DIGITAL, DYNAMIC AND RESPONSIBLE TWINS FOR XR

D2.1 – Requirements and validation methods v1

[WP2 – User-centric development]

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About the project

The digital transformation and the availability of more diverse and cost-effective methods for 3D capture has led to the creation of digitised representations of parts of our public spaces, machinery and processes, so-called Digital Twins. These Digital Twins are an important basis for building advanced XR applications for cityscapes and the industrial environments. These XR applications need high-fidelity models for accurate localization, which are kept in-sync with the real world. The vision of DIDYMOS-XR is to enable advanced, more realistic and more dynamic extended reality (XR) applications, powered through artificial intelligence. The project thus focuses on advancing technologies for creating large-scale digital twins, synchronised with the real world. DIDYMOS-XR will research and develop methods for reconstruction and mapping from heterogeneous inputs, including static and mobile sensors, AI-based data fusion, scene understanding and rendering. Digital twin based XR applications also require means of accurately positioning in the environment, aware of the dynamics of the scene, also addressed by the project. The capture of scenes at scale, as well as using cameras and other sensor data for synchronising the digital representation, bears the risk of capturing personal and sensitive data. Hence, the technologies resulting from DIDYMOS-XR must be and will be ethical and privacy-aware by design. In order to demonstrate and validate the enabling technologies researched and developed in DIDYMOS-XR, the project will address use cases of XR applications in two domains that differ in their scale and characteristics. One is urban planning and smart mobility, the other is the collaboration with autonomous mobile robots at an industrial production facility.

Abstract

This DIDYMOS-XR project deliverable serves as a guide in the initial requirements collection process, defining essential functional and user requirements. The document details use cases, personas, and reports from stakeholder workshops, emphasising active collaboration. It summarises project use cases for easier reading and outlines specific DIDYMOS-XR requirements. It presents user requirements in tabular format, using a user-centric structure, and serves as a roadmap and checklist throughout the project's lifecycle. This deliverable, as a tool, provides stakeholders with insights into project objectives, a user-focused strategy, and fundamental requirements, thereby improving overall project understanding.

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Executive summary

This deliverable serves as a guide for the DIDYMOS-XR project, and it is the foundational step of the requirements collection process that determines the design of the plan. Within the core of the DIDYMOS-XR project, the document outlines the functional and non-functional requirements that should be met in order to design and develop the project.

A comprehensive explanation of use cases and personas is provided in this document. These provide deeper insights into the practical applications of DIDYMOS-XR as well as the user motivations behind its use. Additionally, the deliverable includes documentation on workshops that were held with stakeholders, with an emphasis on active participation and collaboration.

The user requirements are presented in a tabular format in the deliverable, which is organised in a user-centric style. This format serves as the foundation for the subsequent phases of development. Throughout the entirety of the project's lifecycle, it acts as a roadmap and checklist, directing the consortium in the process of monitoring, implementing, and evaluating critical aspects of the project. This ensures that the project is carried out effectively.

The use cases of the project are strategically summarised in the document in order to improve readability. Additionally, the document provides a clear and concise summary of the overall approach. Further, it details the requirements that must be met by the DIDYMOS-XR. In conclusion, this deliverable serves as a valuable tool for stakeholders, as it offers insights into the project's objectives, a user-focused strategy, and fundamental requirements, in addition to providing comprehensive narratives on use cases, personas, and stakeholder workshops.

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List of acronyms/abbreviations

Abbreviation	Explanation
DIDYMOS-XR	Digital, Dynamic and Responsible Twins for Extended Reality
WP	Work Package

Abbreviation	Explanation
UC	Use Case
IoT	Internet of Things
AI	Artificial Intelligence
KPI	Key Performance Indicator
AR	Augmented Reality
VR	Virtual Reality
XR	Extended Reality
VE	Virtual Environment
DT	Digital Twin
POI	Point of Interest
SUS	System Usability Scale
QUIS	Questionnaire for User Interaction Satisfaction
IoU	Intersection over Union
FPS	Frames per Second

Table 1. List of acronyms/abbreviations

Glossary of terms

Term	Explanation
Digital twin	A digital representation of an intended or actual real-world physical product, system, or process
Stakeholder	A relevant actor (persons, groups, or organisations) who: (1) is affected by the project's results and findings; (2) have the potential to use or exploit the project's results and findings; or (3) have a stated interest or stake in the project results and findings.
End-user	A person, group or organisation who has the potential to use or exploit the project's results and findings. Each stakeholder is thus also an end-user, but not vice-versa.
Use Case	A use case is a written description of how a system or project will be used to achieve a specific goal from the perspective of an end user.
Persona	A persona is a fictional character created to represent a typical user in a specific demographic, capturing their behaviors, goals, and motivations to guide the design and development of a product or service.
Design Thinking	Design thinking is a problem-solving approach that involves understanding user needs, redefining problems, and creating innovative solutions through a process of ideation, prototyping, and testing.
Requirement	In the field of user-centric development, a requirement describes a specific functionality, feature or characteristic that a system or product must have to meet the expectations and preferences of its user.

Table 2. Glossary of terms

1 Introduction

Fundamentally, DIDYMOS-XR aims to transform the way in which we engage with industrial domains and public spaces by means of constructing technical Digital Twins. Detailed in its presentation of functional and user requirements, this document provides a comprehensive plan for the DIDYMOS-XR. In addition to the technical specifications, the deliverable uses a reporting perspective to clarify the pragmatic implementations via comprehensive use cases.

Through the creation of detailed Digital Twins, DIDYMOS-XR wants to change the way we interact with public spaces and industrial domains. This document carefully lists the functional and non-functional requirements and gives a detailed plan for how the DIDYMOS-XR framework will work. In addition to the technical details, the deliverable uses a reporting lens to show how it can be used in real life through detailed use cases.

In an effort to humanise the technological discussion, this report examines personas as a means of reporting-driven investigation into the motivations and behaviours, which strongly influence user engagement in the DIDYMOS-XR project. It also carefully documents workshops and group work sessions with stakeholders, highlighting how they were involved and sharing the knowledge gained from these interactions.

As proceeded with the detailed reporting of use cases, personas, and requirements, it is noticeable that this deliverable goes beyond being simple documentation. This report is a constantly evolving collection of technical details, human interactions, and a big picture vision that will be carefully put together into a living document that will change as the project does.

1.1 Background

The DIDYMOS-XR project developed out of a rising need to deploy cutting-edge digital technology to improve the operation of public spaces and factories. The concept of Digital Twins, which is central to this project, is not new, but it has lately gained popularity due to advancements in Internet of Things (IoT), Artificial Intelligence (AI), and data analytics. In this situation, DIDYMOS-XR is an innovative attempt to employ these technologies to create digital reproductions of real-world locations that are very accurate and updated in real time. The idea for this project comes from the belief that these types of digital models may significantly improve decision quality, efficiency, and user experience in a variety of fields, including city planning and industrial management.

1.2 Purpose and scope

The primary purpose of this deliverable is to identify the individual use cases, objectives, and user personas that DIDYMOS-XR targets. In this approach, it requires to develop a clear strategy for improving and applying Digital Twins technology across multiple contexts. This deliverable goes deeper into the technical criteria and guidelines that will determine how the DIDYMOS-XR project runs. It involves analyzing potential applications and how this technology will afffect those who have an interest in it, such as decision-makers, end-users, and professional teams. This deliverable is also intended to serve as a roadmap for future development and a resource for partners seeking to learn about the DIDYMOS-XR framework's features and advantages.

1.3 Deliverable structure

This document is structured to provide a comprehensive yet coherent overview of the DIDYMOS-XR project. It begins with an introduction that sets the context and outlines the overarching objectives.

Subsequent sections include:

- Detailed Use Cases: Illustrating real-world applications and the benefits of the DIDYMOS-XR project (see Chapter 3).
- User Personas and Insights: Providing a human-centric view of the project, focusing on the needs, behaviors, and motivations of different user groups (see Chapter 4).
- Functional and Non-functional Requirements: Enumerating the technical and user-centric requirements that the project wants to fulfill (see Chapter 5).
- Conclusion and Future Directions: Summarizing key points and envisioning the future trajectory of the DIDYMOS-XR initiative (see Chapter 6).

2 Stakeholder Engagement

A stakeholder, in a general sense, refers to any individual or group that has an interest in or is affected by a company, project, or decision. Stakeholders can be internal or external to the organization. Internal stakeholders typically include employees, managers, and owners, while external stakeholders can encompass customers, suppliers, investors, community groups, and government regulators. The key characteristic of stakeholders is that they have a stake — financial, personal, social, or otherwise — in the outcome of the project or the performance of the organization.

Including stakeholders in the design process of an application is crucial for several reasons:

1. Understanding User Needs and Expectations: Stakeholders often represent the end-users or have a deep understanding of their needs and preferences. Their input ensures that the application is designed to meet the actual requirements of its users, which is essential for its success.
2. Diverse Perspectives and Expertise: Different stakeholders bring varied perspectives and areas of expertise. This diversity can lead to a more comprehensive and well-rounded design, as it incorporates different viewpoints and addresses a wider range of issues.
3. Enhancing User Experience: Stakeholders can provide insights into user behavior, expectations, and preferences. This information is vital in creating a user-friendly and intuitive application, leading to a better user experience.
4. Risk Management: Involving stakeholders early in the design process helps in identifying potential risks and challenges. It allows for proactive measures to mitigate these risks, thereby reducing the likelihood of costly mistakes or the need for major revisions later.
5. Ensuring Alignment with Business Goals: Stakeholders often have a clear understanding of the business objectives behind the application. Their involvement ensures that the design aligns with these goals, contributing to the overall success of the project.
6. Building Ownership and Support: When stakeholders are involved in the design process, they are more likely to feel a sense of ownership and support for the application. This can lead to better cooperation during the development phase and stronger advocacy for the application once it's launched.

7. Facilitating Change Management: Applications often bring change to an organization or its customers. Stakeholders can aid in managing this change, ensuring smoother implementation and adoption of the application.
8. Feedback and Continuous Improvement: Stakeholders can provide ongoing feedback during the design process, allowing for iterative improvements. This continuous input helps in refining the application to better meet its intended purpose.

For these reasons two boards were composed in order to assist the project team in the design and development of the solutions. These boards are: a Stakeholder Board (SB) and the Ethics Advisory Board (EAB). More in details:

- Stakeholder Board: A stakeholder board is a group composed of individuals who represent the various stakeholders of a project or organization. This board plays a role in governance or advisory capacities, offering guidance, insights, and decisions that reflect the diverse interests and perspectives of the stakeholders. The composition of a stakeholder board often includes representatives from different all the organization in the consortium, external business partners, customers, and possibly members of the public or community leaders. The primary function of a stakeholder board is to ensure that the interests of all stakeholders are considered in the decision-making process.
- Ethics Advisory Board: An ethics advisory board is a body typically comprised of experts and leaders who provide guidance on ethical issues faced by an organization. This board may include ethicists, legal professionals, industry experts, and sometimes public representatives. The role of an ethics advisory advisory board is to offer advice on how to handle complex ethical issues, ensure compliance with ethical standards and laws, and guide the organization in maintaining ethical practices in its operations. Since in DIDYMOS-XR the collection of sensible data is continuous, this board was mandatory in order to ensure that users' privacy was kept along all the project life and beyond.

2.1 Workshops

Five workshops have been organized so far to involve both the Stakeholder Board and the Ethics Advisory Board in the design process. Three of these have involved the Stakeholder Board, while two have involved the Ethics Advisory Board.

Industrial Stakeholder Workshops

Date: 26/06/2023

Modality: online workshop

Tool used: online board

Goal: i) validate use cases related to the cities, ii) collect user requirements

Cityscape Stakeholder Workshops

Date: 28/06/2023

Modality: online workshop

Tool used: online board

Goal: i) validate use cases related to the industry, ii) collect user requirements

Third Stakeholder Workshops

Date: 29/11/2023

Modality: webinar

Tool used: online presentation

Goal: i) present use cases, user personas and user requirements

The two workshops with the Ethics Advisory Board will be discussed in D2.2

3 Use Cases for DIDYMOS-XR

In this section, we delve into five distinct use cases that exemplify how digital twins can be used exploiting augmented and virtual reality technologies. Each case presents a unique scenario, highlighting how these technologies transcend traditional boundaries and create immersive, interactive experiences. From industry to city planning and tourism, these use cases demonstrate the versatility and transformative potential of digital twins in AR and VR.

Use cases are specific scenarios or situations that demonstrate how a product, system, or service can be used. They typically describe a sequence of actions or events, often involving a user or another system, that lead to a particular outcome. Use cases are used in various fields, including software and systems engineering, to identify, clarify, and organize system requirements. They help in understanding the functional requirements of a system, how users interact with it, and the value it provides in real-world applications. Each use case provides a detailed example of how the system can solve a problem or achieve a goal in a particular context.

The creation of these use cases is part of a design thinking process that is being followed in order to create a set of experiences that will be appreciated by the end users.

3.1 Design Thinking

Design thinking is a non-linear, iterative process that teams use to understand users, challenge assumptions, redefine problems and create innovative solutions to prototype and test. It is most useful to tackle ill-defined or unknown problems and involves five phases: Empathize, Define, Ideate, Prototype and Test.

- Empathize. The team aims to understand the problem, typically through user research. Empathy is crucial to design thinking because it allows designers to set aside your assumptions about the world and gain insight into users and their needs.
- Define. Once the team accumulates the information, they analyze the observations and synthesize them to define the core problems. These definitions are called problem statements. The team may create personas to help keep efforts human-centered.
- Ideate. With the foundation ready, teams gear up to “think outside the box.” They brainstorm alternative ways to view the problem and identify innovative solutions to the problem statement.

- Prototype. This is an experimental phase. The aim is to identify the best possible solution for each problem. The team produces inexpensive, scaled-down versions of the product (or specific features found within the product) to investigate the ideas. This may be as simple as paper prototypes.
- Test. The team tests these prototypes with real users to evaluate if they solve the problem. The test might throw up new insights, based on which the team might refine the prototype or even go back to the Define stage to revisit the problem.

These stages are not always sequential. Teams often run them in parallel, out of order, and repeat them as needed.

The design thinking process aims to satisfy three criteria: desirability, feasibility and viability. Teams begin with desirability and then bring in the other two lenses.

- Desirability. The design thinking process starts by looking at the needs, dreams and behaviors of people—the end users. The team listens with empathy to understand what people want, not what the organization thinks they want or need. The team then thinks about solutions to satisfy these needs from the end user's point of view.
- Feasibility. Once the team identifies one or more solutions, they determine whether the organization can implement them. In theory, any solution is feasible if the organization has infinite resources and time to develop the solution. However, given the team's current (or future resources), the team evaluates if the solution is worth pursuing. The team may iterate on the solution to make it more feasible or plan to increase its resources (say, hire more people or acquire specialized machinery).
- Viability. A desirable and technically feasible product isn't enough. The organization must be able to generate revenues and profits from the solution. The viability lens is essential not only for commercial organizations but also for non-profits.

3.2 Creation Process

An initial draft of the use cases was obtained through user interviews conducted with all the project partners, totaling 10 interviews. Five potential use cases for five different contexts were created (here is an example. For the complete list Appendix).

Tourism	
Historical and cultural heritage	Provide a rich and interactive learning experience for tourists by giving historical and cultural information about a location. This can include information on the architecture, art, and local customs of a destination.
Personalized Experience	Create personalized experiences for tourists based on their preferences and interests. For example, a digital twin of a city could suggest personalized itineraries for visitors based on their interests, making their trip more enjoyable and memorable.
Virtual Tours	Provide virtual tours of tourist destinations, allowing potential visitors to experience the location before they arrive. This can help travelers make more informed decisions about their travel plans and increase interest in less well-known destinations.
Sustainable Tourism	Promote sustainable tourism practices by providing information on eco-friendly activities and highlighting the impact of tourism on the local environment. This can help visitors make more responsible choices and reduce their carbon footprint.
Improved Navigation	Provide accurate navigation for tourists within a destination. This can include real-time updates on traffic, public transportation schedules, and other relevant information that can help visitors better navigate the area.

Table 3. Tourism creation process

After reading the five use cases of a context (i.e., Tourism), users had to choose the two they preferred the most, justifying their choice. From there, following the question trail reported in the Annex 8, users were invited to answer the questions, always justifying their choices. All interviews were conducted remotely via video call. Each interview followed the same order of execution. It started by explaining to the users what they would be doing, then the first context was introduced by showing the set of questions the users had to answer, and then it moved to the second context, and so on until the last one. The average duration of the interviews was about one hour if the video call was face-to-face, an hour and a half for video calls with multiple users from the same organization. The video calls were held from March to April 2023. All video calls were recorded. Each user response was collected in an online document. The voting on the favorite use cases led to the selection of five use cases, still in an embryonic state.

The first real draft of the use cases was presented during the project meeting in Thessaloniki in May 2023. During the meeting, the use cases were discussed and modified to not only consider the desirable aspect but also the feasibility and the profit that can be derived from them. The post-meeting revised version was then presented to the Stakeholder Board in the two workshops organized for the project stakeholders. The feedback collected in these workshops led to the creation of requirements, user personas, and the refinement of the use cases, which were further revised during the third project meeting in Patras held in September 2023. The post-meeting version is the current one, which we present below.

3.3 Use Case 1

Code: UC_IND01

Title: Real Time Mapping of industrial environment with HIL

Domain: Industry

Users: Industry Worker

Partner Responsible for the UC: IW

Technology: Augmented Reality

Device: Handheld (iPad) Headset (Hololens2)

User Actions: Scan Environment, Add New Scan, Edit Scan, Add Point of Interest, Edit Point of Interest, Save, Login, Logout

Sensors (involved in the UC):

Assumption: In this use case the industrial environment already has a digital twin.

Execution: The user is provided with an AR mobile/wearable application and with it, they can scan the industrial environment. The information gathered from the device is processed and compared to the digital twin of the environment. If the two scans are the same, nothing will happen but if the “saved” scan is wrong thus the user can rescan the wrong part and update the digital twin with the right information. The user can do the same not only with parts of the environment that are wrongly scanned but also with the missing ones (for example because some obstacles created misalignments during the creation of the digital twin). Once the error is found the worker can:

- correct errors in the 3D scanning of the industrial environment
- add missing parts in the 3D scanning of the industrial environment.

The user can also add POI (Point of Interest) to the digital twin of the industrial environment. POIs are areas of interest for the robots present in the factory (e.g., loading/unloading points, charging stations). By recognizing a POI the robot can start

a routine related to the POI. For example if the robot scans a charging station and it is out of battery it can stop where the charging station is and recharge independently. After a POI is inserted, it will be part of the digital twin.

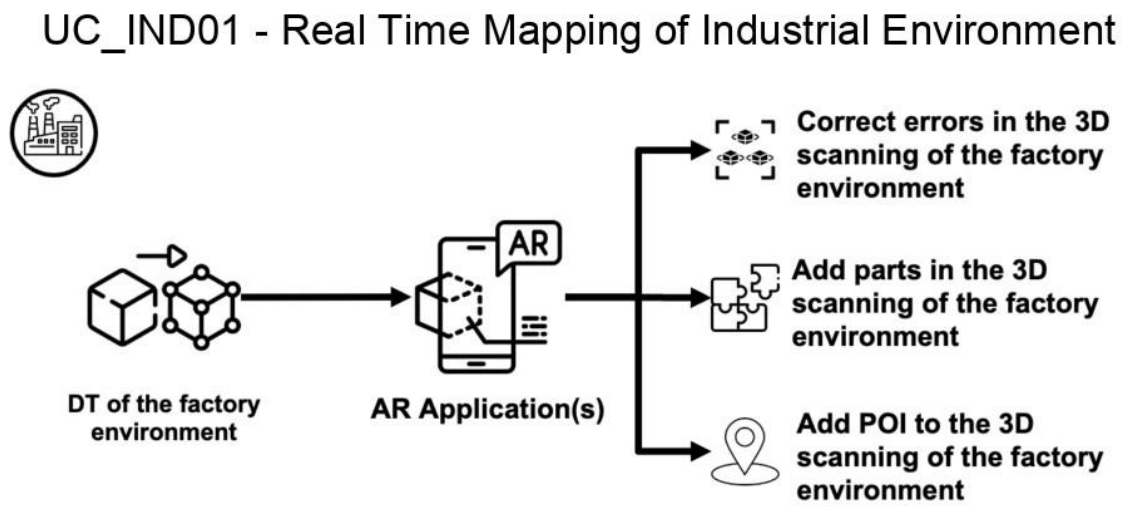


Figure 1. Diagram for the Industrial Use Case

3.4 Use Case 2

Code: UC_CIT01

Title: Digital Twin Creation

Domain: City

Partner Responsible for the UC: VNG, FIWARE

Technology: Virtual Reality

Device: Desktop

User Actions: Create the DT, Update the DT, check quality of DT, Save, Login, Logout

Sensors (involved in the UC): equipped cars, drones, city sensors

Assumptions: The Digital Twins created in this stage will be accessible to all the other applications.

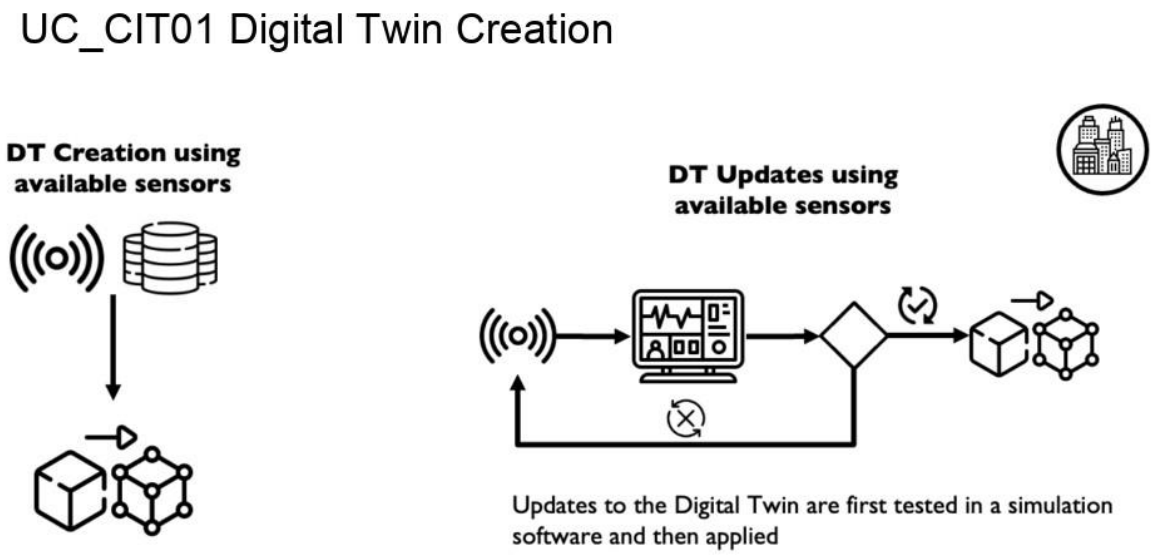


Figure 2. Diagram for the Digital Twin Creation Use Case

Execution: Data from sensors enable the reconstruction of an accurate and up-to-date digital twin. This continuous data gathering from the sensors (equipped cars, drones, city sensors) will also guarantee a frequent update of the digital twins.

After the Login the user can Create a New Digital Twin or Update and existing one. By creating a new digital twin the user will have to select the sensors to use for the creation and confirm their choices. Then the DT is created. The model is then imported into simulation software such as Carla in order to test the process of creation of the digital twin.

By updating the digital twin the user can:

- import data gathered from the sensors
- edit the 3D model of the digital twin through the editor

3.5 Use Case 3

Code: UC_CIT02

Title: City Planning

Domain: City

Partner Responsible for the UC: DTT, FIWARE, VNG

Technology: Virtual Reality

Device: Desktop

Sensors (involved in the UC): Traffic lights sensors, quality air sensors, cameras (control vehicles Low Emission Zones and control traffic in roundabout)

Assumption:

Execution: In this use case the user can apply changes to the digital twin in order to run simulations of different city scenarios.

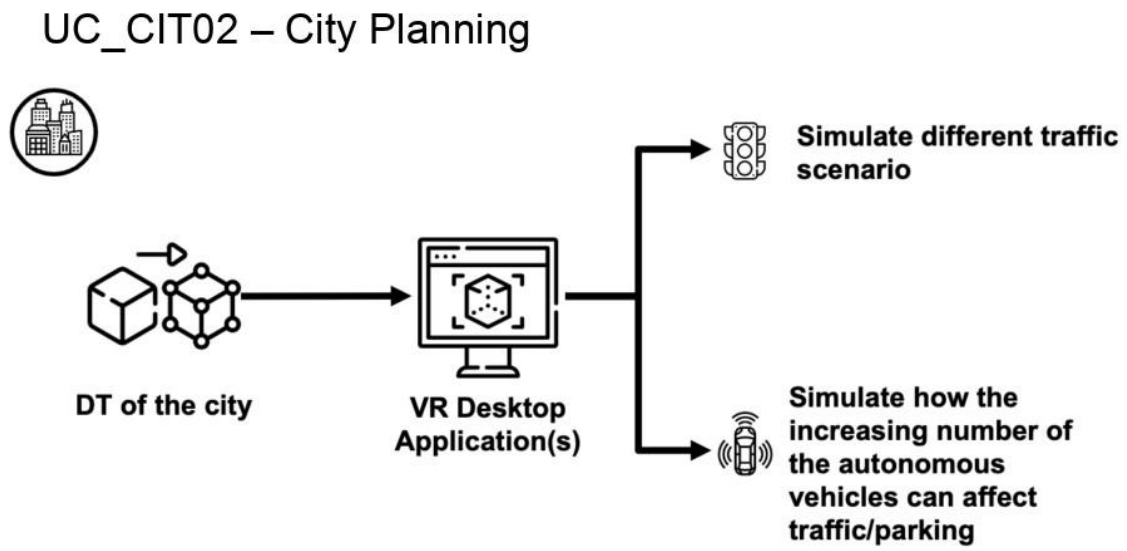


Figure 3. Diagram for the City Planning Use Case

Examples:

- changes to the configuration of city lights/traffic lights can be used to simulate different traffic scenario
- simulate how the increasing number of autonomous vehicles can affect the parking, the traffic lights position and duration.
- changing the configuration of the buildings (creating new ones, deleting old ones) and observing how this affects the quality of the city (how traffic changes, how places can become more or less crowded).

To run the simulations a simulation software such as Carla will be integrated

3.6 Use Case 4

Code: UC_CIT03

Title: City Maintenance

Domain: City

Partner Responsible for the UC: FICOSA, VNG

Technology: Virtual Reality

Device: Desktop

Sensors (involved in the UC):

Assumption:

Execution: In this use case, sensor updates are used to make prompt decisions to safeguard the welfare of the city.

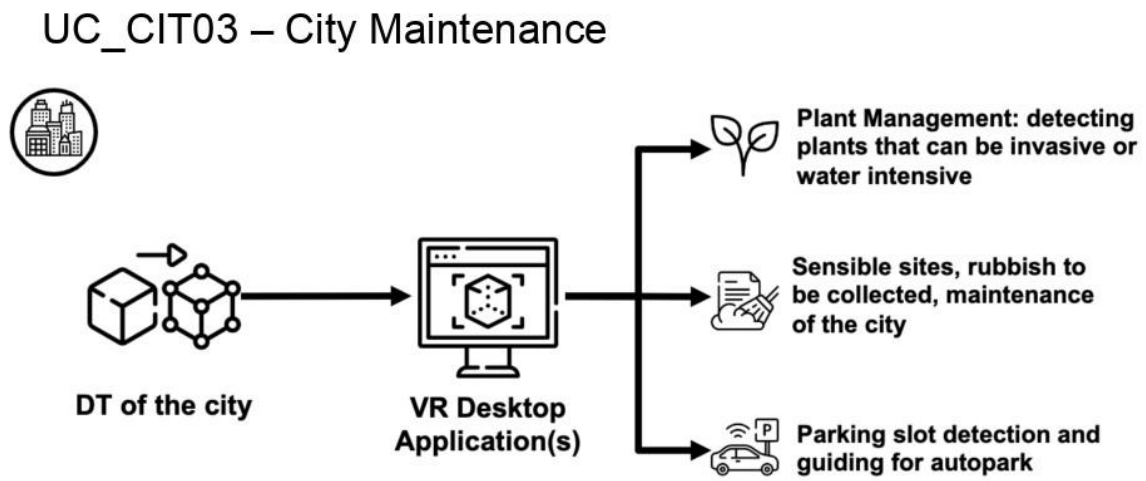


Figure 4. Diagram for the City Maintenance Use Case

Examples:

- Plant management: Detection of areas that need more waters compared to others.
- Vandalism: sensible sites, detection of graffiti, detection of damage to public furniture
- Rubbish: rubbish to be collected
- Parking slot detection
- Pollution detection

3.7 Use Case 5

Code: UC_CIT04

Title: Virtual Tourism

Domain: City

Partner Responsible for the UC: FIWARE, VNG

Technology: Virtual Reality, Augmented Reality

Device: Headset for remote experience, Mobile for on-site experience

Sensors (involved in the UC):

Assumption:

Execution: The use case exploits Virtual and Augmented Reality to offer different experiences to the user according to their location. VR can be used for remote

experiences. The aim of the remote experience is to immerse the user in the life of the city. Users can explore the virtual city, checking when places are more crowded, when there is the most traffic, when it is better to get public transportation, when it is better to go out due to weather or pollution conditions. The tourist can also check information about opening time of shops/museums and restaurants.

A tourist planner can use this app to organize groups, planning tours in specific areas of the city or at specific times/days of the week to avoid traffic and problems with urban mobility. Having information about the opening time of museums allows to create consistent city tours.

AR can be used for on-site experience instead. With AR, users will see augmented information on top of the real world.

VNG: AR experience outside the museum: guide the user in a path from the station to the area of Villanova.

places and length of experience vary according to crowd and weather. The length of the experience inside the museum can be adjusted according to the number of people inside the museums or the weather outside.

special AR contents can be shown in specific points of the path according to weather, time of the year, exposition.

Etteln: AR on site with possibility to have mobile AR experience in front of specific monuments. AR can also provide information in front of shops/museums/restaurants, showing opening times and menus.

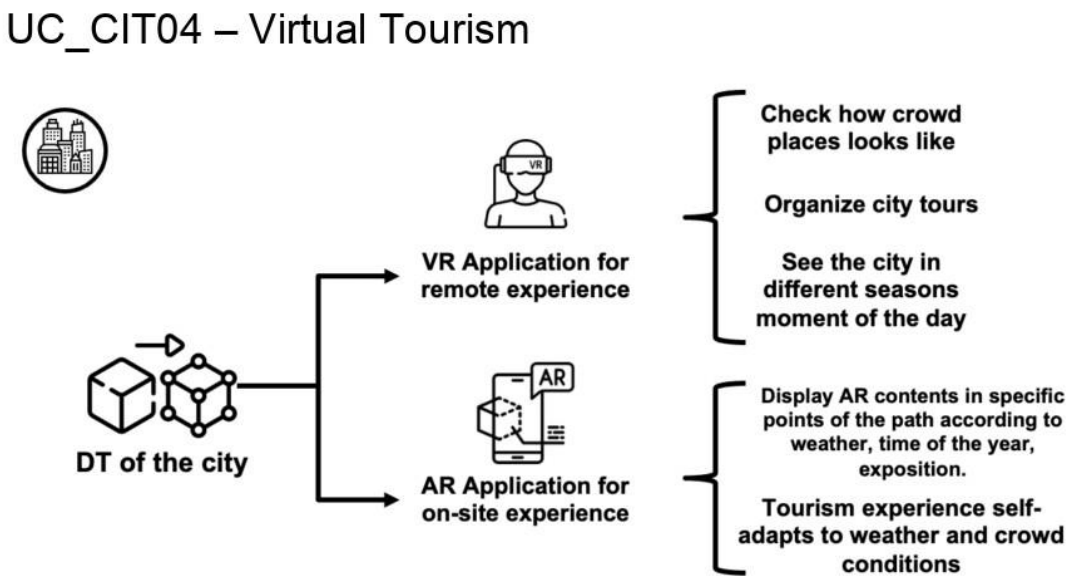


Figure 5. Diagram for the Virtual Tourism Case

4 Personas

4.1 General motivation

User personas are fictional representations, but they are built on real data and research, reflecting different segments of the potential user base. The primary purpose of user personas in the context of digital twin project is to facilitate a deeper understanding of user needs and preferences. These representations provide a more concrete and relatable view of the users, moving beyond mere numbers and demographics. This approach not only fosters empathy but also ensures that the digital twin is developed with a user-centered focus. Moreover, user personas serve as a common reference point for teams involved in the project. This shared understanding of the target user streamlines communication and aligns efforts across different functions, which is particularly valuable in larger or geographically dispersed teams.

Additionally, user personas assist in prioritizing the features and functions of the digital twin. By aligning the development process with the specific needs and goals of the personas, the project can more effectively address user requirements, enhancing both user satisfaction and the competitive edge of the product. In essence, the use of user personas in digital twin projects is not merely theoretical but a practical strategy. It ensures that the development process is guided by a clear understanding of the users, leading to products that are not only technologically advanced but also highly relevant and usable for the intended audience.

Therefore, personas are created accordingly per the use cases like this:

Industry Use Case	Industry (UC1)	User Persona 1 - Linda Robertson User Persona 2 - Juan McDermott
City Use Case	Virtual Tourism (UC5)	User Persona 3 - Marcos Fernandez User Persona 4 - Chiara Valentini
	Digital Twin Creation (UC2)	User Persona 5 - Samuel Lee
	City Planning (UC3)	User Persona 6 - Mia Becker
	City Maintaince (UC4)	User Persona 7 - Stefan Wolff

Table 4. Distribution of personas per use case scenario

4.2 List of personas per use case

Industry Use Case Personas

User Persona 1

Name: Linda Robertson

Role: Plant Manager

Age: 45

Background: Mechanical Engineering degree with 20 years of experience in factory management. Knowledgeable about the importance of digital twins in modern production systems.

Daily tasks:

- Supervising factory operations.
- Ensuring safety protocols are adhered to.
- Planning for the factory's monthly, quarterly, and annual targets.

Goals:

- Ensuring efficient production with minimal downtime.
- Using technology to streamline factory operations.
- Keeping the digital twin of the factory updated for accurate planning and decision-making.

How the AR application benefits Linda:

- Helps maintain an up-to-date digital twin without outsourcing the task to external teams.
- Increases factory efficiency by quickly identifying and resolving errors in the factory's layout.
- Helps in strategic planning by analyzing the updated digital twin for potential enhancements in the layout or identifying bottlenecks.

Challenges:

- Ensuring every staff member is trained to use the application effectively.
- Monitoring the accuracy of updates made to the digital twin.

Tech Tools and Software:

- Factory Management Systems: Platforms such as Siemens SIMATIC IT for managing and monitoring factory operations.
- Digital Twin Software: Custom software for interacting with and updating the factory's digital twin.
- AR Wearable Management: Software to manage and monitor the usage of AR wearables in the factory.

- Safety Protocols Monitoring: Tools like SafetyCulture for ensuring safety standards are upheld in real-time.
- Communication Tools: Slack or Microsoft Teams for factory-wide communication and coordination.

Personal quirks/traits:

- Linda starts every morning by visiting the factory floor to get a firsthand look at operations before diving into her administrative duties.
- She has a personal notebook where she jots down any innovative ideas or thoughts for improving the factory.
- Collects vintage mechanical gears and displays them in her office as a nod to her mechanical engineering background.

Goals & needs:

Linda wants to make sure that production in the plant runs well with as little downtime as possible. She also wants to use technology to make operations run more smoothly and to have an updated digital twin so that decisions are made with knowledge. She needs access to cutting-edge technological tools, efficient staff training, and the ability to check the correctness of the digital twin in order to maximize industrial productivity and safety.

Personality:

Analytical (4/5):

Linda is highly analytical, as her role as a Plant Manager in a factory demands a keen eye for detail, data analysis, and a strong focus on optimizing operations. She needs to make data-driven decisions, supervise processes, and ensure efficiency, which requires a significant degree of analytical thinking.

Introvert (3/5):

While Linda has to engage with her factory staff, she is not overly extroverted. Her daily tasks primarily involve managerial and administrative responsibilities. She is hands-on when it comes to factory operations, but she is not an extrovert who seeks the spotlight. She is likely more comfortable with a balance between social interactions and focused, independent work.

Passive (4/5):

Linda is an active manager who oversees factory operations and safety protocols, ensuring everything runs smoothly. She actively plans and strategizes to meet production targets and is deeply involved in maintaining an up-to-date digital twin. Her

proactive approach to management suggests she is more on the active side of the scale.

Likes:

- Reading: Linda enjoys immersing herself in a good book, whether it's for entertainment or gaining knowledge.
- Cooking: She finds solace and creativity in the kitchen, experimenting with various recipes and cuisines.
- Collecting Vintage Items: Linda has a unique interest in collecting vintage mechanical gears, and she proudly displays them in her office.

Dislikes:

- Crowded Places: She dislikes large, crowded venues and prefers more intimate and peaceful settings.
- Wasting Time: Linda values efficiency and dislikes when time is wasted on trivial matters.
- Unnecessary Complexity: She prefers simplicity and straightforward solutions over unnecessarily complicated processes or systems.

User Persona 2

Name: Juan McDermott

Role: Worker

Age: 28

Background: Has been working in the factory for 3 years. Familiar with the factory's day-to-day operations and layout.

Daily tasks:

- Operating machinery.
- Ensuring work areas are tidy and hazard-free.
- Reporting any discrepancies or issues to the supervisory team.

Goals:

- Completing daily production targets.
- Ensuring personal and coworker safety.
- Learning and adopting new technologies for career growth.

How the AR application benefits Juan:

- Easily reports and rectifies errors in the digital twin, which makes his work environment safer.

- Helps him identify and mark POIs that are important for his daily tasks, such as machinery shut-off points or hazard zones.
- Empowers him to contribute to the betterment of the factory's digital planning and layout.

Challenges:

- Learning to use the application efficiently.
- Ensuring the corrections and updates he makes are accurate.

Tech Tools and Software:

- AR Wearable Device: Uses AR glasses/headsets for 3D scanning and interaction with the digital twin.
- Machine Operating Software: Depending on the machinery, specific software interfaces for optimal operation.
- Reporting Tool: Mobile apps or integrated software for reporting discrepancies or machinery issues.
- Training Platforms: Virtual modules or apps that keep him updated on the latest tech applications in the factory.

Personal quirks/traits:

- Juan always has a band around his wrist, a habit from his early days to remind him to be safety conscious.
- He enjoys playing video games in his free time, which indirectly helps him adapt quickly to new tech tools in the factory.
- Loves to participate in factory football matches and often organizes them.

Goals&Needs:

Juan's goals center around his work, including meeting daily production targets, ensuring personal and coworker safety, and embracing new technologies for career growth. His needs involve effective training to use AR applications efficiently, a supportive work environment that values safety and innovation, and opportunities for skill development and advancement in the factory.

Personality:

Analytical (3/5):

This means Juan is moderately analytical, but the description didn't provide strong evidence for a highly analytical or creative mindset.

Introvert (3/5):

Juan's persona doesn't explicitly mention his social orientation, so he can be assumed

to be moderately introverted, but it's not definitively clear from the information provided.

Passive (2/5):

Juan seems to be somewhat active and engaged in his work, with an interest in safety and adopting new technologies. This suggests a slightly more active disposition than passive.

Likes:

- Football: Juan enjoys playing and participating in football matches, which indicates his passion for the sport and his enjoyment of physical activity.
- Video Games: He likes playing video games as a form of entertainment and relaxation in his free time.
- Family: Although not mentioned in the initial persona, if Juan values spending time with his family, it reflects his strong bond with loved ones.

Dislikes:

- Manipulation: Juan dislikes situations where people are manipulative or dishonest, as he likely values honesty and integrity.
- Uncertainty: He may have a dislike for uncertain or unpredictable situations, as they can be unsettling and challenging to navigate.
- Pressure: Juan may not enjoy high-pressure situations and prefers a more relaxed and stress-free environment.

City Use Case Personas - Virtual Tourism

User Persona 3

Name: Marcos Fernandez

Role: Tour Guide

Age: 34

Background: History major with a passion for storytelling. Worked for 10 years guiding tourists around various cities.

Daily tasks:

- Leading tours around city landmarks.
- Sharing stories and answering questions about the city's history.
- Organizing schedules based on current events and exhibitions.

Goals:

- Providing an immersive experience for tourists.

- Staying updated on city events, exhibitions, and attractions.
- Adapting quickly to changing circumstances like weather and traffic.

How the applications benefit Marcos:

- Uses VR to pre-plan tours, avoiding congested areas and ensuring optimal travel times.
- Leverages AR to enrich his narratives, giving real-time visual context to his stories.
- Can quickly adapt to changes, like redirecting tourists based on sudden weather shifts or traffic jams.

Challenges:

- Ensuring all tourists have the necessary equipment for AR and VR experiences.
- Balancing historical storytelling with augmented content.

Tech Tools and Software:

- VR Software: Platforms like Google Earth VR or custom-built city VR tours for tour pre-planning.
- AR Wearables: Microsoft HoloLens, Google Glass, or AR-enabled mobile apps to add context to his narratives.
- Weather & Traffic Apps: Real-time tools such as AccuWeather and Waze to adapt to changing circumstances.
- Booking Systems: Online tools to manage tour schedules, bookings, and handle changes due to external factors.

Personal quirks/traits:

- Marco often starts his tours with a signature joke related to the city's history.
- Has a small collection of historical trinkets that he uses during tours to add depth to his stories.
- Owns a vintage raincoat that he wears during bad weather tours, making him easily recognizable.

Goals and Needs:

Marcos, the Barcelona tour guide, aims to provide an immersive experience for tourists by staying updated on city events, exhibitions, and adapting swiftly to unforeseen changes like weather and traffic. He balances historical storytelling with augmented content using technology. To meet these goals, Marcos requires access to current information, technology tools, tourist equipment, and flexibility.

Personality:

Analytical (3/5):

Marcos appears to have a balanced approach, incorporating historical facts and storytelling. He uses technology for tour planning but also relies on traditional narratives, indicating a moderate level of analytical thinking.

Introvert (3/5):

While Marcos interacts with tourists daily and incorporates humor into his tours, he also displays a penchant for historical artifacts and trinkets, which could indicate an introverted or reflective aspect of his personality. His introversion and extroversion seem to be well-balanced.

Passive (4/5):

Marcos's role as a tour guide requires him to be active, leading tours, adapting to changing circumstances, and engaging with tourists. His active approach is evident in his use of technology, adaptation to weather and traffic, and delivering a dynamic and engaging tour experience.

Likes:

Outdoor Activities: He has a fondness for outdoor activities, whether it's hiking in the nearby mountains, spending a day at the beach, or simply taking a leisurely stroll in the city's parks.

Reading: When he has downtime, Marcos often delves into historical novels and non-fiction books. He finds great satisfaction in expanding his knowledge of history and world events through reading.

Traveling: Besides his work, he loves to travel and explore new destinations, learning about their history and culture.

Dislikes:

Injustice: He is deeply bothered by injustices in the world and strives to support social causes.

Extreme Weather: Marcos is not a fan of extreme weather conditions, whether it's scorching heat or bitter cold.

Traffic Jams: Marcos dislikes being stuck in traffic, which can disrupt his plans and make it challenging to maintain his tour schedules and adapt to changes.

User Persona 4

Name: Chiara Valentini

Role: Tourist

Age: 28

Background: Software engineer looking for a vacation in Europe. Tech-savvy and loves using gadgets during her travels.

Daily tasks (while on vacation)**:**

- Exploring city landmarks.
- Trying out local cuisines.
- Documenting her travels on social media.

Goals:

- Immersing herself in the local culture.
- Avoiding tourist traps and experiencing genuine local spots.
- Ensuring an efficient and pleasant travel experience.

How the applications benefit Chiara:

- VR helps her visualize her itinerary, allowing her to plan according to real-world conditions.
- AR enriches her travel experience, making historical sites come alive with digital insights.
- Keeps her informed about restaurants, helping her choose based on real-time crowd information, menus, and prices.

Challenges:

- May need to rent or buy specific AR/VR equipment if not provided.
- Balancing between enjoying the moment and using AR tools.

Tech Tools and Software:

- Personal AR and VR Gear: Oculus Quest for VR experiences and AR-enabled smartphone for on-site exploration.
- Travel Apps: TripAdvisor, Yelp for reviews and insights on places, restaurants.
- Social Media Platforms: Instagram, TikTok for documenting her travels.
- Mobile Mapping Software: Google Maps with AR navigation feature.

Personal quirks/traits:

- Chiara carries a small notebook where she jots down non-digital memories and thoughts.
- Has a habit of trying the most unusual dish at some restaurant she visits.
- Maintains a tradition of sending postcards to herself from every city she visits.

Goals&Needs:

Her goals and needs revolve around immersive and efficient travel experiences in Europe. She seeks to deeply connect with local cultures, avoid tourist traps, and

document her adventures. Chiara values technology for planning and enhancing her journeys while striving for a balanced blend of traditional and modern travel practices.

Personality:

Analytical (4/5):

Chiara maintains her relatively high level of analytical thinking, reflecting her logical and systematic approach to problem-solving, which is typical of a software engineer.

Extrovert (4/5):

Chiara is now leaning more toward being an extrovert. This adjustment indicates that she enjoys social interactions, sharing her experiences, and connecting with others to a higher degree.

Active (4/5):

Her inclination towards being an active traveler remains the same. She is proactive in seeking out various activities and experiences during her journeys.

Likes:

Outdoor Activities: Chiara enjoys engaging in outdoor activities during her travels. Whether it's hiking, cycling, or simply exploring the natural beauty of a destination, she finds joy in being outdoors.

Traveling: Traveling is one of Chiara's greatest passions. She loves the thrill of discovering new places, immersing herself in different cultures, and exploring the world.

Documenting Memories: Chiara appreciates documenting her travel experiences to create lasting memories. She values the ability to relive and share her adventures through photos, videos, or traditional means like postcards and personal notes.

Dislikes:

Wasting Time: Chiara dislikes situations or activities that she considers a waste of time. She's an efficient traveler who wants to make the most of her journeys and ensure each moment is meaningful.

Tourist Traps: Chiara has a strong aversion to tourist traps. She aims to avoid overcrowded and overly commercialized places, preferring to discover authentic and less touristy spots during her travels.

City Use Case Personas - Digital Twin Creation

User Persona 5

Name: Samuel Lee

Role: Digital Twin Creator

Age: 38

Background: M.Sc. in Computer Science with a focus on IoT and 3D Modeling.

10+ years experience in digital modeling, simulation, and data analytics.

Previously worked on urban planning simulation projects.

Daily tasks:

- Monitoring real-time sensor data from various sources, including vehicles and stationary sensors.
- Mapping and updating the digital twin to reflect real-world changes.
- Running simulations to validate the accuracy and realism of updates.
- Collaborating with data engineers to ensure seamless data transmission from sensors.

Goals:

- Maintaining a high-fidelity and up-to-date digital twin of the city environment.
- Ensuring the digital twin can be seamlessly imported to simulation software without data loss or misinterpretation.
- Continuous improvement of the digital twin's accuracy by refining the data collection and modeling process.

How the role aligns with the use case:

- Utilizes sensor data to recreate and update the digital twin. Samuel's expertise in data analytics and modeling ensures he understands the nuances of data and can effectively use it to build accurate digital representations.
- Regularly checks and validates the quality of updates, ensuring the digital twin's accuracy. His familiarity with simulation software like Carla helps in testing the real-world applicability and realism of the digital twin.

Challenges:

- Ensuring the digital twin remains accurate even when there are gaps or inconsistencies in sensor data.
- Keeping up with the continuous stream of real-time data and ensuring timely updates to the digital twin.
- Collaborating with other departments and stakeholders to ensure the digital twin meets the needs of various applications.

Tech Tools and Software:

- Custom software for interpreting and visualizing sensor data.
- 3D modeling tools for creating and updating the digital twin.
- Carla simulation software for testing and validation.

- Collaboration tools for team communication and project management.

Personal quirks/traits:

- Passionate about urban planning and its intersection with technology.
- Dedicated in making sure the accuracy of the digital twin is maintained.
- Enjoys attending tech conferences to stay updated on the latest in digital modeling and simulation techniques.

Goals & Needs

Samuel's goals revolve around maintaining a high-fidelity and up-to-date digital twin of the city environment. He aims to ensure seamless integration with simulation software, continuous accuracy improvement through data refinement, and effective collaboration with data engineers. His needs include access to reliable sensor data, advanced modeling tools, and efficient project management for seamless urban planning.

Personality:

Analytical (4/5):

Samuel's role as a Digital Twin Creator requires a strong analytical mindset. He deals with data, modeling, and simulations, which demand a thorough and logical approach. He needs to analyze data to create an accurate digital twin and regularly validate its accuracy. His expertise in data analytics and meticulous nature implies a significant analytical orientation.

Introvert (3/5):

Samuel's role doesn't explicitly require constant interaction with a large number of people. However, his moderate score suggests that he is neither strongly introverted nor extroverted. He collaborates with data engineers and may have to engage with other stakeholders, but the core of his work involves data analysis, modeling, and simulation, which can often be done independently or in smaller team settings.

Passive (2/5):

In his role, Samuel is not passive but moderately active. He is responsible for daily tasks that involve monitoring, mapping, updating, and running simulations. These actions require proactivity and a hands-on approach. His work is essential to maintaining the digital twin's accuracy and ensuring it aligns with real-world changes. While his primary focus may be on data and modeling, his work involves ongoing, active tasks.

Likes:

Gaming: Like many programmers he has an affinity for video games, as they appreciate the logic, design, and interactivity involved in game development. They might enjoy both playing and creating games.
Reading: Samuel may have a liking for reading, whether it's related to his field or for leisure. He might enjoy books on technology, urban planning, or science fiction.
Tech Conferences: He enjoys attending technology conferences to stay updated on the latest trends, network with like-minded individuals, and learn about cutting-edge advancements in the tech world.

Dislikes:

Bugs and Errors: Programmers often have a low tolerance for technical issues and errors, especially when they encounter them in software or systems they use.
Overly Crowded Spaces: As someone who may appreciate urban planning, he might not enjoy overly crowded or congested places, especially during his leisure time.

City Use Case Personas - City Planning

User Persona 6

Name: Mia Becker

Role: Cycling Citizen

Age: 27

Background: Graphic designer working at a local firm.

Lives 5 km away from her office and prefers cycling for daily commuting.

Environmentally conscious and an advocate for sustainable urban living.

Daily tasks:

- Commuting to work and back by bicycle.
- Occasionally cycling for recreational purposes during weekends.
- Participating in local community discussions on sustainable living.

Goals:

- Safe and efficient cycling paths that are separate from main traffic.
- Understanding and advocating for city planning decisions that prioritize cyclists and pedestrian safety.
- Reducing her carbon footprint and promoting sustainable commuting in her community.

How the role aligns with the use case:

- Mia will benefit from simulations that consider the impact of traffic lights vs. roundabouts on cyclist safety and flow.

- Interested in how city planning, especially changes in building configurations, can affect her daily cycling route.
- As a daily commuter, Mia can provide valuable feedback on real-world cycling conditions compared to digital twin simulations.

Challenges:

- Navigating busy intersections that might prioritize motor vehicles over cyclists.
- Encountering unplanned construction or changes in the urban landscape which might not be updated in real-time simulations.

Tech Tools and Software:

- GPS and route planning apps for cycling.
- Local community forums or apps for discussing city planning and cycling conditions.

Personal quirks/traits:

- Enthusiastic about promoting bicycle safety and infrastructure through social media.
- Participates in cycling marathons and charity events.
- Regularly attends city planning meetings to voice the concerns of the cycling community.

Goals&Needs:

To reach her goals, Mia wants to make bike paths safer, support green city planning, and lower her carbon footprint. She needs bike lanes, people who care about riders' safety, and a commitment to green transportation in her area. What she wants is for cities to be safer, healthier, and better for cyclists.

Personality:

Creative (4/5):

Mia's role as a graphic designer and her involvement in advocating for sustainable urban living and cycling infrastructure demonstrate a strong creative orientation. She is actively engaged in creative activities and initiatives.

Extrovert (4/5):

Mia's active involvement in community discussions, advocacy, cycling events, and city planning meetings, as well as her enthusiasm for promoting bicycle safety through social media, indicates extroverted tendencies. She is highly engaged in social and community activities.

Active (4/5):

Mia's active lifestyle, which includes daily cycling commutes, recreational cycling, participation in events, and advocacy for cycling and sustainability, reflects a high level of activity and engagement in her interests and activities.

Likes

Outdoor Adventures: Mia enjoys outdoor activities such as hiking, camping, and exploring nature, which align with her love for cycling and sustainability.

Art and Creativity: She has a passion for creative arts, including painting, drawing, or other artistic expressions as a way to unwind and tap into her creative side.

Music and Concerts: Mia has a fondness for live music events and concerts, finding them a source of inspiration and a way to relax.

Dislikes:

Hot Weather: Mia doesn't like hot weather, preferring milder or cooler climates.

Scammers: She strongly dislikes scammers and fraudulent activities that take advantage of others.

Conflict: Mia has an aversion to conflicts, tensions, and disharmony, whether in personal relationships or on a broader societal scale.

City Use Case Personas - City Maintenance

User Persona 7

Name: Stefan Wolff

Role: City Authorities

Title: City Infrastructure and Maintenance Director

Age: 52

Background: B.A. in Public Administration with a minor in Environmental Science.

25+ years of experience working in city government, with 10 years in his current position.

Oversees multiple departments including city gardening, public works, sanitation, and city infrastructure.

Daily tasks:

- Monitoring reports from different city departments about maintenance needs.
- Reviewing data and feedback from city sensors related to plant management, rubbish detection, sidewalk conditions, and parking.
- Coordinating with teams for timely maintenance and repair work.
- Budget allocation for various city maintenance tasks.

Goals:

- Ensuring the city is clean, safe, and well-maintained for all residents.
- Implementing efficient systems for detecting and addressing maintenance issues proactively.
- Reducing the environmental impact of city maintenance activities, particularly in areas like water usage for plants.

How the role aligns with the use case:

- Uses data to detect and manage potentially invasive or water-intensive plants, ensuring that city gardens and green spaces are sustainable.
- Coordinates with the sanitation department to address rubbish collection in sensible sites.
- Prioritizes maintenance tasks based on urgency, ensuring that things like damaged sidewalks, faded road paintings, and malfunctioning furniture are addressed promptly.
- Leverages technology to detect available parking slots, guiding auto-park systems for efficient and orderly parking.

Challenges:

- Juggling multiple maintenance tasks with a limited budget.
- Staying updated on the latest technologies that can help in efficient city maintenance.
- Balancing the need for rapid response to issues with the bureaucratic processes often present in city governance.

Tech Tools and Software:

- City maintenance management software for tracking tasks and budgets.
- Data visualization tools to analyze sensor data related to plants, rubbish, and parking.
- GPS and mapping software for coordinating tasks across the city.
- Collaboration tools for communication with various city departments.

Personal quirks/traits:

- A strong advocate for sustainable city practices, often pushing for green solutions in city maintenance.
- Enjoy walks in the city parks, using them as an opportunity to inspect the health and state of city plants.
- Actively seeks feedback from city residents, often holding town hall meetings to discuss maintenance concerns and gather suggestions.

Goals&Needs

Stefan Wolff aims to keep the city clean, safe, and eco-friendly for its residents. He wants to use technology to prevent maintenance problems, cut down on environmental impacts, and prioritize urgent issues efficiently. His needs include a manageable budget, access to the latest tech, and a way to navigate bureaucratic hurdles.

Personality:

Analytical (4/5):

Stefan's role as the City Infrastructure and Maintenance Director involves a significant amount of data analysis, budget allocation, and decision-making based on reports and sensor data. He uses technology and data-driven approaches to make informed decisions about city maintenance. While he is analytical in his approach, he may not be the most extreme analytical thinker, but he certainly leans more towards the analytical side.

Introvert (3):

Stefan's persona doesn't strongly indicate that he is an introvert or extrovert. He actively seeks feedback from city residents and holds town hall meetings to gather suggestions, which suggests a willingness to engage with the community. However, there's no indication that he thrives in highly social or extroverted settings, so he falls somewhere in the middle on the introvert-extrovert scale.

Passive (4):

Stefan's daily tasks involve coordinating with various teams and departments to ensure timely maintenance and repair work. He actively reviews reports and data and works on budget allocation, indicating an active approach to his responsibilities. He doesn't seem passive in his role, but he might face challenges related to bureaucracy that could somewhat hinder his level of activeness. Therefore, he leans more towards the active side of the scale.

Likes:

Sustainability: Given his advocacy for sustainable practices in city maintenance, it's likely that he has a personal interest in eco-friendly living, such as recycling, reducing waste, and conserving resources.

Learning and Innovation: To stay updated on the latest technologies and innovative approaches, Stefan might have a general liking for learning and keeping up with advancements in various fields.

Healthy Lifestyle: A person in his position likely values a healthy lifestyle to maintain the energy and stamina required for a demanding job. This could include regular exercise, a balanced diet, and stress management.

Dislikes:

Waste and Inefficiency: Given his focus on efficient city maintenance, Stefan probably dislikes wasteful practices and inefficiency in both professional and personal contexts.

Environmental Neglect: He may have a strong aversion to environmental neglect, such as pollution or the disregard for green practices, given his commitment to sustainability.

5 Requirements for DIDYMOS-XR

5.1 Requirement gathering

Gathering requirements is an indispensable phase in user-centric development to ensure the developed applications and technical solutions align with the preferences of the users. Using a systematic approach to collect and analyze requirements, the expectations between the development team and the users can be bridged. The discussion of the requirements with the DIDYMOS-XR project partners fosters clear communication and the alignment of goals for the applications.

The present set of requirements originated from 3 distinct sources:

- Key Performance Indicators (KPIs)
- Stakeholder Workshop
- Analysis of Use Cases

The first set of requirements was adopted directly from the KPIs, defined in the DIDYMOS-XR project proposal. These requirements could be transformed into a new requirement structure featuring additional parameters important for in-depth definition. The KPIs had already been clearly defined, requiring only minimal additional elaboration. The priority of this group of requirements was set to *high*, given that they must be addressed as specified in the project plan.

The second set of requirements is derived from the stakeholders' workshops. From studying the recording of the workshop, requirements, suggestions and pain points could be identified that are of importance for users. These new requirements were all transformed into the requirement structure and discussed later during the plenary meeting in Patras, to avoid withholding any of the stakeholders' concerns. Together with all partners, requirements that were out of the project scope could be either deleted or marked with a low priority.

The third set of requirements was created by analyzing the use cases internally within WP2. They depict technical prerequisites and expectations of users that are required for usable applications. By adding and discussing these more general requirements to the list, it is ensured that partners have a consistent perspective on the demands of the specific use cases.

5.2 Structure of requirements

Each requirement is collected in a table alongside a set of fields for definition. The field's contents were successively developed and were feedbacked and discussed together with the DIDYMOS-XR project partners on multiple occasions. The following explanations are for all the components in the requirements list that is included in Requirements Detailed Information.

General requirement information:

- **Title**: A concise and clear title that summarizes the essence of the requirement
- **Description**: A brief explanation of the requirement, providing information on what needs to be achieved.

Components for requirement code:

- **Requirement Code**: A unique identifier assigned to the requirement for tracking and referencing. The requirement code is composed of the following elements: “U/T&F/NF&{Number}&v+{Version}”
    - **U/T**: Specifies whether the requirement is a user requirement (U) or a technical requirement (T).
    - **F/NF**: Indicates whether the requirement is functional (F), relating to features or non-functional (NF), relating to parameters.
    - **Number**: A serial number that is gradually incremented as new requirements are added.
    - **Version**: Specifies the version of the requirement, incremented when changing the requirement over time.

Project-related requirements:

- **Priority**: The importance of the requirement is assigned in 3 levels:
    - HIGH: The requirement is mandatory and must be fulfilled.
    - MEDIUM: The requirement is strongly recommended.
    - LOW: The requirement is discretionary and considered optional.
- **Origin**: The source or reason for the requirement is defined with the following codes of origin:
    - Proposal: The requirement derived from the proposal.
    - WS {Domain}: The requirement was suggested by stakeholders during the workshop of the specified domain.

    - UC {Use Case}: The requirement was developed from the demand of the specified use case.
- **Scope**: Defines the phase or demonstrator the requirement is relevant. The current categories are:
    - Initial components: The requirement is related to the technologies that are the basis for the application
    - Initial XR application: The requirement is important in the early stages of the development of the applications
    - Final XR application: The requirement is important for the final evaluation of the applications
- **Milestone**: The specific project phase or point when the requirement should be met. The milestone is specified with the month the milestone should be met (M{x} for the x-th month of the project duration) and the predefined milestone abbreviation (e.g. MS{x}) in brackets.
- **Responsibility**: Identifies the partners responsible for fulfilling the requirement.
- **Linked WP**: Connects the requirement to a specific work package from the project plan.
- **Linked Tasks**: Lists the tasks that are associated with fulfilling the requirement.
- **Means of Validation**: Identifies the deliverable the requirement is addressed and validated.

5.3 User requirements

The DIDYMOS-XR requirements presented in this document represent the interim status in the 12th month of the project duration. The reported list has already gone through several iterations and will be updated further as the project progresses. In order to increase the readability, the requirements in this section are limited to *code*, *title* and *description*. Refer to the Requirements Detailed Information section at the document's end for a comprehensive overview.

Code	Title	Description
UNF13v1	Stakeholder involvement	Users expect the system to handle data securely, especially when it involves location and maintenance-related information.
UF14v1	Approval from the EAB	Develop algorithms for 3D reconstruction and modeling based on the sensor data to create the virtual environment (digital twin).
UNF15v1	User Engagement	Implement a verification mechanism to check the quality and accuracy of updates obtained from

Code	Title	Description
		both sensors and cars.
UNF16v1	Minimum number of user for each validation	The system should allow seamless integration with simulation software like Carla or Omniverse to test the process of updating the digital twin.
UF19v2	Remapping of production line	Implement version control for the digital twin to keep track of changes and updates over time.
UF20v1	Simulation Report Generation	Provide auditing capabilities to trace the origin and history of data used for updating the digital twin.
UNF21v2	Investment and Time Optimization	Users should be able to rely on the system's data verification mechanism to ensure the accuracy and reliability of the digital twin updates.
UNF22v2	Logistics Error Prevention	Users should have the capability to export the digital twin to simulation software for testing and validation purposes.
UF23v2	Addition of New POI	The system should be capable of handling a large number of sensors and cars simultaneously without compromising performance. It should be scalable to accommodate future expansion and increasing data volumes.
UNF24v2	POI location accuracy	The system should have an error reporting and logging mechanism to help users identify and address issues promptly.
UNF25v1	User Experience and Interaction with POIs	Provide clear error messages and notifications for troubleshooting.
UNF26v2	Clear Information for improved work performance	The AR application should support both tablets and headsets with AR capabilities.
UF30v1	Guidance for Workers	The application must be compatible with major operating systems (e.g., iOS, Android) and AR platforms (e.g., ARKit, ARCore).
UNF35v1	Worker Responsibility	The application should provide real-time 3D scanning of the factory environment using the device's camera.
UNF36v1	Worker Application Feedback Mechanism	The 3D scanning process should be efficient and capable of handling large factory environments.
UF37v1	Remote Monitoring and Adjustment of DT Parameters	The application must have a seamless integration with the existing digital twin of the factory.
UF39v1	Identification of Bottlenecks	Users should be able to view the digital twin alongside the scanned environment and overlay the changes in real-time.
UF40v1	Pothole Impact Assessment	The AR app should allow users to identify and correct misalignments, obstacles, and other errors found during scanning.
UF43v1	Traffic simulation for City planning	Users should be able to manipulate 3D objects in the scanned environment to adjust their positions accurately.

Code	Title	Description
UF44v1	Parking Space Impact Simulation	The application should support scanning of uncaptured areas within the factory environment.
UF48v1	Safety and Risk Management	Users should be able to add scanned data of these areas to the digital twin, updating the model.
UNF50v1	Preventive Measures for Vulnerable Targets	The application should handle data storage efficiently, considering the potentially large 3D scanning data.
UF52v1	Temperature and CO2 emission monitoring	The system should support cloud storage integration for managing the digital twin and scanned environment data.
UNF53v1	Seamless Data Integration	The AR app should be optimized for performance to ensure smooth AR experiences.
UF54v2	Real-time Sensor Data Integration	The system should be stable and able to handle prolonged usage without significant crashes or performance degradation.
UF55v1	Integrated Data Collection	The application should have an intuitive and user-friendly interface.
UF56v1	Virtual Museum Analytics	The app should provide clear instructions on how to perform the 3D scanning effectively.
UF57v1	Tourism Information Support	The application should provide visual feedback during the scanning process to indicate the accuracy and alignment of scanned objects with the digital twin and identify errors during the process
UF58v2	Crowd Control data for museums	The AR app should provide a realistic representation of the factory environment in AR, making it easier for users to identify issues and make updates.
UF60v2	Augmented Reality Guided Exploration	Users should have the option to save their progress during scanning and error correction and to later pick up from that state.
UF61v1	Advertisement Integration in AR Pathway	An undo/redo feature should be available to revert changes if needed.

Table 5. List of user requirements

5.4 Technical requirements

The DIDYMOS-XR requirements presented in this document represent the interim status in the 12th month of the project duration. The reported list has already gone through several iterations and will be updated further as the project progresses. In order to increase the readability, the requirements in this section are limited to *code*, *title* and *description*. Refer to the Requirements Detailed Information section at the document's end for a comprehensive overview.

Code	Title	Description
TNF1v1	Reconstruction accuracy	Reconstruction accuracy average error ≤ 15cm
TNF2v1	Minimum number of scenarios	At least 5 capture scenarios / environment conditions covered
TNF3v1	Segmentation pixel accuracy	Segmentation pixel accuracy ≥ 0.8 for realistically complex scenes
TNF4v1	Segmentation classes support	Segmentation supports >500 classes with at least mAP 0.1 @ 0.5 IoU
TF5v1	Number of camera/sensor supported by the digital twin	At least 10 different types of camera/sensor streams supported for updating the digital twin
TNF6v1	Digital twin update rate	Digital twin update rate ≥ 5 fps
TNF7v1	Alignment of volumetric data	Alignment of volumetric data with the scene at ≥ 15 fps
TNF8v1	Data Transfer rate	Data transfer rate (DTR) ≤ 10MB/s (3.5x less than raw data)
TNF9v1	Reliability	Reduce catastrophic failures in localization and the ability to re-initiate tracking
TNF10v1	Texture Robustness	Increased robustness against poorly textured environments, measured by at most 10% drop on performance against "well-behaving" scenes.
TNF11v1	Accuracy	High accuracy localization mean error <5cm
TNF12v1	Mobile Support	Real-time rendering support on state of the art mobile phones
TF17v1	Validation in real environment	Stakeholder analysis and list of at least 500 relevant stakeholders in the EU
TF66v1	Mobile Shops Tracking	The Ethics Advisory Board (EAB) accepts the solutions to the ethical, data protection, legal and social issues put forward by the consortium (which may revise solutions based on advice and suggestions from the EAB)
TNF68v1	VR Application Platform	At least 50 users engaged and consulted in the design of the technologies by M12
TF69v2	City 3D Scanning and Rendering	User evaluation with at least 24 subjects per domain
TF72v1	Location-Based Services	Five XR applications validated in realistic environment
TF73v1	Museum and Shop Information	The system should provide a feature to remap or recapture the 3D data of the digital twin
TF77v2	User preference recommendations	The system should generate a comprehensive report to evaluate the impact of new devices on various aspects such as investment optimization, time optimization, and production time.
TNF78v1	Realistic VR Experience	The application should quantify the improvement

Code	Title	Description
		(gain xx%) in performance
TF79v2	Adaptive AR Content	The system should have features that help identify and prevent errors (e.g. mapping errors), as they undermine the usefulness of the entire system.
TF80v1	Group Planning and Tour Organization	The system should provide functionality to easily create and define new POIs, requiring a minimal number of interactions.
TF84v2	Smart City Lights Simulation	The system should ensure that the POI information is accurately represented within a maximum of 10-15 cm margin of error in the VE.
TF91v1	Data Analysis Tool for Traffic scenarios	The system should provide a user-friendly interface that allows easy interaction with the POIs even for users with limited technical expertise.
TF92v1	Autonomous Vehicle Integration	The system should provide workers with easily accessible information, instructions, and guidelines to improve their work performance, as assessed by the QUIS/SUS metrics.
TNF96v2	Simulation Scalability	The system should provide workers with guidance through the factory.
TNF97v1	Performance Optimization	The system should facilitate worker responsibility by providing them with clear tasks and goals.
TF100v1	Realistic Simulation Environment	The system should have a feedback mechanism that allows workers to receive application performance feedback without direct interaction with the manager.
TF102v2	Data Visualization and Analysis	The system should allow remote monitoring and adjustment of the DT parameters (3D map) enabling managers to make necessary changes without being physically present.
TF110v1	Data Analytics and Visualization	The system should provide tools or analytics that help managers identify areas of improvement (missing parts to be scanned)
TF112v1	Mobile Application for Maintenance Teams	The system should be able to simulate and evaluate of how potholes influence traffic flow, vehicle emissions, and overall road conditions.
TF114v2	Infrastructure Notifications	The system should accurately model the traffic flow and patterns across the city, considering various factors like road networks, traffic lights, pedestrian crossings, and public transport.
TF118v1	Geolocation and Mapping	The system should be able to simulate the effects of removing or adding parking spaces in specific areas of the city.
TNF119v	Efficient City Maintenance	The system should provide tools to identify and

Code	Title	Description
1		mark areas of risk, including accident-prone locations
TNF125v1	Data Security and Privacy	The system should incorporate preventive measures for potentially vulnerable targets, such as places of worship, by hiding sensitive information or blurring image content.
TF131v1	3D Reconstruction and Modeling	The system should continuously collect, update, and display real-time temperature and CO2 emission data from various areas within the city.
TF133v1	Data Verification Mechanism	The system should have a robust data integration process and allow the merging of diverse datasets.
TF135v2	Integration with Simulation Software (e.g., Carla):	The system should continuously update with the latest sensor information, enabling observation of real-time changes and dynamic behavior. (e.g. crowd information, traffic conditions, weather updates, and pollution levels.)
TF137v1	Version Control and Auditing	The system should collect point cloud data, high-resolution images, and 360-degree panoramic images for digital twin creation.
TF138v1	Data Sources audit	The system should monitor and analyze user interaction with exhibits in the virtual museum to make data-driven evaluation
TNF143v1	Data Quality Assurance	The system should provide essential information such as museum availability, ticket prices, and highlights of exhibits.
TF144v2	Export for Simulation Testing	The system should offer real-time crowd data to optimize crowd control for museums.
TNF146v1	Scalability and Performance	The system should include a wayfinding features and enable the creation of interactive AR routes, guiding tourists to lesser-known zones of interest and hidden places.
TF149v1	Error Reporting and Logging	The system should support (targeted) advertisements during the AR pathway to promote other museums or tourist attractions.
TF150v1	Clear Troubleshooting	Develop a tracking system for mobile shops to help locals and tourists find them based on crowd and traffic information.
TF151v1	Device Compatibility	Develop the application to work on major VR platforms (at least two), such as Oculus, HTC Vive, or other compatible headsets.
TF152v1	OS Compatibility	Use 3D scanning technology to create realistic representations of the city's small areas and monuments for the experience.
TF153v2	Factory 3D Scanning and Rendering	Use device location to provide relevant information based on the user's current position.
TNF154v	Scanning of large	Integrate a database of museums, shops, and

Code	Title	Description
1	environments	restaurants with their opening hours and relevant details.
TF156v1	Digital Twin Integration	Users should receive recommendations based on preferences, such as avoiding crowded places or choosing public transportation over private vehicles.
TF158v1	Overlay changes in realtime	The application should offer an immersive and realistic experience, providing a detailed representation of the city's small areas and monuments.
TF159v1	Error Correction Functionality	AR content should adapt dynamically based on real-time factors and location based triggers, based on weather conditions, time of year, and the number of visitors at a location.
TF160v1	3D objects manipulation	The application should facilitate group planning for tourists, allowing them to organize tours efficiently based on various factors like crowd density and transportation options.
TF161v1	Hidden/Covered Area Scanning	The system should simulate smart city lights with variable positions, timing, and synchronization.
TF162v1	Update of the model	Implement data analysis tools to compare different traffic scenarios and draw meaningful insights.
TNF165v1	Data Management	Integrate autonomous vehicles into the simulation environment with varying levels of autonomy.
TF166v1	Cloud Storage	Ensure that the simulation environment is scalable and capable of handling an increasing number of vehicles and complex scenarios.
TNF167v1	Performance and Stability	Optimize the performance of the simulation to provide real-time or near-real-time results.
TNF168v1	Long duration	Users expect the simulation environment to closely replicate real-world traffic behavior, considering factors like vehicle interactions, pedestrian crossings, and traffic rules.
TF169v1	Intuitive User Interface	Users need visualizations and analysis tools to evaluate simulation results and understand the impact of different factors on traffic and parking.
TF171v1	Clear Scanning Instructions	Develop data analytics tools to process and interpret sensor data for city maintenance.
TF173v2	Visual Feedback and Guidance	Create a mobile app for maintenance teams to receive and update tasks related to city maintenance, such as sidewalk repairs, road painting, gardening, and furniture maintenance.
TF177v1	Realistic Representation	Implement a notification system to alert maintenance teams about sensible sites that require immediate attention (e.g. rubbish accumulation, broken infrastructure)

Code	Title	Description
TF178v2	Save Functionality	Integrate GPS and mapping services to accurately locate maintenance tasks and parking spots for efficient allocation of resources.
TF179v1	Redo/Undo Functionality	The system should help maintenance teams efficiently plan and execute tasks related to city maintenance, saving time and resources.

Table 6. List of technical requirements

6 User Journey and User Flow

After defining the use cases, requirements, and personas, there was a gap in understanding the specific actions the user would take to accomplish the goals listed in each use case. To bridge this gap, and in preparation for validation, we needed to clarify the user's actions and flows to understand what exactly needed to be tested. This is where the creation of the User Journey and User Flow became essential.

The process of creating a user journey and user flow involved a structured approach using online workshops, each dedicated to a specific use case. The goal of these workshops was to collaboratively map out both the user journey and user flow for the six different use cases, such as virtual tourism (in both VR and AR), digital twin creation, city planning, city maintenance, and the industrial.

By focusing on each use case individually, this approach allows for the creation of tailored user experiences that are specific to the unique requirements of each scenario, whether it be for virtual tourism, city planning, or industrial applications.

6.1 User Journey Map

In each workshop, participants focus on defining the user journey—the overall experience that a user goes through when interacting with a product or service. The journey is typically broken down into several stages that represent different phases of the user's interaction, such as onboarding, setup, operation, and completion.

For each stage, the workshop participants identify the actions that the user takes, considering what tasks need to be completed at each step, what challenges might arise, and what outcomes are expected. This high-level mapping process helps to create a shared understanding of the user's objectives, pain points, and areas of opportunity for improvement. By working collaboratively, the participants align on the key steps the user will take and how the system should respond.

Figure 6 shows the customer journey for the Digital Twin Creation UC.

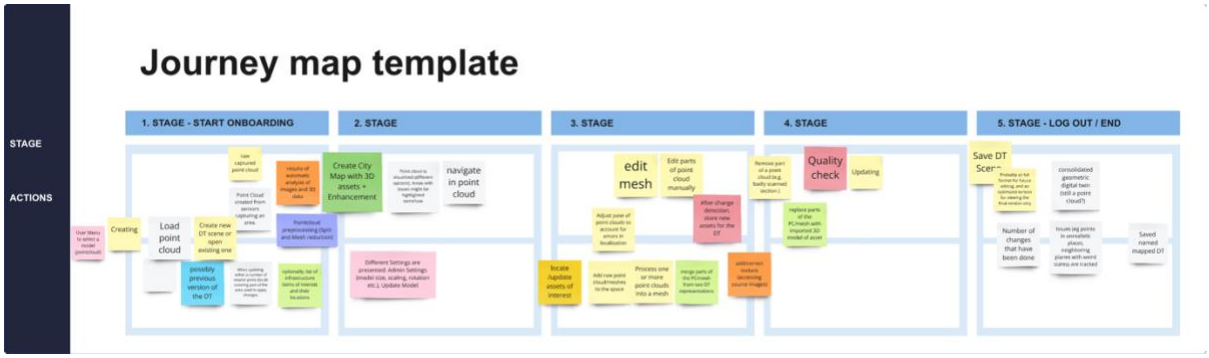


Figure 6 User Journey for the Digital Twin Creation UC

6.2 User Flow Creation

Following the user journey mapping, the next step is developing the user flow. The user flow represents a more detailed, step-by-step process of how users interact with a system, often visualized through a series of connected actions and decision points. The flow begins with the user initiating an action (such as logging into a platform or starting a process) and moves through various system responses and user decisions that guide the experience.

During the workshops, each use case was examined to identify the most common decision paths and actions a user might take. These flows include potential branches or alternatives depending on user input, such as whether a user is a first-time visitor or returning, whether the data they interact with is newly created or existing, and other variables that might influence the experience. Users were given a list of possible shapes to use (Figure 7) that they had to combine in order to build a given flow.

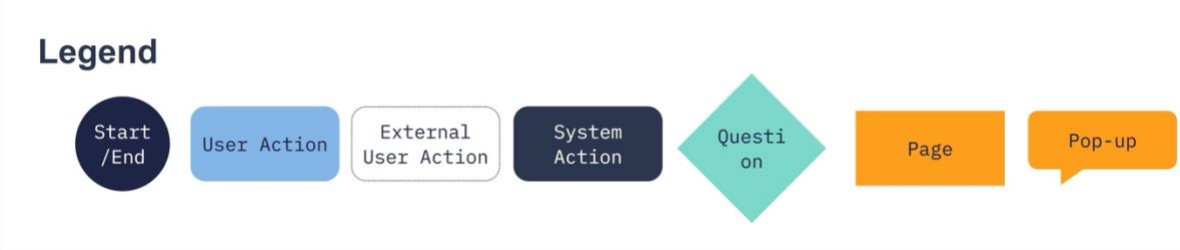


Figure 7 Available options to build the user flow

Each symbol corresponded to a specific type of user interaction or system event, helping to create clarity in complex workflows. Here the list of available shapes:

1. **Start/End (Circle):**
    a. **Function**: This circular shape represents the beginning or end of a process or flow.
    b. **User Action:** The user initiates or concludes an interaction. For example, this could be the start of a login process or the end of a session after completing an action.
2. **User Action (Rounded Rectangle - Blue):**

a. **Function**: This shape is used to indicate an action taken directly by the user.
b. **User Action:** Represents tasks or inputs such as clicking a button, entering data, or making a selection. The user actively interacts with the system during this step.

3. **External User Action (Dashed Rounded Rectangle - White):**
   a. **Function**: This indicates an action taken outside the immediate system or by an external user.
   b. **User Action:** Users may be required to interact with an external system, tool, or third-party service as part of their overall flow, such as filling out a form in a separate system or authorizing a process through an external platform.
4. **System Action (Rounded Rectangle - Dark Blue):**
   a. **Function**: Represents an action that the system performs automatically without user input.
   b. **User Action:** The user waits while the system completes a task, such as processing data, saving a file, or sending a notification. No active user involvement is required at this stage.
5. **Question (Diamond - Teal):**
   a. **Function**: Indicates a decision point where a question is posed, and different paths can be taken based on the answer.
   b. **User Action:** Users are prompted to make a choice, which determines the next step. For example, the system might ask if this is the user's first login, and the answer will lead to different flows.
6. **Page (Rectangle - Orange):**
   a. **Function**: Represents a full page or screen in the interface.
   b. **User Action**: Users navigate to a new page where they can view and interact with more detailed information or actions, such as a dashboard, login screen, or content page.
7. **Pop-up (Speech Bubble - Orange):**
   a. **Function**: Indicates a pop-up window or modal that overlays the current page.
   b. **User Action:** Users interact with temporary information or options within a pop-up, such as confirming an action, dismissing a message, or responding to a prompt without leaving the current page.

Each workshop focused on a specific use case and at the end of it user flows about the main functionalities of the use case were extracted.
Figure 8 shows the user flow from the Industrial Use Case

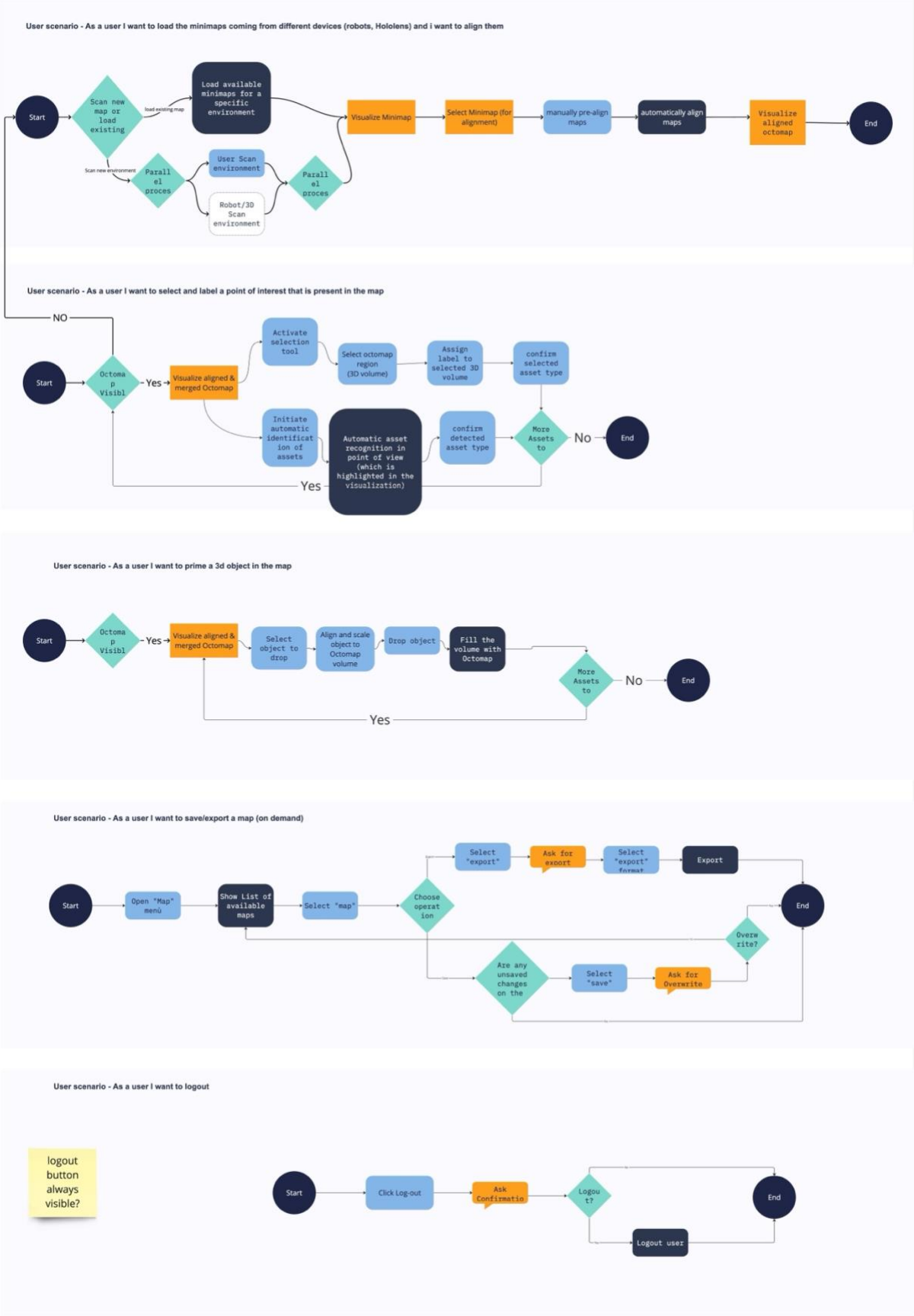


Figure 8 User Flow Diagrams for the Industrial Use Case

For the complete list of User Flows refer to Annex 11.

7 Conclusion

The deliverable presents the current versions of use cases, personas, and requirements that were gathered for the user-centric development process. The process of defining and iterating the use cases is described to highlight how partners and stakeholders contributed to the design process. The components of the requirements are itemized and explained. The document contains the full lists of all the developed specifications of use cases, personas and requirements.

With the first versions of use cases, personas and requirements, the future attention will be shifted to the validation methods that can now be specified and recorded. After discussion with the other partners and refinement, these validation methods will then be applied in WP5 for the validation of the XR applications.

As this document represents the first version (v1) of the deliverable (D2.1), the contents will undergo refinement and enhancement for the update (v2) of the deliverable (D2.3) by M32. Further, the next version of the deliverable will be expanded to contain the validation methods that are being developed in the upcoming time frame.

8 Annex - Personas Visualisations

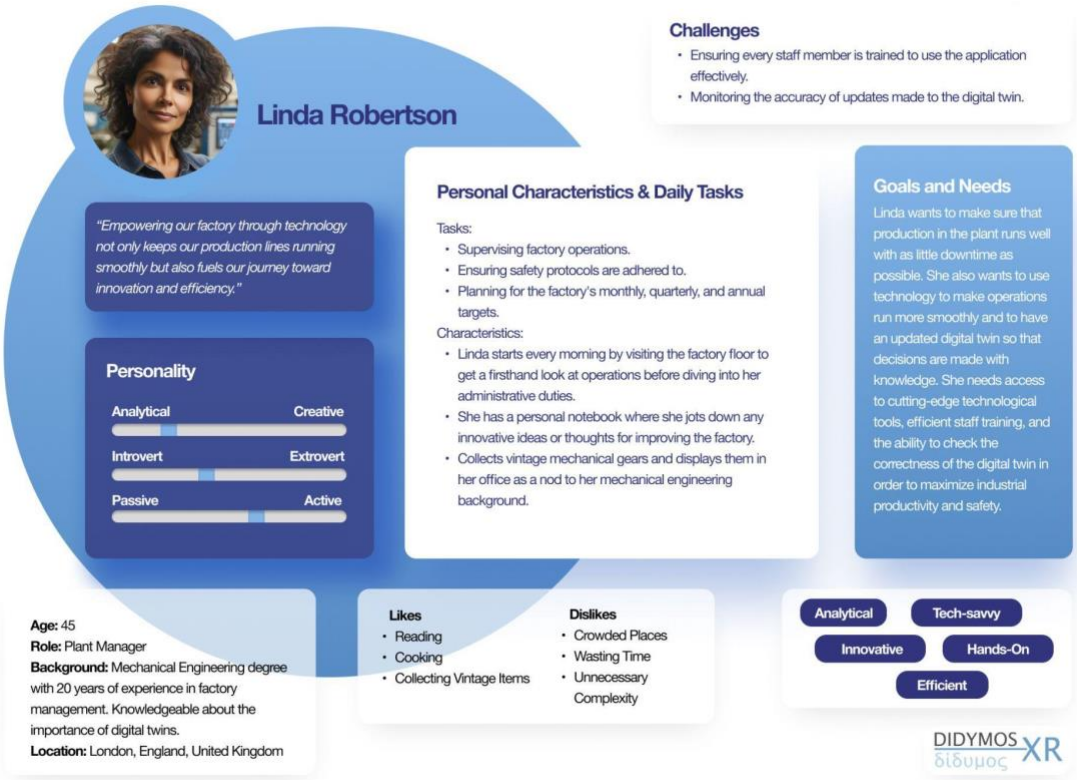


Figure 9. User Persona - Linda Robertson

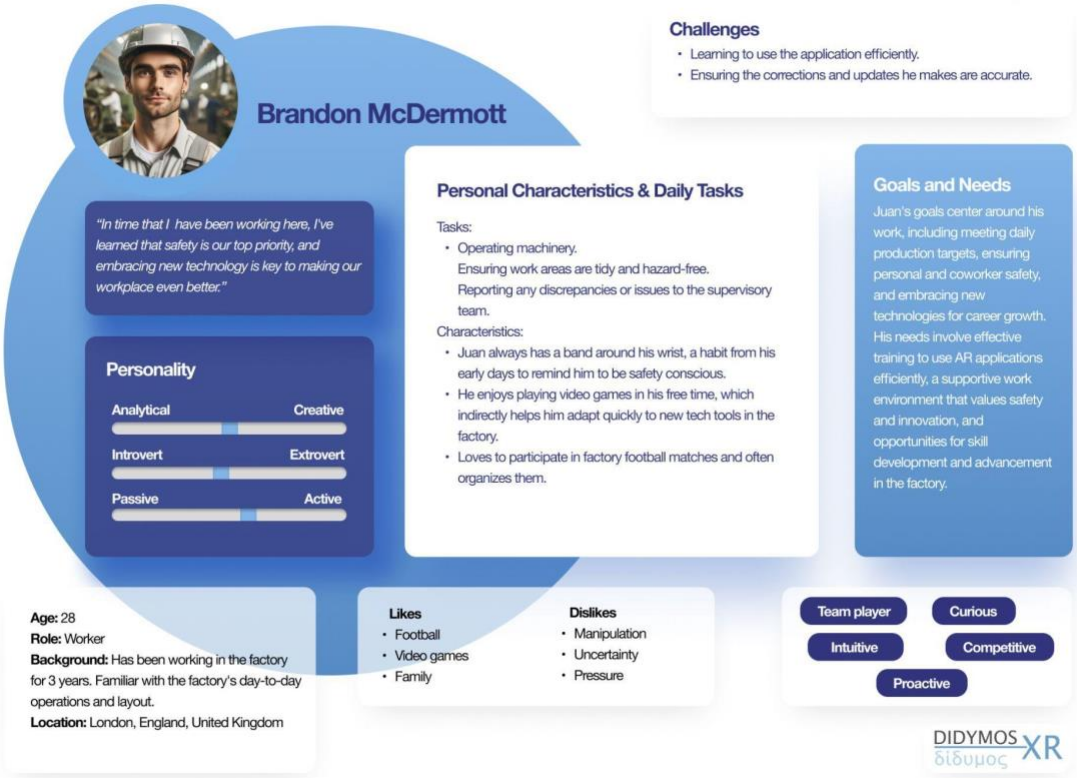


Figure 10. User Persona - Brandon McDermott

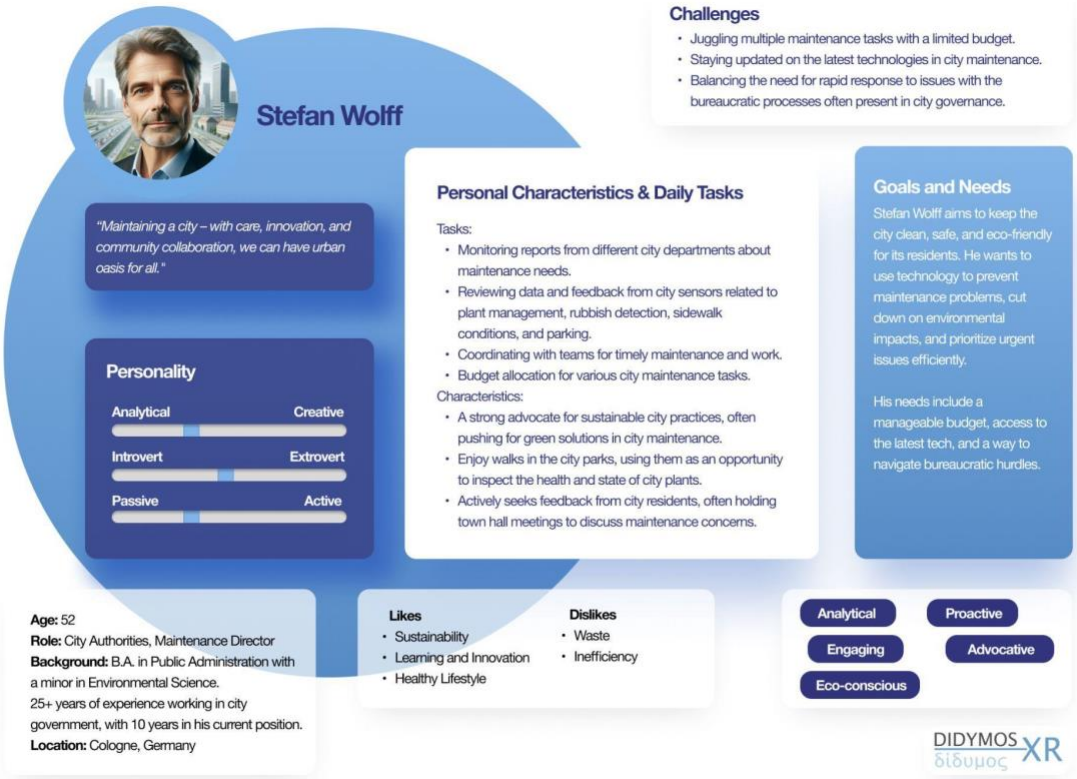


Figure 11. User Persona - Stefan Wolff

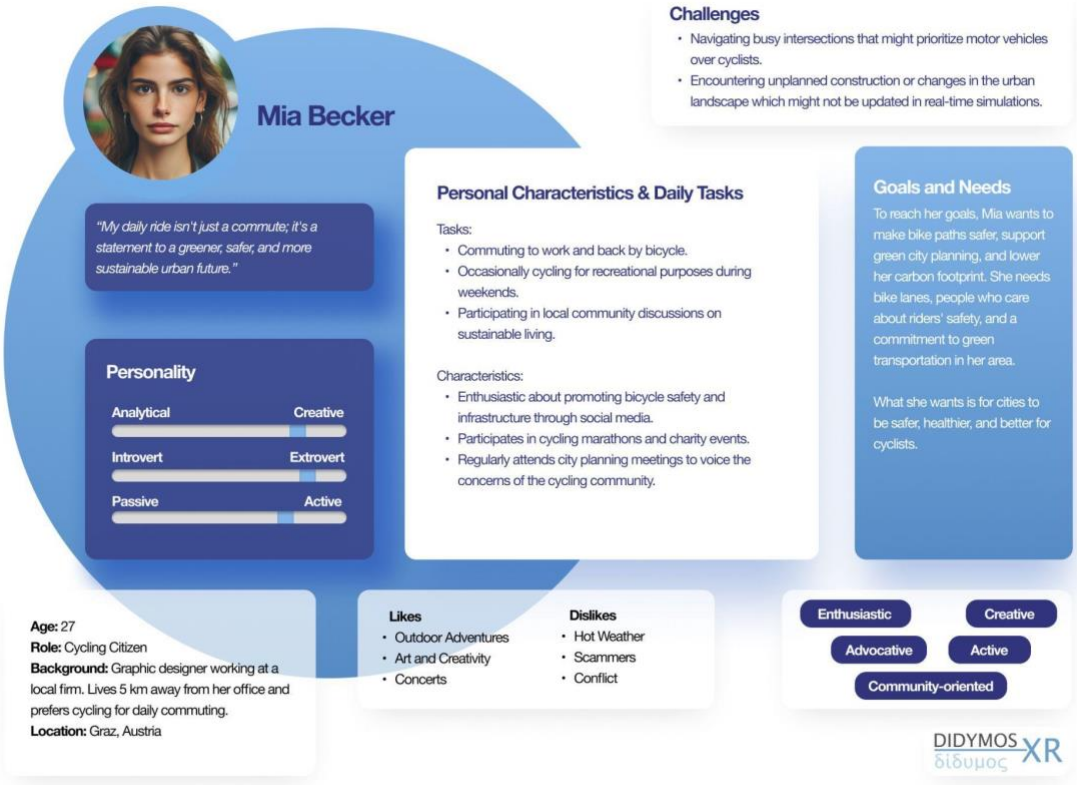


Figure 12. User Persona - Mia Becker

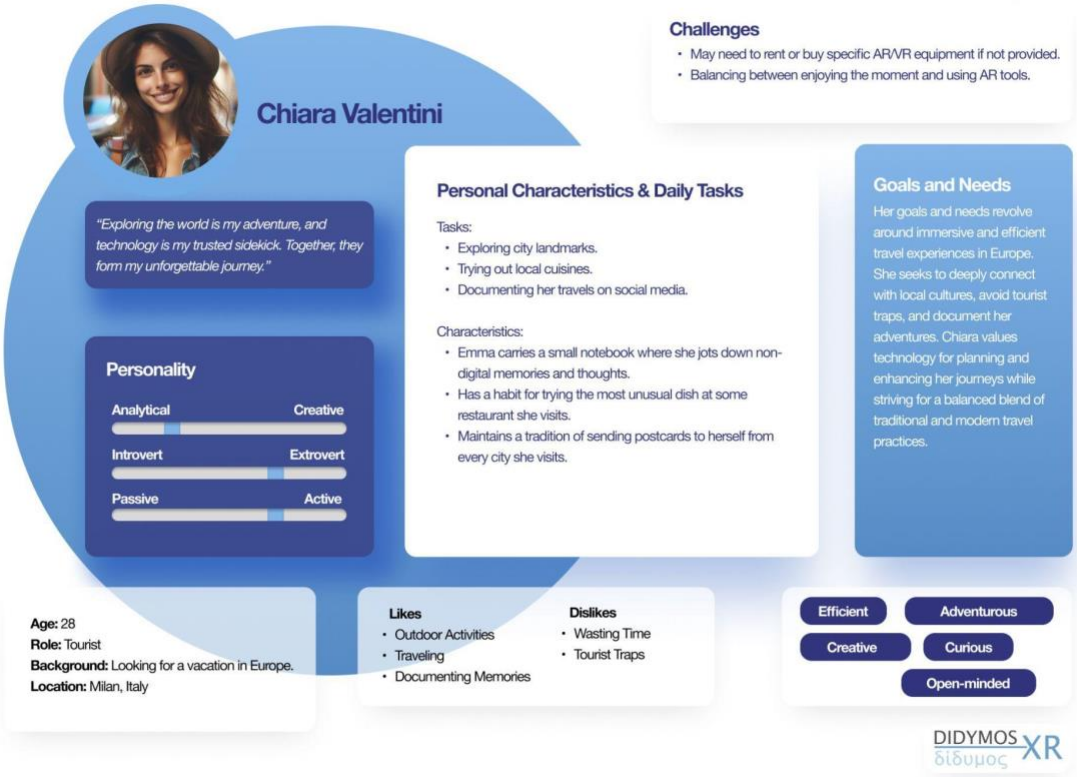


Figure 13. User Persona - Chiara Valentini

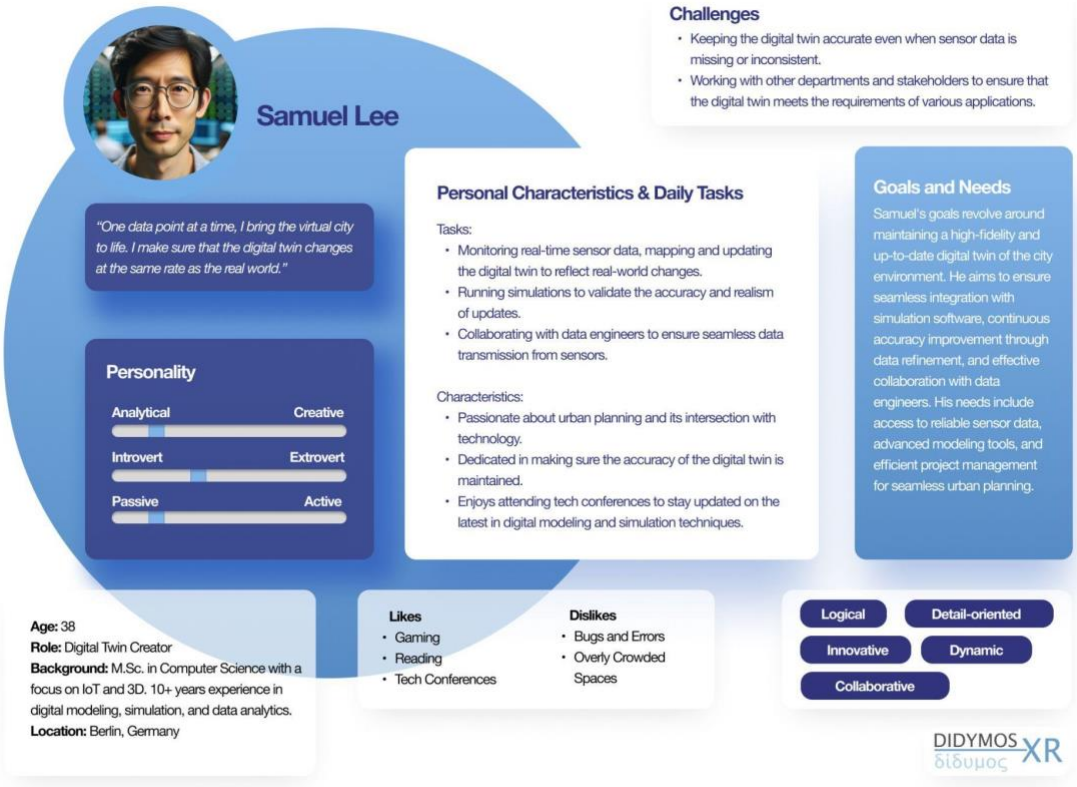


Figure 14. User Persona - Samuel Lee

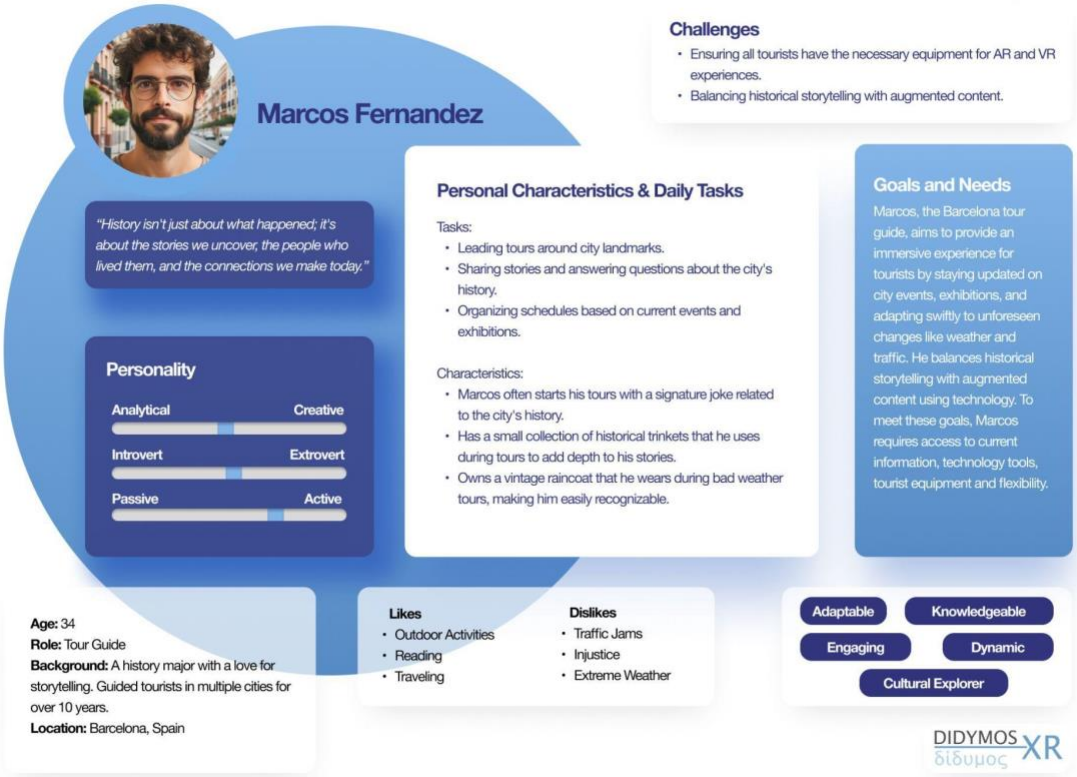


Figure 15. User Persona - Marcos Fernandez

9 Annex - Use Cases Questionnaires

Applications for citizen involvement in urban planning, tourism, and smart mobility in cities/villages, and collaboration with autonomous mobile robots in industrial production environment.

Tourism	
Historical and cultural heritage	Provide a rich and interactive learning experience for tourists by giving historical and cultural information about a location. This can include information on the architecture, art, and local customs of a destination.
Personalized Experience	Create personalized experiences for tourists based on their preferences and interests. For example, a digital twin of a city could suggest personalized itineraries for visitors based on their interests, making their trip more enjoyable and memorable.
Virtual Tours	Provide virtual tours of tourist destinations, allowing potential visitors to experience the location before they arrive. This can help travelers make more informed decisions about their travel plans and increase interest in less well-known destinations.
Sustainable Tourism	Promote sustainable tourism practices by providing information on eco-friendly activities and highlighting the impact of tourism on the local environment. This can help visitors make more responsible choices and reduce their carbon footprint.
Improved Navigation	Provide accurate navigation for tourists within a destination. This can include real-time updates on traffic, public transportation schedules, and other relevant information that can help visitors better navigate the area.

Choose among two of the following use case related to tourism

- ☐ Historical and cultural heritage
- ☐ Personalized Experience
- ☐ Virtual Tours
- ☐ Sustainable Tourism
- ☐ Improved Navigation
- ☐ Other proposal: …

Sort these use cases from the one you preferred most to the one you preferred least

Urban Planning	
Environmental Planning	Monitor and analyze environmental data, such as air quality, noise levels, and water usage. By simulating the impact of proposed developments on the environment, planners can identify the most sustainable solutions and minimize the negative effects on the ecosystem.
Infrastructure Planning	Enable real-time monitoring of urban infrastructure, such as transportation networks, energy systems, and water supply. Planners can use this information to optimize the performance of existing infrastructure and make informed decisions about future investments, ensuring efficient and sustainable development.
Land Use Planning	Provide a holistic view of the urban landscape, integrating data on land use, zoning, and development. This helps planners to balance competing demands for space, such as residential, commercial, and recreational uses, while minimizing conflicts
Emergency Response Planning	Simulate the impact of natural disasters or other emergencies to help planners to design more resilient urban environments. In the event of an emergency, real-time data and digital twin simulations can inform response efforts
Community Engagement	Create interactive visualizations of proposed urban projects, allowing the public to better understand and engage with the planning process. This can improve the overall quality of urban plans by incorporating valuable feedback from the community

Choose among two of the following use case related to urban planning:

- ☐ Environmental Planning
- ☐ Infrastructure Planning
- ☐ Land Use Planning
- ☐ Emergency Response Planning
- ☐ Community Engagement
- ☐ Other proposal…

Sort these use cases from the one you preferred most to the one you preferred least

Smart Mobility	
Mobility as a Service	Simulate and test new MaaS models, such as ride-sharing and on-demand transportation services. This can help to optimize the use of vehicles and infrastructure, and provide more convenient and affordable transportation options for users.

Risk Assessment	Assess the risks associated with different transportation scenarios, such as traffic accidents and disruptions. This can help to develop strategies to mitigate these risks and improve the safety and resilience of the transportation system.
Autonomous Vehicle Testing	Simulate and test autonomous vehicles in a safe and controlled environment, before they are deployed on public roads. This can help to ensure that autonomous vehicles are safe and reliable, and can operate effectively in a range of different conditions.
Traffic Optimization	Simulate and optimize traffic flow in real-time, based on current and predicted traffic patterns. This can help to reduce congestion, improve travel times, and minimize the environmental impact of transportation.
Predictive Maintenance	Monitor the condition of vehicles, infrastructure, and other components of the transportation system in real-time. This can help to identify potential issues before they become major problems, and schedule maintenance and repairs more efficiently.

Choose among two of the following use case related to smart mobility:

- ☐ Mobility as a Service
- ☐ Risk Assessment
- ☐ Autonomous Vehicle Testing
- ☐ Traffic Optimization
- ☐ Predictive Maintenance
- ☐ Other proposal…

Sort these use cases from the one you preferred most to the one you preferred least

Industry

Collaboration with AMR	
Real-time Data Analytics	Collect and analyze real-time data from the production process, including data from sensors and other sources. This information can be used to optimize the production process and improve overall efficiency.
Quality Control	Monitor the quality of production output and identify potential defects. This information can be used to optimize the production process and improve product quality.
Predictive Maintenance	Monitor the condition of AMRs and predict when maintenance will be needed. This can help prevent

	breakdowns and reduce downtime, ensuring that the production process remains efficient.
Training and Simulation	Simulate different scenarios and train workers on how to collaborate effectively with AMRs. This can include simulating different production scenarios and teaching workers how to program and operate the robots.
Monitoring and Control	Monitor the status of AMRs, including their location, speed, and battery life. This information can be used to optimize the performance of the robots and ensure that they are operating safely and efficiently.
Beyond AMR	Human in the loop can overcome the limitation of AMR improving the output of processes

Choose among two of the following use case related to industry:

- ☐Real-time Data Analytics
- ☐Quality Control
- ☐Predictive Maintenance
- ☐Training and Simulation
- ☐Monitoring and Control
- ☐Beyond AMR
- ☐Other proposal…

Sort these use cases from the one you preferred most to the one you preferred least

Questions

User → who is going to use the application
Related to the use case:
What kind of user is involved in the experience?
What should be is Affinity to the technology? Is an evaluation needed (ATI scale)

Is the user active or passive in the experience?

- ☐active: interacts with the system
- ☐passive: only content visualization

If active what can the user do?

If passive what does the user see?

What XR technology you would like to use?

- ☐Augmented Reality (AR): Computer-generated and Real world are combined
- ☐Virtual Reality (VR): Computer-generated world
- ☐Mixed - AR+VR → **Constraint**: Cross-reality device

User Interaction in the XR experience → what the user can do in the experience?

Related to the technology chosen:

Can the user move in the virtual environment?

- ☐Yes
- ☐No

If yes, how do you imagine movement?

- ☐Continuos movement
- ☐Real mapped movement
- ☐Teleport movement

What interaction enabler can the user use during the experience?

- ☐Gaze
- ☐Hands
- ☐Controllers
- ☐Voice

Which user senses are involved in the experience?

- ☐Haptic
- ☐Visual
- ☐Auditory

Augmented Reality specific

How addictive information is presented?

- ☐Constructive: additive to the natural environment
- ☐Destructive: masking of the natural environment

Which device you would like to use?

- ☐Headset: Hololens2, nReal glasses, Magic Leap
- ☐Projectors
- ☐Handheld/Mobile

Virtual Reality specific

How the environment should be presented to the user? (This will depend also from the data capturing and rendering technique)

- ☐Real capturing/360
- ☐Virtual/3D

Which device you would like to use?

- ☐Headset: 1. tethered: HTC, 2. wireless: Pico, MetaQuest
- ☐CAVE
- ☐ Mobile/Desktop

10 Annex - Requirements and Use Case Details

10.1 Requirements Detailed Information

Code	Title	Priority	Origin	Scope	Milestone	Responsibility	Linked WP	Means of Validation
TNF1v1	Reconstruction accuracy	High	Proposal	Initial Components	M18 (MS3)	i2CAT	WP3	D3.1
TNF2v1	Minimum number of scenarios	High	Proposal	Initial Components	M18 (MS3)	FICO	WP3	D3.1
TNF3v1	Segmentation pixel accuracy	High	Proposal	Initial Components	M18 (MS3)	JRS	WP3	D3.1
TNF4v1	Segmentation classes support	High	Proposal	Initial Components	M18 (MS3)	JRS	WP3	D3.1
TF5v1	Number of camera/sensor supported by the digital twin	High	Proposal	Initial Components	M18 (MS3)	All	WP3, WP4	D3.1
TNF6v1	Digital twin update rate	High	Proposal	Initial Components	M18 (MS3)	i2CAT	WP3, WP4	D4.1
TNF7v1	Alignment of volumetric data	High	Proposal	Initial Components	M18 (MS3)	UPAT	WP3, WP4	D4.1
TNF8v1	Data Transfer rate	High	Proposal	Initial Components	M18 (MS3)	i2CAT	WP3, WP4	D3.1
TNF9v1	Reliability	High	Proposal	Initial Components	M18 (MS3)	CERTH	WP4	D4.1
TNF10v1	Texture Robustness	High	Proposal	Initial Components	M18 (MS3)	UPAT	WP4	D4.1
TNF11v1	Accuracy	High	Proposal	Initial Components	M18 (MS3)	CERTH	WP4	D4.1
TNF12v1	Mobile Support	High	Proposal	Initial Components	M18 (MS3)	i2CAT	WP4	D4.1
UNF13v1	Stakeholder involvement	High	Proposal	Final XR Application	M4 (MS1)	TRI	WP6	D6.1
UF14v1	Approval from the EAB	High	Proposal	Final XR Application	M18 (MS3)	TRI	WP2	D2.2
UNF15v1	User Engagement	High	Proposal	Final XR Application	M12	TRI	WP6, WP2	D2.1
UNF16v1	Minimum number of user for each validation	High	Proposal	Initial XR Application	M24 (MS5)	VNG, IW	WP5	D5.1
TF17v1	Validation in real environment	High	Proposal	Initial XR Application	M24 (MS5)	VNG, IW	WP5	D5.1
UF19v2	Remapping of production line	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UF20v1	Simulation Report Generation	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UNF21v2	Investment and Time Optimization	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UNF22v2	Logistics Error Prevention	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UF23v2	Addition of New POI	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UNF24v2	POI location accuracy	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UNF25v1	User Experience and Interaction	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1

Code	Title	Priority	Origin	Scope	Milestone	Responsibility	Linked WP	Means of Validation
	with POIs							
UNF26v2	Clear Information for improved work performance	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UF30v1	Guidance for Workers	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UNF35v1	Worker Responsibility	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UNF36v1	Worker Application Feedback Mechanism	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UF37v1	Remote Monitoring and Adjustment of DT Parameters	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UF39v1	Identification of Bottlenecks	Medium	WS industry	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
UF40v1	Pothole Impact Assessment	Low	WS city	Initial XR Application	M22 (MS4)	DTT, FICOSA	WP5	D5.1
UF43v1	Traffic simulation for City planning	Medium	WS city	Initial XR Application	M22 (MS4)	DTT	WP5	D5.1
UF44v1	Parking Space Impact Simulation	Medium	WS city	Initial XR Application	M22 (MS4)	DTT	WP5	D5.1
UF48v1	Safety and Risk Management	Low	WS city	Initial XR Application	M22 (MS4)	DTT	WP5	D5.1
UNF50v1	Preventive Measures for Vulnerable Targets	Low	WS city	Initial Components	M18 (MS3)	TRI	WP2	D2.2
UF52v1	Temperature and CO2 emission monitoring	Medium	WS city	Initial Components	M18 (MS3)	DTT	WP3	D3.1
UNF53v1	Seamless Data Integration	Medium	WS city	Initial Components	M18 (MS3)	i2CAT	WP3	D3.1
UF54v2	Real-time Sensor Data Integration	Medium	WS city	Initial Components	M18 (MS3)	DTT	WP3	D3.1
UF55v1	Integrated Data Collection	Medium	WS city	Initial Components	M18 (MS3)	VNG, FIWARE	WP3	D3.1
UF56v1	Virtual Museum Analytics	Medium	WS city	Initial XR Application	M22 (MS4)	VNG	WP5	D5.1
UF57v1	Tourism Information Support	Medium	WS city	Initial XR Application	M22 (MS4)	VNG, UPAT	WP5	D5.1
UF58v2	Crowd Control data for museums	Medium	WS city	Initial XR Application	M22 (MS4)	VNG, UPAT	WP5	D5.1
UF60v2	Augmented Reality Guided Exploration	Medium	WS city	Initial XR Application	M22 (MS4)	VNG, UPAT	WP5	D5.1
UF61v1	Advertisement Integration in AR Pathway	Medium	WS city	Initial XR Application	M22 (MS4)	VNG, UPAT	WP5	D5.1
TF66v1	Mobile Shops Tracking	Low	UC Virtual Tourism	Initial XR Application	M22 (MS4)	FIWARE	WP5	D5.1

Code	Title	Priority	Origin	Scope	Milestone	Responsibility	Linked WP	Means of Validation
TNF68v1	VR Application Platform	Medium	UC Virtual Tourism	Final XR Application	M32 (MS6)	FIWARE, VNG	WP5	D5.2
TF69v2	City 3D Scanning and Rendering	Medium	UC Virtual Tourism	Initial Components	M18 (MS3)	FIWARE, VNG	WP3	D3.1
TF72v1	Location-Based Services	Medium	UC Virtual Tourism	Initial Components	M18 (MS3)	CERTH	WP4	D4.1
TF73v1	Museum and Shop Information	Medium	UC Virtual Tourism	Initial XR Application	M22 (MS4)	FIWARE, VNG	WP5	D5.1
TF77v2	User preference recommendations	Medium	UC Virtual Tourism	Initial XR Application	M22 (MS4)	FIWARE, VNG	WP5	D5.1
TNF78v1	Realistic VR Experience	Medium	UC Virtual Tourism	Initial XR Application	M22 (MS4)	FIWARE, VNG	WP5	D5.1
TF79v2	Adaptive AR Content	Medium	UC Virtual Tourism	Initial XR Application	M22 (MS4)	FIWARE, VNG	WP5	D5.1
TF80v1	Group Planning and Tour Organization	Medium	UC Virtual Tourism	Initial XR Application	M22 (MS4)	FIWARE, VNG	WP5	D5.1
TF84v2	Smart City Lights Simulation	Medium	UC City Planning	Initial XR Application	M22 (MS4)	DTT	WP5	D5.1
TF91v1	Data Analysis Tool for Traffic scenarios	Medium	UC City Planning	Initial XR Application	M22 (MS4)	DTT	WP5	D5.1
TF92v1	Autonomous Vehicle Integration	Medium	UC City Planning	Initial XR Application	M22 (MS4)	DTT	WP5	D3.1
TNF96v2	Simulation Scalability	Medium	UC City Planning	Initial XR Application	M22 (MS4)	DTT	WP5	D5.1
TNF97v1	Performance Optimization	Medium	UC City Planning	Initial XR Application	M22 (MS4)	DTT	WP5	D5.1
TF100v1	Realistic Simulation Environment	Medium	UC City Planning	Initial XR Application	M22 (MS4)	DTT	WP5	D5.1
TF102v2	Data Visualization and Analysis	Medium	UC City Planning	Initial XR Application	M22 (MS4)	DTT	WP5	D5.1
TF110v1	Data Analytics and Visualization	Medium	UC City Maintenance	Initial XR Application	M22 (MS4)	VNG, DTT	WP5	D5.1

Code	Title	Priority	Origin	Scope	Milestone	Responsibility	Linked WP	Means of Validation
TF112v1	Mobile Application for Maintenance Teams	Low	UC City Maintenance	Initial XR Application	M22 (MS4)	VNG, DTT	WP5	D5.1
TF114v2	Infrastructure Notifications	Medium	UC City Maintenance	Initial XR Application	M22 (MS4)	VNG, DTT	WP5	D5.1
TF118v1	Geolocation and Mapping	Medium	UC City Maintenance	Initial Components	M18 (MS3)	DTT	WP4	D4.1
TNF119v1	Efficient City Maintenance	Low	UC City Maintenance	Initial XR Application	M22 (MS4)	FICO	WP5	D5.1
TNF125v1	Data Security and Privacy	Medium	UC City Maintenance	Initial Components	M18 (MS3)	FICO, TRI	WP2, WP3	D2.2, D3.1
TF131v1	3D Reconstruction and Modeling	Medium	UC DT creation	Initial Components	M18 (MS3)	VNG, FIWARE, IW	WP3	D3.1
TF133v1	Data Verification Mechanism	Medium	UC DT creation	Initial Components	M18 (MS3)	FICO	WP3	D3.1
TF135v2	Integration with Simulation Software (e.g., Carla):	Medium	UC DT creation	Final XR Application	M22 (MS4)	VNG, FIWARE	WP5	D5.1
TF137v1	Version Control and Auditing	Medium	UC DT creation	Initial Components	M18 (MS3)	i2CAT	WP3, WP4	D3.1,D4.1
TF138v1	Data Sources audit	Medium	UC DT creation	Initial Components	M18 (MS3)	FICO	WP3	D3.1
TNF143v1	Data Quality Assurance	Medium	UC DT creation	Initial Components	M18 (MS3)	i2CAT	WP3	D3.1
TF144v2	Export for Simulation Testing	Medium	UC DT creation	Initial XR Application	M22 (MS4)	VNG, FIWARE	WP5	D5.1
TNF146v1	Scalability and Performance	Medium	UC DT creation	Initial Components	M18 (MS3)	i2CAT	WP3	D3.1
TF149v1	Error Reporting and Logging	Medium	UC DT creation	Initial XR Application	M22 (MS4)	VNG, FIWARE	WP5	D5.1
TF150v1	Clear Troubleshooting	Medium	UC DT creation	Initial XR Application	M22 (MS4)	VNG, FIWARE	WP5	D5.1
TF151v1	Device Compatibility	Medium	UC DT creation	Final XR Application	M32 (MS6)	VNG, FIWARE	WP5	D5.2

Code	Title	Priority	Origin	Scope	Milestone	Responsibility	Linked WP	Means of Validation
TF152v1	OS Compatibility	Medium	UC Factory	Final XR Application	M32 (MS6)	IW	WP5	D5.2
TF153v2	Factory 3D Scanning and Rendering	Medium	UC Factory	Initial Components	M18 (MS3)	IW	WP3	D3.1
TNF154v1	Scanning of large environments	Medium	UC Factory	Initial Components	M18 (MS3)	IW	WP3	D3.1
TF156v1	Digital Twin Integration	Medium	UC Factory	Initial Components	M18 (MS3)	IW	WP3	D3.1
TF158v1	Overlay changes in realtime	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TF159v1	Error Correction Functionality	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TF160v1	3D objects manipulation	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TF161v1	Hidden/Covered Area Scanning	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TF162v1	Update of the model	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TNF165v1	Data Management	Medium	UC Factory	Initial Components	M18 (MS3)	FICO	WP3	D3.1
TF166v1	Cloud Storage	Medium	UC Factory	Initial Components	M18 (MS3)	IW	WP3, WP4	D3.1,D.41
TNF167v1	Performance and Stability	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW, VNG	WP5	D5.1
TNF168v1	Long duration	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW, VNG	WP5	D5.1
TF169v1	Intuitive User Interface	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TF171v1	Clear Scanning Instructions	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TF173v2	Visual Feedback and Guidance	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TF177v1	Realistic Representation	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TF178v2	Save Functionality	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1
TF179v1	Redo/Undo Functionality	Medium	UC Factory	Initial XR Application	M22 (MS4)	IW	WP5	D5.1

10.2 Requirement Use Case Assignment

Code	Title	Industry	DT creation	City Planning	City Maintenance	Parking Detection	AR Virtual Tourism	VR Virtual Tourism
TNF1v1	Reconstruction accuracy	x	x	x	x	x	x	x
TNF2v1	Minimum number of scenarios	x	x	x	x	x	x	x
TNF3v1	Segmentation pixel accuracy	x	x	x	x	x	x	x
TNF4v1	Segmentation classes support	x	x	x	x	x	x	x
TF5v1	Number of camera/sensor supported by the digital twin	x	x	x	x	x	x	x
TNF6v1	Digital twin update rate	x	x		x	x		
TNF7v1	Alignment of volumetric data	x	x		x	x	x	
TNF8v1	Data Transfer rate	x	x		x	x	x	
TNF9v1	Reliability	x			x		x	x
TNF10v1	Texture Robustness	x	x		x		x	
TNF11v1	Accuracy	x			x		x	x
TNF12v1	Mobile Support	x			x	x	x	
UNF13v1	Stakeholder involvement							
UF14v1	Approval from the EAB	x	x	x	x	x	x	x
UNF15v1	User Engagement							
UNF16v1	Minimum number of user for each validation	x	x	x	x	x	x	x
TF17v1	Validation in real environment	x	x	x	x	x	x	x
UF19v2	Remapping of production line	x	x					
UF20v1	Simulation Report Generation	x						
UNF21v2	Investment and Time Optimization	x						
UNF22v2	Logistics Error Prevention	x	x					
UF23v2	Addition of New POI	x			x			
UNF24v2	POI location accuracy	x			x			
UNF25v1	User Experience and Interaction with POIs	x			x			
UNF26v2	Clear Information for improved work performance	x						
UF30v1	Guidance for Workers	x						

Code	Title	Industry	DT creation	City Planning	City Maintenance	Parking Detection	AR Virtual Tourism	VR Virtual Tourism
UNF35v1	Worker Responsibility	x						
UNF36v1	Worker Application Feedback Mechanism	x						
UF37v1	Remote Monitoring and Adjustment of DT Parameters	x						
UF39v1	Identification of Bottlenecks	x						
UF40v1	Pothole Impact Assessment			x	x			
UF43v1	Traffic simulation for City planning			x				
UF44v1	Parking Space Impact Simulation			x				
UF48v1	Safety and Risk Management	x	x		x			
UNF50v1	Preventive Measures for Vulnerable Targets	x	x	x	x	x	x	x
UF52v1	Temperature and CO2 emission monitorig		x	x	x			
UNF53v1	Seamless Data Integration	x	x	x				
UF54v2	Real-time Sensor Data Integration	x	x		x	x	x	x
UF55v1	Integrated Data Collection		x					
UF56v1	Virtual Museum Analytics							x
UF57v1	Tourism Information Support						x	x
UF58v2	Crowd Control data for museums						x	
UF60v2	Augmented Reality Guided Exploration						x	
UF61v1	Advertisement Integration in AR Pathway						x	
TF66v1	Mobile Shops Tracking						x	
TNF68v1	VR Application Platform			x			x	x
TF69v2	City 3D Scanning and Rendering		x				x	x
TF72v1	Location-Based Services	x			x	x	x	
TF73v1	Museum and Shop Information						x	x
TF77v2	User preference recommendations						x	
TNF78v1	Realistic VR Experience							x
TF79v2	Adaptive AR Content						x	

Code	Title	Industry	DT creation	City Planning	City Maintenance	Parking Detection	AR Virtual Tourism	VR Virtual Tourism
TF80v1	Group Planning and Tour Organization							x
TF84v2	Smart City Lights Simulation			x				
TF91v1	Data Analysis Tool for Traffic scenarios			x				
TF92v1	Autonomous Vehicle Integration			x				
TNF96v2	Simulation Scalability			x				
TNF97v1	Performance Optimization			x				
TF100v1	Realistic Simulation Environment			x				
TF102v2	Data Visualization and Analysis			x				
TF110v1	Data Analytics and Visualization				x			
TF112v1	Mobile Application for Maintenance Teams				x			
TF114v2	Infrastructure Notifications				x			
TF118v1	Geolocation and Mapping				x	x		
TNF119v1	Efficient City Maintenance				x			
TNF125v1	Data Security and Privacy	x	x	x	x	x	x	x
TF131v1	3D Reconstruction and Modeling	x	x					
TF133v1	Data Verification Mechanism	x	x					
TF135v2	Integration with Simulation Software (e.g., Carla):			x				
TF137v1	Version Control and Auditing	x	x	x	x			
TF138v1	Data Sources audit	x	x		x			
TNF143v1	Data Quality Assurance	x	x		x			
TF144v2	Export for Simulation Testing	x	x	x				
TNF146v1	Scalability and Performance		x					
TF149v1	Error Reporting and Logging	x	x		x			
TF150v1	Clear Troubleshooting	x	x	x	x	x	x	x
TF151v1	Device Compatibility	x			x	x	x	
TF152v1	OS Compatibility	x			x	x	x	
TF153v2	Factory 3D Scanning and Rendering	x						

Code	Title	Industry	DT creation	City Planning	City Maintenance	Parking Detection	AR Virtual Tourism	VR Virtual Tourism
TNF154v1	Scanning of large environments	x						
TF156v1	Digital Twin Integration	x						
TF158v1	Overlay changes in realtime	x			x		x	
TF159v1	Error Correction Functionality	x						
TF160v1	3D objects manipulation	x	x					
TF161v1	Hidden/Covered Area Scanning	x						
TF162v1	Update of the model	x	x					
TNF165v1	Data Management	x	x	x	x	x	x	x
TF166v1	Cloud Storage	x	x					
TNF167v1	Performance and Stability	x			x	x	x	x
TNF168v1	Long duration	x	x	x	x	x	x	x
TF169v1	Intuitive User Interface	x	x	x	x	x	x	x
TF171v1	Clear Scanning Instructions	x						
TF173v2	Visual Feedback and Guidance	x						
TF177v1	Realistic Representation	x						
TF178v2	Save Functionality	x						
TF179v1	Redo/Undo Functionality	x	x	x				

11 Annex – User Flow Diagrams

11.1 Digital Twin Creation UC

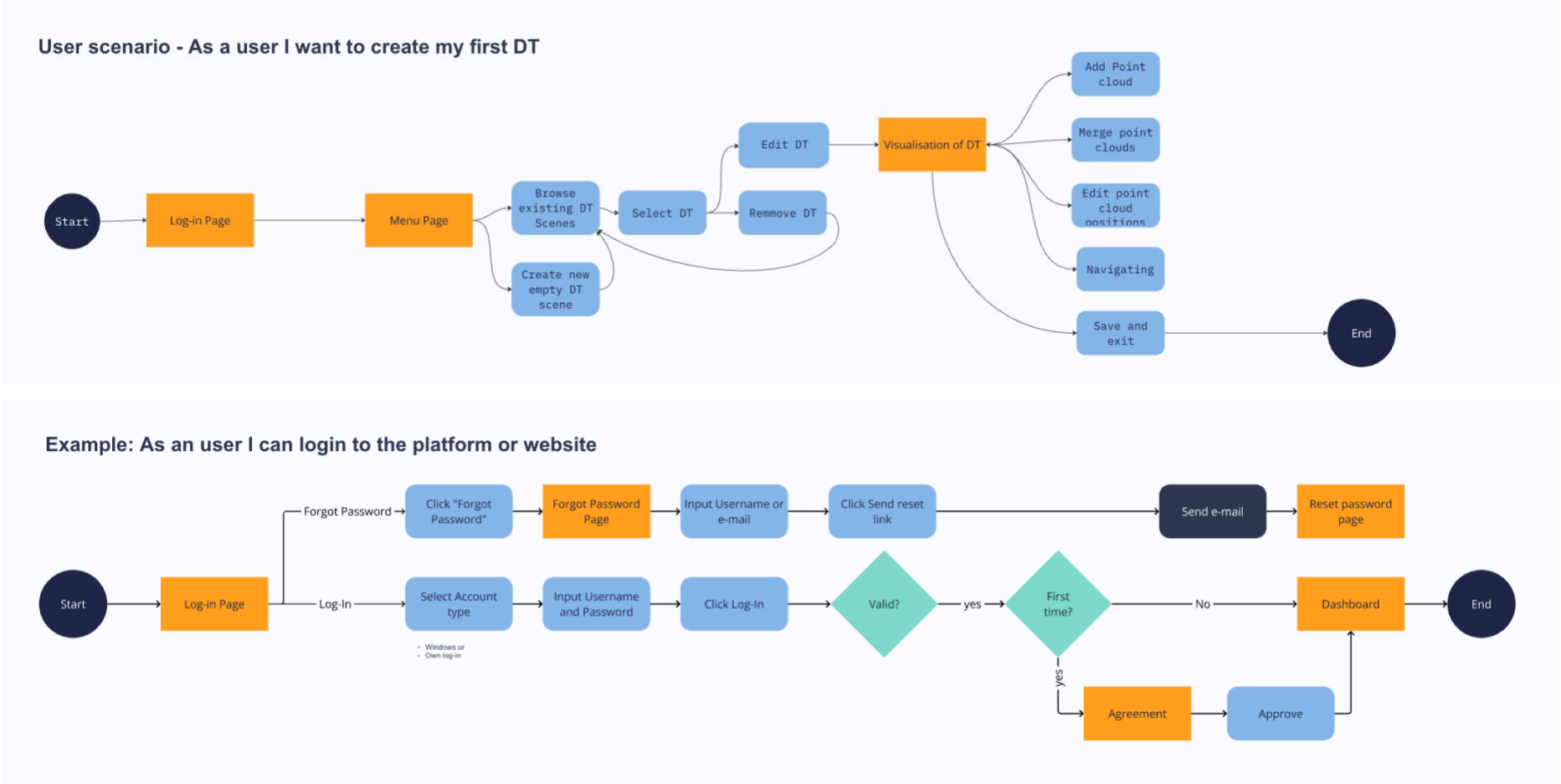


Figure 16 User Flow Diagrams for the Digital Twin Creation Use Case

11.2 City Planning UC

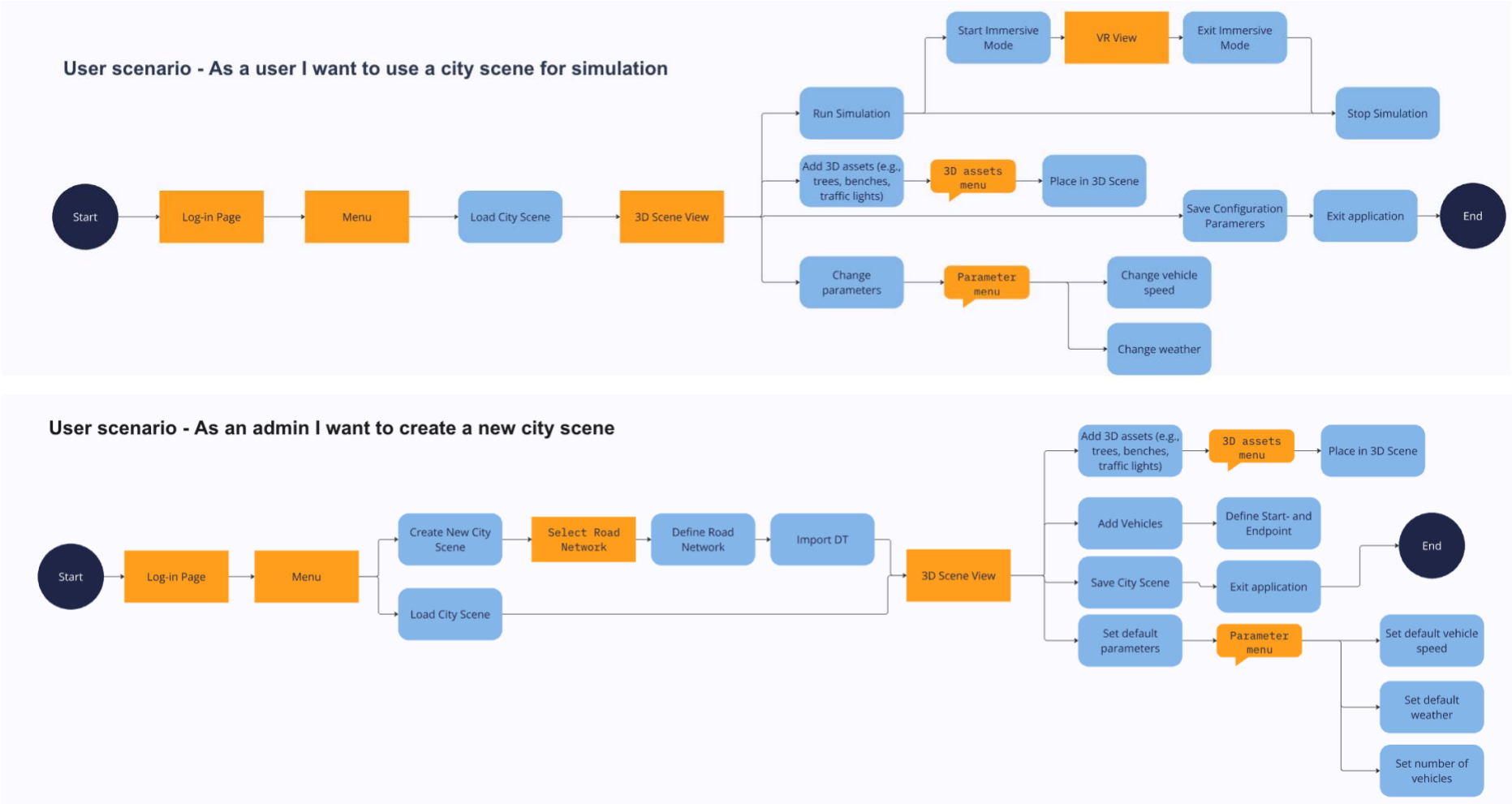


Figure 17 User Flow Diagrams for the City Planning Use Case

11.3 City Maintenance UC

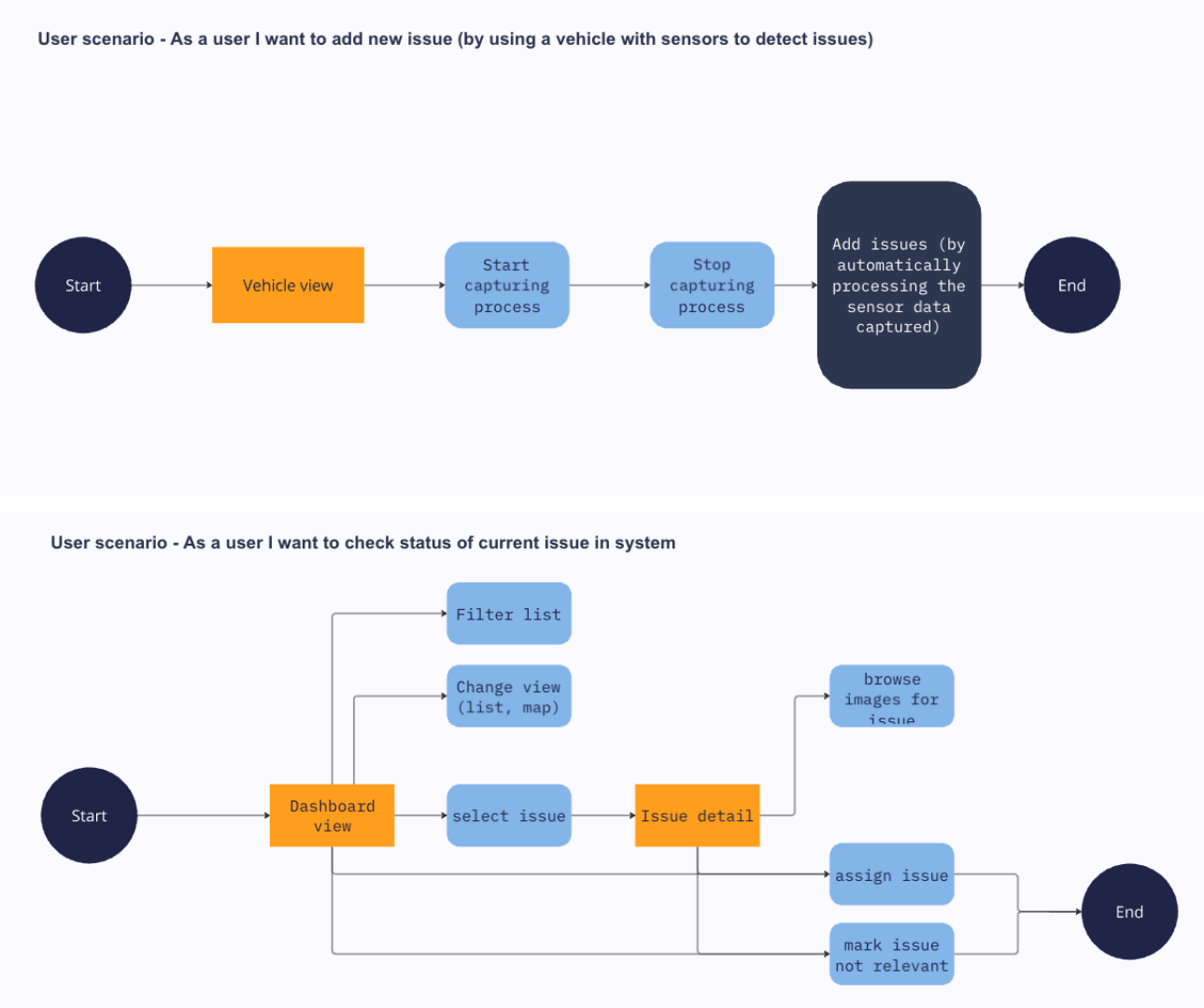


Figure 18 User Flow Diagrams for the City Maintenance Use Case

11.4 AR Virtual Tourism UC

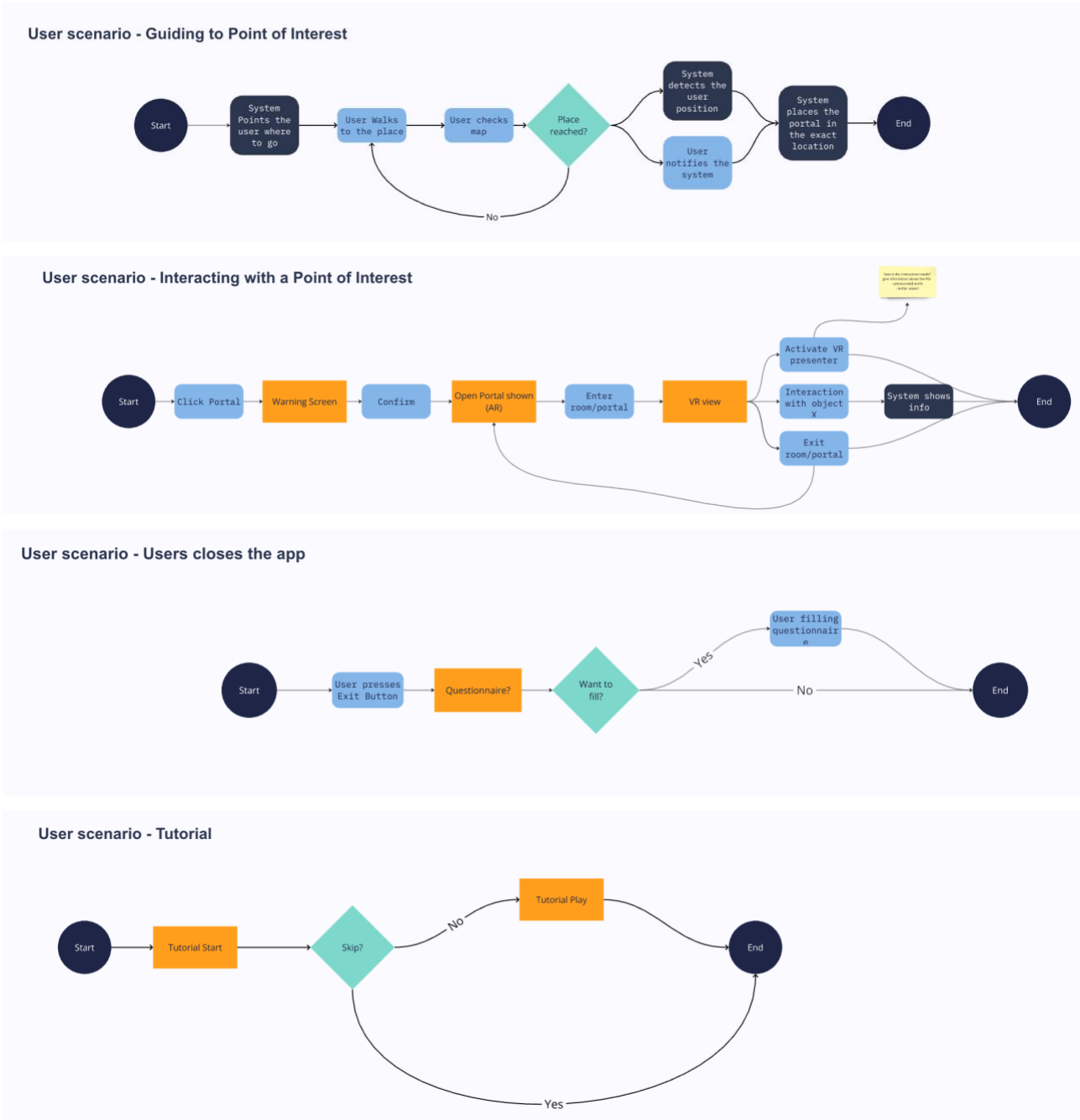
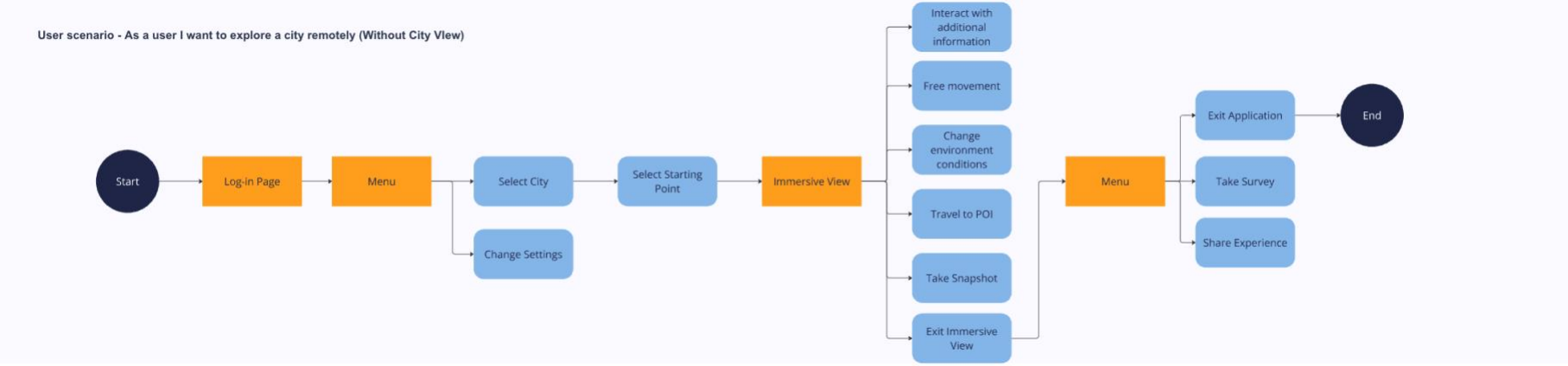
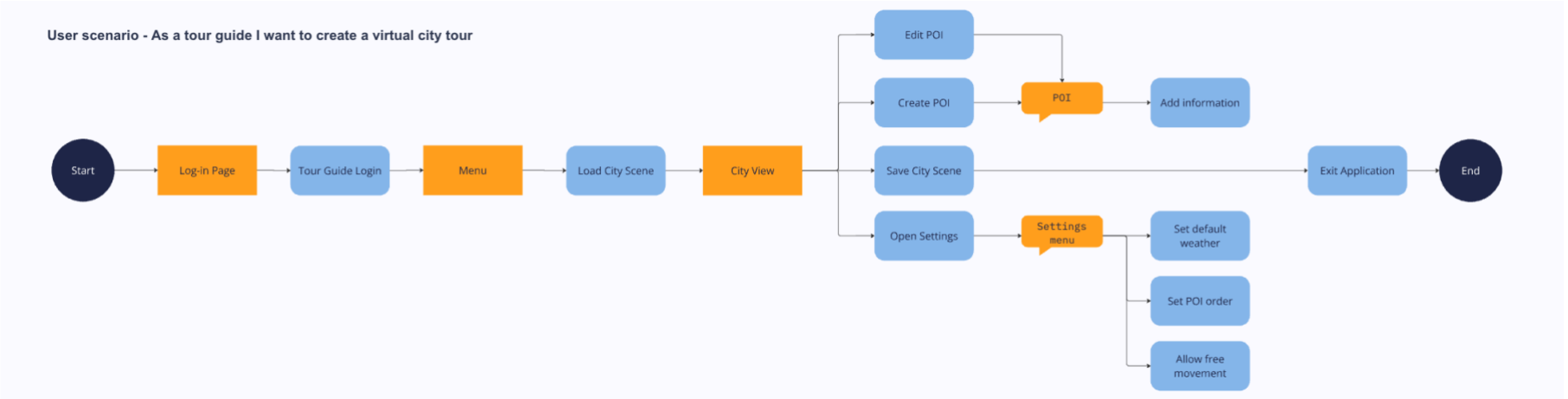


Figure 19 User Flow Diagrams for the AR Virtual Tourism Use Case

11.5 VR Virtual Tourism UC





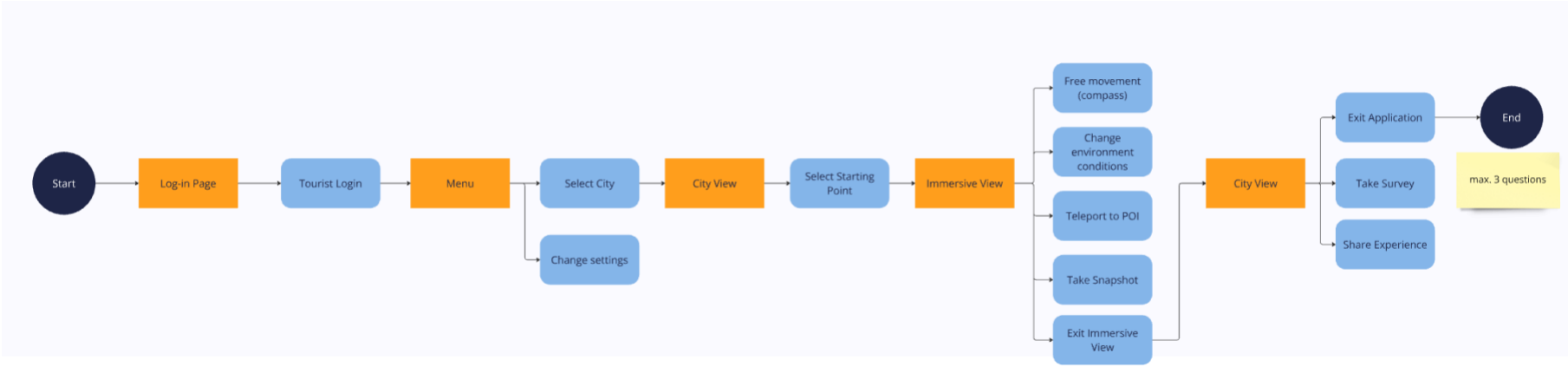


Figure 20 User Flow Diagrams for the VR Virtual Tourism Use Case

11.6 Industrial UC

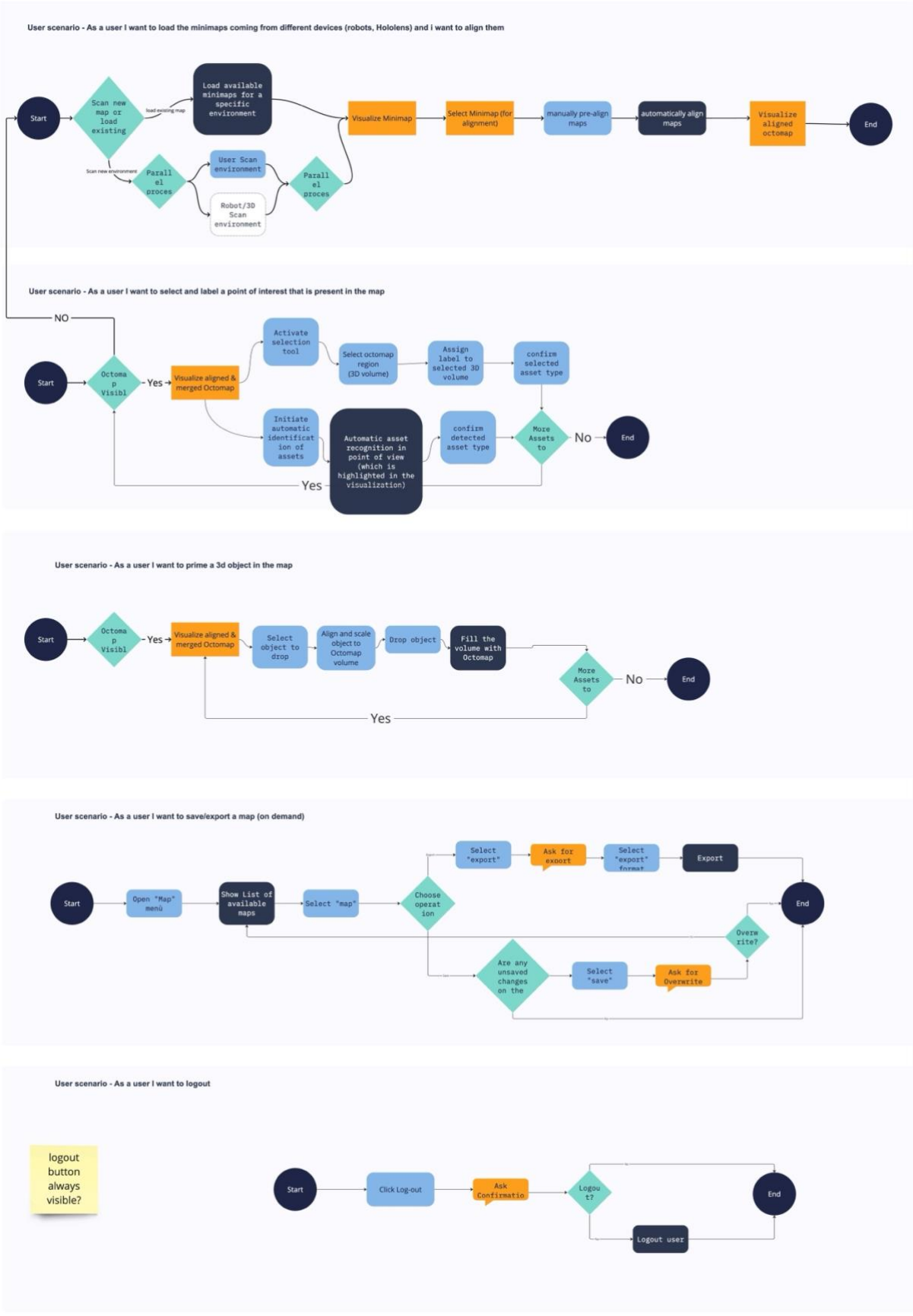


Figure 21 User Flow Diagrams for the Industrial Use Case