scenario	3	0	1	1	1	0	0	3	1	0	3	3	3	1	1	1	1	3	1	1	3	3	3	3	3	3	3	3	1	3	1	3	3	66	3,3	4%		
UN-3300-P1 - Reviewing on exercise execution	1	1	3	1	1	0	0	3	1	0	1	3	3	0	0	0	0	1	0	0	1	3	3	3	3	3	3	1	3	0	1	0	1	1	43	2,2	3%	
UN-3400-P1 - Storage spare parts	3	3	1	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0	1	1	3	1	0	3	0	0	0	0	0	1	1	22	1,1	1%	
																																				76,0		

FIGURE 22: PILOT 1 USER NEEDS AHP MATRIX.

	UN-0100-P3	UN-0200-P3	UN-0300-P3	UN-0400-P3	UN-0500-P3	UN-0600-P3	UN-0700-P3	UN-0800-P3	UN-0900-P3	UN-1000-P3	UN-1100-P3	UN-1200-P3	UN-1300-P3	UN-1400-P3	UN-1500-P3	UN-1600-P3	UN-1700-P3	UN-1800-P3	UN-1900-P3	UN-2000-P3	UN-2100-P3	UN-2200-P3	UN-2300-P3	UN-2400-P3	UN-2500-P3	UN-2600-P3	UN-2700-P3	UN-2800-P3	UN-2900-P3	TOTAL	Normalized value	Relative %				
UN-0100-P3 - Aluminum information	1	1	0	0	0	0	0	0	1	0	1	3	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	10	0,6	0,9%				
UN-0200-P3 - Gripping points information	1	1	0	1	0	0	0	3	0	0	1	3	1	0	1	1	0	3	0	0	0	3	0	0	0	0	3	0	1	23	1,4	2,1%				
UN-0300-P3 - Required PPE	3	3	1	1	3	0	3	3	1	0	3	3	1	1	1	1	1	3	3	1	0	1	1	1	1	0	3	1	3	47	2,8	4,3%				
UN-0400-P3 - Equipment guidance	3	3	1	1	1	1	1	3	1	0	1	1	1	0	1	1	1	3	1	1	0	1	0	3	0	1	3	1	1	36	2,1	3,3%				
UN-0500-P3 - Expert support request	3	3	0	1	1	1	1	3	1	0	1	3	3	0	1	1	0	3	1	0	0	1	0	1	3	0	1	1	1	35	2,1	3,2%				
UN-0600-P3 - Step by step guidance	3	3	3	1	1	1	1	3	3	1	1	3	3	1	1	1	1	3	3	1	3	3	1	3	1	1	3	3	3	59	3,5	5,4%				
UN-0700-P3 - Clear visibility of the procedure	3	3	0	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	1	1	3	1	1	3	1	3	3	3	3	60	3,5	5,5%				
UN-0800-P3 - Time coherence	3	0	0	0	0	0	1	1	1	0	0	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	1	1	17	1,0	1,6%				
UN-0900-P3 - Correct tool handling	1	3	1	1	1	0	1	1	1	0	1	1	1	1	0	0	1	3	1	0	0	1	0	1	3	0	3	3	1	31	1,8	2,8%				
UN-1000-P3 - Assembly process	3	3	3	3	3	1	1	3	3	1	3	3	1	3	3	3	3	3	3	1	1	1	3	3	3	1	3	3	3	71	4,2	6,5%				
UN-1100-P3 - Documentation access	1	1	0	1	1	1	0	3	1	0	1	3	1	1	1	1	1	3	1	0	0	1	0	1	3	0	3	1	1	32	1,9	2,9%				
UN-1200-P3 - Different languages	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	8	0,5	0,7%				
UN-1300-P3 - Low cost	3	1	1	1	0	0	0	1	1	0	1	3	1	0	1	1	0	3	0	0	0	1	3	3	1	0	1	0	1	28	1,6	2,6%				
UN-1400-P3 - User hands free	3	3	1	3	3	1	0	3	1	1	1	3	3	1	1	1	1	3	1	1	3	1	3	3	3	1	3	3	3	58	3,4	5,3%				
UN-1500-P3 - Stable wearability	0	1	1	1	1	1	0	1	3	0	1	3	1	1	1	1	1	3	1	0	1	1	1	3	3	1	3	1	3	39	2,3	3,6%				
UN-1600-P3 - Adaptable wearability	3	1	1	1	1	1	0	1	3	0	1	3	1	1	1	1	1	1	0	0	1	1	1	3	1	0	3	3	3	38	2,2	3,5%				
UN-1700-P3 - Comfortable UX	3	3	1	1	3	1	1	1	1	0	3	3	3	1	1	1	1	3	1	1	1	1	0	3	3	0	3	3	3	50	2,9	4,6%				
UN-1800-P3 - Distinctive layout	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	5	0,3	0,5%			
UN-1900-P3 - Clear and defined layout	3	3	0	1	1	0	1	1	1	0	1	3	3	1	1	3	1	3	1	1	1	1	1	3	0	1	3	3	3	45	2,6	4,1%				
UN-2000-P3 - Well defined elements visibility	3	3	1	1	3	1	1	3	3	1	3	3	3	1	3	3	1	3	1	1	3	1	3	3	1	1	3	3	3	63	3,7	5,8%				
UN-2100-P3 - Stable internet connection	3	3	3	3	3	0	0	3	3	1	3	3	3	0	1	1	1	3	1	0	1	1	3	3	3	1	3	3	3	59	3,5	5,4%				
UN-2200-P3 - Indoor environment	1	0	1	1	1	0	1	1	1	1	1	3	1	1	1	1	1	3	1	1	1	1	1	3	3	0	3	1	3	38	2,2	3,5%				
UN-2300-P3 - N.4 hours runtime	3	3	1	3	3	1	1	3	3	0	3	3	0	0	1	1	3	3	1	0	0	1	1	3	1	0	3	3	3	51	3,0	4,7%				
UN-2400-P3 - Audio indications	3	3	1	0	1	0	0	3	1	0	1	3	0	0	0	0	0	3	0	0	0	0	0	1	1	0	3	1	3	28	1,6	2,6%				
UN-2500-P3 - Saving steps mode	3	3	1	3	0	1	1	3	0	0	0	3	1	0	0	1	0	3	3	1	0	0	1	1	1	0	3	0	0	33	1,9	3,0%				
UN-2600-P3 - Tracking	3	3	3	1	3	1	0	3	3	1	3	3	3	1	1	3	3	3	1	1	1	3	3	3	3	1	3	3	3	66	3,9	6,0%				
UN-2700-P3 - Work area identification	1	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	7	0,4	0,6%			
UN-2800-P3 - Feedback on using correct tools	3	3	1	1	1	0	0	1	0	0	1	3	3	0	1	0	0	3	0	0	0	1	0	1	3	0	3	1	1	31	1,8	2,8%				
UN-2900-P3 - Searching info on the manuals	3	1	0	1	1	0	0	1	1	0	1	3	1	0	0	0	0	3	0	0	0	0	0	0	3	0	3	1	1	24	1,4	2,2%				
																																		64,2		

FIGURE 24: PILOT 3 USER NEEDS AHP MATRIX.

	UN-0100-P4	UN-0200-P4	UN-0300-P4	UN-0400-P4	UN-0500-P4	UN-0600-P4	UN-0700-P4	UN-0800-P4	UN-0900-P4	UN-1000-P4	UN-1100-P4	UN-1200-P4	UN-1300-P4	UN-1400-P4	UN-1500-P4	UN-1600-P4	UN-1700-P4	UN-1800-P4	UN-1900-P4	UN-2000-P4	UN-2100-P4	UN-2200-P4	UN-2300-P4	UN-2400-P4	UN-2500-P4	UN-2600-P4	UN-2700-P4	UN-2800-P4	UN-2900-P4	UN-3000-P4	UN-3100-P4	UN-3200-P4	UN-3300-P4	TOTAL	Normalized value	Relative %
UN-0100-P4 - Pole registration	1	3	3	1	3	0	1	1	0	1	1	1	0	3	3	3	1	1	1	0	0	0	1	1	1	3	3	3	1	1	1	1	3	47	2,4	3,3%
UN-0200-P4 - Type of performed action	0	1	1	1	1	1	1	1	0	1	0	1	0	3	0	3	0	1	1	0	0	0	3	1	1	3	3	3	1	1	1	0	3	35	1,8	2,5%
UN-0300-P4 - Required PPE	0	1	1	1	1	0	0	0	0	1	0	1	0	3	1	3	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	1	18	0,9	1,3%	
UN-0400-P4 - Maintenance onsite	1	1	1	1	3	1	1	1	1	1	1	3	1	3	3	3	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	65	3,4	4,6%	
UN-0500-P4 -Tool guide	0	1	1	0	1	0	1	1	0	0	0	1	0	3	1	3	0	1	1	0	0	0	1	0	0	1	1	0	0	1	1	21	1,1	1,5%		
UN-0600-P4 - Clear and defined layout	3	1	3	1	3	1	3	1	0	0	0	1	1	3	1	3	1	1	1	1	1	1	0	1	1	3	3	3	3	1	1	53	2,7	3,7%		
UN-0700-P4 - Inspection guidance	1	1	3	1	1	0	1	1	0	0	1	1	0	3	1	3	0	0	0	0	0	1	1	3	1	3	1	1	1	0	1	34	1,8	2,4%		
UN-0800-P4 - Maintenance training	3	1	3	1	1	1	1	1	1	1	1	3	1	3	3	3	1	1	1	1	1	1	3	3	3	3	3	1	1	1	1	57	2,9	4,0%		
UN-0900-P4 - Step by step guidance	3	3	3	1	3	3	3	1	1	1	1	3	1	3	3	3	1	1	1	1	3	3	3	3	3	3	3	1	1	1	1	71	3,7	5,0%		
UN-1000-P4 - Safety information	1	1	1	1	3	3	3	1	1	1	0	3	3	3	3	3	0	1	1	1	1	3	3	3	1	3	1	3	3	1	1	63	3,2	4,4%		
UN-1100-P4 - Tracking	1	3	3	1	3	3	1	1	1	3	1	3	1	3	3	3	1	0	0	0	3	1	3	3	3	3	3	3	3	1	1	68	3,5	4,8%		
UN-1200-P4 - Credentials access	1	1	1	0	1	1	1	0	0	0	0	1	0	3	1	3	0	0	0	0	0	1	3	1	1	3	1	3	1	1	1	34	1,8	2,4%		
UN-1300-P4 - Outdoor elements visibility	3	3	3	1	3	1	3	1	1	0	1	3	1	3	3	3	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	76	3,9	5,3%		
UN-1400-P4 - Low cost	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	1	1	0	0	1	1	0	0	0	0	0	0	0	1	10	0,5	0,7%		
UN-1500-P4 - Documentation access	0	3	1	0	1	1	1	0	0	0	0	1	0	3	1	3	0	0	0	0	0	1	1	1	1	3	3	1	1	1	0	29	1,5	2,0%		
UN-1600-P4 - Different languages	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	0	0	1	1	0	0	0	0	6	0,3	0,4%		
UN-1700-P4 - User hands free	1	3	3	1	3	1	3	1	1	3	1	3	1	3	3	3	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	75	3,9	5,3%		
UN-1800-P4 - Stable wearability	1	1	3	1	1	1	3	1	1	1	3	3	1	1	3	3	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	77	4,0	5,4%		
UN-1900-P4 - Adaptable warability	1	1	3	1	1	1	3	1	1	1	3	3	1	1	3	3	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	77	4,0	5,4%		
UN-2000-P4 - Comfortable UX	3	3	3	1	3	1	3	1	1	1	3	3	1	3	3	1	1	1	1	1	1	3	3	1	3	3	1	1	1	3	1	63	3,2	4,4%		
UN-2100-P4 - Well defined elements	3	3	3	1	3	1	3	1	0	1	0	3	0	3	3	3	0	0	0	1	1	3	3	1	3	3	3	1	3	3	3	65	3,4	4,6%		
UN-2200-P4 - Stable internet connection	3	3	1	1	3	1	3	0	0	1	1	0	1	1	1	0	0	0	0	0	0	1	3	3	3	3	3	3	1	1	1	1	46	2,4	3,2%	
UN-2300-P4 - Audio indications	1	0	1	0	1	3	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	14	0,7	1,0%		
UN-2400-P4 - Upgrade processed poles	1	1	3	0	3	1	1	0	0	0	0	1	0	3	1	3	0	0	0	0	1	0	3	1	1	3	3	3	1	1	1	40	2,1	2,8%		
UN-2500-P4 - Saving executed process	1	1	3	0	3	1	0	0	0	1	0	1	0	3	1	3	0	0	0	1	0	0	3	1	1	3	1	3	3	3	3	46	2,4	3,2%		
UN-2600-P4 - N.8 hours runtime	0	0	1	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	16	0,8	1,1%		
UN-2700-P4 - Saving steps mode	0	0	1	0	1	0	0	0	0	1	0	1	0	3	0	1	0	0	0	0	0	0	3	0	1	1	1	3	3	1	1	28	1,4	2,0%		
UN-2800-P4 - Speech to text	0	1	3	0	3	0	1	1	0	0	0	0	0	3	1	3	1	0	0	1	1	0	1	0	0	1	0	1	1	1	1	33	1,7	2,3%		
UN-2900-P4 - Evaluation - calculation algorithm	1	1	3	0	3	0	1	1	1	0	0	1	0	3	1	3	0	0	0	1	0	1	3	1	0	1	0	0	1	1	3	3	37	1,9	2,6%	
UN-3000-P4 - Evaluation result	1	1	3	0	3	0	1	1	1	0	0	1	0	3	1	3	0	0	0	1	0	1	3	1	0	1	0	0	1	1	3	3	37	1,9	2,6%	
UN-3100-P4 - Real time information	1	1	3	0	1	1	3	1	1	1	1	1	0	3	3	3	0	0	0	0	0	1	3	1	0	1	1	1	0	0	1	1	37	1,9	2,6%	
UN-3200-P4 - Connection to company DB	1	3	3	0	1	1	1	1	1	1	1	1	0	3	3	3	0	0	0	0	1	0	1	3	1	0	1	1	1	0	1	1	38	2,0	2,7%	
UN-3300-P4 - Easy upload/create documentation	0	0	1	0	1	0	0	1	0	0	0	0	0	1	1	3	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	11	0,6	0,8%	
																																	73,6			

FIGURE 25: PILOT 4 USER NEEDS AHP MATRIX.

	UN-0100-P5	UN-0200-P5	UN-0300-P5	UN-0400-P5	UN-0500-P5	UN-0600-P5	UN-0700-P5	UN-0800-P5	UN-0900-P5	UN-1000-P5	UN-1100-P5	UN-1200-P5	UN-1300-P5	UN-1400-P5	UN-1500-P5	UN-1600-P5	UN-1700-P5	UN-1800-P5	UN-1900-P5	UN-2000-P5	UN-2100-P5	UN-2200-P5	UN-2300-P5	UN-2400-P5	UN-2500-P5	UN-2600-P5	UN-2700-P5	UN-2800-P5	TOTAL	Normalized value	Relative %
UN-0100-P5 - Robot information	1	1	0	0	0	0	0	0	1	0	1	3	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	10	0,6	1,0%
UN-0200-P5 - Gripping points information	1	1	0	1	0	0	0	3	0	0	1	3	1	0	1	1	0	3	0	0	0	3	0	0	0	0	3	0	22	1,3	2,2%
UN-0300-P5 - Required PPE	3	3	1	1	3	0	3	3	1	0	3	3	1	1	1	1	1	3	3	1	0	1	1	1	1	0	3	1	44	2,7	4,3%
UN-0400-P5 - Process picture	3	3	1	1	1	1	1	3	1	0	1	1	1	0	1	1	1	3	1	1	0	1	0	3	0	1	3	1	35	2,1	3,4%
UN-0500-P5 - Expert support request	3	3	0	1	1	1	1	3	1	0	1	3	3	0	1	1	0	3	1	0	0	1	0	1	3	0	1	1	34	2,1	3,3%
UN-0600-P5 - Step by step guidance	3	3	3	1	1	1	1	3	3	1	1	3	3	1	1	1	1	3	3	1	3	3	1	3	1	1	3	3	56	3,4	5,5%
UN-0700-P5 - Clear visibility of the procedure	3	3	0	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	1	1	3	1	1	3	1	3	3	3	57	3,5	5,6%
UN-0800-P5 - Time coherence	3	0	0	0	0	0	1	1	0	0	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	0	1	1	16	1,0	1,6%
UN-0900-P5 - Correct tool handling	1	3	1	1	1	0	1	1	1	0	1	1	1	1	0	0	1	3	1	0	0	1	0	1	3	0	3	3	30	1,8	3,0%
UN-1000-P5 - Assembly process	3	3	3	3	3	1	1	3	3	1	3	3	3	1	3	3	3	3	3	1	1	1	3	3	3	1	3	3	68	4,1	6,7%
UN-1100-P5 - Documentation access	1	1	0	1	1	1	0	3	1	0	1	3	1	1	1	1	1	3	1	0	0	1	0	1	3	0	3	1	31	1,9	3,1%
UN-1200-P5 - Different languages	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	8	0,5	0,8%
UN-1300-P5 - Low cost	3	1	1	1	0	0	0	1	1	0	1	3	1	0	1	1	0	3	0	0	0	1	3	3	1	0	1	0	27	1,6	2,7%
UN-1400-P5 - User hands free	3	3	1	3	3	1	0	3	1	1	1	3	3	1	1	1	1	3	1	1	3	1	3	3	3	1	3	3	55	3,4	5,4%
UN-1500-P5 - Stable wearability	0	1	1	1	1	1	0	1	3	0	1	3	1	1	1	1	1	3	1	0	1	1	1	3	3	1	3	1	36	2,2	3,5%
UN-1600-P5 - Adaptable wearability	3	1	1	1	1	1	0	1	3	0	1	3	1	1	1	1	1	1	0	0	1	1	1	3	1	0	3	3	35	2,1	3,4%
UN-1700-P5 - Comfortable UX	3	3	1	1	3	1	1	1	1	0	3	3	3	1	1	1	1	3	1	1	1	1	0	3	3	0	3	3	47	2,9	4,6%
UN-1800-P5 - Distinctive layout	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	5	0,3	0,5%
UN-1900-P5 - Clear and defined layout	3	3	0	1	1	0	1	1	1	0	1	3	3	1	1	3	1	3	1	1	1	1	1	3	0	1	3	3	42	2,6	4,1%
UN-2000-P5 - Well defined elements visibility	3	3	1	1	3	1	1	3	3	1	3	3	3	1	3	3	1	3	1	1	3	1	3	3	1	1	3	3	60	3,7	5,9%
UN-2100-P5 - Stable internet connection	3	3	3	3	3	0	0	3	3	1	3	3	3	0	1	1	1	3	1	0	1	1	3	3	3	1	3	3	56	3,4	5,5%
UN-2200-P5 - Indoor environment	1	0	1	1	1	0	1	1	1	1	1	3	1	1	1	1	1	3	1	1	1	1	1	3	3	0	3	1	35	2,1	3,4%
UN-2300-P5 - N.4 hours runtime	3	3	1	3	3	1	1	3	3	0	3	3	0	0	1	1	3	3	1	0	0	1	1	3	1	0	3	3	48	2,9	4,7%
UN-2400-P5 - Audio indications	3	3	1	0	1	0	0	3	1	0	1	3	0	0	0	0	0	3	0	0	0	0	0	1	1	0	3	1	25	1,5	2,5%
UN-2500-P5 - Saving steps mode	3	3	1	3	0	1	1	3	0	0	0	3	1	0	0	1	0	3	3	1	0	0	1	1	1	0	3	0	33	2,0	3,3%
UN-2600-P5 - Tracking	3	3	3	1	3	1	0	3	3	1	3	3	3	1	1	3	3	3	1	1	1	3	3	3	3	1	3	3	63	3,8	6,2%
UN-2700-P5 - Work area identification	1	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	7	0,4	0,7%
UN-2800-P5 - Feedback on using correct tools	3	3	1	1	1	0	0	1	0	0	1	3	3	0	1	0	0	3	0	0	0	1	0	1	3	0	3	1	30	1,8	3,0%
																													61,9		

FIGURE 26: PILOT 5 USER NEEDS AHP MATRIX.