MetaCities Excellence Hub in South-Eastern Europe

D4.1 A: Report on PoC studies, demos and pilots

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Responsible Author	Filitsa Charalambous (PRT)		
Contributions from	Kosmas Adam (PRT), Ioanna Ioannou (eBOS), Savvas Antoniou (CYENS), Vasos Vasiliou (CYENS), Christiana Ioannou (CYENS), Natalie Temene (CYENS), Marios Pafitis (CYENS), UoP Team, Angelos Thrasyvoulou (UCM), Eleftherios Loizou (UCM), Virginia Christou (CCA), Elena Poulli (DMRID), Sotir Sotirov (Digihub), Ina Agafonova (Digihub), Petko Georgiev (Digihub), Stoyan Nikolov (Digihub), Daniela Aleksieva (ISBUR), Dian Raikov (ISBUR), Kremena Chilikova (ISBUR), Boyan Popunkyov (BUR), Vladimir Poulkov (TUS), Agata Manolova (TUS), Nikos Kostis (YDW), Tanya Politi (UPAT) Spyros Denazis (UPAT), Ioannis Tsampras (UPAT), Panayotis Kalozoumis (HAEC), Marios Nicolaou (p-NET),Evi Faliagka (UoP)		

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Glossary of terms and abbreviations

Abbreviation / Term	Description
AI	Artificial Intelligence
APIs	Application Programming Interfaces
BG	Bulgarian
BIM	Building Information Modelling
CY	Cyprus
Demos	The demonstration instance of the Digital Twin used to present the implemented capabilities to stakeholders and illustrate the intended user workflow. A demo is designed to show how the solution works in practice, but it does not necessarily rely on fully operational data flows, production hosting conditions, or large-scale multi-user operation.
DT	Digital Twin
Digital Twin - BG	A digital representation of the urban environment in Burgas that integrates spatial, real-time and historical information related to energy consumption, indoor environmental conditions, renewable energy production potential, and building performance indicators to analyse building energy efficiency and building roof-top energy production capacity, using simulations to assess resource use for more effective decision-making.

Digital Twin - GR	The Patras Mobility Digital Twin is a virtual, data-driven replica of the urban mobility system of Patras, Greece, designed to simulate, monitor, and optimise how people, vehicles, and goods move within the city in real time and under different planning scenarios. It integrates real-world and simulated data (such as traffic sensors, parking systems, road networks, public transport information, and mobility APIs) into a 3D digital environment of the city, enabling stakeholders to analyse current conditions and test future interventions before applying them in the physical world.
Digital Twin - CY	UHI Digital Twin is a digital representation of the urban environment in Nicosia that integrates spatial, environmental, and meteorological information to analyse Urban Heat Island effects, support simulations and what-if analyses, evaluate mitigation measures, and assist climate-resilient urban planning.
DTDs	Digital Twin Descriptor Service
EE	Energy Efficiency
GDPR	General Data Protection Regulation
GIS	Geographic Information Systems
GR	Greek
GA	Grant Agreement
ICT	Information and communication technology
KPIs	Key Performance Indicators
Large Scale Pilot	An extended real-world deployment of the Digital Twin across a broader geographical area and/or wider operational scope, using real operational data and conditions. Its purpose is to be used after scaling a Small-Scale Pilot, proving the robustness, interoperability, and capacity of the solution to support wider adoption in practice.
Large-scale pilot - BG	The scaled extension of the Bulgarian Small-Scale Pilot beyond the single-building implementation, using real operational data and relevant infrastructure, for up to 50 building assets within the city.
Large-Scale Pilot - GR	A future expanded deployment of the Patras Digital Twin extending beyond the initial pilot area to support city-wide mobility planning, parking management, stakeholder engagement, and policy evaluation. Building on the lessons learned from the Proof of Concept and Small Scale Pilot, the Large Scale Pilot would integrate additional districts, mobility datasets, third-party applications and data and operational systems to evaluate interventions at a broader urban scale and support strategic decision-making across the municipality.
Large-Scale Pilot - CY	The scaled extension of the Cyprus pilot beyond the initial small-scale deployment, applying the UHI reduction approach to a broader operational context and/or additional urban area(s) using real operational data to validate the solution at larger scale.
ODTF	Open Digital Twin Framework
PoCs	Proof-of-Concepts
Proof of Concept (PoC)	An initial implementation developed to demonstrate that the core idea is technically feasible. A PoC is primarily used to validate the proposed concept, architecture, and essential functions under controlled conditions, without requiring full operational maturity or deployment at city scale.

Proof of concept (BG-PoC)	An initial implementation of the Burgas Energy Efficiency and Resource Planning Digital Twin developed to demonstrate the technical feasibility of the approach. Its purpose is to validate the core concept, architecture, and essential functionalities within a controlled and limited operational scope in Burgas.
Proof of Concept (GR- PoC)	An initial validation phase of the METACITIES Digital Twin for Patras, demonstrating the feasibility of using a smart mobility and smart parking Digital Twin to evaluate parking-related mobility measures through "what-if" scenario simulations. The Proof of Concept focuses on selected functionalities such as fusion of live position of GPS tracked cars on 3D representation of an area, parking supply adjustments with adding and deleting parking spaces, in reaction to avatar cars, integration of simulators like SUMO on the 3D representation of an area
Proof of Concept (CY PoC)	An initial implementation of the Cyprus UHI Digital Twin developed to demonstrate the technical feasibility of the approach. Its purpose is to validate the core concept, architecture, and essential functionalities within a controlled and limited operational scope in Nicosia.
PV	Photovoltaic
PwD	People with Disabilities
R&I	Research and Innovation
Small Scale Pilot	A deployment of the Digital Twin in a real-world setting using real data, but limited to a defined geographical area, operational scope, or set of Use Cases. Its purpose is to validate the functionality, usability, and practical value of the solution under realistic conditions before broader roll-out.
Small scale pilot - BG	Pilot Use Case implementation focused on Buildings Energy Performance Analysis through integration of real-time monitoring systems, Digital Twin, geospatial data, and simulation-based analytical tool. The Use Case enables the collection, processing, and visualisation of real-time and historical information related to energy consumption, indoor environmental conditions, renewable energy production potential, and building performance indicators. The small-scale pilot is applied for one public building based on set in exploitation platform with scaling capacity to process data coming from up to 50 buildings.
Small-Scale Pilot-GR	A pilot deployment of the Patras Smart Mobility Digital Twin within a representative urban district of approximately 1 km², characterised by high parking demand and recurring congestion patterns. The pilot integrates/fuses real and simulated parking, traffic, and mobility data to support scenario testing, stakeholder consultation, and citizen participation through web-based and immersive 3D interfaces. The scope is: Street-level representation of roads, parking infrastructure, and curb space, Integration of smart parking sensors, traffic monitoring systems, parking facilities, and mobility services, Evaluation of parking-oriented mobility measures through simulation and Collection of citizen feedback and stakeholder input for scenario refinement
Small-Scale Pilot-CY	The UHI reduction Use Case implemented in the METACITIES framework for the city of Nicosia, using real data and a defined operational scope in order to validate the solution in a real urban environment.
SUMO	Simulation of Urban Mobility
UHI	Urban Heat Island
VR	Virtual reality

2D	Two-dimensional
3D	Three-dimensional

Executive Summary

Deliverable D4.1 corresponds to the activities carried out within Task T.4.1 and focuses on the METACITIES PoC studies, demonstrators, and pilots. Building upon the stakeholder requirements, socio-economic analysis, and Digital Twin architecture developed in WP3, the deliverable presents the experimental studies, user requirements analysis, feasibility assessment activities, and preliminary pilot designs that support the implementation of the METACITIES pilots across the participating clusters.

Building on the pilot design framework developed in Objective 2, this deliverable establishes a structured methodology for translating stakeholder needs into implementable technical specifications for Digital Twin-enabled Smart City services. Based on the socio-economic requirements, architectural specifications, and stakeholder engagement activities presented in D3.1 and D3.2, the document further refines and validates the requirements through extensive user-story analysis and participatory co-creation activities involving Quadruple Helix stakeholders, including public authorities, businesses, academia, and citizens.

A Hybrid Agile–Waterfall methodology combined with a Living Lab approach was adopted to collect user stories and translate them into a comprehensive set of functional and non-functional technical requirements. Through the experimentation and co-creation process, each cluster selected one representative Use Case that will guide the implementation of the small-scale pilots in Task T4.2 and support the design of the large-scale pilot deployment in Task T4.3.

The selected Use Cases are:

Smart Mobility: The selected pilot Use Case focuses on Patras Smart Parking & Smart Mobility through the development of a Digital Twin environment that integrates real-time and historical parking, traffic, public transport, geospatial, and user-generated data with simulation and 3D/VR visualisation tools. The pilot addresses key mobility challenges in Patras, including traffic congestion, parking-search traffic, limited availability of real-time mobility information, and the environmental and accessibility impacts of inefficient transport flows. The Use Case enables municipal authorities, mobility experts, businesses, researchers, and citizens to configure, simulate, and compare what-if scenarios related to parking and curb-space management, such as double-parking mitigation, parking supply adjustments, park-and-ride assessment, road-network changes, and pedestrianisation measures. Through this approach, the pilot supports evidence-based planning, stakeholder consultation, and the design of more efficient, transparent, and sustainable urban mobility policies.

Green City: The selected pilot Use Case focuses on Buildings Energy Performance Analysis through the integration of real-time monitoring systems, Digital Twin technologies, geospatial data, and simulation-based analytical tools. The Use Case enables the collection, processing, and visualisation of real-time and historical information related to energy consumption, indoor environmental conditions, renewable energy production potential, and building performance indicators. The pilot addresses the growing need for municipalities to better understand and optimize the energy performance of public and residential buildings while supporting long-term sustainability and climate adaptation objectives.

Urban Planning, Urban Heat Stress Reduction Case: The Urban Heat Stress Reduction Use Case focuses on reducing the Urban Heat Island (UHI) effect in Nicosia using data-driven planning and nature-based solutions. A Digital Twin application is used to identify heat-stress areas and simulate interventions to assess how they can reduce urban heat.

A systematic gap analysis is conducted to assess the feasibility of implementation within the project's timeframe and budget, while identifying potential limitations associated with the selected Use Cases. The analysis highlights the current maturity of the available ICT infrastructure and identifies areas

requiring additional development, optimisation, or future extension beyond the project duration, including opportunities for further evolution through future funding initiatives.

The final architecture of each pilot is then defined, together with the corresponding KPIs used to evaluate the effectiveness, usability, responsiveness, and decision-support value of the implemented solution.

The outcomes of this deliverable provide a concrete foundation for the development teams, supporting the implementation of pilot demonstrations and small-scale pilots in Task T4.2, as well as the large-scale pilot deployment planning activities in Task T4.3. Furthermore, the methodologies, architectural principles, participatory processes, and requirement-engineering framework established in this work contribute toward the development of scalable, interoperable, and transferable Smart City Digital Twin solutions that can be replicated and adapted across different urban environments.

Overall, the document aims to ensure that the proposed solutions are technically feasible, user-driven, interoperable, and fully aligned with the common METACITIES architecture and strategic objectives.

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1 Introduction

1.1 Mapping METACITIES outputs

This section presents the METACITIES Grant Agreement (GA) commitments, as extracted from the formal deliverable and task description, in respect to their outputs and work to be performed. The purpose is to aid the reviewer in finding the specific sections of the document where the respective tasks' requirements are addressed but also to guide the author through and serve as a checklist to address everything that is needed to be addressed.

TABLE 1: ADHERENCE TO METACITIES GA DELIVERABLE & TASKS DESCRIPTIONS.

METACITIES GA Component Title	METACITIES GA Component Outline	Respective Document Chapter(s)	Justification
TASKS			
Task 4.1 PoC Studies and Feasibility Assessment	*This task is responsible for the definition of the proof-of-concept experimental studies, and their realisation. It will identify the main requirements of the PoC studies and will utilize the architectural references for the vertical services validation, from the infrastructure capabilities perspective. Specifically, the task will focus on three main components, (1) the Use Case requirements and analysis of corresponding application areas (mobility, e-services, energy) as stems from end - users, (2) social requirements imposed by the societal actors assessment and (3) gap analysis of the ICT technology that is required that will provide in the second phase the technical requirements that will be translated in ICT infrastructure and the interfaces with the open digital framework that is developed in WP3. The output of this Task will describe the design of the PoC with functional and non-functional requirements, the interfaces with the existing infrastructure per cluster and will suggest specific technical and nontechnical KPIs for each Pilot.*	*Chapter 2* *Chapter 3* Chapter 4	*Chapter 2 analyses the Use Case Requirements* Chapter 3 presents the gap analysis of existing ICT technologies Chapter 4 describes the Final Pilot architecture and interfaces, along with the KPIs
DELIVERABLE			
Deliverable 4.1 - A: Report on PoC studies, demos and pilots *PoCs, Demonstrators and Pilots Report. This deliverable will report on the findings and feasibility assessments of the PoC experimentation studies and demonstrations.*			

1.2 Deliverable Overview and Report Structure

The deliverable D4.1 – Report on PoC Studies, Demos and Pilots, establishes the foundation of the implementation phase of the METACITIES project. Building on the socio-economic requirements and technical specifications of the Open Digital Twin Framework (ODTF) defined in Task T3.1 (Elicitation of socio-techno-economic requirements), together with the functional and non-functional requirements and architectural components identified in Deliverable D3.2 [1], this deliverable represents the final refinement stage of the requirements analysis process and describes the design of the PoCs through the necessary experimental studies and feasibility assessments.

Based on the defined objectives, the document begins with an Executive Summary and an Introduction in Chapter 1.

Chapter 2 presents the experimental studies and feasibility assessment process through a comprehensive user-story analysis framework, in which user needs and stakeholder requirements are captured, validated against the requirements proposed in WP3 (Joint Research and Innovation Project), and subsequently translated into the technical components required for the development of the Digital Twins (DTs).

Chapter 3 presents the selected pilots for implementation within the METACITIES project. It further provides the gap analysis and feasibility assessment, organised through extensive evaluation tables and divided into three main dimensions: ICT Systems and Communication Infrastructure, Data Availability and Access, and Operational and Application Gaps.

Chapter 4 describes the architecture of the pilots and the design of the Pilots and proposes common technical and non-technical Key Performance Indicators (KPIs).

Finally, the Annexes provide the detailed supporting material used throughout the analysis and design process, including the complete user-story tables, requirement analysis and traceability tables and gap analysis matrices.

2 User Stories

The purpose of this chapter is to conduct PoC experimental studies to define the requirements and enabling technologies for the design of the pilots. Building on the socio-economic requirements collected in D3.1[2], and the functional and non-functional requirements identified in D3.2 a structured methodology was developed to capture the specific needs for each PoC across the three pilot clusters.

The Figure below (Figure 1) presents the overall methodological approach followed in this chapter, which is grounded in the Use Cases described in detail in D3.2. The process starts from the definition of the overarching problem: the development of a Digital Twin (DT) for each pilot cluster and its associated application domains, Smart Mobility, Green City, and Urban Planning. Each Digital Twin is deployed within its respective smart city context, while also enabling a transferable technological framework that can be adapted and reused across different urban environments within the project.

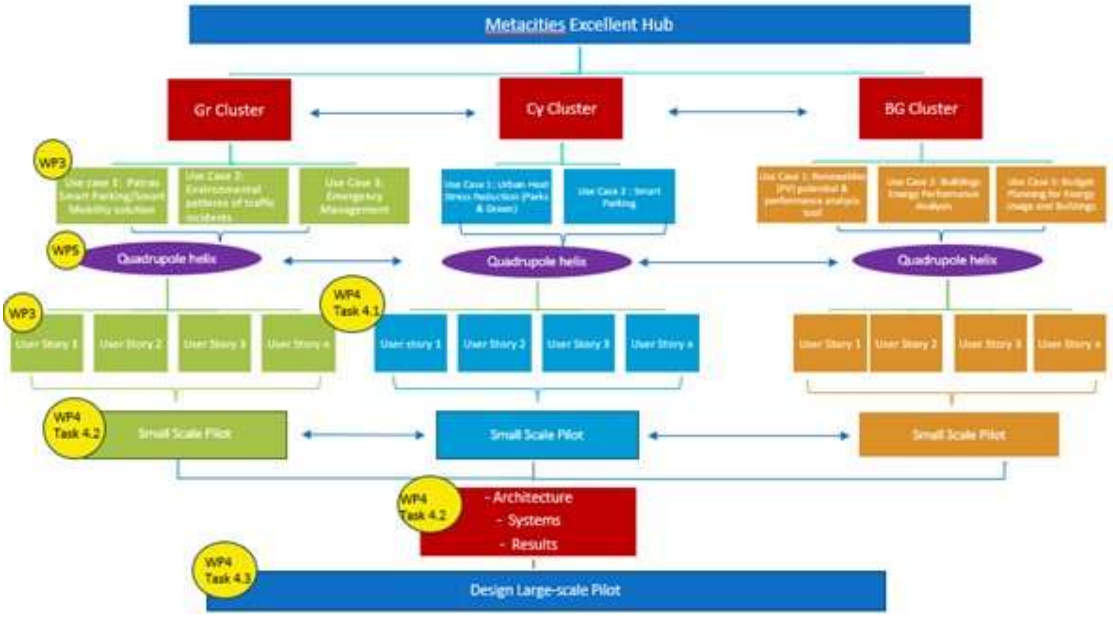

FIGURE 1: METHODOLOGY DIAGRAM

Each cluster has defined a set of Use Cases, as analysed in D3.2. These Use Cases are further refined through the active involvement of the quadruple helix stakeholders, whose needs are captured and translated into user stories (WP3). The user stories are then further elaborated within Task 4.1, building on the questionnaires distributed during D3.1 and enriched through physical meetings and co-creation workshops, where stakeholders actively contributed to their refinement. At this stage, the user stories are consolidated and prepared for implementation, while a subset of them can be directly considered as PoCs.

Based on these user stories, user needs were identified and used to validate and refine the functional and non-functional requirements defined in D3.2. These requirements were then consolidated and mapped to the specific needs of each Digital Twin and Use Case. In a final step, the requirements were translated into technical components, forming the foundation for the architecture that will support the design and implementation of each Pilot (one per cluster). Based on this, small-scale pilots are developed in each cluster (Task 4.2-Design of small-scale Pilots, Demonstrators), enabling the

validation of concepts in real-world conditions. The outcomes of these pilots covering architecture, systems, and results, are then used to inform the design of large-scale pilots (Task 4.3-Design of large-scale pilots).

The methodology and the relevant findings are presented in detail in the following sub-sections, supported by structured tables for each user story. These tables highlight the user needs, corresponding requirements, necessary for the design and implementation of the pilots.

2.1 Methodology

The requirement analysis followed a Hybrid Agile–Waterfall approach [3] combining a structured process with iterative, user-centred feedback. This approach was chosen because the project has fixed deliverables, timeframes, milestones, and budget, while still requiring flexibility for user feedback and validation. The process, therefore, balanced the structured planning of the Waterfall model with the adaptive and participatory practices of Agile. To further strengthen the user-centric dimension of the methodology, a Living Lab approach [4] was adopted across the pilot clusters. This approach enables the active involvement of stakeholders from the quadruple helix, fostering co-creation, experimentation, and continuous feedback.

The information used for this analysis was collected through participatory and user-centred activities, including questionnaires developed in WP3, individual interviews, participant observation, and interactive workshops held during WP4. These activities enabled direct engagement with end users and stakeholders, ensuring that the defined requirements and user stories accurately reflect real needs and operational contexts.

User stories are widely adopted as a contemporary alternative to traditional requirement specifications for eliciting and documenting user needs [5]. A user story is a short description of a requirement. Each user story comprises the following structure:

As a <user>, I want to < Requirement> so that < reason>

This identifies the role, activity, and value. The systematic collection and analysis of multiple user stories enable the capture of a holistic view of user requirements, thereby facilitating rapid iteration, continuous feedback, and timely adaptation throughout the development process [6].

For the purposes of this deliverable, a comprehensive set of User Story Tables has been developed and is provided in (Annex 1), to capture user stories with the following information per Use Case.

- User Role: Identify the actors of the QH
- Actors: The role of the subject of the story
- Title: The functional Topic that will be broken down to find the requirements
- User story: A short description of the requirements structured in the following:
    - ‘I want to’ describes the intended goal that the user expects to be fulfilled;
    - ‘So that’ describes the reason, which is the added value of the development;
- Acceptance Criteria = The requirements, the actual needs of the user

User Role	ID	Actors	Title	User Story	Acceptance Criteria -Requirements
	No of user story	*Identify the costumer job(s) to which this user story relates.*		*Describe the intended goal that the user expects to be fulfilled.*	*Identify the reason(s) to which this user story relates. The needs of the user*
GOVEREMENT	UHI-US1	As a government official (e.g., urban planner)	Access and analyze data to make informed urban planning decisions	As an urban-planning officer, I want to access real-time and historical environmental data for new or renovated city infrastructure (e.g., par So that I can make data-driven decisions to improve city infrastructure, urban living conditions and the environmental impact.	1. **Data Visualization on Digital Twin** a. The platform uses TerriaMap to display city infrastructures and related information on an interactive map. b. Users can view real-time utilization data (e.g., heatmaps, graphs) and predictive models. 2. **Real-Time and Historical Data:** a. Real-time data is updated dynamically. b. Historical data is updated periodically. 3. **Decision-Making Tools:** a. Users can simulate the impact of decisions (e.g., adding/removing trees, adjusting b. Simulations are visualized on the platform and include metrics like reduced urban heat index. 4. **User Roles and Access Levels:** a. Different roles (e.g., urban planners) have access to specific data and tools based on their b. Access is controlled through the platform's login functionality. 5. **Data Export:** a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes. 6. **Urban Heating Index Inputs** a. City tree stock b. Parks c. Urban planning zones d. Water bodies e. Soil sealing f. Building density g. Environmental data (air pollution, weather, wind)

FIGURE 2: SNAPSHOT FROM METACITIES USER STORIES AND ACCEPTANCE CRITERIA

A set of user stories was developed for each selected Use Case, reflecting the needs and expectations of the relevant stakeholders. The user stories were subsequently reviewed and refined to ensure alignment with the objectives and requirements of each Use Case. (Figure 3) provides an overview of the user stories identified per cluster and Use Case.

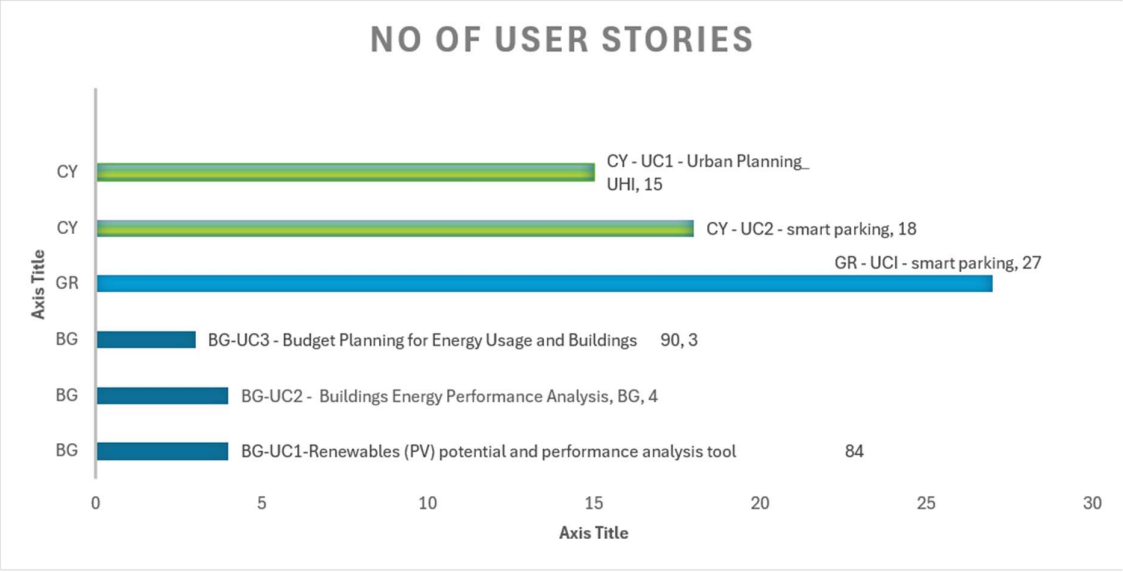

FIGURE 3: USER STORIES PER CLUSTER

To ensure the quality and completeness of the collected user stories, the INVEST criteria [7] a widely used framework in Agile methodologies for evaluating user stories, were adopted. Each user story was assessed to confirm that it is Independent, Negotiable, Valuable, Estimable, Small, and Testable. This evaluation ensured that the stories are independent, clear, and capable of delivering measurable

value to the end users. Furthermore, the application of the INVEST principles supported the prioritization and refinement of the stories during the validation workshops, ensuring that only high-quality, actionable, and verifiable stories were retained for the design and implementation phases.

Each cluster followed a flexible approach for the creation and refinement of user stories. Specifically, clusters could either (i) independently derive user stories based on literature, project objectives, and stakeholder engagement activities, applying the INVEST methodology to assess their quality. In this case, user stories were evaluated against the six INVEST dimensions using a simple scoring scheme (G = Pass, A = Partial, R = Fail), combined with decision codes (K = Keep, RW = Rewrite, DEL = Delete, M01–M07 = Merge groups). The results of this evaluation were captured in a dedicated assessment table (Figure 4), providing a clear overview of the quality status and the corresponding actions for each user story.

ID	Act	Summary	I	N	V	E	S	T	Decision
GR.24	Gov	Scenario compare	G	G	G	G	G	G	K
GR.26	Gov	Publish scenario	G	G	G	A	A	G	K
GR.1	Gov	Enforce no-double-park	G	G	G	G	G	G	K
GR.5	Gov	Add on-street parking	G	G	G	G	G	G	K
GR.6	Gov	Remove on-street parking	G	G	G	G	G	G	K
GR.13	Gov	Pedestrianize street	G	G	G	G	G	G	K
GR.9	Gov	Add park-and-ride	G	G	G	G	G	G	K
GR.21	Gov	Bike parking placement	A	G	G	A	A	A	M02
GR.28	Gov	Auto-satisfy citizens	R	R	R	R	R	R	DEL
GR.61	Bus	Integrate parking feed	G	A	G	A	A	G	K
GR.62	Bus	Integrate detector feed	A	A	G	A	A	A	M01
GR.7	Bus	Private parking facility	A	A	G	A	A	A	M01
GR.22	Bus	Bike parking sponsor	A	G	G	A	A	A	M02
GR.31	Acad	Calibrate congestion	A	G	G	A	A	A	M03
GR.32	Acad	Validate vs observed	G	G	G	A	A	G	K
GR.33	Acad	Back-test on history	G	G	G	A	A	G	K
GR.42	Acad	Find mismatch hotspots	G	G	G	A	A	G	K
GR.34	Acad	Compare model variants	A	G	G	A	A	A	M03
GR.29	Acad	Real-time vs historic	G	G	G	A	A	G	K
GR.3	Acad	Compare interventions	A	G	G	G	G	A	RW
GR.11	Acad	Calibrate P&R uptake	G	G	G	G	G	G	K
GR.43	Acad	Equity/access analysis	G	G	G	A	A	G	K
GR.47	Pub	3D concern pin	A	G	G	A	A	A	M04
GR.49	Pub	Commute impact compare	A	G	G	A	A	A	M07
GR.55	Pub	Anon feedback scoring	A	G	G	A	A	A	M06
GR.56	Pub	Feedback heatmaps	G	G	G	G	G	G	K
GR.51	Pub	Mobile usability	G	G	G	G	G	G	K
GR.53	Pub	Filter proposals	G	G	G	G	G	G	K
GR.57	Pub	Share viewpoint link	G	G	G	G	G	G	K
GR.58	Pub	Accessibility mode	G	G	G	G	G	G	K
GR.48	Pub	Scenario annotations	A	G	G	A	A	A	M04
GR.30	Pub	VR walkthrough	A	G	G	A	A	A	M05
GR.52	Pub	VR comfort assess	A	G	G	A	A	A	M05
GR.50	Pub	Landmark impact view	R	R	R	R	R	A	DEL
GR.27	Pub	Geo-notes feedback	A	G	G	A	A	A	M06
GR.10	Pub	P&R for commute	A	G	G	A	A	A	M07
GR.59	Pub	Citizen publish official	R	R	R	R	R	R	DEL

FIGURE 4: USER STORIES ASSESSMENT

Alternatively, (ii) organise co-creation workshops, where user stories were elicited directly from stakeholders and structured by the project team using the INVEST criteria. In parallel, an initial set of user stories was developed from questionnaires, literature, and project objectives. During the co-creation workshops, these initial user stories were explicitly reviewed, validated, and refined based on stakeholder feedback, while additional user stories were identified where necessary. Following this process, each cluster filtered the resulting set by removing stories that were out of scope, ensuring alignment with the project objectives and resulting in a consistent and high-quality set of requirements.

2.2 User stories for Smart Mobility

The Smart Mobility Digital Twin focuses on developing a comprehensive digital ecosystem capable of representing, analysing, and predicting complex urban scenarios in the domain of urban mobility, parking, and curb-space management. Its main objective is to enable data-driven decision-making that fosters safer, more efficient, and more accessible urban transportation systems, addressing concrete mobility challenges in the city of Patras, such as traffic congestion, illegal and double parking, parking search traffic, inadequate public transport information, and the environmental and safety externalities of inefficient transport flows. The proposed system integrates multi-source geospatial data, road network and curb-space information, real-time and historical traffic data, smart parking sensor events, public transport telemetry, and behavioural data into an interactive 3D digital representation of the city.

Through the integration of advanced analytics, AI-driven prediction, and simulation capabilities, the platform is designed to operate not only as a decision-support and visualisation tool but also as a city-scale digital testbed: a virtual environment in which alternative mobility policies, infrastructure interventions, and operational strategies can be examined, refined, and discussed before any real-world implementation. In this capacity, it empowers municipal authorities, mobility engineers, traffic scientists, technology providers, parking operators, and citizens to visualise current mobility conditions, design and compare alternative scenarios, and assess their operational, environmental, and societal impacts on congestion, accessibility, travel time, parking availability, safety, and citizen acceptability.

In support of these objectives, a comprehensive user story and requirements analysis process was carried out to capture both functional and non-functional stakeholder needs and to guide the architectural design of the Smart Mobility Digital Twin. The user stories formed the backbone for requirement elicitation and validation, ensuring that the developed system remains aligned with the practical needs of urban mobility planning in Patras, with broader societal objectives, and with sustainability and accessibility goals defined at the municipal and European level.

The user stories were elicited through a multilayered participatory framework that combined quantitative and qualitative approaches to ensure inclusiveness, representativeness, and alignment with the project's technical requirements, in line with the Quadruple Helix participatory model. As initially outlined in Deliverable D3.1, dedicated questionnaires were prepared for the pilot Use Case to collect feedback from end users, stakeholders, and thematic experts in urban mobility, transport engineering, and information technology. The questionnaires were reviewed by technical partners to verify feasibility and consistency with project goals and subsequently distributed through Google Forms in Greek and English in order to maximise outreach among different stakeholder groups.

Based on the collected feedback, a series of co-creation workshops were subsequently organised, during which participants collaboratively formulated user stories using structured templates describing stakeholder roles, needs, and expected outcomes (WP6-Dissemination, Engagement and Knowledge Transfer). In parallel, individual interviews and formal discussions were conducted with municipal representatives, Smart City managers, urban mobility planners, traffic scientists, technology providers developing IoT and mobility platforms, and parking lot owners and operators (WP5-Business, Investment and Sustainability Plans). These activities contributed to validating practical user scenarios and refining them according to stakeholder expectations and operational priorities in the Patras context.

Furthermore, insights gathered from earlier discussions on the deployment of parking sensors, traffic monitoring infrastructure, and bus telemetry in the city of Patras were also taken into account. This additional feedback from citizens, mobility experts, and technology providers supported the further consolidation and validation of the user stories initially identified in D3.1. All finalised user stories were then systematically assessed according to the INVEST principles (Independent, Negotiable, Valuable, Estimable, Small, and Testable), ensuring clarity, feasibility, and practical value for the subsequent stages of requirements analysis and system design.

The validated user stories for the Patras Smart Mobility Use Case are presented below.

2.2.1 Use Case 1: Patras Smart Parking & Smart Mobility

2.2.1.1 The User Stories

The Patras Smart Parking & Smart Mobility Use Case aims to support evidence-based planning, assessment, communication, and refinement of parking-oriented and broader mobility interventions in the city of Patras through the development of a Digital Twin (DT) application that combines real-time and historical mobility data with what-if simulation capabilities. The Use Case covers a wide scope of mobility-related interventions, including targeted enforcement against double parking, modifications to on-street parking supply, pedestrianisation of selected street segments, deployment of park-and-ride facilities, speed-limit adjustments, protected bike lanes and bike-parking infrastructure, real-time and historical mobility data visualisation, public feedback collection, and immersive 3D and VR-based scenario exploration. The platform is therefore designed not only to address parking availability, but also to examine how parking-related behaviour affects traffic circulation, accessibility, curb-space allocation, multimodal movement, and everyday mobility patterns in the city. The pilot will be implemented in a representative urban district of Patras of approximately one to three square kilometres, selected for its high parking demand, mixed land use, and recurrent congestion patterns, and the Digital Twin will model street-level geometry, the road network, curb-space allocation, parking infrastructure, and traffic flows influenced by parking search behaviour. Input data include events from approximately 530 LoRa-interconnected smart parking sensors, video streams from specialised traffic-flow cameras, traffic monitoring APIs, double-parking detection systems, real-time bus telemetry, third-party 2D and 3D city datasets (Google 3D Tiles, OpenStreetMap), and simulation components such as SUMO-based traffic and travel-time models. The system exposes its results through two complementary 3D interfaces: a professional interface for municipal, academic, and business users, supporting scenario configuration, simulation execution, baseline-versus-variant comparison, and analytics review through a side panel that can be expanded into a 2D analytical view; and a public-facing interface accessible via desktop, mobile, and virtual reality clients, in which citizens can explore published scenarios, compare before-and-after conditions for daily routes, and submit structured feedback or geo-anchored 3D annotations.

A total of 27 finalised user stories were retained for the Patras Smart Mobility Use Case, reflecting the perspectives of four distinct stakeholder categories aligned with the Quadruple Helix model. Governance users (municipal mobility engineers and officials of the Municipality of Patras) are represented through stories addressing scenario configuration, policy testing, official publication of vetted proposals, targeted double-parking enforcement, on-street parking supply adjustments, pedestrianisation, park-and-ride placement, and curb-space reallocation. Business users (developers of IoT and mobility platforms, and parking lot owners and operators) contribute stories focused on integrating operational data feeds into the twin, sponsoring mobility infrastructure such as bike parking, and analysing scenarios from a commercial-access perspective. Academia users (traffic

scientists and engineering students collaborating with local research institutions) are reflected in stories concerned with model calibration, controlled experiments, validation against observed data, back-testing, sensitivity analysis, model-data mismatch diagnosis, and reproducible research workflows. Public users (residents and commuters) are represented through stories addressing route-level impact comparison, park-and-ride exploration, geo-anchored feedback and 3D annotations, community feedback heatmaps, accessibility, mobile usability, viewpoint sharing, and immersive VR inspection of proposed changes. Collectively, the user stories capture key functional needs, including real-time and historical data access, simulation of mobility interventions, scenario comparison, data export, and integration of business and sensor data feeds, as well as non-functional requirements such as interoperability, role-based access control, privacy protection, accessibility, reproducibility of simulation runs, and mobile-friendly visualisation. They also emphasise advanced visualisation capabilities, including interactive 2D and 3D representations of the urban environment that allow users to explore spatial patterns of parking demand, traffic redistribution effects, and the impact of different intervention scenarios in an intuitive and accessible manner.

To ensure that the user stories accurately reflect stakeholder needs and remain technically viable, the Greek cluster conducted a series of participatory activities, including interviews with municipal services and Smart City managers, as well as workshops under WP6 involving public authorities, technology providers, and citizens. The initial collection produced 62 candidate user stories spanning all four stakeholder categories, of which 37 were shortlisted and submitted to a structured INVEST review carried out jointly with the technical partners of the consortium. Each story was assessed against the six INVEST criteria (Independent, Negotiable, Valuable, Estimable, Small, and Testable) using a three-level rating scale (Pass, Partial, Fail), and assigned a decision code corresponding to one of four outcomes: keep, merge, rewrite, or delete. **The review** produced a refined backlog of **27 user stories**, obtained as:

- 19 stories were retained without modification
- 14 overlapping stories were consolidated into 7 merged user stories,
- 1 story was rewritten to improve generality and reusability
- 3 stories were deleted as non-actionable.

The three deleted entries (GR.28, GR.50, and GR.59) corresponded to idealised formulations that respectively proposed to “automatically change the simulation until citizens are happy,” to provide an isolated landmark-area impact view duplicating existing visualisation capabilities, and to allow citizens to publish their own proposed changes as official city proposals. These stories failed multiple INVEST criteria simultaneously, most notably Valuable, Estimable, and Testable, and were documented as out-of-scope with an accompanying decision rationale. The seven merge operations consolidated stories originating from different stakeholder groups but addressing the same underlying capability, in order to avoid duplication and clarify responsibilities: GR.62 and GR.7 were combined into GR.M01, covering the integration of business parking operations and curbside compliance data into the Digital Twin; GR.21 and GR.22 were combined into GR.M02, covering the joint planning and business sponsorship of bike-parking placement at points of interest with appropriate access-control safeguards on sponsor metadata; GR.31 and GR.34 were combined into GR.M03, covering congestion model calibration and model-variant benchmarking on the same network; GR.47 and GR.48 were combined into GR.M04, covering geo-anchored 3D annotations on published scenarios; GR.30 and GR.52 were combined into GR.M05, covering VR walkthrough and comfort-assessment workflows; GR.55 and GR.27 were combined into GR.M06, covering structured anonymous citizen feedback enriched with optional geo-

anchored notes; and GR.49 and GR.10 were combined into GR.M07, covering route-level commute impact analysis with optional park-and-ride exploration. The rewritten story, GR.3, originally formulated as a fixed comparison of three specific enforcement strategies (patrol, cameras, and sensors), was reframed as a generic controlled-experiment workflow for traffic scientists, allowing arbitrary intervention strategies to be defined, run with shared baseline inputs, reproducible random seeds, and consistent analytics, and exported for citation through versioned run identifiers. This iterative refinement process ensured that the resulting backlog is independent, actionable, testable, and aligned with the practical requirements of the Patras pilot implementation.

Overall, the Patras Smart Parking & Smart Mobility Use Case provides a Digital Twin environment for testing, communicating, and refining mobility interventions before real-world implementation. Through the combination of scenario exploration, parking and mobility data integration, simulation, 3D and VR visualisation, analytics, and structured public participation, the Use Case supports the Municipality of Patras and its stakeholders in developing more effective, transparent, and sustainable mobility policies, while also offering a reusable methodological reference for similar pilot deployments in other Smart City contexts. The complete set of finalised user stories is provided in Annex [Table 18].

2.2.1.2 Functional Requirements and Non-Functional Requirements Analysis

Through the above process a final set of user requirements for Use Case 1 was established. The corresponding acceptance criteria are presented below.

TABLE 2: USER REQUIREMENTS - SMART PARKING & SMART MOBILITY

1. Data Visualisation on the Digital Twin Platform:	**2. Scenario Configuration and Simulation Tools:**	**3. Decision-Making and Scenario Comparison Tools:**	**4. Automated Data Retrieval, Data Integration, and Data Validation:**
a. The platform provides 3D Digital Twin and map visualisation for mobility, parking, traffic, curb-space and scenario data. b. Simulation outputs are displayed in a side analytics panel and can be expanded into a 2D analytical view. c. Users can view before and after visualisations for proposed mobility interventions. d. Synchronized views and layer consistency are maintained during	a. Users can define scenario areas, routes, corridors, street segments and time windows. b. Users can edit mobility infrastructure, parking supply, curb-space allocation, bike infrastructure or pedestrian space. c. Users can configure park-and-ride sites and adoption assumptions. d. Users can modify compliance, detection, behavioural, pricing, service or model parameters. e. The system validates input values, geometry, attributes and scenario configurations before simulation. f. Scenarios can be saved, duplicated, reloaded and	a. Users can compare baseline conditions with scenario results. b. Users can compare two scenarios side by side. c. The platform provides analytics and deltas for mobility impacts, including traffic, access, adoption, utilization and network effects. d. Comparison snapshots can be shared or exported. e. Vetted scenarios can be published to the public portal by authorized municipal users. f. Published proposals can be filtered and discovered by users.	a. The platform supports secure ingestion of parking, sensors, business and detector feeds. b. Ingested data are mapped to the correct spatial locations in the Digital Twin. c. Real-time status, availability and event layers update when valid feeds are connected. d. Stale or invalid data are flagged and excluded from real-time displays.

scenario comparison. e. Users can view real-time and historical mobility layers, selected time windows and data gaps. f. Users can visualise spatial impact maps and thematic layers for affected streets, zones and routes. g. The platform supports 3D annotations and geo-anchored notes on published scenarios.	persisted as scenario configurations. g. Users can execute simulations or what-if experiments for configured mobility scenarios.	g. Users can assess route, commute and park-and-ride impacts.	e. Aggregations update as data arrive, including counts, trends and feedback statistics. f. Incoming data are validated through schema checks, range checks and time synchronization. g. Integrated or observed data can be used as baseline or model input.
5. Data Export, Reporting, Versioning, and Reproducibility: a. Users can export analytics and data outputs. b. Users can export snapshots, run summaries, annotations or ingested time series. c. Scenario and run configurations are versioned. d. Results, logs, metrics, parameters and timestamps are saved. e. Simulation and calibration runs are reproducible using saved seeds and parameter sets. f. Runs can be cited through a run ID. g. Share links are stable or versioned and restore selected view settings.	**6. Access Levels, Governance, and Role-Based Control:** a. Only Governance users can publish scenarios to the public portal. b. Publishing actions are audit-logged. c. Business-submitted scenarios remain private by default unless shared with Governance for review. d. Raw or sensitive data access is controlled by user role. e. Public views expose only aggregated and privacy-safe analytics. f. Access-denied messages are clear and do not leak protected details. g. Feedback dashboards and sensitive data access follow role-based access control.	**7. Public Participation, Feedback, and Consultation:** a. Users can submit structured feedback, acceptability scores, reason tags and text notes. b. Feedback can be submitted anonymously and does not require personally identifying information. c. Users can control the precision of their location before posting feedback. d. Geo-notes and annotations are tied to scenario, version and location. e. Feedback aggregations are visible on scenario dashboards. f. Feedback and annotations can be filtered by area, time window or category. g. Feedback heatmaps and top-issue	**8. Public Interface, Mobile Usability, Accessibility, and VR Interaction:** a. The public interface is accessible through mobile browsers and touch-first controls. b. Core public functions, including view, filter, inspect and feedback submission, remain usable on mobile. c. Accessibility basics are met for text size, contrast and tap targets. d. Accessibility settings apply immediately, persist and are consistent across views. e. Labels and critical UI elements

		summaries are available for published proposals. h. Citizen feedback can be used as input to scenario refinement.	remain readable in 3D and VR views. f. A lightweight mode supports limited bandwidth conditions. g. Users can navigate and inspect proposed changes in VR with stable performance. h. Users can flag issues and save markers during VR walkthroughs. i. Exiting VR returns users to the same location and layer state. j. Location permission can be granted, revoked and used only with opt-in storage.

During the development process, additional needs emerged that were not originally captured in D3.1. Based on this feedback, new functional and non-functional requirements were incorporated to ensure that the system specification fully reflects end-user expectations and real-world deployment needs. The table of the new requirement is listed below.

TABLE 3: NEW USER REQUIREMENTS - SMART PARKING & SMART MOBILITY

New Requirements			
RQ-ID	**Use Case**	**RQ-TITLE**	**Specification**
F-RQ-T-18	GR-UC1	Ability to configure and run what-if mobility scenarios by selecting areas, streets, corridors, time windows, intervention types, and scenario parameters.	**Architectural Component:** Modeling & Simulation
F-RQ-T-19	GR-UC1	Ability to visualise simulation outputs through a 3D city interface, side analytics panel, expandable 2D views, impacted-street maps, and real-time or historical mobility layers.	**Architectural Component:** Modeling & Simulation, 3D Metaverse Engine
F-RQ-T-20	GR-UC1	Ability to support VR walkthroughs of proposed mobility changes, including inspection of proposed interventions and issue flagging within the 3D environment.	**Architectural Component:** 3D Metaverse Engine

All requirements are aligned with the system layers (e.g., Device Layer, Data Acquisition Layer, Data Storage Layer, and Service Layer) defined in D2.1 (METACITIES cross-border R&I strategy). This alignment supports architectural coherence, implementation planning, and a clear linkage between user needs and system architecture.

For the purposes of the requirements analysis, a comprehensive mapping table Annex 1 [Table 24] has been developed to link the identified user needs with the corresponding functional and non-functional requirements defined in D3.2. That table maps each user story to its associated requirements, stakeholder groups, and the relevant system layers of the Digital Twin Framework.

Each requirement is cross-referenced with its user story ID, ensuring full traceability from stakeholder needs to technical system functionalities. Furthermore, the table distinguishes between functional and non-functional requirement codes introduced in D3.1.

Please see the respective table in Annex 1 [Table 24]

This structured methodology ensures that the Digital Twin platform integrates user-validated needs, maintains transparent requirement traceability, and adheres to a scalable, interoperable, and user-centric design approach.

2.2.1.3 Final Functional Requirements and Non-Functional Requirements

Table 4: Final Functional and Non-Functional Requirements - Smart Parking & Smart Mobility

Functional Requirements (F-RQ-T)	**Non-Functional Requirements (NF-RQ-T)**
F-RQ-T-1: Real-time information on parking availability	NF-RQ-T-1: Privacy-preserving mechanism to safeguard drivers' information
F-RQ-T-2: Integration with other transportation and urban planning systems	NF-RQ-T-2: Protection of personal and financial information
F-RQ-T-3: Ability to work across different parking systems and providers	NF-RQ-T-3: Accessibility and usability for people with disabilities
F-RQ-T-4: Ability to work with multiple parking sensor vendors	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
F-RQ-T-6: Ability to receive notifications about parking spot availability	NF-RQ-T-5: Predicting parking demand and optimizing space usage using AI algorithms
F-RQ-T-7: Ability to receive navigation instructions to available parking spots	NF-RQ-T-6: Data encryption and protection for security and privacy
F-RQ-T-8: User-friendly interface	NF-RQ-T-7: Data must be encrypted in-transit and at-rest
F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform	NF-RQ-T-8: All API endpoints must employ authentication and must mandate encryption

F-RQ-T-18 :: Ability to configure and run what-if mobility scenarios by selecting areas, streets, corridors, time windows, intervention types, and scenario parameters	NF-RQ-T-9: Mobile application interface for accessing the smart parking Digital Twin
F-RQ-T-19 : Ability to visualise simulation outputs through a 3D city interface, side analytics panel, expandable 2D views, impacted-street maps, and real-time or historical mobility layers	NF-RQ-T-10: Users must uniquely authenticate with the Digital Platform
F-RQ-T-20 : Ability to support VR walkthroughs of proposed mobility changes, including inspection of proposed interventions and issue flagging within the 3D environment	NF-RQ-T-11: Digital Platform must employ Role-Based Access Controls (RBAC) for logged-in users

Following the refinement of the Patras Smart Parking and Smart Mobility Use Case, the final requirements set was aligned with the post-INVEST user stories and their acceptance criteria. The retained requirements focus on real-time parking availability, interoperability with transport and urban planning systems, multi-provider and multi-sensor integration, notifications and navigation to available parking, user-friendly digital access, management of parking spaces through the digital platform, what-if mobility simulation, 3D/2D visualisation of simulation outputs, and VR walkthroughs of proposed mobility interventions.

The requirements **F-RQ-T-5, F-RQ-T-9, F-RQ-T-10, F-RQ-T-11, F-RQ-T-12, F-RQ-T-13, F-RQ-T-14, F-RQ-T-15, and F-RQ-T-16** were removed from the final Patras scope. These requirements mainly concern transactional parking-session services, such as payment methods, mobile payment integration, time-expiration reminders, remote extension of parking time, parking receipts and history, as well as PwD-badge identification and automated ticketing for misuse of accessible parking spaces.

Although these requirements remain relevant to a broader smart parking ecosystem, they are not directly supported by the final post-INVEST user stories for the Patras pilot. The refined Use Case is centred on decision support, scenario-based mobility planning, smart parking and curb-space simulation, stakeholder consultation, and Digital Twin visualisation. Therefore, the removed requirements were considered outside the immediate implementation scope of the pilot and were excluded to maintain consistency between the final requirements, the validated user stories, and the acceptance criteria.

The non-functional requirements were retained because they continue to support the final scope of the Patras Digital Twin. Privacy preservation, protection of personal and financial information, accessibility, IoT-based monitoring, AI-supported demand prediction, data encryption, authenticated APIs, mobile access, user authentication, and role-based access control remain necessary for the secure and usable operation of the platform across government, citizen, academia, and business stakeholder groups.

2.3 User Stories for Green City

The Burgas Digital Twin focuses on developing a comprehensive digital system capable of representing, analysing and predicting complex urban scenarios in the Energy efficiency and resource

management domain. Its main objective is to enable data-driven decision-making that fosters sustainable, resilient, and inclusive cities. The proposed system integrates multi-source geospatial data, energy use and energy efficiency information, and sensor-based environmental datasets to generate an interactive 3D digital virtual representation of the real city environment.

The Digital Twin in the Green City domain is aimed at developing an advanced digital platform capable of modelling, analysing, and forecasting complex urban scenarios related to energy efficiency and resource management. The system is designed to support data-informed decision-making processes that contribute to the development of sustainable, resilient, and citizen-oriented urban environments. To achieve this, it combines geospatial information from multiple sources, energy consumption and efficiency data, as well as sensor-generated environmental datasets into an interactive 3D virtual representation of the city.

Through the integration of advanced analytics, artificial intelligence, and simulation functionalities, the Digital Twin enables urban planners, municipal authorities, energy experts, and citizens to better understand current urban conditions, test alternative development scenarios, and evaluate their potential impacts. In this way, the platform facilitates more effective investment planning, optimised resource allocation, increased citizen engagement, and the transition toward more sustainable urban development.

In support of these objectives, a comprehensive user story and requirements analysis process was carried out to identify both functional and non-functional stakeholder needs within the pilot city of Burgas. This process guided the conceptualisation and implementation of the Green City Digital Twin as an integral component of the Smart Burgas ecosystem. The resulting user stories served as a foundation for requirement definition and validation, ensuring that the integrated platform for energy efficiency and resource management responds to actual urban challenges, strategic priorities, and sustainability ambitions.

The user stories were gathered through a multi-level participatory methodology that combined quantitative and qualitative approaches in order to ensure inclusiveness, representativeness, and consistency with the technical framework of the project. As initially outlined in Deliverable D3.1, dedicated questionnaires were prepared for each of the three pilot Use Cases to collect feedback from end users, stakeholders, and thematic experts in line with the Quadruple Helix participatory model. The questionnaires were reviewed by technical partners to verify feasibility and consistency with project goals, and subsequently distributed through Google Forms in Bulgarian, Greek, and English to maximise outreach among different stakeholder groups.

Based on the collected feedback, several co-creation workshops were subsequently organised, during which participants collaboratively formulated user stories using structured templates describing stakeholder roles, needs, and expected outcomes (WP6). At the same time, individual interviews and formal discussions were conducted with municipal representatives, Smart City managers, urban planners, and technology providers (WP5). These activities contributed to validating practical user scenarios and refining them according to stakeholder expectations and operational priorities.

Furthermore, insights gathered from previous public presentations of the existing Burgas Digital Twin and from discussions concerning the future 3D development of the SmartBurgas platform were also

taken into account. This additional feedback from citizens and technical experts supported the further consolidation and validation of the user stories initially identified in D3.1.

All finalized user stories were then systematically assessed according to the INVEST principles (Independent, Negotiable, Valuable, Estimable, Small, and Testable), ensuring clarity, feasibility, and practical value for the subsequent stages of requirements analysis and system design. This process also contributed to refining the selection and overall design of the pilot cases.

The validated user stories for the Burgas project Use Cases are presented in Annex 1: USER STORIES TABLES.

2.3.1 Use Case 1: Renewables (PV) potential and performance analysis tool

2.3.1.1 The User Stories

The Renewables (PV) potential and performance analysis tool Use Case aims to provide a useful source for the identification and analysis of existing and designed PV systems in the city of Burgas. The tool should be a part of the Energy efficiency and resource management Digital Twin of Burgas, incorporated in the Burgas Smart city platform. In time, consistent information for municipal, private and business buildings will be incorporated to enable the new tool to create different models that accurately assess and determine their production potential and energy use for each building and/or for groups of buildings classified by different parameters.

This Use Case is designed to provide users with tools for monitoring the photovoltaic (PV) energy production potential within the urban environment, while also enabling the exploration of different development scenarios related to the city's 2030 sustainability objectives. In addition, the system aims to support building owners and citizens by providing information about the economic viability of future PV installations as well as the performance and energy generation of already deployed systems.

The platform combines both real-time and historical datasets, creating a flexible and scalable digital environment that supports continuous monitoring, analysis, and informed decision-making processes.

For this Use Case, a total of four user stories were identified, reflecting a broad spectrum of stakeholder expectations and requirements. These include the need for greater awareness of urban solar energy generation opportunities, support for scenario-based strategic planning, and the facilitation of participatory decision-making mechanisms. The collected user stories also outline important functional requirements such as access to real-time and historical energy consumption data, simulation functionalities, and data export capabilities. Furthermore, they highlight the importance of interoperability, ensuring seamless data integration and utilisation within the unified Burgas Digital Twin ecosystem to support coherent analyses and reliable decision-making.

The identified user stories additionally emphasise the need for enhanced visualisation functionalities, including interactive 2D and 3D representations of the urban environment. These capabilities enable users to examine spatial patterns, analyse energy consumption, and assess various solar energy generation scenarios in a more intuitive and accessible manner.

The full collection of user stories is presented in Annex 1 [Table 19].

2.3.1.2 Functional Requirements and Non-Functional Requirements

Through the above process, a final set of user requirements for Use Case 1 was established. The corresponding acceptance criteria are presented below.

TABLE 5: USER REQUIREMENTS -RENEWABLES (PV) POTENTIAL AND PERFORMANCE ANALYSIS TOOL

1. Data Visualisation on Digital Twin Platform: a. The platform uses GIS platform to display data on the energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and trends (e.g., monthly and annual).	**2. Decision-Making Tools:** a. Users can analyse the trend of energy use b. Simulations are visualised on the platform and include metrics like projected energy use.	**3. Automated data retrieval**	**4. Data Export and API:** a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.

During the co-development process with stakeholders, additional needs and user stories emerged that were not originally captured in D3.1. Based on this feedback, a new non-functional requirement was incorporated to ensure that the system specification fully reflects end-user expectations and real-world deployment needs. The table of the new requirement is listed below.

This requirement is applicable to all Bulgarian Use Cases.

TABLE 6: NEW USER REQUIREMENTS - RENEWABLES (PV) POTENTIAL AND PERFORMANCE ANALYSIS TOOL

New Requirements			
RQ-ID	**Use Case**	**RQ-TITLE**	**Specification**
NF-RQ-E-4	BG-UC1	Processing of required data flows	**Architectural Component:** Edge Equipment

All requirements are aligned with the system layers (e.g., Device Layer, Data Acquisition Layer, Data Storage Layer, and Service Layer) defined in D2.1. This alignment supports architectural coherence, implementation planning, and a clear linkage between user needs and system architecture.

The applied structured methodology described above, which the Burgas Digital Twin platform in the Energy efficiency and resource management domain integrates, user-validated needs for the Use Case 1, maintains transparent requirement traceability, and adheres to a scalable, interoperable, and user-centric design approach.

For the purposes of the requirements analysis, a comprehensive mapping table, Annex 1 [Table 26 has been developed to link the identified user needs with the corresponding functional and non-functional requirements defined in D3.2. That table maps each user story to its associated requirements, stakeholder groups, and the relevant system layers of the Digital Twin Framework.

Each requirement is cross-referenced with its user story ID, ensuring full traceability from stakeholder needs to technical system functionalities. Furthermore, the table distinguishes between functional and non-functional requirement codes introduced in D3.1.

Please see the respective table in Annex 1: USER STORIES TABLES

2.3.1.3 Final Functional Requirements and Non-Functional Requirements

TABLE 7: FINAL FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS -RENEWABLES (PV) POTENTIAL AND PERFORMANCE ANALYSIS TOOL

Functional Requirements (F-RQ-E)	Non-Functional Requirements (NF-RQ-E)
F-RQ-E-1: Real-time data such as energy consumption, CO2 levels in interior spaces, consumption of electricity, water and heat, level of lighting	NF-RQ-E-1: Security and privacy measures to protect user data and the data of the city
F-RQ-E-2: Historical data representing timeline	NF-RQ-E-3: Data updates on daily/weekly basis which appropriate
F-RQ-E-3:data updates on daily/weekly basis which appropriate	NF-RQ-E-4: Processing of required data flows
F-RQ-E-4: Interoperability between renewable energy sources, smart lighting, ventilation and air conditioning	
F-RQ-E-5: Public buildings and residential buildings are in the focus of interest for the city Digital Twin	
F-RQ-E-6: Real-time data such as PV energy production potential, weather, and air quality	
F-RQ-E-7: Access to detailed data about the city's infrastructure, existing PV systems in the city	
F-RQ-E-8: Ability to interact with a Digital Twin of the city and make changes	
F-RQ-E-9: Access to future projections about the city’s infrastructure, such as PV installations on the buildings, energy management data	
F-RQ-E-10: Compatibility with other planning tools and software used by city officials and planners	
F-RQ-E-12: Real-time data such as PV energy production potential, temperature, humidity, solar exposure	
F-RQ-E-13: Access to detailed data about the city’s infrastructure, the buildings’ energy performance, buildings insulation capacity at the roof level	
F-RQ-E-14: Ability to interact with a Digital Twin of the city and make changes	
F-RQ-E-15: Access to future projections about the city`s infrastructure, such as buildings' energy performance consumption, energy management data	

2.3.2 Use Case 2: Buildings Energy Performance Analysis

2.3.2.1 The User Stories

By using a BIM-based Digital Twin city platform, which incorporates data from a newly built public building (kinder garden) in the METACITIES project, we will be able to showcase the energy performance of a building. Through analysis and visualisation of gathered real-time data and historical data, we will provide users with the ability to better understand the buildings' energy consumption and energy behaviour.

In the provided simulation tool, analysis of available data sets will focus on the assessment of how external variables (e.g., temperature, humidity, solar exposure) and infrastructural measures (like building insulation) influence the building energy performance and energy consumption.

The goals are manifold and include: understanding of energy performance of different buildings, incorporated in the BIM platform. This can drive further multiple buildings analysis on the city's investment needs and (possibly) support the decision-making related to the definition of potential financial approaches and mechanisms.

The applied scenarios may help the understanding how energy consumption varies with meteorological conditions through root cause analysis, as well as better understanding the impacts of different energy-related interventions performed in the buildings.

This analytical methodology may be also used to better plan future interventions for public buildings, and later on - for buildings with non-public ownership. A total of 4 user stories were collected for this Use Case, capturing a wide range of stakeholder needs, such as visualisation of buildings parameters including solar energy generation if applicable, possibilities for implementation of different automation settings based on scenario planning and an awareness-raising tool for experts. The user stories capture key functional needs, including real-time and historical energy use data, living conditions data, monitoring of automation equipment, simulation of processes and data export capabilities. They also reflect the need for interoperability, enabling the seamless integration and utilisation of data within the unified Digital Twin of Burgas in order to support consistent analysis and decision-making processes.

In addition, the user stories capture the need for advanced visualisation and interactive 2D and 3D representations of the building/buildings in urban environment, enabling users to explore spatial patterns, assess energy use, and evaluate the solar generation scenarios.

This structured methodology ensures that the Burgas Digital Twin platform in the Energy efficiency and resource management domain integrates user-validated needs for Use Case 2, maintains transparent requirement traceability, and adheres to a scalable, interoperable, and user-centric design approach. The complete set of user stories is provided in Annex 1 [Table 20].

2.3.2.2 Functional Requirements and Non-Functional Requirements Analysis

Through the above process a final set of user requirements for Use Case 2 was established. The corresponding acceptance criteria are presented below.

TABLE 8: USER REQUIREMENTS- CASE 2: BUILDINGS ENERGY PERFORMANCE ANALYSIS

1.Data Visualisation on Digital Twin BIM Platform:	**2. Decision-Making Tools:** a. Users can simulate the trend of energy use	**3. Access Levels and roles:** a. Access after log in.	**4 4. Data Export and API:** a. Users can export data (e.g., CSV, PDF,

a. The platform uses GIS and BIM platform to display data on energy use of buildings. b. Users can view historical and real-time data (e.g., heat, energy, water consumption graphs, spreadsheets, 3D visualisation of installations and dashboards of different IoT devices) and predictive trends (e.g., daily, monthly and annually).	(e.g., changing energy use parameters or building parameters in the scope of assessment). b. Simulations are visualised on the BIM/GIS platform and include metrics.	b. Public interface: citizens, public organisations, external third parties. c. Internal municipal interface - Energy manager of the Municipality, municipal officer, public policy makers of municipality.	EXCEL) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.

All requirements are aligned with the system layers (e.g., Device Layer, Data Acquisition Layer, Data Storage Layer, and Service Layer) defined in D2.1. This alignment supports architectural coherence, implementation planning, and a clear linkage between user needs and system architecture.

Please see the respective detailed table in Annex 1

For the purposes of the requirements analysis, a comprehensive mapping table Annex 1 [Table 20] has been developed to link the identified user needs with the corresponding functional and non-functional requirements defined in D3.2. That table maps each user story to its associated requirements, stakeholder groups, and the relevant system layers of the Digital Twin Framework.

Each requirement is cross-referenced with its user story ID, ensuring full traceability from stakeholder needs to technical system functionalities. Furthermore, the table distinguishes between functional and non-functional requirement codes introduced in D3.1.

2.3.2.3 Final Functional Requirements and Non-Functional Requirements

TABLE 9: FINAL FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS - BUILDINGS ENERGY PERFORMANCE ANALYSIS

Functional Requirements (F-RQ-E)	Non-Functional Requirements (NF-RQ-E)
F-RQ-E-1: Real-time data such as energy consumption, CO2 levels in interior spaces, consumption of electricity, water and heat, and the level of lighting	NF-RQ-E-1: Security and privacy measures to protect user data and the data of the city
F-RQ-E-2: Historical data representing timeline	NF-RQ-E-2: User-friendliness of the platform, emphasizing visual representations and ease of use
F-RQ-E-3:data updates on daily/weekly basis which appropriate	NF-RQ-E-3: Data updates on daily/weekly basis which is appropriate

F-RQ-E-4: Interoperability between renewable energy sources, smart lighting, ventilation and air conditioning	NF-RQ-E-4: Processing of required data flows
F-RQ-E-5: Public buildings and residential buildings are in the focus of interest for the city Digital Twin	
F-RQ-E-6: Real-time data such as PV energy production potential, weather, and air quality	
F-RQ-E-8: Ability to interact with a Digital Twin of the city and make changes	
F-RQ-E-9: Access to future projections about the city's infrastructure, such as PV installations on the buildings, energy management data	
F-RQ-E-10: Compatibility with other planning tools and software used by city officials and planners	
F-RQ-E-11: Ability to view the Digital Twin of the city in virtual reality	
F-RQ-E-12: Real-time data such as PV energy production potential, temperature, humidity, solar exposure	
F-RQ-E-13: Access to detailed data about the city's infrastructure, the buildings' energy performance, buildings insulation capacity at the roof level	
F-RQ-E-14: Ability to interact with a Digital Twin of the city and make changes	
F-RQ-E-15: Access to future projections about the city`s infrastructure, such as buildings` energy performance /consumption, energy management data	

2.3.3 Use Case 3: Budget Planning for Energy Usage and Buildings

2.3.3.1 The User Stories

Following the results from Use Case 2, the Digital Twin model can be upgraded to become a *valuable tool for policy-making decisions* on budget planning and effective use of resources, recoupment of initial investments, and managing the costs of energy use both for public and private users.

For this purpose, data related to historical costs and prices of resources should be added/incorporated into the platform, preferably in a separate dashboard.

In time, when data for more buildings is being constantly accumulated, it will help the experts of the city of Burgas to better estimate investment needs, define priorities for potential local investments, and evaluate financial mechanisms and business models aimed at improving the energy efficiency indicators and overall energy performance of the city, all these in line with its strategic goals.

A total of 3 user stories were collected for this Use Case, capturing stakeholder needs, such as visualisation of scenarios based on budget planning data, an awareness-raising tool for citizens and public experts. The user stories captured key functional needs for processing spatial data, financial and economic statistical data and historical data. They also reflect the need for interoperability,

enabling the seamless integration and utilisation of data within the unified Digital Twin of Burgas in order to support future economic analysis and decision-making processes.

In addition, the user stories capture the need for advanced visualisations and representations of the analyses and urban environment, enabling users to explore spatial patterns and economic patterns.

This ensures that the Burgas Digital Twin platform in the Energy efficiency and resource management domain integrates user-validated needs for Use Case 3, maintains transparent requirement traceability, and adheres to a scalable, interoperable, and user-centric design approach.

The complete set of user stories is provided in Annex 1 [Table 21].

2.3.3.2 Functional Requirements and Non-Functional Requirements Analysis

Through the above-described process, a final set of user requirements for Use Case 3 was established. The corresponding acceptance criteria are presented below.

TABLE 10: USER REQUIREMENTS - USE CASE 3: BUDGET PLANNING FOR ENERGY USAGE AND BUILDINGS

1. Data Visualisation on Digital Twin Platform:	**2. Decision-Making Tools:**	**3. Access Levels and Roles:**	**4. Data Export:**
a. The platform uses GIS platform to display data on the energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and predictive trends (e.g., monthly and annual).	a. Users can simulate the trend of energy use (e.g., adding/removing energy use parameters or buildings in the scope of assessment). b. Simulations are visualised on the platform and include metrics like projected energy use.	a. Access after log in. b. Public interface: citizens, public organisations, external third parties. c. Internal municipal interface - Energy manager of the Municipality, municipal officer, public policy makers of municipality	a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.

All requirements are aligned with the system layers (e.g., Device Layer, Data Acquisition Layer, Data Storage Layer, and Service Layer) defined in D2.1. This alignment supports architectural coherence, implementation planning, and a clear linkage between user needs and system architecture.

Please see the respective detailed table in Annex 1: USER STORIES TABLES

For the purposes of the requirements analysis, a comprehensive mapping table, Annex 1 [Table 21] has been developed to link the identified user needs with the corresponding functional and non-functional requirements defined in D3.2. That table maps each user story to its associated requirements, stakeholder groups, and the relevant system layers of the Digital Twin Framework.

Each requirement is cross-referenced with its user story ID, ensuring full traceability from stakeholder needs to technical system functionalities. Furthermore, the table distinguishes between functional and non-functional requirement codes introduced in D3.1.

2.3.3.3 Final Functional Requirements and Non-Functional Requirements

TABLE 11: FINAL FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS-BUDGET PLANNING FOR ENERGY USAGE &BUILDINGS

Functional Requirements (F-RQ-E)	Non-Functional Requirements (NF-RQ-E)
F-RQ-E-1: Real-time data such as energy consumption, CO2 levels in interior spaces, consumption of electricity, water and heat, level of lighting	NF-RQ-E-1: Security and privacy measures to protect user data and the data of the city
F-RQ-E-2: Historical data representing a timeline	NF-RQ-E-2: User-friendliness of the platform, emphasising visual representations and ease of use
F-RQ-E-3:data updates on a daily or weekly basis, whichever is appropriate	NF-RQ-E-3: Data updates on a daily or weekly basis, whichever is appropriate
F-RQ-E-4: Interoperability between renewable energy sources, smart lighting, ventilation and air conditioning	NF-RQ-E-4: Processing of required data flows
F-RQ-E-5: Public buildings and residential buildings are in the focus of interest for the city Digital Twin	
F-RQ-E-7: Access to detailed data about the city's infrastructure, existing PV systems in the city	
F-RQ-E-8: Ability to interact with a Digital Twin of the city and make changes	
F-RQ-E-9: Access to future projections about the city's infrastructure, such as PV installations on the buildings, energy management data	
F-RQ-E-10: Compatibility with other planning tools and software used by city officials and planners	
F-RQ-E-12: Real-time data such as PV energy production potential, temperature, humidity, solar exposure	
F-RQ-E-13: Access to detailed data about the city's infrastructure, the buildings' energy performance, buildings insulation capacity at the roof level	
F-RQ-E-14: Ability to interact with a Digital Twin of the city and make changes	
F-RQ-E-15: Access to future projections about the city`s infrastructure, such as buildings` energy performance /consumption, energy management data	

2.4 User Stories for Urban Planning

The Urban Planning Digital Twin focuses on developing a comprehensive digital ecosystem capable of representing, analysing, and predicting complex urban scenarios. Its main objective is to enable data-driven decision-making that fosters sustainable, resilient, and inclusive cities. The proposed system

integrates multi-source geospatial data, demographic information, and sensor-based environmental datasets to generate an interactive 3D digital representation of the city.

By combining advanced analytics, AI-driven insights, and simulation tools, the platform empowers urban planners, municipal authorities, and citizens to visualise current conditions, evaluate alternative development scenarios, and assess their environmental and societal impact. This supports better planning, efficient resource use, active citizen engagement, and the creation of more sustainable cities.

Within this context, user stories and requirements analysis were conducted to capture the functional and non-functional needs of stakeholders and to guide the architectural design of the Urban Planning Digital Twin. These user stories formed the backbone for requirement elicitation and validation, ensuring that the developed system remains aligned with real urban needs, societal objectives, and sustainability goals.

The user stories were elicited through a multi-layer participatory framework, integrating both quantitative and qualitative inputs to ensure inclusiveness, representativeness, and coherence with technical requirements. Initially, as described in Deliverable D3.1, tailored questionnaires were designed for each of the three pilot Use Cases to gather insights from end-users, stakeholders, and domain experts in urban planning, management, and technology. The questionnaires were reviewed by technical partners to ensure feasibility and alignment with project objectives, then distributed via Google Forms, Greek and English, to reach broader citizen groups.

Building upon these findings, a series of co-creation workshops was organised, during which participants collaboratively developed user stories by filling structured user-story cards, describing needs, roles, and desired outcomes (WP6 -Dissemination, Engagement and Knowledge Transfer). In parallel, personal interviews were conducted with key stakeholders, including municipal officials, Smart Cities Managers, urban planners, and technology providers (WP5 - Business, Investment and Sustainability Plans), through formal meetings and interactive podcast-style discussions. These exchanges enabled the team to raise targeted questions, validate the user stories derived from the theoretical framework and the questioners, and refine them according to real-world constraints and stakeholder priorities.

Additionally, open public conversations were held with citizens and community representatives to collect spontaneous feedback, ensuring that social and ethical dimensions were adequately captured. Through this iterative process, the project team both validated the user stories originally derived from D3.1 and introduced new ones that emerged from these engagement activities. All finalized user stories were then structured and evaluated according to the INVEST principles (Independent, Negotiable, Valuable, Estimable, Small, Testable), ensuring they met recognized standards of clarity, feasibility, and value for subsequent requirement analysis and system design.

2.4.1 Use Case 1- Urban Heat Stress Reduction (Parks and Green)

2.4.1.1 The User Stories

The Urban Heat Stress Reduction Use Case aims to mitigate the Urban Heat Island (UHI) effect in the city of Nicosia through data-driven planning and nature-based interventions. To achieve this, it leverages a Digital Twin (DT) application to identify high-risk areas and simulate alternative mitigation strategies, such as green infrastructure deployment, urban redesign, and policy interventions. The platform integrates real-time and historical environmental data, providing a dynamic and scalable environment for monitoring, analysis, and decision support.

A total of 15 user stories were collected for the UHI Use Case, capturing a wide range of stakeholder needs, such as improved awareness of urban heat conditions, support for scenario-based planning, and participatory decision-making processes. The user stories capture key functional needs, including real-time and historical data access, simulation of urban interventions, alert generation, and data export capabilities. They also reflect the need for interoperability, enabling the seamless integration and utilisation of data within a unified Digital Twin environment to support consistent analysis and decision-making. In addition, the user stories capture the need for advanced visualisation capabilities, including interactive 2D and 3D representations of the urban environment, enabling users to explore spatial patterns, assess heat distribution, and evaluate the impact of different intervention scenarios.

To ensure that the user stories accurately reflect stakeholder needs, the Cypriot cluster conducted a series of participatory activities, including interviews with municipalities and Smart Cities managers (D5.1), as well as two workshops under WP6, one with public authorities and one with citizens. With the support of the technical partners, the user stories were co-created and iteratively refined following the INVEST criteria, ensuring that they are relevant, actionable, and aligned with the practical requirements of the pilot implementation. The complete set of user stories is provided in Annex 1 [Table 22].

2.4.1.2 Functional Requirements and Non-Functional Requirements Analysis

Through the experimentation studies and the systematic use of user stories, a final set of user requirements was established. The corresponding acceptance criteria are presented below.

TABLE 12: USER REQUIREMENTS-USE CASE 1- URBAN HEAT STRESS REDUCTION (PARKS AND GREEN)

1. Data Visualisation on Digital Twin Platform: a. The platform uses TerriaMap to display city infrastructures and related information on an interactive map. b. Users can view real-time data (e.g., UHI, heatmaps, graphs) and utilization data. c. The platform displays predictive models.	**2. Real-Time and Historical Data:** a. Real-time data is updated dynamically. b. Historical data is updated periodically. c. The system supports collection and analysis of real-time and historical data.	**3. Decision-Making Tools:** a. Users can simulate the impact of decisions (e.g., adding/removing trees, adjusting environmental data). b. Simulations are visualised and include UHI-related metrics (e.g., reduced urban heat index). c. AI algorithms support decision-making processes.	**4. User Roles and Access Levels:** a. Different roles (e.g., urban planners) have access to specific data and tools based on permissions. b. Access is controlled through login functionality
5. Data Export: a. Users can export data (e.g., CSV, PDF) for analysis and reporting. b. Simulated data and results can also be exported.	**6. Alerts and Notifications:** a. Users receive alerts for critical environmental conditions. b. Alert zones and thresholds can be configured based on regional risk strategies.	**7. Urban Heating Index Inputs:** a. City tree stock b. Parks c. Urban planning zones d. Water bodies e. Soil sealing f. Building density	**8. Security, Privacy, and Compliance:** a. Personal data is encrypted in transit and at rest. b. Access to personal data is restricted based on user roles.

		g. Environmental data (air pollution, weather, wind)	c. Users can manage consent and request deletion of their data. d. The system complies with data protection regulations (e.g., GDPR). e. Security events and unauthorized access attempts are logged and monitored.

For the purposes of the requirements analysis, a comprehensive mapping table Annex 1 [Table 22] has been developed to link the identified user needs with the corresponding functional and non-functional requirements defined in D3.2. The table maps each user story to its associated requirements, stakeholder groups, and the relevant system layers of the Digital Twin Framework.

Each requirement is cross-referenced with its user story ID, ensuring full traceability from stakeholder needs to technical system functionalities. Furthermore, the table distinguishes between functional and non-functional requirement codes introduced in D3.1.

During the co-development process with stakeholders, additional needs and user stories emerged that were not originally captured in D3.1. Based on this feedback, new functional and non-functional requirements were incorporated to ensure that the system specification fully reflects end-user expectations and real-world deployment needs. The table of the new requirements is listed below.

TABLE 13: NEW USER REQUIREMENTS-USE CASE 1- URBAN HEAT STRESS REDUCTION (PARKS AND GREEN)

New Requirements			
RQ-ID	**Use Case**	**RQ-TITLE**	**Specification**
F-RQ-U-19	UHI	AI algorithms for decision-making and scenario simulation	**Architectural Component:** Modelling & Simulation, Digital Twin Analytics **Performance Metrics:** At least two scenarios
F-RQ-U-20	UHI	Ability to export data and simulation results for reporting and analysis	**Architectural Component:** Digital Twin Analytics **Performance Metrics:** At least one dataset or simulation result available for export in a standard format (CSV, Pdf)
F-RQ-U-21	UHI	Configuration and Management of Environmental Alert Zones and Critical Condition Notifications	**Architectural Component:** GIS / BIM Services, Rule Engines Guided AI/ML **Performance Metrics:** At least one configurable spatial alert zone

All requirements are aligned with the system layers (e.g., Device Layer, Data Acquisition Layer, Data Storage Layer, and Service Layer) defined in D2.1. This alignment supports architectural coherence, implementation planning, and a clear linkage between user needs and system architecture.

This structured methodology ensures that the Digital Twin platform integrates user-validated needs, maintains transparent requirement traceability, and adheres to a scalable, interoperable, and user-centric design approach.

2.4.1.3 Final Functional Requirements and Non-Functional Requirements

TABLE 14:FINAL FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS-UHI

Functional Requirements (F-RQ-U)	Non-Functional Requirements (NF-RQ-U)
F-RQ-U-1: Real-time data such as traffic, weather, and air quality	NF-RQ-U-2: Implementation of security and privacy measures to protect user data
F-RQ-U-2: Access to detailed data about the city's infrastructure, including roads, buildings, and utilities	NF-RQ-U-4: Seamless integration of remote sensing and in-situ monitoring systems, utilizing IoT sensors for data collection
F-RQ-U-3: Ability to interact with a Digital Twin of the city and perform modifications and scenario testing	NF-RQ-U-11: Users must be uniquely authenticated when accessing the Digital Platform
F-RQ-U-4: Access to historical data about the city's infrastructure	NF-RQ-U-12: The Digital Platform must implement Role-Based Access Control (RBAC) for authorization
F-RQ-U-5: Access to future projections about the city's infrastructure, such as population growth and economic development	
F-RQ-U-7: Ability to visualise the Digital Twin of the city using virtual reality (VR) or augmented reality (AR) technologies	
F-RQ-U-13: Periodic data updates on a weekly and/or monthly basis	
F-RQ-U-19 (new): Integration of AI algorithms for decision-making and scenario simulation	
F-RQ-U-20 (new): Ability to export data and simulation results for reporting and analysis purposes	
F-RQ-U-21 (new): Configuration of spatial alert zones and threshold-based notification mechanisms	
F-RQ-U-22 (new): Generation of alerts and notifications for critical environmental conditions	
F-RQ-U-23 (new): Integration of data sources required for Urban Heat Island (UHI) index calculation (e.g., tree stock, parks, water bodies, soil sealing, building density)	

2.4.2 Use Case 2 - Smart Parking

2.4.2.1 The User Stories

The Smart Parking Management Use Case aims to address parking-related challenges in the city of Nicosia through data-driven planning and Digital Twin-enabled services. It leverages a DT application that supports the monitoring and visualisation of parking availability, user behaviour, and traffic conditions, while also providing tools for analysing and simulating interventions related to parking allocation, accessibility, pricing, and wider mobility management.

A total of 18 validated user stories were retained for the Smart Parking Use Case, representing the perspectives of the Quadruple Helix stakeholders. The user stories reflect stakeholder needs related to real-time parking information, route guidance, reservation and payment services, parking policy analysis, accessibility, and integration with wider urban mobility services. Governance stakeholders, including municipal authorities and parking management services, contributed user stories related to parking monitoring, policy evaluation, parking allocation, and decision support. Business stakeholders focused on parking operations, service provision, and data integration. Academic stakeholders contributed user stories related to data analysis, simulation, and evidence-based assessment of parking policies, while citizens expressed needs associated with parking availability information, accessibility, route planning, and user-friendly interaction with the Digital Twin platform. Collectively, the user stories capture key functional needs including real-time and historical parking data access, parking availability monitoring, parking demand analysis, simulation of parking management interventions, scenario comparison, user feedback collection, and integration of heterogeneous data sources. They also identify important non-functional requirements such as interoperability, scalability, usability, accessibility, privacy protection, and secure access to data and services. Each user story was mapped to the corresponding functional and non-functional requirements, validating and refining the framework proposed in D3.1 and D3.2.

The methodology used to collect user needs and expectations is based on stakeholder engagement and a Living Lab approach. It involved a series of interviews with municipalities and Smart City managers, as well as participatory workshops and open discussions with stakeholders under WP6. With the support of the technical team, user stories were co-created and iteratively refined following the INVEST criteria, ensuring that they are relevant, feasible, implementation-oriented, and aligned with the practical needs of the pilot. The complete set of user stories is provided in ANNEX 1 [Table 23].

2.4.2.2 Functional Requirements and Non-Functional Requirements Analysis

The functional and non-functional requirements for the Smart Parking Use Case were derived through experimentation studies and the systematic use of user stories. Based on this process, a consolidated set of user requirements was defined and further structured through the corresponding acceptance criteria.

The acceptance criteria are presented below and capture the key system capabilities and operational needs identified during the user story elicitation process.

TABLE 15: USER REQUIREMENTS -USE CASE 2 - SMART PARKING.

1. Data Visualisation on Digital Twin Platform a. The platform uses TerriaMap to display	2. Real-Time and Historical Data a. Real-time data is updated dynamically.	3. Decision-Making Tools a. Users can simulate the impact of decisions (e.g., parking	4. Traffic and Navigation a. The system displays real-time traffic congestion levels.

parking locations, capacity, and related information on an interactive map. b. The platform displays prediction models. c. Users can view real-time utilization data (e.g., heatmaps, graphs) and predictive trends (hourly, daily, weekly). d. The system supports 3D visualisation of parking usage, congestion levels, and movement patterns. e. Users can navigate, zoom, and filter the environment by time, location, or data layer. f. Key indicators (occupancy, dwell time, traffic flow) are accessible. g. The map updates within seconds to reflect changes in availability. h. Real-time dashboards display congestion, emissions, and environmental indicators.	b. Historical data is updated periodically (hourly, daily, weekly). c. The system supports collection and analysis of real-time and historical data. d. Temporal analysis is supported (daily, weekly, seasonal trends). e. Archival datasets are available (parking, traffic, accidents, weather). f. Data is synchronized with real or simulated time.	allocation, pricing strategies). b. Simulations include metrics such as utilization, revenue, traffic impact, and UHI indicators. c. AI algorithms support decision-making processes. d. The system evaluates environmental impact (e.g., CO_2 reduction through reduced search time). e. Scenario analysis supports planning (e.g., new parking zones, policy changes).	b. Traffic data is integrated from external sources (APIs). c. Parking recommendations consider real-time traffic conditions. d. Users can view congestion along routes. e. Alternative parking options are suggested when needed. f. Users can define route preferences (price, distance, accessibility).
5. Parking Management a. Users can reserve parking spaces through the platform. b. Booking includes calendar and time selection. c. Users can cancel, modify, or extend reservations. d. Real-time parking availability is provided.	6. Pricing and Restrictions a. Users can view pricing tiers and restrictions (time limits, vehicle types). b. Admins can set and update pricing dynamically (time-based, event-based). c. Pricing rules (e.g., first hour free) and promotions are supported.	7. Data Export, Import, and Access a. Users can export data (CSV, PDF) for analysis and reporting. b. Simulation results and datasets are exportable. c. Standardized formats (CSV, JSON) and bulk download are supported. d. APIs enable data access and	8. Alerts and Notifications a. Users receive alerts for critical issues (e.g., overutilization, underutilization). b. Alerts can be configured based on thresholds and regions. c. Notifications are provided for reservations, errors, and system events.

e. Admins can manage parking zones and availability. f. The system supports issue reporting with photos, comments, and status tracking.	d. Users can see accurate pricing before booking/payment.	interoperability across systems. e. Documentation and data quality indicators are provided.	d. Users receive reminders (e.g., before parking expiration). e. Real-time alerts support rerouting and decision-making.
9. Sensor Monitoring and System Performance a. The system visualises sensor coverage and data quality. b. Performance metrics include uptime, latency, and failure rates. c. Alerts are triggered for sensor malfunctions. d. Scenario analysis supports sensor placement optimisation.	10. Payments and Transactions a. The system supports major payment platforms (Apple Pay, Google Pay, PayPal). b. Payments can be completed within the application. c. Users receive instant receipts and notifications. d. Failed transactions are handled with clear feedback and retry options.	11. User Roles and Access Levels a. Role-based access is supported (e.g., owner, manager, operator). b. Permissions define access to data and functionalities. c. Admins can manage users and system roles.	12. Privacy, Security, and Data Protection a. Personal data is encrypted in transit and at rest. b. Access is restricted based on roles and permissions. c. Users can manage consent and request data deletion. d. The system complies with GDPR and relevant regulations. e. Security events are logged and monitored.

Following the definition of the acceptance criteria, a mapping process was carried out to associate user needs with the corresponding functional and non-functional requirements defined in D3.2. This mapping, presented in Table 3, ensures consistency between the identified user needs and the system-level specifications, while supporting the overall design of the Digital Twin architecture.

During this process, additional requirements emerged that were not initially identified in D3.1. These were incorporated into the system specification to better reflect operational constraints and real-world usage scenarios. The newly defined requirements are presented below.

TABLE 16: NEW USER REQUIREMENTS -USE CASE 2 - SMART PARKING.

Newly Added Requirements			
RQ-ID	**User story**	**RQ-TITLE**	**Specification**
F-RQ-T-18	SP-US13	Access to historical data about parking and traffic	**Architectural Component:** Digital Twin Analytics. **Performance Metrics:** Predictive models and trends.
F-RQ-T-19	SP-US4	Estimate environmental impact of parking and traffic management strategies	**Architectural Component:** Modeling & Simulation, Digital Twin Analytics **Performance Metrics:** Support scenario comparison (before vs after measures)

F-RQ-T-20	SP-US10, SP-US11	Support simulation of parking and urban mobility scenarios	**Architectural Component:** Modelling & Simulation, Digital Twin Analytics, Rule Engines Guided AI/ML **Performance Metrics:** Provide measurable outputs
F-RQ-T-21	SP-US1,SP-US6, SP-US8	Provide role-based access control and user management	**Architectural Component:** Field-use apps, Directory Services, User Input Data, Relational Storage **Performance Metrics:** Support at least 3 hierarchical roles (e.g., Owner, Manager, Operator), Secure login-based authentication for all users
F-RQ-T-22	SP-US1,SP-US3	Ability to export data and simulation results for reporting and analysis	**Architectural Component:** Digital Twin Analytics **Performance Metrics:** At least one dataset or simulation result available for export in a standard format (e.g., CSV, Pdf)
F-RQ-T-23	SP-US1, SP-US4, SP-US6, SP-US8, SP-US14, SP-US16, SP-US17	Provide alerts and notification management for system events	**Architectural Component:** Rule Engines Guided AI/ML, Edge Equipment, Traffic Data, Field-use apps, Semantics Transform, Time-series Storage **Performance Metrics:** Support real-time alerts with delivery latency ≤ 30 seconds
F-RQ-T-24	SP-US1,SP-US3,SP-US6, SP-US8	Manage parking pricing, rules, promotions, and restrictions	**Architectural Component:** Rule Engines Guided AI/ML, Field-use apps, Digital Twin Analytics, GIS/BIM Services, Semantics Transform **Performance Metrics:** Ability to manage and schedule prices and promotions for multiple parking zones
F-RQ-T-25	SP-US17	Enable issue reporting, documentation, and follow-up	**Architectural Component:** Field-use apps, Digital Twin Analytics, User Input Data, Relational Storage, Edge Equipment **Performance Metrics:** Support submission of multiple issue types with photos and comments
NF-RQ-T-10	SP-US11	Ensure standardised data interoperability	**Architectural Component:** Semantics Transform, Traffic Data, GIS/BIM Services **Performance Metrics:** Support at least 2 standard data formats/protocols (e.g., JSON, XML, REST APIs)

2.4.2.3 Final list of Functional Requirements and Non-Functional Requirements

The requirement analysis phase translated the validated user stories into a structured list of functional and non-functional requirements, guiding the Pilot implementation. Each user story was examined through its acceptance criteria, and corresponding requirements were identified and mapped to the Open Digital Twin Framework (ODTF) components defined in D3.2.

TABLE 17: FINAL LIST OF FUNCTIONAL REQUIREMENTS AND NON-FUNCTIONAL REQUIREMENTS-USE CASE 2 - SMART PARKING.

Functional Requirements (F-RQ-T)	Non-Functional Requirements (NF-RQ-T)
F-RQ-T-1: Real-time information on parking availability	NF-RQ-T-1: Privacy-preserving mechanisms to safeguard drivers' information
F-RQ-T-2: Integration with other transportation and urban planning systems	NF-RQ-T-2: Protection of personal and financial information
F-RQ-T-3: Ability to work across different parking systems and providers	NF-RQ-T-3: Accessibility and usability for people with disabilities
F-RQ-T-5: Ability to pay using different payment methods	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
F-RQ-T-6: Ability to receive notifications about parking spot availability	NF-RQ-T-5: AI algorithms for predicting parking demand and optimising space usage
F-RQ-T-8: User-friendly interface	NF-RQ-T-6: Data encryption and protection for security and privacy
F-RQ-T-9: Reminders about parking time expiration	NF-RQ-T-9: Mobile application interface for accessing the smart parking Digital Twin
F-RQ-T-11: Ability to extend parking time remotely	NF-RQ-T-10: Ensure standardised data interoperability
F-RQ-T-12: Ability to view parking history and receipts	
F-RQ-T-13: Showing number of handicap-accessible parking spots	
F-RQ-T-16: Integration of mobile payment system	
F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform	
F-RQ-T-18: Access to historical data about parking and traffic	
F-RQ-T-19: Estimate environmental impact of parking and traffic management strategies	
F-RQ-T-20: Support simulation of parking and urban mobility scenarios	
F-RQ-T-21: Provide role-based access control and user management	
F-RQ-T-22: Ability to export data and simulation results for reporting and analysis	
F-RQ-T-23: Provide alerts and notification management for system events	
F-RQ-T-24: Manage parking pricing, rules, promotions, and restrictions	
F-RQ-T-25: Enable issue reporting, documentation, and follow-up	

3 GAP Analysis and feasibility assessment

3.1. Greek Cluster Patras Smart Parking & Smart Mobility Use Case

3.1.1. Selected Pilot Use Case

The selected pilot Use Case focuses on Patras Smart Parking & Smart Mobility by developing a Digital Twin environment that supports evidence-based planning, assessment, communication, and refinement of parking-oriented and broader mobility interventions in the city of Patras. The pilot addresses mobility-related challenges that affect the efficiency, safety, accessibility, and sustainability of urban transport systems, including traffic congestion, illegal and double parking, parking search traffic, limited availability of real-time mobility information, and the environmental impacts of inefficient transport flows.

The selection of this particular Use Case was driven by stakeholder priorities identified during the requirement analysis and co-creation process. Among the alternative mobility-oriented Use Cases considered by the Greek cluster, including scenarios related to environmental effects on mobility and emergency vehicle route planning, stakeholders prioritised smart parking and smart mobility because of their immediate relevance to traffic congestion, illegal and double parking, accessibility, and day-to-day mobility management in Patras. The selected Use Case therefore reflects a practical municipal need and is aligned with the importance of parking and mobility interventions for the city's operational and strategic planning objectives.

The Use Case is designed as a decision-support and participation instrument that enables the Municipality of Patras and its stakeholders to explore, compare, and refine mobility measures before their implementation in the real urban environment. The pilot will support the configuration and execution of what-if scenarios related to parking and curb-space management, such as double-parking mitigation, parking supply adjustment, park-and-ride assessment, and traffic-flow impacts associated with changes in parking behaviour. Through these scenarios, users will be able to compare baseline and alternative conditions and assess expected effects on traffic circulation, accessibility, local delays, parking availability, and everyday mobility patterns.

The pilot will be implemented in a representative urban district of Patras, selected for its high parking demand, mixed land use, recurrent congestion patterns, and relevance to parking-search traffic. The Digital Twin will model street-level geometry, the road network, curb-space allocation, parking infrastructure, and traffic flows influenced by parking-related behaviour. The pilot will integrate data from 530 LoRa-interconnected smart parking sensors, roadway sensors, traffic-flow cameras, traffic APIs, double-parking detection systems, real-time bus telemetry, bus-arrival data sources, and third-party spatial datasets such as Google 3D Tiles and OpenStreetMap. Where access to real devices or real-time data feeds is not available, simulated devices and emulated datasets will be used to support testing, validation, and scenario execution within the pilot environment.

The Use Case will be accessed through two complementary three-dimensional interfaces. The first interface is intended for professional and institutional users, including municipal engineers and officials, academic researchers, and local businesses. Through this interface, users will be able to configure alternative scenarios, execute simulations, review impacts through analytics views, and compare results within a three-dimensional representation of the city. The second interface is public-facing and will be accessible through web, mobile, and virtual reality clients. It will allow citizens to explore published scenarios, compare before-and-after conditions around routes or areas of interest,

and provide structured feedback or geo-anchored three-dimensional annotations related to proposed interventions.

The pilot ecosystem integrates multiple digital components, including a 3D Metaverse Services Engine, Digital Twin Descriptor Service capabilities, geospatial data services, traffic simulation tools, smart parking sensing infrastructure, storage systems, analytics and dashboard services, access-control services, semantic transformation mechanisms, and public-facing feedback applications. In particular, PlayCanvas.JS, DTDS, and the Earthatile PlayCanvas plugin for 3D Tiles support the development of the 3D Digital Twin viewer, while SUMO supports traffic and mobility simulation through scenario-based workflows. Overall, the pilot demonstrates how Digital Twin technologies, simulation, urban sensing, 3D visualisation, and structured public participation can support municipalities in designing more effective, transparent, and sustainable mobility policies.

3.1.2. Gap Analysis

The gap analysis assessment was conducted to evaluate the readiness of the existing ICT environment to support the Patras Smart Parking & Smart Mobility pilot Use Case and its associated digital platform requirements. The assessment focused on identifying infrastructure, communication, data availability, operational, and application gaps related to the successful implementation of the proposed Digital Twin ecosystem. Since the Use Case was selected on the basis of stakeholder priorities, the assessment focused specifically on the ICT components required to support parking-oriented mobility planning, scenario simulation, operational visualisation, and stakeholder participation in Patras.

The analysis examined the availability of existing technologies, the level of modification required for deployment, the accessibility of required datasets, the communication mechanisms needed for integration, the interoperability of existing and new components, and the feasibility of implementing the identified components within the project scope. The assessment also considered the role of simulated devices and synthetic data where real feeds are unavailable, in order to support testing and validation without blocking pilot implementation.

The findings of the assessment are categorised into ICT systems, communication infrastructure, data availability and access, and operational and application gaps. These categories provide a structured view of the current readiness level of the Greek cluster and identify the main areas where development, integration, adaptation, or further validation activities are required. Detailed results of the gap analysis assessment are provided in Annex 2 Table 320.

3.1.2.1. ICT Systems Communication Infrastructure

The ICT systems communication infrastructure assessment evaluated the capability of the existing technology environment to support the technical and operational requirements of the Patras Smart Parking & Smart Mobility pilot. The assessment considered the availability of infrastructure components, required modification levels, communication interfaces, and integration mechanisms necessary to enable data exchange, simulation, analytics, visualisation, and user interaction across the pilot ecosystem.

The analysis identified that several core components are already available within the current environment and can be used with limited or no modification. These include blob storage through MinIO, directory services through Keycloak, document storage through MongoDB, relational storage through MySQL, time-series storage through InfluxDB, LoRaWAN gateway infrastructure, existing edge-processing infrastructure from the business actor involved in the pilot, Google 3D Tiles for GIS data, OpenStreetMap for map data, and the SenseCity API for road issue reports. These components

provide a relevant technological baseline for data storage, access management, spatial representation, sensing, and user-generated input.

At the same time, several components require development, integration, or adaptation in order to support the intended pilot functionality. The 3D Metaverse Services Engine requires development and integration based on PlayCanvas.JS, DTDS, and Earthatile. While these technologies provide a strong basis for web-based three-dimensional visualisation and Digital Twin representation, the Digital Twin viewer itself must be implemented for the needs of the Patras pilot. Digital Twin analytics also require further development, as Grafana is available for visualisation, but custom analytics calculators are required to generate aggregate, recalculable indicators and connect them with storage and visualisation services.

Additional integration needs were identified for modelling and simulation, semantic transformation, GIS/BIM services, traffic data, simulators, and field-use applications. SUMO is available as the core mobility simulation tool, but integration with the TraCI API is required to connect simulation execution with the Metacity data and scenario-management workflow. Semantic transformation services require translators capable of encoding raw data into Smart Data Models and DTDS-compatible descriptions. GIS/BIM services require integration of OpenStreetMap networks and 3D Tiles into the pilot environment. Traffic data are available through Google Maps API and related interfaces, but adapter development is required because raw traffic rates are not uniformly available from all sources. A public-facing PWA must also be developed to support citizen feedback and field-use interaction.

Communication across the pilot ecosystem is primarily supported through API-based integration mechanisms, LoRa and NB-IoT communication, municipal APIs, university APIs and equipment, local business APIs, Google service APIs, SenseCity API access, database connectivity, and open map-data sources. These mechanisms support the exchange of sensor events, spatial data, traffic information, user feedback, and simulation outputs across the different layers of the Digital Twin environment. DTDS further supports the integration of representation assets and context information by providing a descriptor-based approach for linking urban 3D assets, dynamic data, and runtime synchronization across heterogeneous applications and simulators.

Overall, the assessment indicates that the current ICT systems communication infrastructure provides a solid baseline for the Patras Smart Parking & Smart Mobility pilot. However, additional development and integration activities are required to establish a fully operational and interoperable Digital Twin environment. The most important infrastructure gaps concern the implementation of the 3D Digital Twin viewer, integration of simulation and scenario-management services, development of traffic-data adapters, creation of semantic translators, development of public-facing feedback applications, and integration of analytics calculators with storage and visualisation components.

3.1.2.2. Data Availability and Access

The data availability and access assessment evaluated the readiness, accessibility, and usability of the datasets and information sources required to support the Patras Smart Parking & Smart Mobility Use Case. The assessment focused on the availability of spatial, mobility, sensing, simulation, storage, user-input, and analytics-related data, as well as the access mechanisms through which these data can be exchanged and used across the pilot ecosystem.

The analysis identified that a substantial portion of the required data environment is already available. Spatial and representation data are supported through Google 3D Tiles and OpenStreetMap sources. Smart parking and mobility-related sensing are supported through municipal and university sensor

equipment, LoRaWAN gateway infrastructure, and business-operated edge-processing infrastructure. Storage components are also available, including MinIO for blob storage, MongoDB for document storage, MySQL for relational storage, and InfluxDB for time-series storage. User input and citizen-generated issue reporting are supported through the SenseCity API, while traffic-related information can be accessed through Google Maps API and other mobility-related interfaces.

The pilot data environment will include events from 530 LoRa-interconnected parking sensors, including status, tag, and temperature data, as well as additional operational inputs from roadway sensors, traffic-flow cameras, traffic APIs, double-parking detection systems, bus telemetry, bus-arrival platforms, and simulation components. These data sources support the creation of baseline mobility conditions, the monitoring of parking availability and traffic behaviour, and the execution of parking-oriented what-if scenarios. The data environment also supports the visualisation of simulation results, spatial impact maps, before-and-after comparisons, and feedback-linked scenario refinement.

Several components, however, remain unavailable or only partially available from a data and access perspective. Digital Twin analytics require the development of custom calculators before analytical outputs can be generated and visualised in a consistent way. Field-use applications are not currently available and must be developed to support public feedback and mobile interaction. Use-case-specific simulators must also be developed where real devices or feeds are not present. In addition, access to municipal equipment may not always be complete, and therefore simulated devices based on observation data will be implemented where necessary to support testing and validation.

The access mechanisms identified in the assessment include municipal APIs, university APIs and equipment, local business APIs, Google 3D Tiles API, Google Maps API, OpenStreetMap sources, SenseCity API, and system-level connectivity between storage, analytics, simulation, and visualisation components. Some sources are based on open-source or freely distributed technologies, while others rely on licensed or API-based access. The resulting data ecosystem therefore combines public data, licensed spatial data, municipal and university data, business-provided operational data, and simulated data streams.

Overall, the current data environment provides a strong baseline for the implementation of the Patras Smart Parking & Smart Mobility pilot. The main remaining needs concern data integration, adapter development, semantic transformation, analytics generation, management of heterogeneous access mechanisms, and the use of simulated data where real feeds are unavailable. Addressing these needs will allow the pilot to establish a scalable and interoperable data environment capable of supporting scenario execution, operational visualisation, stakeholder feedback, and evidence-based mobility planning.

3.1.2.3. Operational and application Gaps

The operational and application gap assessment evaluated the capability of the existing ICT environment to support the functional, operational, analytical, and integration requirements of the Patras Smart Parking & Smart Mobility pilot. The assessment identified gaps across the visualisation, simulation, sensing, storage, analytics, semantic transformation, traffic data, and user-interaction layers. These gaps were categorised according to implementation priority in order to support phased deployment planning and resource allocation.

The analysis identified three main high-priority components. The first is the 3D Metaverse Services Engine, which is essential for the implementation of the Digital Twin viewer and the presentation of mobility scenarios within a three-dimensional representation of Patras. Although PlayCanvas.JS, DTDS,

and Earthatile provide the technological basis for this component, development and integration work are required to deliver the viewer functionality. The second high-priority component is modelling and simulation, where SUMO is available but requires integration through the TraCI API in order to connect scenario execution with the wider data and scenario-management environment. The third high-priority component is traffic data, where adapter development is required to transform available traffic information into forms usable by the pilot, since raw traffic rates are not directly available from all sources.

Medium-priority gaps are associated with components that support operational intelligence, public interaction, semantic interoperability, and the enrichment of the Digital Twin environment. These include Digital Twin analytics, edge equipment, field-use applications, GIS/BIM services, GIS data, map data, semantic transformation services, and simulators. Digital Twin analytics require the development of custom calculators and integration with Grafana and storage systems. Field-use applications require the development of a public PWA to support feedback collection and citizen interaction. GIS/BIM services require integration of OpenStreetMap networks and 3D Tiles into the pilot workflow. Semantic transformation requires translators capable of converting raw data into Smart Data Models and DTDS-compatible structures. Simulators must be developed for use-case-specific devices and data streams where real devices or live feeds are not available.

Low-priority gaps are mainly associated with components that are already available and can be used as part of the pilot with no significant modification. These include blob storage, directory services, document storage, edge processors, gateways, relational storage, time-series storage, and user-input data. MinIO, Keycloak, MongoDB, MySQL, InfluxDB, LoRaWAN, existing business infrastructure, and the SenseCity API provide a stable technical baseline for the pilot. These components are not expected to represent major implementation blockers, although they must still be configured and connected correctly within the wider Digital Twin environment.

The proposed mitigation actions include implementation of the 3D Digital Twin viewer, development of custom analytics calculators, integration of SUMO through TraCI, development of traffic-data adapters, integration of GIS/BIM and 3D Tiles services, creation of semantic transformation mechanisms, development of simulated devices and use-case-specific simulators, and implementation of the public-facing PWA for citizen feedback. The assessment also identifies the need to evaluate the availability of municipal and university equipment and to implement simulated devices based on observation data where access to real equipment is incomplete.

From a feasibility perspective, the majority of the identified components are considered addressable within the project through phased implementation. Existing storage, access-control, sensing, mapping, and user-input components provide an operational foundation, while the main development effort will focus on visualisation, simulation integration, semantic transformation, analytics, adapters, and user-facing applications. Simulated data and devices will reduce implementation risk by allowing development and validation to continue even when real feed or equipment are temporarily unavailable.

Overall, the assessment confirms that the existing ICT environment provides a relevant technical baseline for the Patras Smart Parking & Smart Mobility pilot. However, several operational, analytical, and integration gaps must be addressed in order to achieve the intended functionality, interoperability, and scalability of the Digital Twin ecosystem. The identified priority structure supports a phased implementation approach, enabling the most critical components to be addressed

first while allowing supporting capabilities to be progressively integrated during the pilot implementation.

3.2. Bulgarian Cluster: Buildings Energy Performance Analysis Use Case

3.2.1. Selected Pilot Use Case

The selected pilot Use Case focuses on Building Energy Performance Analysis through the integration of real-time monitoring systems, Digital Twin technologies, geospatial data, and simulation-based analytical tools. The pilot addresses the growing need for municipalities to better understand and optimise the energy performance of public and residential buildings while supporting long-term sustainability and climate adaptation objectives.

The Use Case enables the collection, processing, and visualisation of real-time and historical information related to energy consumption, indoor environmental conditions, renewable energy production potential, and building performance indicators. The pilot further supports scenario-based analysis and predictive modelling capabilities, allowing users to evaluate future projections related to photovoltaic installations, energy efficiency measures, and energy management strategies.

The pilot ecosystem integrates multiple digital components, including GIS data, BIM services, environmental monitoring systems, relational and document storage systems, modelling and simulation services, semantic transformation services, and Digital Twin analytics functionalities. In addition, the pilot supports interoperability between renewable energy systems, smart lighting, ventilation, and air-conditioning systems through API-based communication mechanisms and digital platform services.

Overall, the pilot demonstrates how Digital Twin technologies and integrated urban data ecosystems can support municipalities in improving building energy performance, increasing operational efficiency, supporting evidence-based urban planning, and advancing sustainable city management objectives.

3.2.2. Gap Analysis

The gap analysis assessment was conducted to evaluate the readiness of the existing ICT environment to support the proposed pilot Use Case and its associated digital platform requirements. The assessment focused on identifying infrastructure, communication, operational, and application gaps related to the successful implementation of the Buildings Energy Performance Analysis pilot ecosystem.

The analysis examined the availability of existing technologies, the level of modification required for operational deployment, the accessibility of required datasets, interoperability capabilities, and the feasibility of implementing the identified components within the pilot environment. The findings of the assessment are categorised into ICT systems, communication infrastructure, data availability and access, and operational and application gaps. Detailed results of the gap analysis assessment are provided in Annex 2 Table 321.

3.2.2.1. ICT Systems Communication Infrastructure

The ICT systems communication infrastructure assessment evaluated the capability of the existing technology environment to support the operational and technical requirements of the Buildings Energy Performance Analysis Pilot Use Case.

The assessment identified that several core components are already available within the current environment, including GIS data services, map data services, relational storage systems, document storage systems, semantic transformation services, directory services, GIS/BIM services, edge

equipment, and time-series storage systems. Most of these components are considered operationally sufficient and require either no modification or only limited configuration adjustments.

At the same time, several critical components were identified as unavailable and requiring full implementation within the pilot ecosystem. These components include APIs and web/mobile application capabilities, Digital Twin analytics services, modelling and simulation services, and advanced Digital Twin interaction functionalities. These systems are essential to support real-time monitoring, simulation-based forecasting, user interaction, and operational visualisation within the Digital Twin environment.

The assessment further identified different levels of required modification. Certain components, such as semantic transformation services, map data services, GIS/BIM services, and directory services, are considered complete or usable in their current form. Other components, including time-series storage, APIs, and Digital Twin analytics, require additional development activities, integration improvements, or operational customisation to support the intended pilot functionalities.

Communication across the pilot ecosystem is primarily supported through API-based integration mechanisms, municipal data services, public data interfaces, and GIS-based visualisation platforms. The communication infrastructure supports the integration of environmental monitoring systems, building energy datasets, renewable energy information, and spatial analysis services into a unified digital environment.

Overall, the assessment indicates that the existing ICT infrastructure provides an initial technological foundation for the pilot implementation. However, additional development, interoperability enhancements, and integration activities are required to establish a scalable and fully operational Digital Twin ecosystem capable of supporting advanced building energy performance analysis.

3.2.2.2. Data Availability and Access

The data availability and access assessment evaluated the readiness and accessibility of the datasets and information sources required to support the proposed pilot Use Case.

The analysis identified that the majority of the required datasets and supporting systems are already available within the current environment. These include GIS data, map data, environmental monitoring information, relational storage systems, document storage systems, edge equipment data, semantic transformation services, GIS/BIM services, directory services, and time-series storage systems.

The assessment further identified that a significant portion of the required information is accessible through municipal data sources and public datasets. The available datasets support the collection and processing of real-time and historical information related to energy consumption, indoor environmental indicators, photovoltaic energy potential, weather conditions, solar exposure, temperature, humidity, and building insulation performance.

Several components, however, remain unavailable or only partially operational within the current environment. These include advanced APIs and web/mobile application capabilities, Digital Twin analytics services, and modelling and simulation functionalities required for predictive analysis and interactive Digital Twin operations.

The analysis identified multiple access mechanisms across the pilot ecosystem. Most of the identified components rely on municipal data access and system-based connectivity. In addition, several components support both municipal and public data access, particularly those related to spatial visualisation, simulation services, and future urban projections.

Overall, the assessment demonstrates that the current data environment provides a substantial baseline of accessible operational and analytical information required to support the pilot

implementation. Nevertheless, additional efforts related to data integration, interoperability, user accessibility, and advanced analytical services are required to establish a fully scalable and interoperable data ecosystem.

3.2.2.3. Operational and application Gaps

The operational and application gap assessment evaluated the capability of the existing ICT environment to support the functional, operational, and integration requirements of the Buildings Energy Performance Analysis pilot Use Case.

The assessment identified several operational gaps associated with real-time data processing, Digital Twin interaction, simulation capabilities, interoperability mechanisms, and advanced analytical services. These gaps were categorised according to implementation priority in order to support phased deployment planning and resource allocation.

The analysis identified that the majority of the critical gaps are classified as high-priority items. These include time-series storage systems, relational storage systems, document storage systems, GIS data services, environmental monitoring systems, Digital Twin analytics, modelling and simulation services, and user interaction functionalities. Most of these components already exist within the current environment but require further development, operational enhancement, testing, and integration activities.

Medium-priority gaps are primarily associated with the implementation of advanced analytical and simulation functionalities, including Digital Twin analytics services and predictive modelling capabilities. These components are necessary to support future scenario analysis, building energy forecasting, and infrastructure optimisation.

Low-priority gaps are mainly related to advanced APIs and mobile application services required for enhanced user interaction and extended platform accessibility. These components are considered supportive functionalities that can be progressively integrated during later implementation phases.

The proposed mitigation actions include the implementation of real data flows, completion of testing activities, integration of simulation and analytical services, deployment of API-based communication mechanisms, and gradual implementation of advanced Digital Twin functionalities according to the project implementation plan.

From a feasibility perspective, the assessment indicates that the majority of the identified high-priority components are feasible for deployment within the pilot scope of the project. Additional medium-priority and low-priority components are considered feasible for phased implementation through future development and scaling activities.

Overall, the assessment confirms that the existing ICT environment provides a foundational baseline for the proposed pilot implementation. However, several operational, analytical, and integration gaps must be addressed in order to achieve the intended functionality, interoperability, and scalability objectives of the Buildings Energy Performance Analysis Digital Twin ecosystem.

3.3. Cyprus Cluster: Urban Heat Stress Reduction (Parks and Green)

3.3.1. Selected Pilot Use Case

Urban heat stress has become one of the most pressing climate-related challenges affecting cities across Europe, particularly in densely built urban environments such as Nicosia. Urban areas experience the Urban Heat Island (UHI) effect, where temperatures are significantly higher than in surrounding rural areas due to the concentration of buildings, paved surfaces, limited vegetation, and heat generated by human activities. These conditions increase thermal discomfort and negatively impact public health, productivity, and quality of life, especially during prolonged heatwaves. At the same time, municipalities require accessible and evidence-based tools to better understand the

spatial distribution of heat stress, identify persistent hotspot areas, and evaluate the effectiveness of adaptation measures. The selected Use Case therefore addresses a highly relevant urban challenge while demonstrating how geospatial data and digital technologies can support climate adaptation planning and nature-based solutions in cities.

The pilot implements a Use Case focused on Urban Heat Island reduction in Nicosia through the integration of satellite-derived urban heat data, tree inventory information, and an interactive scenario-based simulation tool. The pilot identifies persistent Urban Heat Island hotspots across the city, allows the user to select a hotspot area for intervention, and uses a set of representative urban tree species to simulate how targeted planting could reduce heat stress over time. The result is presented directly on the map as an easy-to-understand visual scenario, showing both the location of problematic areas and the projected cooling effect of a tree planting intervention. Overall, the pilot demonstrates how digital tools can support municipalities in exploring practical nature-based solutions for improving urban thermal comfort.

3.3.2. Gap Analysis

The gap analysis assessment was conducted to evaluate the readiness of the existing ICT environment to support the proposed pilot Use Case and its associated digital platform requirements. The assessment focused on identifying gaps, limitations, and enhancement needs across infrastructure, data availability, communication mechanisms, operational processes, and application functionalities required for the successful implementation of the pilot ecosystem. The analysis further examined the availability of existing technologies, required modification levels, accessibility of data sources, interoperability requirements, and the operational feasibility of implementing the identified components within both small-scale and large-scale pilot environments. The findings of the assessment are categorized into ICT systems communication infrastructure, data availability and access, and operational and application gaps. Detailed results of the gap analysis assessment are provided in Annex 2 Table 322.

3.3.2.1. ICT Systems Communication Infrastructure

The ICT systems communication infrastructure assessment evaluated the capability of the existing technology environment to support the proposed pilot Use Case and its associated digital platform requirements. The analysis considered the availability of infrastructure components, the level of modification required, and the communication mechanisms necessary to enable data exchange, processing, integration, and presentation across the pilot ecosystem.
The analysis identified that the majority of the required components are classified under the “From Scratch” category, indicating that full implementation is required. These components include simulator capabilities, blob storage environments, modeling and simulation services, semantic transformation services, rule-engine guided AI/ML services, simulation engine functionalities, and mobile application capabilities.

For the components that already exist and are available within the current ICT environment, the assessment classified them into two main categories: components requiring modification and components requiring no modification. No modifications are required for seven components, including edge equipment, gateways, edge processors, GIS data, map data, time-series storage systems, and GIS/BIM services, as these are considered operationally sufficient for the scope of the proposed pilot implementation.

The modification category is further divided into two subcategories: major modifications and minor modifications. The major modification category includes four components — user input data systems, environmental data services, relational storage systems, and document storage systems — which require significant enhancements and integration improvements to meet the operational and technical requirements of the project. On the other hand, the minor modification category includes

traffic data services, Digital Twin analytics, directory services, and the Digital Twin platform, which require only limited updates and enhancement activities to support the intended pilot functionalities.

Communication across the infrastructure is primarily supported through API-based integration, public data interfaces, database connectivity, processing services, and presentation platforms. API communication mechanisms are currently utilised for edge devices, gateways, and edge processing components, enabling connectivity between field-level infrastructure and higher-level applications. Public data sources are also available for GIS, mapping, traffic, and environmental datasets, supporting external data integration into the pilot environment. In addition, processing services are partially supported through existing analytics and GIS/BIM capabilities.

Overall, the assessment indicates that the current ICT systems' communication infrastructure provides a foundational baseline for the proposed pilot Use Case. However, additional system development, integration enhancements, and communication capability improvements are required to establish a fully interoperable and scalable environment capable of supporting the intended operational and Digital Twin objectives.

3.3.2.2. Data Availability and Access

The data availability and access assessment evaluated the accessibility and readiness of the datasets and information sources required to support the proposed pilot Use Case and associated digital platform functionalities. The assessment focused on the availability of operational, spatial, analytical, and application-related data, as well as the access mechanisms through which data can be exchanged and utilised across the pilot ecosystem.

The analysis identified that the majority of the required components are currently available within the existing environment. These components include edge equipment, gateways, edge processors, user input data systems, GIS data, map data, traffic data services, environmental data services, relational storage systems, document storage systems, modelling and simulation services, Digital Twin analytics, semantic transformation services, GIS/BIM services, rule-engine guided AI/ML services, directory services, the Digital Twin platform, simulation engine functionalities, and mobile application capabilities.

Only three components, simulator capabilities, blob storage environments, and time-series storage systems, were identified as currently unavailable within the existing environment.

The assessment further identified that the majority of the component data access types are classified as system-based access, including both the available and unavailable components. Only a limited number of components are categorized under user-based access, specifically user input data systems, the Digital Twin platform, and mobile application capabilities. In addition, modelling and simulation services support both user and system-based access mechanisms.

Overall, the current data environment provides a substantial baseline of accessible information required to support the proposed pilot Use Case. However, targeted improvements in data integration, storage capabilities, and accessibility management will be necessary to establish a fully scalable and interoperable data ecosystem capable of supporting the long-term operational and analytical objectives of the pilot implementation.

3.3.2.3. Operational and application Gaps

The operational and application gap assessment evaluated the capability of the existing ICT environment to support the functional, operational, and integration requirements of the proposed pilot Use Case. The assessment identified several gaps across infrastructure, data acquisition, storage, service, and application layers. These gaps were categorised according to implementation priority in order to support phased deployment planning and resource allocation for the pilot environment.

The analysis identified that the majority of the required components are classified as high-priority items. These high-priority gaps represent the most critical components required to support the successful operation and functional objectives of the proposed pilot implementation. The identified components include edge equipment, user input data systems, GIS data, map data, environmental data, relational storage systems, document storage systems, modelling and simulation services, Digital Twin analytics, GIS/BIM services, and the Digital Twin platform. Most of these components already exist within the current environment and primarily require updates, enhancements, or integration improvements to support the operational requirements of the proposed pilot Use Case. Only a limited number of high-priority components were identified as new capabilities requiring full implementation within the pilot environment.

The analysis further identified that only six required components are classified as medium-priority items. These medium-priority gaps relate to supporting operational intelligence, advanced analytics, and enhanced automation capabilities within the pilot ecosystem. Components within this category include simulator capabilities, traffic data services, blob storage environments, semantic transformation services, rule-engine guided AI/ML services, and directory services. Of these components, only two currently exist and require updates or enhancements, while the remaining components are new capabilities that will need to be implemented based on the operational requirements of the pilot Use Case.

In addition, the analysis identified four required components classified as low-priority items. These low-priority gaps include gateways, edge processors, time-series storage systems, and mobile application capabilities. Of these components, only one was identified as a new capability requiring implementation, while no significant operational gaps were identified for the remaining components within the scope of the pilot Use Case. Proposed actions for the existing components primarily involve data collection and integration through API-based connectivity to support operational communication and interoperability requirements.

From a feasibility perspective, the assessment indicates that the majority of the identified high-priority components are feasible for deployment and validation within the small-scale pilot scope of this project. On the other hand, all medium-priority and low-priority components are considered feasible for deployment and validation within the large-scale pilot scope of the project.

Overall, the assessment indicates that the current ICT environment provides a foundational baseline for the proposed pilot implementation; however, several operational and application gaps must be addressed to achieve the intended functional and integration objectives. The identified priority classifications support a phased implementation approach, enabling critical components to be addressed during the initial pilot phase while allowing additional capabilities to be progressively integrated in future large-scale deployments.

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4 Final Pilot architecture interfaces and associated KPIs

4.1 Patras Smart Parking and Smart Mobility

4.1.1 Pilot architecture

The pilot architecture for the Patras Smart Parking and Smart Mobility Use Case is represented through complementary architectural views that describe both the structural organisation of the solution and the interaction flow between its components.

The Component Diagram provides a high-level overview of the architectural layers and functional capabilities that support data acquisition, processing, analysis, simulation, and user interaction. The Sequence Diagram complements this perspective by illustrating the operational workflow and the exchange of information between the different system components during the execution of the Use Case.

The Component Diagram (Figure 5) presents the overall architecture as a set of logically separated but tightly interconnected layers. At the foundation of the architecture, the Device Layer and Edge Computing Layer capture parking, mobility, and smart-city observations, while enabling local forwarding, preprocessing, and communication with the higher-level platform components. The physical data sources include 530 LoRa-based parking sensors deployed within the small-scale pilot area, GPS-tracked buses whose active number varies during the day, emulated traffic-flow camera feeds, live SenseCity data, and simulated entities used for sandbox testing.

The Data Acquisition and Data Processing Layers collect information from multiple sources, including the Patras municipal API, city bus telemetry services, TomTom traffic services, OpenStreetMap-derived road-network data, SenseCity, and user-provided scenario inputs submitted through the 3D Digital Twin environment. These heterogeneous datasets are transformed and harmonised into formats suitable for mobility analysis, road-network editing, parking-layout configuration, and simulation execution.

The processed information persisted through dedicated storage and context-management components. The GR pilot uses Orion with Cygnus and a MySQL sink for context and data persistence, while MongoDB is used by Orion to maintain the broker state. Selected data are saved or forwarded to InfluxDB for quick retrieval and simulation-related storage, while MinIO is used to store, serve, and manage blob resources such as 3D files, OpenStreetMap files, images, and other static assets required by the Digital Twin environment.

The Service Layer provides the main analytical and computational capabilities of the pilot, including Digital Twin analytics, scenario management, traffic simulation, semantic transformation, and mobility-oriented modelling services. The simulation workflow is orchestrated through a Flask-based backend that uses SUMO and TraCI to execute mobility scenarios and stores scenario and run information in InfluxDB. Authentication and access control are handled through Keycloak, with access mediated through the Nginx reverse proxy that gates the Digital Twin services.

At the Application Layer, these capabilities are exposed through the professional 3D viewer, analytics side panel, expanded 2D analytical view, public web and PWA interfaces, mobile view, VR view, feedback dashboard, export/report view, and AR tabletop miniature for VR headsets and mobile devices. These interfaces enable users to inspect the Patras pilot area, modify parking and road-network conditions, execute traffic simulations, review results, and communicate selected scenarios to wider stakeholder groups.

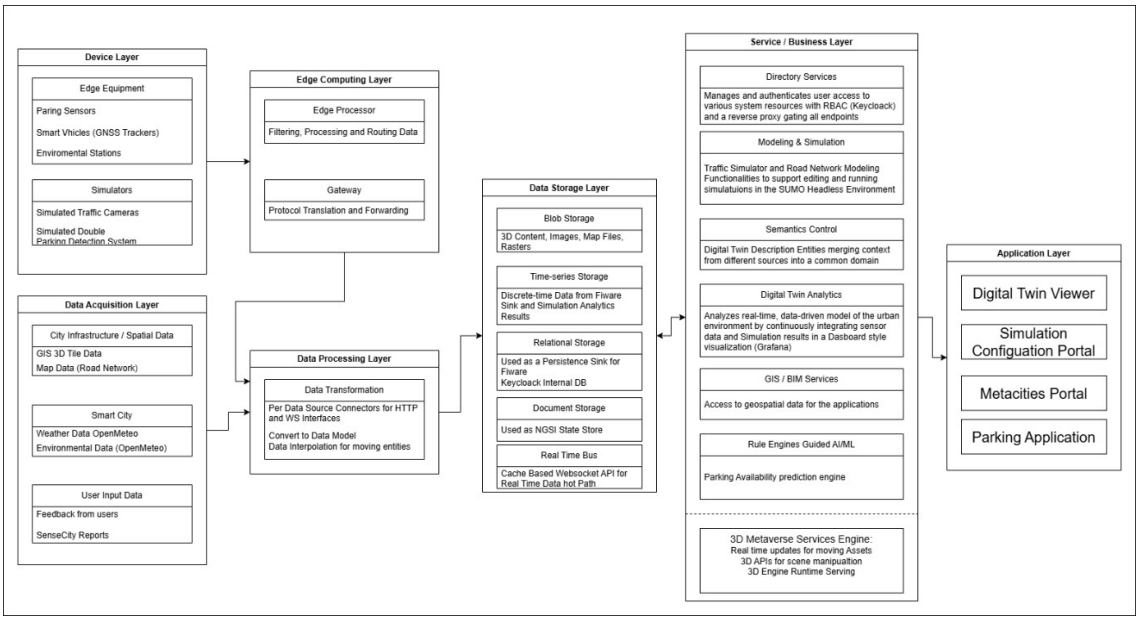

FIGURE 5: COMPONENT DIAGRAM FOR PATRAS SMART PARKING AND SMART MOBILITY USE CASE

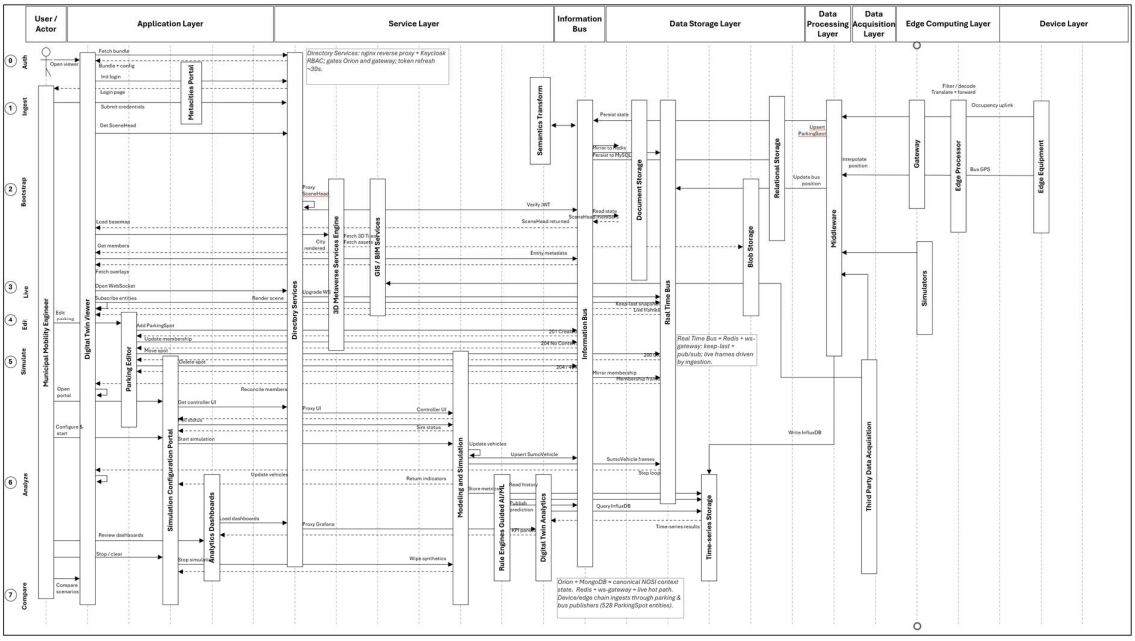

FIGURE 6: SEQUENCE DIAGRAM FOR PATRAS SMART PARKING AND SMART MOBILITY USE CASE

The Sequence Diagram (Figure 6) illustrates the end-to-end execution flow of the Patras Smart Parking and Smart Mobility Use Case, beginning with the user's actions in the 3D interface and progressing through the platform's layered architecture. After authentication through Keycloak and access mediation through the Nginx reverse proxy, the user enters the 3D Digital Twin environment and selects the central Patras pilot area for scenario definition.

The Digital Twin Platform retrieves the required spatial, mobility, and smart-city layers from the relevant context, storage, and external data services. Live parking availability is obtained through the Patras municipal API over HTTP, while the underlying parking sensors are LoRa-based. GPS-tracked

buses are accessed through the city bus telemetry API over HTTP, with the physical GPS devices operating through NB-IoT. Historical and estimated current traffic conditions are retrieved through the TomTom API, while SenseCity provides municipal issue tracking events and user reports. OpenStreetMap-derived road-network data provide the spatial basis for the simulation area and for the visual interpolation of live vehicle movement.

The user then defines a scenario by editing parking supply, modifying the general layout of parking locations, adding popular areas or points of interest, editing traffic-flow assumptions, changing speed limits, closing roads, editing the direction of one-way roads, converting roads to pedestrian-only use, or removing lanes. These user inputs are submitted to the Flask simulation backend, which prepares the OSM-sliced network for the selected pilot area and executes the corresponding SUMO/TraCI simulation.

The simulation results are returned to the platform as global and road-specific indicators, including average time to free parking spot, average speed, parking search time, emission estimates, and congestion metrics. Scenario identifiers and run identifiers are stored in InfluxDB, allowing the generated outputs to be retrieved and reused. The resulting data flow returns to the Digital Twin interface and associated visualisation components, enabling users to inspect the outcome of the scenario in a coherent and responsive environment.

4.1.2 Interfaces and Data Integration

The interfaces and data integration architecture of the Patras Smart Parking and Smart Mobility Use Case is designed to connect the different stages of the workflow into a single user journey, covering the complete process from mobility and parking data exploration to scenario editing, traffic simulation, and result visualisation.

At a high level, the platform integrates live parking data, live bus telemetry, historical and estimated traffic conditions, SenseCity inputs, OpenStreetMap-derived road-network information, emulated traffic-camera feeds, and user-defined scenario parameters through a common 3D Digital Twin environment. This enables users to move from observing the current mobility context of the Patras city centre, to defining parking and road-network changes, and finally to evaluating the simulated effects of those changes through visual and analytical outputs.

The pilot area covers approximately 1 km² in the central commercial core of Patras. It is centred around Georgiou I Square, Apollon Theatre, and the Patras Open Mall area, including parts of the dense street grid around Maizonos, Korinthou, Gerokostopoulou, Riga Feraiou, and Agiou Nikolaou. In practical terms, the selected area represents the main downtown retail and civic area of Patras and constitutes the full small-scale pilot area used for the demonstration.

From a data integration perspective, the Use Case combines real-time, historical, estimated, emulated, static, and user-generated inputs. The parking sensors and bus telemetry operate as live feeds, with parking sensor updates occurring at seconds-level frequency and bus updates at minutes-level frequency. Visual interpolation on the OpenStreetMap road-network grid supports smoother representation of real traffic movement, including bus movement, with refresh rates up to 5 Hz per live vehicle where applicable. Traffic conditions are based on historical and estimated TomTom data, while traffic-flow camera data are emulated and SenseCity data are real and live.

The interface components do not operate as isolated tools but as interconnected entry points into a unified mobility planning workflow. All data layers used in the selected demo are visible to the viewer, supporting the combined inspection of parking availability, traffic conditions, bus movement,

SenseCity information, road geometry, points of interest, and scenario-specific changes. This integrated interface allows users to edit parking spot layouts, define road-network adjustments, execute traffic simulations, and review the resulting effects without needing to interact directly with the underlying data-management and simulation components.

FIGURE 7: METAVERSE ENABLED DIGITAL TWIN 3D USER INTERFACES FOR THE PATRAS MOBILITY USE CASE PILOT

The final stage of the workflow extends this integration into visual communication and stakeholder engagement. Simulation outputs are presented through the 3D viewer, analytics side panel, expanded 2D analytical view, public web and PWA interfaces, mobile view, VR view, feedback dashboard, export/report view, and AR tabletop miniature. Where public participation is enabled, users can add points of interest with short messages and sentiment scores, which are visible both in the 3D viewer and in a side-panel list view. This creates a continuous workflow that links data acquisition, processing, scenario execution, result visualisation, and citizen feedback while shielding end users from the underlying technical complexity.

4.1.3 Demos/Test Cases and KPIs

This section presents the demonstration scenario and the Key Performance Indicators (KPIs) defined for the Patras Smart Parking and Smart Mobility Use Case. The demonstration scenario illustrates how the architectural components are integrated into a coherent operational workflow, while the KPIs provide a framework for evaluating the effectiveness, usability, responsiveness, and decision-support capabilities of the implemented solution. Together, these elements enable the assessment of both the technical performance of the platform and its ability to fulfil the objectives of the Use Case.

Demonstration Scenario

The Patras Smart Parking and Smart Mobility Use Case is demonstrated through a complete end-to-end workflow showing how the platform supports mobility planning and decision-making through parking layout editing, road-network scenario configuration, simulation execution, and visualisation of results.

The demonstration begins with the user exploring the Patras city-centre Digital Twin environment in order to inspect parking availability, road-network conditions, traffic estimates, bus movement,

SenseCity information, and relevant points of interest. The user then defines a scenario by adding, editing, or removing parking spots directly inside the 3D viewer. The same workflow also supports secondary road-network scenarios, including road closures, pedestrian-only conversions, one-way direction changes, speed-limit changes, lane removals, and modifications to traffic-flow assumptions.

Once the scenario has been configured, the platform initiates the simulation process. The Flask-based simulation backend uses the OpenStreetMap road network sliced to the Patras pilot area and executes SUMO/TraCI simulations based on the selected scenario configuration. Traffic conditions are supported by TomTom data and historical bus-route information from the previous month relative to the simulation date, while users can also edit traffic metrics inside the sandbox environment in order to test alternative mobility assumptions.

The platform subsequently generates simulation results that estimate the impact of the selected intervention. These outputs include average time to free parking spot, average speed, parking search time, emission estimates, and congestion metrics, provided both as global indicators and as road-specific outputs. Through the 3D viewer, analytics side panel, expanded 2D analytical view, VR and AR interfaces, public web and mobile views, and export functions, users can understand both the analytical findings and their spatial implications in a clear and accessible manner.

The primary value of the Use Case lies in the continuity of the overall workflow rather than in the isolated operation of individual system components. The methodology can therefore be described as a sequence of operational steps:

1. Identification of a parking or mobility planning issue within the Patras city-centre pilot area
2. Review of supporting spatial, mobility, traffic, parking, bus, and smart-city information
3. Definition of a feasible parking layout or road-network intervention scenario
4. Execution of mobility simulations and generation of global and road-specific indicators
5. Assessment of projected outcomes for planning, stakeholder communication, and decision support

This approach makes the workflow suitable both as a technical demonstration and as a practical decision-support process that can be communicated effectively to non-technical stakeholders. The emphasis is placed on user actions, the architectural components enabling those actions, and the indicators used to evaluate the usefulness, responsiveness, and planning relevance of the overall workflow.

KPIs

The evaluation framework for the Patras Smart Parking and Smart Mobility Use Case combines the common KPIs used across the Chapter 4 pilot sections with technical Use Case-specific KPIs tailored to the GR platform implementation. The Use Case-specific KPIs focus on measurable platform behaviour, including live entity handling, update rates, interpolation, simulation configurability, forecasting, rendering performance, and resource usage.

Common KPIs

•**End-to-End Workflow Completion Rate** - measures the ability of users to successfully complete the full workflow from data exploration to result visualisation.
•**Time to Result** - measures the time required to progress from selecting an area of interest to obtaining actionable simulation outputs.

•**Integration Readiness** - evaluates the extent to which heterogeneous data sources are integrated into a unified user workflow.
•**Visualisation Responsiveness** - measures loading and interaction times for maps, layers, simulations, and visual outputs.
•**User Task Success Rate** - assesses whether users can successfully complete intended planning and analysis tasks.
•**Decision-Support Clarity** - evaluates how understandable and actionable the generated outputs are for stakeholders and decision-makers.
Use Case-Specific KPIs
•**Maximum Live Vehicles Supported** - measures the maximum number of live or simulated vehicles that can be visualised and updated in the Patras 3D Digital Twin environment without platform degradation.
•**Maximum Entity Update Rate** - measures the maximum update rate supported for dynamic entities, including vehicles, parking spots, POIs, feedback markers, and scenario objects.
•**Bus Position Interpolation Rate** - measures the interpolation frequency used to display bus movement on the OSM-derived road-network grid between telemetry updates.
•**Parking Spot Availability Forecasting Accuracy** - measures the accuracy of short-term parking availability forecasts compared with observed parking sensor states.
•**Simulation Environment Alteration Coverage** - measures the number and type of simulation environment modifications supported by the platform, including parking layout edits, lane changes, road status changes, road closures, direction changes, pedestrian-only conversions, speed changes, and POI placement.
•**Simulation Execution Scalability** - measures the maximum scenario duration, network size, vehicle load, and simulation-output volume that can be handled through the SUMO/TraCI backend within acceptable execution limits.
•**3D Viewer Pilot Load Performance** - measures the rendering performance of the 3D viewer under the Patras pilot workload, including average frame rate, minimum frame rate, initial scene load size, runtime network usage, and stable operation across the supported device classes.

4.2 Buildings Energy Performance Analysis

4.2.1 Pilot architecture

The pilot architecture for the Buildings Energy Performance Analysis Use Case is represented through complementary architectural views that describe both the structural organisation of the solution and the interactions between its components.

The Component Diagram provides a high-level overview of the architectural layers and functional capabilities that support data acquisition, processing, analysis, simulation, and user interaction. The Sequence Diagram complements this perspective by illustrating the operational workflow and the exchange of information between the different system components during the execution of the Use Case.

The Component Diagram (Figure 8) presents the overall architecture as a set of logically separated but tightly interconnected layers.

At the foundation of the architecture, the Device Layer and Edge Computing Layer capture environmental measurements, building-related observations, and simulated conditions, while performing local filtering, aggregation, and preprocessing of data before transmission.

The Data Acquisition and Data Processing Layers collect information from multiple sources, including city infrastructure systems, GIS and BIM repositories, smart city platforms, and user-provided inputs. These heterogeneous datasets are transformed into harmonised formats suitable for further analysis and modelling activities.

The processed information is stored within dedicated repositories designed for structured, semi-structured, unstructured, and time-series data, ensuring efficient management and retrieval across different data types.

The Service Layer provides the core analytical and computational capabilities of the platform, including Digital Twin analytics, semantic interpretation services, GIS/BIM processing functions, modelling and simulation tools, directory services, and AI/ML-based rule engines.

At the highest level, the Application Layer exposes these capabilities through the Digital Twin Platform and Simulation Engine, enabling users to monitor building energy performance, evaluate alternative intervention scenarios, and support evidence-based planning and decision-making processes.

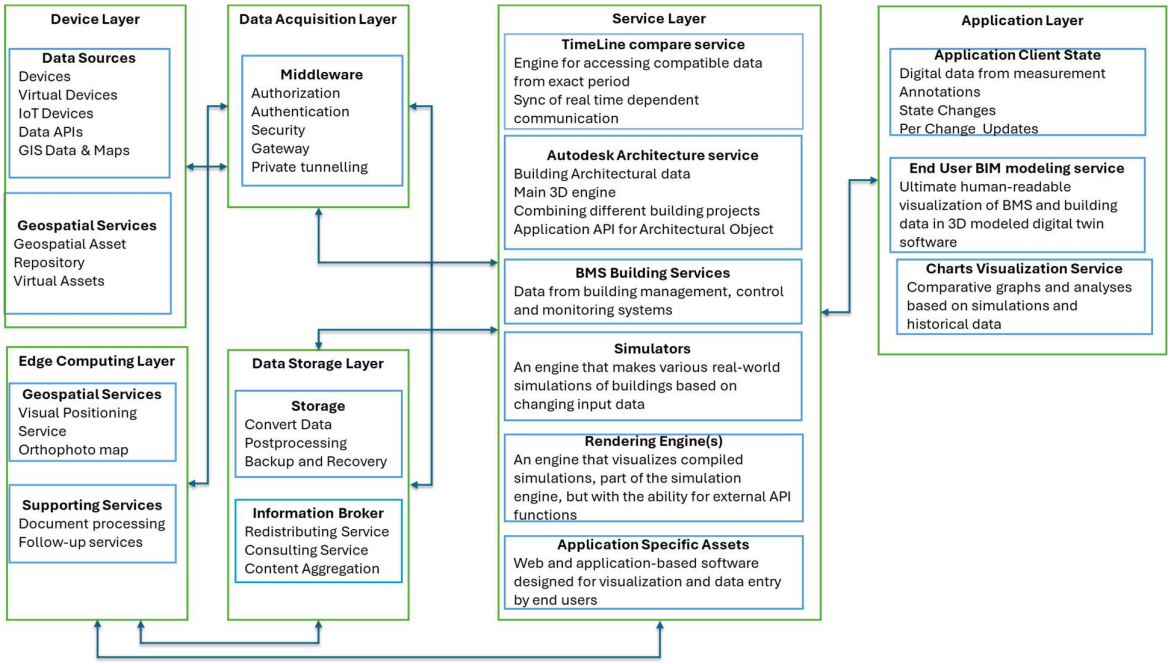

FIGURE 8: COMPONENT DIAGRAM - BUILDINGS ENERGY PERFORMANCE ANALYSIS

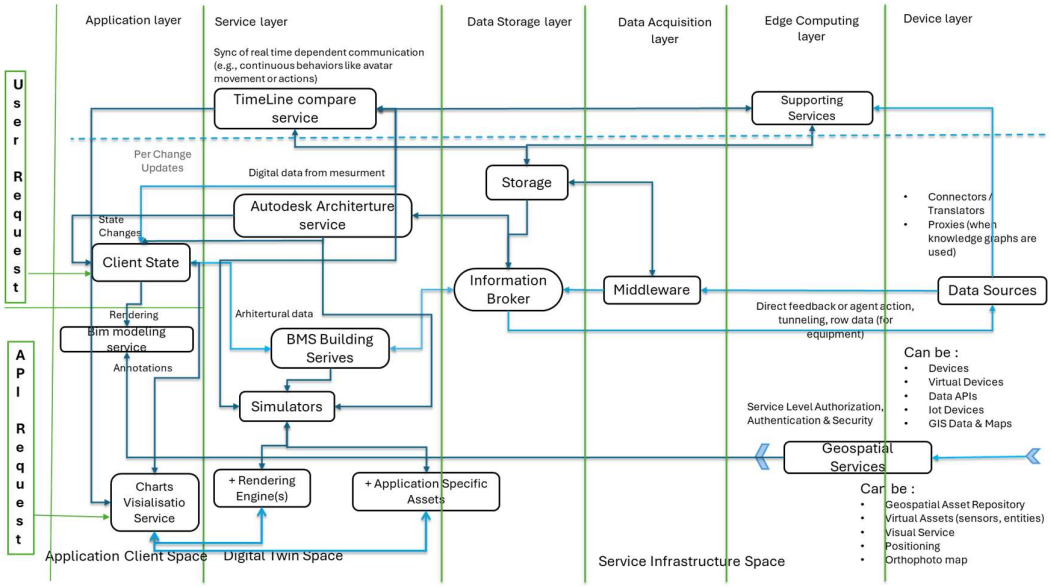

FIGURE 9: SEQUENCE DIAGRAM - BUILDINGS ENERGY PERFORMANCE ANALYSIS

Sequence diagram

The Sequence Diagram (Figure 9) illustrates the end-to-end execution flow of the Buildings Energy Performance Analysis Use Case, beginning with user interaction and progressing through the different architectural layers of the platform.

Following user authentication through the Directory Services component, requests submitted via the Digital Twin Platform are routed to the relevant analytical and modelling services. Depending on the requested functionality, the platform orchestrates interactions with components such as Digital Twin Analytics, Semantic Services, GIS/BIM Services, and Modelling and Simulation Services.

These services access and update the relevant storage repositories while simultaneously invoking data transformation mechanisms that retrieve and harmonise information originating from sensor networks, spatial datasets, smart city platforms, and external data services.

The workflow extends to the Edge Computing and Device Layers, where gateways, edge processors, simulators, and connected devices provide real-time observations, historical records, or simulated building performance conditions.

The generated outputs are subsequently processed and returned through the platform, allowing users to access analytical results, performance indicators, scenario evaluations, and simulation outcomes through a unified and responsive interface.

4.2.2 Interfaces and Data integration

The interfaces and data integration architecture of the Buildings Energy Performance Analysis Use Case is designed to connect the various stages of the workflow into a seamless user experience, covering the complete process from energy performance assessment to intervention planning and result visualisation.

At a high level, the platform integrates processed analytical products, spatial city information, building inventory datasets, and user-defined simulation parameters through a unified map-based

environment. This enables users to move naturally from identifying buildings with energy performance challenges, to exploring relevant contextual information, and finally to defining and evaluating alternative improvement scenarios.

The interface components therefore function not as isolated tools, but as interconnected access points to a single analytical workflow that supports exploration, planning, and decision-making activities.

From a data integration perspective, the Use Case combines heterogeneous information sources and transforms them into standardised, frontend-ready assets that can be consistently utilised across all platform modules.

The Buildings Energy Performance Analysis products provide the baseline representation of existing building conditions, while the simulation engine leverages historical datasets and scenario parameters to generate projections for future performance under different intervention strategies.

The final stage of the workflow extends this integration into the visual communication of results. Simulation outputs are reused within immersive 3D visualisation environments, allowing users to explore selected buildings or urban areas and assess projected energy performance improvements over time.

This creates a continuous workflow that links data acquisition, processing, analysis, scenario evaluation, and spatial communication while shielding end users from the underlying technical complexity.

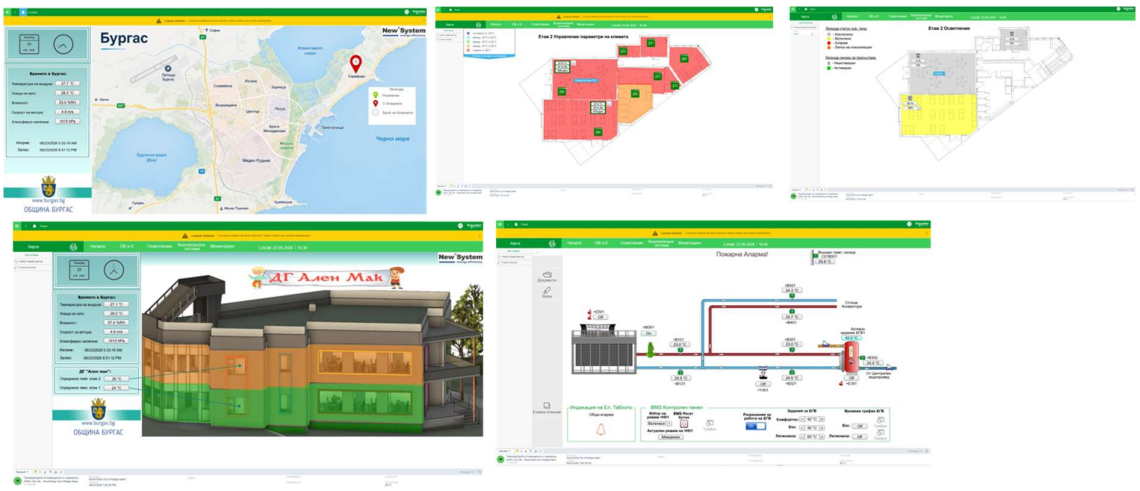

FIGURE 10:METAVERSE ENABLED DIGITAL TWIN 3D USER INTERFACES FOR THE BUILDINGS ENERGY PERFORMANCE ANALYSIS USE CASE PILOT BG.

4.2.3 Demos/Test Cases and KPIs

This section presents the demonstration scenario and the Key Performance Indicators (KPIs) defined for the Buildings Energy Performance Analysis Use Case.

The demonstration scenario illustrates how the architectural components are integrated into a coherent operational workflow, while the KPIs provide a framework for evaluating the effectiveness, usability, responsiveness, and decision-support capabilities of the implemented solution.

Together, these elements enable the assessment of both the technical performance of the platform and its ability to fulfil the objectives of the Use Case.

Demonstration Scenario

The Buildings Energy Performance Analysis Use Case is demonstrated through a complete end-to-end workflow showing how the platform supports planning and decision-making through integrated energy performance assessment, scenario development, and visualisation of results.

The demonstration begins with the user exploring processed energy performance datasets in order to identify buildings or areas that exhibit persistent energy inefficiencies or performance challenges.

Once a priority area has been identified, the user initiates the simulation workflow, selects the target building or intervention area directly within the 3D environment, and configures an improvement scenario using available building inventory information and predefined intervention options.

The platform subsequently generates projected performance results that estimate the impact of the selected measures. Through map-based views and immersive visualisation environments, users can understand both the analytical findings and their spatial implications in a clear and intuitive manner.

The primary value of the Use Case lies in the continuity of the overall workflow rather than in the isolated operation of individual system components. The methodology can therefore be described as a sequence of operational steps:

6. Identification of a building performance issue;
7. Review of supporting spatial and contextual information;
8. Definition of a feasible intervention scenario;
9. Execution of simulations and performance projections;
10. Assessment of projected outcomes for planning and decision support.

This approach makes the workflow suitable both as a technical demonstration and as a practical decision-support process that can be communicated effectively to non-technical stakeholders.

The emphasis is placed on user actions, the architectural components enabling those actions, and the indicators used to evaluate the usefulness, responsiveness, and planning relevance of the overall workflow.

KPIs

The evaluation framework for the Buildings Energy Performance Analysis Use Case combines generic indicators applicable across multiple Digital Twin Use Cases with indicators specifically tailored to the objectives of this pilot.

Common KPIs

- **End-to-End Workflow Completion Rate** – measures the ability of users to successfully complete the full workflow from data exploration to result visualisation.
- **Time to Result** – measures the time required to progress from selecting a building or area of interest to obtaining actionable outputs.
- **Integration Readiness** – evaluates the extent to which heterogeneous data sources are integrated into a unified user workflow.

- **Visualisation Responsiveness** – measures loading and interaction times for maps, layers, simulations, and visual outputs.
- **User Task Success Rate** – assesses whether users can successfully complete intended planning and analysis tasks.
- **Decision-Support Clarity** – evaluates how understandable and actionable the generated outputs are for stakeholders and decision-makers.

Use Case-Specific KPIs

- **Scenario Configuration Usability** – measures how easily users can define intervention areas and configure energy-efficiency improvement scenarios.
- **Energy Efficiency Improvement Estimation** – measures the projected reduction in energy consumption or improvement in building performance resulting from the selected intervention.
- **Scenario Flexibility** – evaluates the ability to compare multiple intervention alternatives and parameter combinations.
- **Projected Building Performance Improvement** – measures the expected change in energy performance indicators following implementation of the selected scenario.
- **Temporal Insight Coverage** – assesses the availability of projections across multiple future time horizons to support long-term planning.
- **Result Communication Quality** – evaluates the effectiveness of 2D and 3D visualisations in communicating simulation outcomes to users.
- **Scalability Potential** – measures the ability of the solution to support larger building inventories, additional datasets, and broader urban areas without significant degradation of performance

4.3 Urban Heat Stress Reduction (Parks and Green)

4.3.1 Pilot architecture

The pilot architecture for the Urban Heat Island (UHI) reduction Use Case is presented through complementary architectural views that illustrate both the structural composition of the solution and the interaction flow between its components. The components diagram provides an overview of the main architectural layers and system capabilities that enable data collection, processing, analysis, and user interaction. The sequence diagram then illustrates how these components interact during the execution of the Use Case, showing the flow of information from user requests to data processing, simulation, and result presentation.

The components diagram (Figure 11) presents the overall architecture required to support the UHI Use Case as a set of clearly separated yet interconnected high-level layers. At the foundation, the Device and Edge Computing layers capture environmental observations and simulated conditions while enabling local filtering, processing, and forwarding of data. The Data Acquisition and Data Processing layers then collect information from city infrastructure, GIS/BIM sources, smart city systems, and user input, transforming these heterogeneous inputs into a common format suitable for analysis. This information is persisted across dedicated storage components for structured, semi-structured, unstructured, and time-series data. The Service Layer then provides the core intelligence of the system through analytics, semantic interpretation, GIS/BIM functions, modelling and simulation, directory services, and AI/ML-driven rule engines. At the top, the Application Layer exposes these capabilities through the Digital Twin Platform and Simulation Engine, offering an integrated environment for monitoring urban heat conditions, exploring scenarios, and supporting evidence-based decision-making.

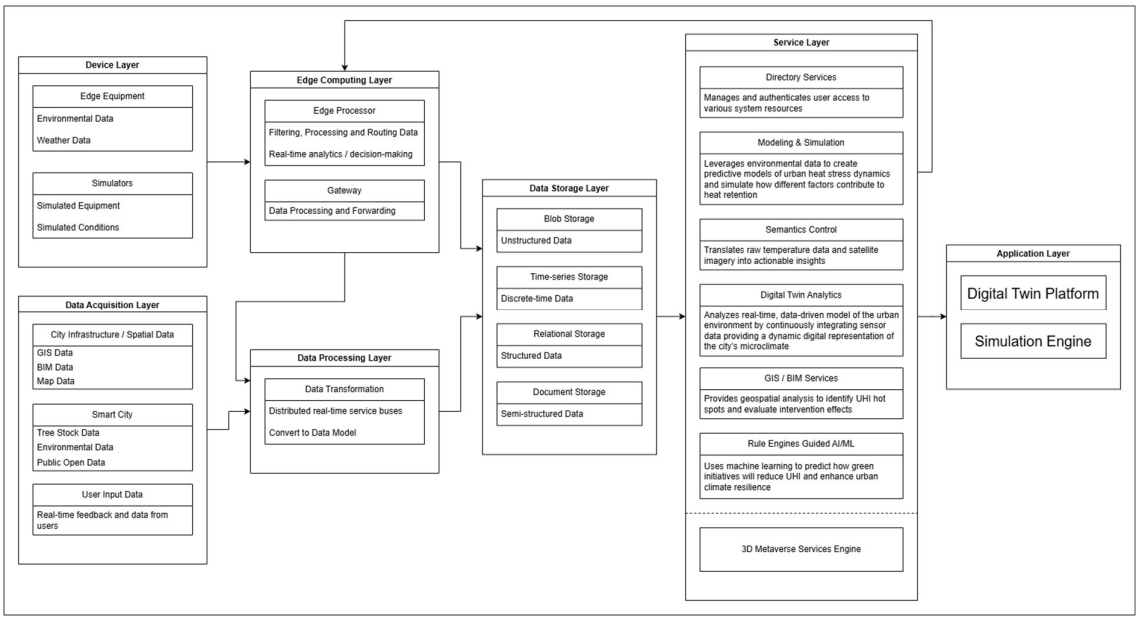

FIGURE 11: COMPONENT DIAGRAM FOR URBAN HEAT STRESS REDUCTION

The sequence diagram (Figure 12) illustrates the end-to-end interaction flow for the Urban Heat Island reduction Use Case, beginning with the user's actions in the interface and progressing through the platform's layered architecture. After authentication through the Directory Services component, the Digital Twin Platform handles requests for data, analytics, and modelling tasks by orchestrating the relevant service-layer components, including Digital Twin Analytics, Semantics Control, GIS/BIM Services, and Modelling and Simulation. These services query and update the appropriate storage components while also invoking the Data Transformation layer to retrieve and harmonize live sensor streams, spatial data, and smart city information from external APIs and infrastructure sources. The interaction then extends to the edge computing and device layers, where gateways, edge processors, simulators, and edge equipment provide real-time observations or simulated conditions. The resulting data flows back through the platform, enabling users to receive processed outputs, insights, and simulation results in a coherent and timely manner.

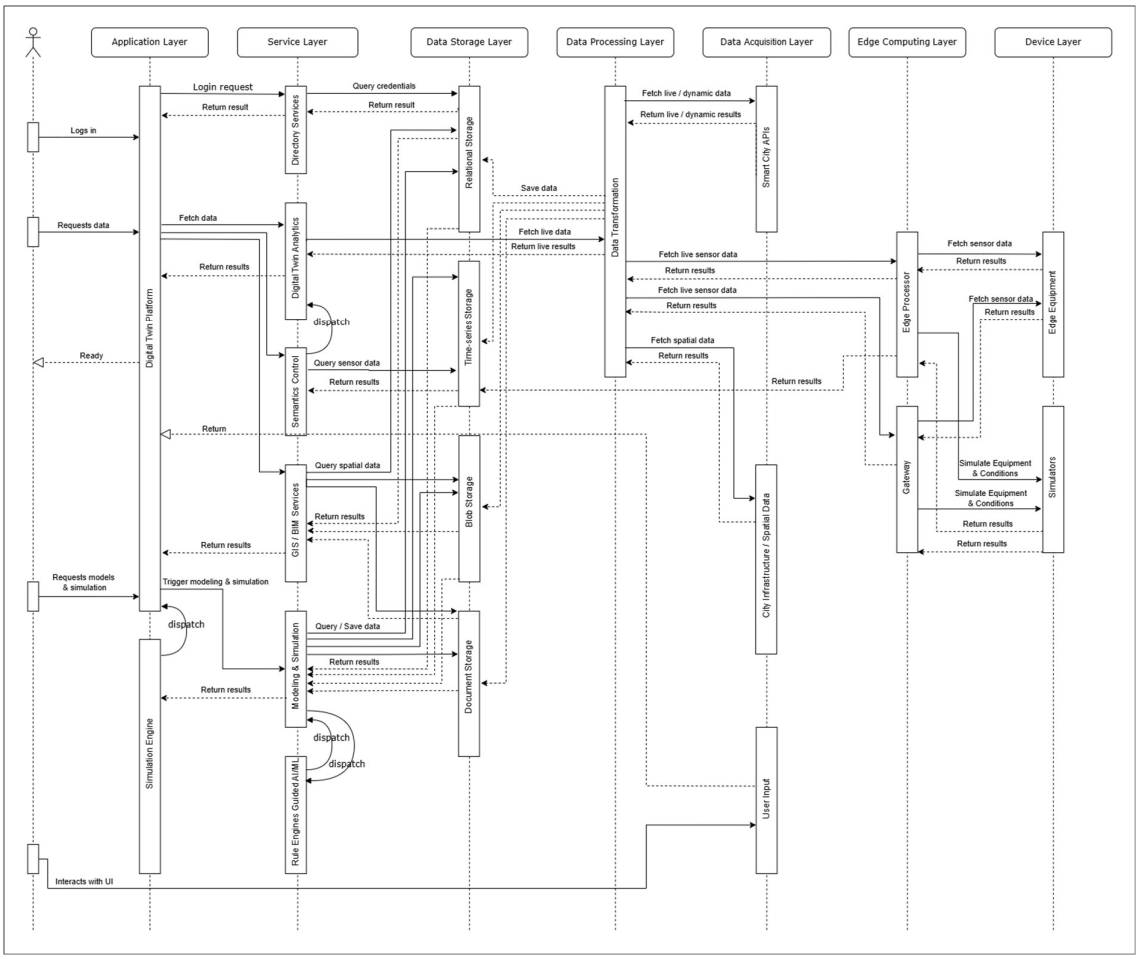

FIGURE 12: SEQUENCE DIAGRAM -URBAN HEAT STRESS REDUCTION

4.3.2 Interfaces and Data integration

The interfaces and data integration layer of the UHI Use Case is designed to connect the different parts of the workflow into a single, coherent user journey, from environmental analysis to intervention planning and result presentation. At a high level, the platform brings together processed UHI calculated products, spatial city information, tree inventory data, and user-defined simulation inputs through a common map-based interface. This allows users to move naturally from identifying areas of persistent heat stress, to inspecting supporting contextual layers, and finally to selecting a hotspot for scenario testing. In this way, the interfaces do not operate as isolated tools but as connected entry points into an integrated analytical process that supports exploration, planning, and decision-making.

From a data integration perspective, the UHI Use Case combines heterogeneous inputs and transforms them into frontend-ready assets that can be used consistently across the different modules. The UHI calculated products provide the environmental baseline, the tree inventory contributes vegetation-related context and species information, and the simulator builds on the persistent hotspot layer to generate scenario-specific outputs for projected years. The final stage of the workflow extends this integration into the visual presentation of results, where the simulation outputs are reused in an immersive 3D experience to present the selected hotspot area, planting locations, and projected tree growth over time. This completes the overall chain from data acquisition and processing to scenario evaluation and spatial communication while keeping the underlying technical complexity hidden from the end user.

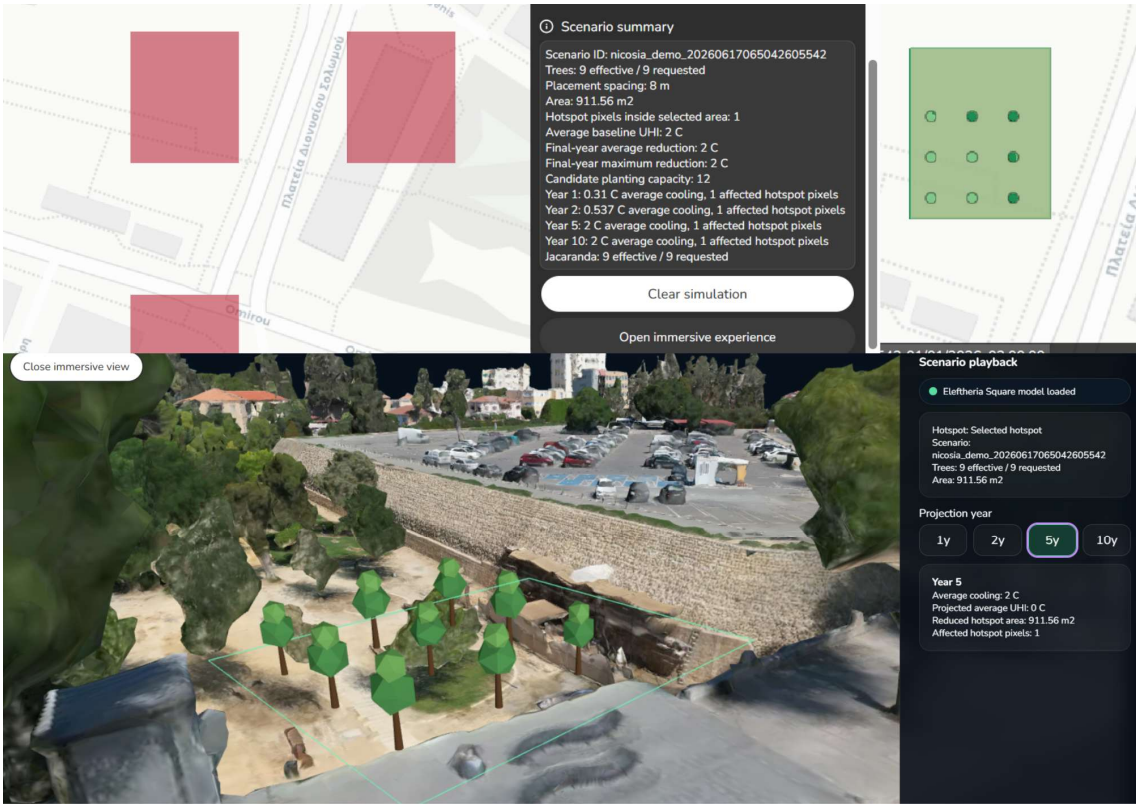

FIGURE 13: METAVERSE ENABLED DIGITAL TWIN 3D USER INTERFACES FOR THE UHI USE CASE PILOT CY.

4.3.3 Demos/Test Cases and KPIs

This section presents the demonstration scenario and the KPIs defined for the Urban Heat Island (UHI) reduction Use Case. The demonstration scenario illustrates how the different components of the pilot architecture are combined into a coherent user workflow, while the KPIs provide a framework for assessing the effectiveness, usability, responsiveness, and decision-support value of the implemented solution. Together, they support the evaluation of both the technical performance of the platform and its ability to address the objectives of the Use Case.

Demo Scenario

The UHI Use Case is presented as a practical end-to-end workflow showing how the platform can support urban intervention planning through integrated spatial analysis, scenario definition, and result visualisation. The demonstration begins with the user exploring processed UHI products to identify areas that exhibit persistent heat stress over time. Once a priority hotspot is identified, the user opens the simulation workflow, selects the intervention area directly on the map, and defines a planting scenario using available tree inventory and species information. The platform then generates projected results for a set of future years and returns the outcome through map-based views and an immersive visual environment, allowing the user to understand both the analytical results and their spatial implications in a clear and accessible manner.

The value of the Use Case lies in the continuity of the overall user journey rather than in the isolated operation of individual components. The methodology can therefore be described at a high level as a sequence of operational steps: identifying a problem area, reviewing supporting spatial information,

defining a plausible intervention, executing a scenario, and assessing the projected outcome for planning support. This makes the workflow suitable not only as a technical demonstration but also as a decision-support process that can be communicated to non-specialist stakeholders. The emphasis is placed on the user actions enabled by the platform, the way the architectural components support those actions, and the indicators that can later be used to evaluate the usefulness, responsiveness, and planning relevance of the overall workflow.

KPIs

The assessment framework for the UHI Use Case includes both common indicators that can be applied across multiple Use Cases and specific indicators tailored to the objectives of this scenario.

Common KPIs include:

- **End-to-end workflow completion rate**, measuring whether a user can complete the full process from data exploration to result visualisation without interruption.
- **Time to result**, measuring the time required to move from selecting an area of interest to receiving a usable output.
- **Integration readiness**, measuring the extent to which heterogeneous inputs are combined into a consistent user-facing workflow.
- **Visualisation responsiveness**, measuring the time required for layers, scenario outputs, and visual views to load and become usable.
- **User task success**, measuring whether target users can complete the intended planning task using the provided tools.
- **Decision-support clarity**, measuring the extent to which the outputs are understandable and actionable for stakeholder discussions.

UHI-specific KPIs include:

- **Scenario configuration usability**, measuring how easily a user can define an intervention area and create a planting scenario.
- **Planting capacity estimation**, measuring the number of feasible planting locations generated within the selected hotspot.
- **Species-based scenario flexibility**, measuring the ability to compare alternative planting combinations using available species information.
- **Projected hotspot improvement**, measuring the change in hotspot conditions after the intervention scenario has been applied.
- **Temporal insight coverage**, measuring the availability of projected results across multiple future years to demonstrate how the intervention develops over time.
- **Result communication quality**, measuring the effectiveness of map-based and immersive views in helping users interpret scenario outcomes.
- **Scalability readiness**, measuring whether the workflow architecture, data integration approach, and visualisation pipeline can be extended to support broader city-scale or multi-area deployment in a future pilot phase.

5 Conclusions

This deliverable presents the outcomes of Task 4.1, focusing on the Proof-of-Concept (PoC) studies and feasibility assessment conducted within the METACITIES project. Building upon the stakeholder requirements, socio-economic analysis, and Digital Twin architecture defined in previous work packages, this deliverable advances the project by validating the proposed architectural approach and establishing the final feasible architecture, together with the key performance indicators (KPIs) that will guide the implementation and evaluation activities in Tasks 4.2 and 4.3.

The work reported on this deliverable was carried out through four main steps. First, a series of co-creation activities were conducted with stakeholders across the pilot clusters, resulting in the collection and refinement of user stories that validated stakeholder needs and led to the final definition of functional and non-functional requirements. Second, the pilot Use Cases were selected and refined based on stakeholder priorities, technical feasibility, and expected impact. Then, a gap analysis was performed to assess the readiness and suitability of the identified technological components and determine the additional developments required to support the selected Use Cases. Finally, the target architecture and the associated technical and non-technical KPIs were defined to support the implementation and validation phases.

In conclusion, this deliverable resulted in the selection and specification of three representative pilot Use Cases aligned with the METACITIES objectives: Patras Smart Parking & Smart Mobility (Smart Mobility), Buildings Energy Performance Analysis (Green City), and Urban Heat Stress Reduction (Urban Planning). Through the performed gap analysis and feasibility assessment, the required technological components, integration needs, and implementation priorities were identified, leading to the definition of the target architectures and evaluation framework. Furthermore, the first Proof-of-Concept demonstrations were developed, providing an initial validation of the proposed Digital Twin solutions and establishing a solid foundation for the implementation, integration, and pilot validation activities in Tasks 4.2 and 4.3.

The outcomes of this deliverable provide a clear roadmap for the next project phases, supporting the development, integration, demonstration, and validation of the METACITIES solutions within the pilot environments. More broadly, the work lays the foundation for the adoption of data-driven urban management practices, enabling municipalities and stakeholders to leverage Digital Twin technologies for more efficient, sustainable, and resilient cities.

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Annex 1: USER STORIES TABLES

This section presents the consolidated user stories along with their corresponding acceptance criteria, as derived from the user story elicitation process.

TABLE 18: THE USER STORIES –USE CASE: PATRAS SMART PARKING & MOBILITY

This table presents the user stories developed for the *Use Case* – Patras Smart Parking & Mobility.

No: GR.24	**Title: Compare two scenarios side-by-side with consistent analytics and maps**	**Actor Type: Governance**
Description: As a municipal mobility engineer, I want to compare two scenarios side-by-side with consistent analytics and maps so that I can select baseline + variant, view deltas, and save comparison.		
	Acceptance Criteria:	
F-RQ-T-2	Selecting scenarios renders analytics/deltas with synchronised views.	
NF-RQ-T-10	Layer toggles keep camera/view consistent across scenarios.	
NF-RQ-T-11	A comparison snapshot can be exported or shared.	
NF-RQ-T-8	Simulation results appear in the side analytics panel and can be expanded to a 2D view.	
F-RQ-T-8	Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned.	
	Only Governance users can publish a scenario to the public portal; all publish actions are logged.	
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, DirectoryServices, RelationalStorage		

No: GR.26	**Title: Publish a vetted scenario to the public portal (with explanation)**	**Actor Type: Governance**
Description: As a municipal mobility engineer, I want to publish a vetted scenario to the public portal (with explanation) so that I can promote selected proposals to a citizen-facing view.		
F-RQ-T-2 NF-RQ-T-10 NF-RQ-T-11 NF-RQ-T-8 F-RQ-T-8	**Acceptance Criteria:** Publishing makes the scenario visible in the public interface with metadata. Updates create a new version (no overwrite). Publish actions are audit-logged. Simulation results appear in the side analytics panel and can be expanded to a 2D view. Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned. Only Governance users can publish a scenario to the public portal; all publish actions are logged.	
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, DirectoryServices, RelationalStorage		
No: GR.1	**Title: Targeted double-parking enforcement what-if on selected streets**	**Actor Type: Governance**
Description: As a municipal mobility engineer, I want to run a targeted double-parking enforcement what-if on selected streets so that I can configure enforcement zones/times and simulate mobility impacts.		
F-RQ-T-1 F-RQ-T-17 NF-RQ-T-4 F-RQ-T-4 F-RQ-T-3 F-RQ-T-2 NF-RQ-T-10 NF-RQ-T-11	**Acceptance Criteria:** Given an area and time window, when the scenario is run, then analytics are produced and viewable. Changing compliance/detection parameters updates results and is auditable. Scenario can be saved, duplicated, and compared to baseline. Simulation results appear in the side analytics panel and can be expanded to a 2D view. Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned. Only Governance users can publish a scenario to the public portal; all publish actions are logged.	
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, TrafficData, Time-seriesStorage, EdgeEquipment, Gateways, SemanticsTransform		

No: GR.5	Title: Add on-street parking bays and re-run congestion & search-for-parking effects	Actor Type: Governance
Description: As a municipal mobility engineer, I want to add on-street parking bays and re-run congestion & search-for-parking effects so that I can adjust curb inventory and simulate traffic circulation changes.		
	Acceptance Criteria:	
F-RQ-T-1	Editing parking supply updates the map layer and validates inputs.	
F-RQ-T-17	After simulation, parking-related analytics and network impacts are visible.	
NF-RQ-T-4	Baseline vs scenario comparison is available for the configured period.	
F-RQ-T-2	Simulation results appear in the side analytics panel and can be expanded to a 2D view.	
NF-RQ-T-10	Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned.	
NF-RQ-T-11	Only Governance users can publish a scenario to the public portal; all publish actions are logged.	
NF-RQ-T-8		
F-RQ-T-8		
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, TrafficData, Time-seriesStorage, DirectoryServices, RelationalStorage		

No: GR.6	Title: Remove on-street parking from a corridor to reallocate space (bus/bike/walk)	Actor Type: Governance
Description: As a municipal mobility engineer, I want to remove on-street parking from a corridor to reallocate space (bus/bike/walk) so that I can test curb removal and observe mode/flow redistribution.		
	Acceptance Criteria:	
F-RQ-T-1	Bike edits validate geometry/attributes and persist.	
F-RQ-T-17	Bike-related analytics and network impacts are visible after a run.	
NF-RQ-T-4	Before/after comparison is available.	
F-RQ-T-2	Simulation results appear in the side analytics panel and can be expanded to a 2D view.	
NF-RQ-T-10	Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned.	
NF-RQ-T-11	Only Governance users can publish a scenario to the public portal; all publish actions are logged.	
NF-RQ-T-8		
F-RQ-T-8		
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, TrafficData, Time-seriesStorage, DirectoryServices, RelationalStorage		
No: GR.13	**Title: Convert a street segment to pedestrian-only and simulate rerouting impacts**	**Actor Type: Governance**
Description: As a municipal mobility engineer, I want to convert a street segment to pedestrian-only and simulate rerouting impacts so that I can replace road access with walkability and measure network effects.		
	Acceptance Criteria:	
F-RQ-T-2	Setting a segment to pedestrian-only updates routing and outputs.	
NF-RQ-T-10	Before/after analytics and impacted street maps are produced.	
NF-RQ-T-11	Change is visible in 3D with clear styling.	
NF-RQ-T-8	Simulation results appear in the side analytics panel and can be expanded to a 2D view.	
F-RQ-T-8	Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned.	
	Only Governance users can publish a scenario to the public portal; all publish actions are logged.	
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, DirectoryServices, RelationalStorage		

No: GR.9	Title: Place a park-and-ride site and simulate catchment demand	Actor Type: Governance
Description: As a municipal mobility engineer, I want to place a park-and-ride site and simulate catchment demand so that I can add a site, define pricing/service, and estimate diversion from car trips.		
	Acceptance Criteria:	
F-RQ-T-1	Configured sites produce adoption and network analytics after a run.	
F-RQ-T-17	Invalid configurations are flagged before simulation.	
NF-RQ-T-4	Results can be shared and (if authorised) published.	
F-RQ-T-2	Simulation results appear in the side analytics panel and can be expanded to a 2D view.	
NF-RQ-T-10	Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned.	
NF-RQ-T-11	Only Governance users can publish a scenario to the public portal; all publish actions are logged.	
NF-RQ-T-8		
F-RQ-T-8		
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, TrafficData, Time-seriesStorage, DirectoryServices, RelationalStorage		

No: GR.M02 (from GR.21, GR.22)	Title: Plan and sponsor bike parking at key POIs and assess utilisation	Actor Type: Governance
Description: As a municipal mobility planner, I want to add bike parking at key POIs (including business-sponsored locations) so that I can estimate utilisation and understand before/after impacts using the 3D view and analytics.		
	Acceptance Criteria:	
F-RQ-T-1	Bike-parking edits validate geometry/attributes and persist as scenario configuration.	
F-RQ-T-17	Optional sponsor metadata (e.g., business-funded) can be attached without exposing sensitive data publicly.	
NF-RQ-T-4	After a run, utilisation and network-related analytics are shown in the side analytics panel (expandable to 2D).	
F-RQ-T-2	Before/after comparison against a baseline is available for the selected area and time window.	
NF-RQ-T-10	Analytics outputs can be exported (CSV/image), and the scenario configuration is versioned.	
NF-RQ-T-11	Only Governance users can publish a scenario to the public portal; publish actions are logged.	
NF-RQ-T-8		
F-RQ-T-8		
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, TrafficData, Time-seriesStorage, DirectoryServices, RelationalStorage		

No: GR.61	Title: Integrate my parking facility occupancy and pricing feed into the Digital Twin	Actor Type: Business
Description: As a local business stakeholder, I want to integrate my parking facility occupancy and pricing feed into the Digital Twin so that I can expose availability and pricing so the twin reflects operations and can simulate impacts.		
	Acceptance Criteria:	
F-RQ-T-1	When a valid feed is connected, then facility status updates are visible in the twin.	
F-RQ-T-17	Stale/invalid updates are flagged and excluded from real-time displays.	
NF-RQ-T-4	Authorised users can export the ingested time series for analysis.	
F-RQ-T-6	Simulation results appear in the side analytics panel and can be expanded to a 2D view.	
F-RQ-T-4	Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned.	
F-RQ-T-3	Business-submitted scenarios remain private by default unless shared with Governance for review.	
NF-RQ-T-1		
NF-RQ-T-2		
Components: Modeling & Simulation, Digital Twin Analytics, MapData, GISData, Traffic Data, Time-series Storage, Edge Equipment, Gateways, Edge Processors, Semantics Transform		

No: GR.M01 (from GR.62, GR.7)	Title: Integrate business parking operations and curbside compliance data into the Digital Twin	Actor Type: Business
Description: As a business operator, I want to integrate my parking facility operations data and curbside double-parking detection events into the Digital Twin so that simulations reflect real conditions and I can evaluate operational and policy scenarios with accurate analytics.		
	Acceptance Criteria:	
F-RQ-T-1	Parking operations data and detector events can be ingested via secure APIs and mapped to correct locations.	
F-RQ-T-17	An events/availability layer shows current state and supports filtering by time and area.	
NF-RQ-T-4	Aggregations (e.g., counts per segment/time, occupancy trends) update as new data arrives.	
F-RQ-T-6	Scenario runs can use the integrated data as baseline inputs and produce comparable before/after analytics.	
F-RQ-T-4	Access to raw feeds is role-controlled; public views expose only aggregated, privacy-safe analytics.	
F-RQ-T-3	Analytics outputs can be exported (CSV/image) and scenario/run configurations are versioned.	
NF-RQ-T-1		
NF-RQ-T-2		
F-RQ-T-2		
NF-RQ-T-10		
NF-RQ-T-11		
NF-RQ-T-8		
F-RQ-T-8		
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, TrafficData, Time-seriesStorage, EdgeEquipment, Gateways, EdgeProcessors, SemanticsTransform, DirectoryServices, RelationalStorage		

No: GR.M03 (from GR.31, GR.34)	Title: Calibrate and benchmark congestion model variants using observed data	Actor Type: Academia
Description: As a traffic scientist, I want to calibrate congestion model parameters and compare modelling approaches on the same network so that I can quantify fit to observed data and report uncertainty using reproducible runs and analytics.		
	Acceptance Criteria:	
F-RQ-T-4	Users can select observed datasets/metrics and a model variant (approach) for calibration runs.	
F-RQ-T-3	After a run completes, results, error metrics, and logs are saved with parameters and timestamps.	
NF-RQ-T-4	Model variants can be compared on the same network and period using synchronised views and deltas.	
NF-RQ-T-1	Re-running with the same inputs reproduces results when stochasticity is controlled (saved seed).	
NF-RQ-T-2	Results are visible in the side analytics panel and can be expanded to a 2D view for detailed plots.	
NF-RQ-T-6	Outputs can be exported and cited via a run ID (versioned configuration).	
NF-RQ-T-7		
F-RQ-T-2		
NF-RQ-T-10		
NF-RQ-T-11		
NF-RQ-T-8		
F-RQ-T-8		
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, TrafficData, Time-seriesStorage, EdgeEquipment, Gateways, SemanticsTransform, DirectoryServices, RelationalStorage		

No: GR.32	Title: Validate simulated vs observed travel times for a corridor after a real intervention	Actor Type: Academia
Description: As a traffic-science researcher, I want to validate simulated vs observed travel times for a corridor after a real intervention so that I can compare predicted vs measured outcomes once implemented.		
	Acceptance Criteria:	
F-RQ-T-2 NF-RQ-T-10 NF-RQ-T-11 NF-RQ-T-8 F-RQ-T-8	Given selected data/metrics, when a run completes, then results and logs are saved. Users can export outputs and a run summary with parameters and timestamps. Re-running with the same inputs reproduces results when stochasticity is controlled. Simulation results appear in the side analytics panel and can be expanded to a 2D view. Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned. Runs support reproducibility (saved random seed and parameter set) and can be cited via a run ID.	
Components: Modeling & Simulation, DigitalTwinAnalytics, MapData, GISData, DirectoryServices, RelationalStorage		
No: GR.33	**Title: Back-test a proposed policy using a known historical day (event/incident)**	**Actor Type: Academia**
Description: As a traffic-science researcher, I want to back-test a proposed policy using a known historical day (event/incident) so that I can run on past conditions to quantify realism before forecasting.		
	Acceptance Criteria:	
F-RQ-T-2 NF-RQ-T-10 NF-RQ-T-11 NF-RQ-T-8 F-RQ-T-8	Given selected data/metrics, when a run completes, then results and logs are saved. Users can export outputs and a run summary with parameters and timestamps. Re-running with the same inputs reproduces results when stochasticity is controlled. Simulation results appear in the side analytics panel and can be expanded to a 2D view. Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned. Runs support reproducibility (saved random seed and parameter set) and can be cited via a run ID.	
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, Directory Services, Relational Storage		

No: GR.42	Title: Diagnose model-data mismatch hotspots (where simulation diverges most)	Actor Type: Academia
Description: As a traffic-science researcher, I want to diagnose model-data mismatch hotspots (where simulation diverges most) so that I can locate systematic error zones for targeted improvement.		
	Acceptance Criteria:	
F-RQ-T-2	Given selected data/metrics, when a run completes, then results and logs are saved.	
NF-RQ-T-10	Users can export outputs and a run summary with parameters and timestamps.	
NF-RQ-T-11	Re-running with the same inputs reproduces results when stochasticity is controlled.	
NF-RQ-T-8	Simulation results appear in the side analytics panel and can be expanded to a 2D view.	
F-RQ-T-8	Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned.	
	Runs support reproducibility (saved random seed and parameter set) and can be cited via a run ID.	
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, Directory Services, Relational Storage		
No: GR.29	**Title: Visualise real-time vs historic mobility layers for the same area**	**Actor Type: Academia**
Description: As a traffic-science researcher, I want to visualise real-time vs historic mobility layers for the same area so that I can toggle time windows/layers to understand variability and anomalies.		
	Acceptance Criteria:	
F-RQ-T-2	Switching layers updates the view without losing context.	
NF-RQ-T-10	Selected time windows persist in the session.	
NF-RQ-T-11	Data gaps are indicated clearly.	
NF-RQ-T-8	Simulation results appear in the side analytics panel and can be expanded to a 2D view.	
F-RQ-T-8	Analytics outputs can be exported (CSV/image) and the scenario configuration is versioned.	
	Runs support reproducibility (saved random seed and parameter set) and can be cited via a run ID.	
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, Traffic Data, Time-series Storage, Directory Services, Relational Storage		

No: GR.3	Title: Run controlled experiments comparing intervention strategies	Actor Type: Academia
Description: As a traffic scientist, I want to design and run controlled what-if experiments comparing intervention strategies (e.g., enforcement variants) so that I can quantify differences using reproducible runs and consistent analytics.		
	Acceptance Criteria:	
F-RQ-T-4	Users can define an experiment set (multiple scenario variants) with shared baseline inputs.	
F-RQ-T-3	Runs support reproducibility (saved random seed and parameter set) and can be cited via a run ID.	
NF-RQ-T-4	Results are comparable via synchronized views and deltas in the side analytics panel (expandable to 2D).	
NF-RQ-T-1	A comparison snapshot can be exported or shared and includes experiment metadata.	
NF-RQ-T-2	Analytics outputs can be exported (CSV/image) and scenario configurations are versioned.	
NF-RQ-T-6		
NF-RQ-T-7		
F-RQ-T-2		
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, Traffic Data, Time-series Storage, Edge Equipment, Gateways, Semantics Transform		

No: GR.11	Title: Academic calibrates park-and-ride uptake assumptions using historic data	Actor Type: Academia
Description: As a traffic-science researcher, I want to run park-and-ride uptake assumptions using historic data so that I can fit adoption parameters to observed patterns before forecasting.		
	Acceptance Criteria:	
F-RQ-T-1 F-RQ-T-17 NF-RQ-T-4 NF-RQ-T-1 NF-RQ-T-2 NF-RQ-T-6 NF-RQ-T-7 F-RQ-T-2	Configured sites produce adoption and network analytics after a run. Invalid configurations are flagged before simulation. Results can be shared and (if authorised) published. Simulation results appear in the side analytics panel and can be expanded to a 2D view. Analytics outputs can be exported (CSV/image), and the scenario configuration is versioned. Runs support reproducibility (saved random seed and parameter set) and can be cited via a run ID.	
Components: Modelling & Simulation, Digital Twin Analytics, Map Data, GIS Data, Traffic Data, Time-series Storage, User Input Data, Field-use apps, Document Storage, Directory Services		

No: GR.43	Title: Equity/accessibility impact analysis by neighborhood under a scenario	Actor Type: Academia
Description: As a traffic-science researcher, I want to run an equity/accessibility impact analysis by neighborhood under a scenario so that I can measure distributional effects beyond averages.		
	Acceptance Criteria:	
NF-RQ-T-3	Accessibility settings apply immediately and persist.	
F-RQ-T-2	Text remains readable, and controls remain reachable across views.	
NF-RQ-T-10	Settings apply consistently in 3D, lists, and dialogues.	
NF-RQ-T-11	Simulation results appear in the side analytics panel and can be expanded to a 2D view.	
NF-RQ-T-8	Analytics outputs can be exported (CSV/image), and the scenario configuration is versioned.	
F-RQ-T-8	Runs support reproducibility (saved random seed and parameter set) and can be cited via a run ID.	
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, Directory Services, Relational Storage		

No: GR.M04 (from GR.47, GR.48)	**Title: Create geo-anchored 3D annotations on published scenarios**	**Actor Type: Public**
Description: As a citizen, I want to place geo-anchored annotations (category + message) on a specific published scenario so that I can communicate local concerns in context while preserving my privacy.		
	Acceptance Criteria:	
NF-RQ-T-1	A user can place an annotation at a chosen location with category and message text.	
NF-RQ-T-2	Annotations are associated with a specific scenario/version and appear when that scenario is viewed.	
NF-RQ-T-6	Annotations can be filtered by category and time window; authorised roles can export them.	
NF-RQ-T-7	Feedback can be submitted anonymously; no personally identifying information is required.	
NF-RQ-T-9	Users can control location precision (exact pin vs approximate area) before posting.	
F-RQ-T-2		
NF-RQ-T-10		
NF-RQ-T-11		
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, 3D Metaverse Services Engine, GIS/BIM services, User Input Data, Field-use apps, Document Storage		

No: GR.M07 (from GR.49, GR.10)	Title: See how scenarios affect my commute, including park-and-ride options	Actor Type: Public
Description: As a citizen, I want to compare before/after impacts on my typical route and see nearby park-and-ride options so that I can understand how a scenario changes my travel time, distance, and mode choices (with optional location use).		
	Acceptance Criteria:	
NF-RQ-T-5	Users can compare baseline vs scenario for a saved route (time, distance, modes) with synchronised views.	
NF-RQ-T-1	Park-and-ride options can be included in route comparison outputs when relevant sites exist.	
NF-RQ-T-2	With explicit permission, the app can use current location to show nearby impacts and suggested routes.	
NF-RQ-T-6	Location permission can be revoked, and location is not stored unless the user opts in.	
NF-RQ-T-7	Before/after views are available in 3D and summarised in the side analytics panel (expandable to 2D).	
NF-RQ-T-9	A comparison snapshot can be exported or shared.	
F-RQ-T-2		
NF-RQ-T-10		
F-RQ-T-1		
F-RQ-T-17		
NF-RQ-T-4		
F-RQ-T-7		
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, User Input Data, Field-use apps, Document Storage, Blob Storage, Simulators, Traffic Data, Time-series Storage		

No: GR.M06 (from GR.55, GR.27)	Title: Submit private feedback with acceptability scoring and geo-notes	Actor Type: Public
Description: As a citizen, I want to submit private or anonymous feedback (acceptability score, reason tags, and optional geo-notes) so that planners can quantify acceptance and improve simulations while protecting my data.		
	Acceptance Criteria:	
F-RQ-T-4	Feedback is stored with scenario ID, timestamp, and optional geo-note/area.	
F-RQ-T-3	Users can submit an acceptability score and reason tags; optional text notes are supported.	
NF-RQ-T-4	Feedback can be submitted anonymously; no personally identifying information is required.	
NF-RQ-T-1	Users can control location precision (exact pin vs approximate area) before posting.	
NF-RQ-T-2	Aggregations update and are visible on the scenario dashboard; filters by area/time are supported.	
NF-RQ-T-6	Data access is role-based; sensitive business data is not shown to the public.	
NF-RQ-T-7		
NF-RQ-T-9		
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, Traffic Data, Time-series Storage, Edge Equipment, Gateways, Semantics Transform, 3D Metaverse Services Engine, GIS/BIM services		

No: GR.56	Title: View community feedback heatmaps and top issues for a proposal	Actor Type: Public
Description: As a resident or commuter, I want to view community feedback heatmaps and top issues for a proposal so that I can see where concerns cluster and what themes dominate.		
	Acceptance Criteria:	
F-RQ-T-4	Submitted feedback is stored with scenario ID and timestamp.	
F-RQ-T-3	Aggregations update and are visible on the scenario dashboard.	
NF-RQ-T-4	Feedback can be filtered by area and time window.	
NF-RQ-T-1	Feedback can be submitted anonymously; personally, identifying information is not required.	
NF-RQ-T-2	Users can control location precision (exact pin vs approximate area) before posting.	
NF-RQ-T-6	Before/after views are available in 3D and summarised in the side analytics panel (expandable to 2D).	
NF-RQ-T-7	Incoming data is validated (schema/range checks) and time-synchronised before use in simulation.	
NF-RQ-T-9		
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, Traffic Data, Time-series Storage, Edge Equipment, Gateways, Semantics Transform		

No: GR.51	Title: Use the public interface on my mobile phone with simplified controls	Actor Type: Public
Description: As a resident or commuter, I want to use the public interface on my mobile phone with simplified controls so that I can quickly check while at work, and I can respond to touch-first UI and guided camera controls.		
	Acceptance Criteria:	
NF-RQ-T-1 NF-RQ-T-2 NF-RQ-T-6 NF-RQ-T-7 NF-RQ-T-9 F-RQ-T-2 NF-RQ-T-10 NF-RQ-T-11	On mobile, core functions (view, filter, inspect, feedback) remain usable. Touch gestures work consistently without UI conflicts. Accessibility basics (text size, contrast, tap targets) are met. The public interface is usable on mobile browsers with touch-first controls and readable labels. A lightweight mode works on limited bandwidth and loads within a reasonable time on 4G.	
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, User Input Data, Field-use apps, Document Storage		

No: GR.53	Title: Filter published proposals by neighborhood, change type, and status	Actor Type: Public
Description: As a resident or commuter, I want to filter published proposals by neighborhood, change type, and status so that I can find relevant scenarios quickly without full-map browsing.		
NF-RQ-T-1 NF-RQ-T-2 NF-RQ-T-6 NF-RQ-T-7 NF-RQ-T-9 F-RQ-T-2 NF-RQ-T-10 NF-RQ-T-11	**Acceptance Criteria:** Publishing makes the scenario visible in the public interface with metadata. Updates create a new version (no overwrite). Publish actions are audit-logged. Before/after views are available in 3D and summarised in the side analytics panel (expandable to 2D). Filters persist during the session and are easy to reset on mobile and desktop.	
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, User Input Data, Field-use apps, Document Storage		

No: GR.57	Title: Share a link to a specific viewpoint (camera + layer settings)	Actor Type: Public
Description: As a resident or commuter, I want to share a link to a specific viewpoint (camera + layer settings) so that I can send others exactly what I'm seeing for discussion.		
	Acceptance Criteria:	
NF-RQ-T-1 NF-RQ-T-2 NF-RQ-T-6 NF-RQ-T-7 NF-RQ-T-9 F-RQ-T-2 NF-RQ-T-10 NF-RQ-T-11	Opening the link restores camera and layers to the saved viewpoint. Access-denied shows a clear message without leaking details. Links remain stable or are versioned. Shared links do not expose personal data; they only include scenario/view settings.	
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, User Input Data, Field-use apps, Document Storage		

No: GR.58	Title: Accessibility mode (high contrast, larger labels, reduced motion)	Actor Type: Public
Description: As a resident or commuter, I want to run an accessibility mode (high contrast, larger labels, reduced motion) so that I can make the 3D interface usable for more citizens.		
	Acceptance Criteria:	
NF-RQ-T-1 NF-RQ-T-2 NF-RQ-T-6 NF-RQ-T-7 NF-RQ-T-3 NF-RQ-T-9 F-RQ-T-2 NF-RQ-T-10	Accessibility settings apply immediately and persist. Text remains readable and controls remain reachable across views. Settings apply consistently in 3D, lists, and dialogues. Accessibility settings persist per device and do not require account creation.	
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GISD ata, User Input Data, Field-use apps, Document Storage		

No: GR.M05 (from GR.30, GR.52)	Title: Use VR to walk through proposed changes and assess comfort/safety	Actor Type: Public
Description: As a citizen, I want to use VR to walk/drive through a proposed change so that I can assess walkability, comfort, and safety issues before it is implemented.		
	Acceptance Criteria:	
NF-RQ-T-1 NF-RQ-T-2 NF-RQ-T-6 NF-RQ-T-7 NF-RQ-T-9 F-RQ-T-2 NF-RQ-T-10 NF-RQ-T-11	In VR mode, the user can navigate and inspect the proposed change with stable performance. Critical UI remains readable (labels, legend, selection) and supports basic layer toggles. Users can flag an issue during VR walkthrough and save the location as a note/marker. Exiting VR returns to the same location and layer state in the standard 3D view.	
Components: Modeling & Simulation, Digital Twin Analytics, Map Data, GIS Data, 3D Metaverse Services Engine, GIS/BIM services, User Input Data, Field-use apps, Document Storage		

TABLE 19: THE USER STORIES –USE CASE: RENEWABLES (PV) POTENTIAL AND PERFORMANCE ANALYSIS TOOL.

This table presents the user stories developed for the Use Case – Renewables (PV) potential and performance analysis tool.

ID	Title	User Story	Acceptance Criteria -Requirements
Government			
BG-US1	Track data trends about energy use to make data-driven decisions	As a policy maker I would like to know the parameters of energy use so that I can make data-driven decisions.	1. Data Visualisation on Digital Twin Platform: a. The platform uses GIS platform to display data on the energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and trends (e.g., monthly and annually).
			2. Decision-Making Tools: a. Users can analyse the trend of energy use b. Simulations are visualised on the platform and include metrics like projected energy use.
			3.Automated data retrieval
			4. Data Export and API: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.
Academia			
BG-US2	Assess data about the energy performance of buildings in order to create better models of energy use	As a researcher, I would like to know to have better data about the energy performance of buildings in order to create better models of energy use	1. Data Visualisation on Digital Twin Platform: a. The platform uses a GIS platform to display data on the energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and predictive trends (e.g., monthly and annually).
			Simulation-Making Tools: a. Users can simulate the trend of energy use (e.g., adding/removing energy use parameters or buildings in the scope of assessment). b. Simulations and comparing them to be visualised on the platform and include metrics like projected energy use.
			3. Customising data retrieval with automated data updates to simulation tools

			4. Data Export and API: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.
Industry			
BG-US3	Assess the data about the type of energy systems and insulation to use to provide optimum thermal conditions for building occupancy based on the information for energy use and energy behavior of the buildings.	As a designer, I would like to know what type of energy systems and insulation to use to provide optimum thermal conditions for building occupancy based on the information for energy use and energy behavior of the buildings.	1. Data Visualisation on Digital Twin Platform: a. The platform uses GIS platform to display data on energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and predictive trends (e.g., monthly and annually).
			Decision-Making Tools: a. Users can simulate the trend of energy use (e.g., adding/removing energy use parameters or buildings in the scope of assessment). b. Simulations are visualised on the platform and include metrics like projected energy use.
			3.Automated data retrieval
			4. Data Export and API: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.
Citizens			
BG-US4	Assess data on the energy use to refine energy saving guidelines for citizens	As an NGO member It is important for me to have access on data on the energy use, so I can do more informed advocacy work.	1. Data Visualisation on Digital Twin Platform: a. The platform uses GIS platform to display data on energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and predictive trends (e.g., monthly and annual).
			Decision-Making Tools: a. Users can simulate the trend of energy use (e.g., adding/removing energy use parameters or buildings in the scope of assessment). b. Simulations are visualised on the platform and include metrics like projected energy use.
			3.Automated data retrieval

			4. Data Export and API: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.

TABLE 20:THE USER STORIES –USE CASE: BUILDINGS ENERGY PERFORMANCE ANALYSIS

This table presents the user stories developed for the *Use Case* – Buildings Energy Performance Analysis.

ID	Title	User Story	Acceptance Criteria -Requirements
Government			
BG-US5	Access data from the model for energy use in public properties for assess and optimisation of costs and planning the upgrades	As an officer I would like to have a good model for energy use in public properties, so I can optimize costs and plan upgrades	1.Data Visualisation on Digital Twin BIM Platform: a. The platform uses GIS and BIM platform to display data on energy use of buildings. b. Users can view historical and real-time data (e.g., heat, energy, water consumption graphs, spreadsheets, 3D visualisation of installations and dashboards of different IoT devices) and predictive trends (e.g., daily, monthly and annually).
			2. Decision-Making Tools: a. Users can simulate the trend of energy use (e.g., changing energy use parameters or building parameters in the scope of assessment). b. Simulations are visualised on the BIM/GIS platform and include metrics.
			3. Access Levels and Roles: a. Access after login. b. Public interface: citizens, public organisations, external third parties. c. Internal municipal interface - Energy manager of the Municipality, municipal officer, public policy makers of the municipality.
			4. Data Export and API: a. Users can export data (e.g., CSV, PDF, EXCEL) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.
Academia			

BG-US6	Assess data about the energy performance of buildings in order to create better models of energy use	As a researcher, I would like to have better data on the energy performance of buildings in order to create better models of energy use.	1.Data Visualisation on Digital Twin BIM Platform: a. The platform uses GIS and BIM platform to display data on energy use of buildings. b. Users can view historical and real-time data (e.g., heat, energy, water consumption graphs, spreadsheets, 3D visualisation of installations and dashboards of different IoT devices) and predictive trends (e.g., daily, monthly and annually).
			2. Simulation-Making Tools: a. Users can simulate the trend of energy use (e.g., adding/removing energy use parameters or buildings in the scope of assessment). b. Simulations and comparing to be visualised on the platform and include metrics like projected energy use.
			3.Customizing data retrieve with automated data updates to simulation tools
			4. Data Export and API: a. Users can export data (e.g., CSV, PDF, EXCEL) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.
Industry			
BG-US 7	Real-time energy, heating and cooling use and costs of the building	As a building manager I would like to know what the heating/cooling costs would be so that building visitors feel comfortable and healthy.	Data Visualisation on Digital Twin BIM Platform: a. The platform uses GIS and BIM platform to display data on energy use of buildings. b. Users can view historical and real-time data (e.g., heat, energy, water consumption graphs, spreadsheets, 3D visualisation of installations and dashboards of different IoT devices) and predictive trends (e.g., daily, monthly and annually).
			2. Decision-Making Tools: a. Must compare the energy for building comfort for the different weather conditions and building accuracy. b. Simulations for different scenarios are visualised on the BIM/GIS platform and to include these metrics.
			3. Access Levels and roles: a. Access to owned and shared buildings. b. Public interface: citizens, public organisations, external third parties.
			4. Data Export and API: a. Users can export data (e.g., CSV, PDF, EXCEL) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.
Citizens			

BG-US8	Assess energy use in private /public building	As a building user I would like to have real-time data models so that I can adjust my behaviour accordingly.	Data Visualisation on Digital Twin BIM Platform: a. The platform uses GIS and BIM platform to display data on the energy use of buildings. b. Users can view historical and real-time data (e.g., heat, energy, water consumption graphs, spreadsheets, 3D visualisation of installations and dashboards of different IoT devices) and predictive trends (e.g., daily, monthly and annually).
			2. Decision-Making Tools: a. Users can simulate the trend of energy use (e.g., changing energy use parameters or building parameters in the scope of assessment). b. Simulations are visualised on the BIM/GIS platform and include metrics.
			3. Access Levels and Roles: a. Access to owned and shared buildings. b. Public interface: citizens, public organisations, external third parties.
			4. Data Export and API: a. Users can export data (e.g., CSV, PDF, EXCEL) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.

TABLE 21:THE USER STORIES –USE CASE: BUDGET PLANNING FOR ENERGY USAGE AND BUILDINGS

This table presents the user stories developed for the *Use Case* – Budget Planning for Energy Usage and Buildings.

ID	Title	User Story	Acceptance Criteria -Requirements
Government			
BG-US9	Assess data on PV energy potential	As a policy maker, I would like to have a good model of PV uptake, so I know whether the city is meeting its goals of energy from RES	1. Data Visualisation on Digital Twin Platform: a. The platform uses GIS platform to display data on the energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and predictive trends (e.g., monthly and annual).
			2. Decision-Making Tools: a. Users can simulate the trend of energy use (e.g., adding/removing energy use parameters or buildings in the scope of assessment). b. Simulations are visualised on the platform and include metrics like projected energy use.

			3. Access Levels: a. Access after log in.
			4. Data Export: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.
Academia			
BG-US10	Assess data on PV energy potential	As a researcher, I would like to have enough rich data to do good models of RES use and performance in order to find ways to improve it.	1. Data Visualisation on Digital Twin Platform: a. The platform uses GIS platform to display data on the energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, and maps of PV installations) and predictive trends (e.g., monthly and annual).
			2. Decision-Making Tools: a. Users can simulate the trend of energy use (e.g., adding/removing energy use parameters or buildings in the scope of assessment). b. Simulations are visualised on the platform and include metrics like projected energy use.
			3. Customising data retrieval with automated data updates to simulation tools
			4. Data Export: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.
Citizens			
BG-US11	Assess data on PV energy potential	As a citizen, I would like to know how quickly I can recuperate my investment in PV so I can make more sound decisions.	1. Data Visualisation on Digital Twin Platform: a. The platform uses GIS platform to display data on energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and predictive trends (e.g., monthly and annual).
			2. Decision-Making Tools: a. Users can simulate the trend of energy use (e.g., adding/removing energy use parameters or buildings in the scope of assessment). b. Simulations are visualised on the platform and include metrics like projected energy use.

			3. Access Levels and roles: a. Access after log in. b. Public interface: citizens, public organisations, external third parties. c. Internal municipal interface - Energy manager of the Municipality, municipal officer, public policy makers of municipality.
			4. Data Export: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.

TABLE 22: THE USER STORIES –USE CASE: UHI REDUCTION. THIS TABLE PRESENTS THE USER STORIES DEVELOPED FOR THE *USE CASE – UHI REDUCTION*. THE GAPS IN THE USER STORY NUMBERING CORRESPOND TO ENTRIES THAT WERE FILTERED OUT DURING THE EVALUATION AND ASSESSMENT PROCESS.

ID	Title	User Story	Acceptance Criteria / Requirements
GOVERNMENT			
UHI-US1	Access and analyse data to make informed urban planning decisions	As an urban-planning officer, I want to access real-time and historical environmental data for new or renovated city infrastructure, So that I can make data-driven decisions to improve city infrastructure, urban living conditions and the environmental impact.	1. Data Visualisation on Digital Twin Platform: a. The platform uses TerriaMap to display city infrastructures and related information on an interactive map. b. Users can view real-time utilisation data (e.g., heat maps, graphs) and predictive models. 2. Real-Time and Historical Data: a. Real-time data is updated dynamically. b. Historical data is updated periodically. 3. Decision-Making Tools: a. Users can simulate the impact of decisions (e.g., adding/removing trees, adjusting environmental data). b. Simulations are visualised on the platform and include metrics like reduced urban heat index. 4. User Roles and Access Levels: a. Different roles (e.g., urban planners) have access to specific data and tools based on their permissions. b. Access is controlled through the platform's login functionality. 5. Data Export: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported. 6. Urban Heating Index Inputs: a. City tree stock b. Parks c. Urban planning zones d. Water bodies e. Soil sealing f. Building density g. Environmental data (air pollution, weather, wind)
UHI-US2	Configure alert zones and thresholds	As a city official, I want to configure alert zones and thresholds based on	1. Targeted relevant alerts a. Configure alert zones and thresholds based on a region's risk strategy

		my region's risk strategy, so alerts are targeted and relevant	
UHI-US7	Introducing non-traditional data sources	As a city planner or decision-maker I want to import data from external sources (e.g. telecom provider data, sensor networks, public APIs, government data) into the Digital Twin So that I can run what-if scenarios and verify whether specific measures are appropriate before implementation.	1. Data Visualisation on Digital Twin Platform: a. The platform uses TerriaMap b. Users can view real-time data (UHI, heatmaps, graphs) c. Prediction models 2. Real-Time and Historical Data: a. Real-time updates b. Historical data c. Analysis of both 3. Decision-Making Tools: a. AI algorithms b. Simulations with UHI metrics 4. User Roles & Access Levels: a. Urban planners' access b. Login control 5. Data Export: a. CSV, PDF b. Simulation export 6. Alerts and Notifications: a. Environmental alerts 7. Targeted alerts: a. Region-based configuration 8. Urban Heating Index Inputs: a. Tree stock b. Parks c. Zones d. Water bodies e. Soil sealing

			f. Density g. Environmental data
CITIZENS			
UHI-US3	View information of Urban Conditions	As a citizen, I want to be informed about the urban conditions, So that I can suggest improvements and improve my living conditions	1. Data Visualisation on Digital Twin Platform: a. The platform uses TerriaMap to display city infrastructures and related information on an interactive map. b. Users can view real-time data (e.g., UHI, heat maps, graphs) and predictive models. 2. Real-Time and Historical Data: a. Real-time data is updated dynamically. b. Historical data is updated periodically. 3. Alerts and Notifications: a. Users receive alerts for critical environmental warnings.
UHI-US9	Visualise indicators in my neighborhood	As a citizen, I want to visualise indicators in my neighbourhood through the DT So that I can adapt my behaviour	1. Data Visualisation on Digital Twin Platform: a. The platform uses TerriaMap to display city infrastructures and related information on an interactive map. b. Users can view real-time utilisation data (e.g., heatmaps, graphs) and predictive models. d. Users can view real-time data (e.g., UHI, heatmaps, graphs) and predictive models. e. The platform uses TerriaMap to display prediction models. 2. Real-Time and Historical Data: a. Real-time data is updated dynamically. b. Historical data is updated periodically. c. Collect and analyse real-time and historical data. 6. Targeted relevant alerts a. Configure alert zones and thresholds based on a region's risk strategy 7. Alerts and Notifications: a. Users receive alerts for critical environmental warnings.
UHI-US11	DT for schools	As a teacher or student, I want to observe environmental impact in real time	1. Data Visualisation on Digital Twin Platform: a. The platform uses TerriaMap to display city infrastructures and related information on an interactive map.

		So that I understand sustainable behaviour	b. Users can view real-time utilisation data (e.g., heatmaps, graphs) and predictive models. d. Users can view real-time data (e.g., UHI, heatmaps, graphs) and predictive models. f. The platform uses TerriaMap to display prediction models. 2. Real-Time and Historical Data: a. Real-time data is updated dynamically. b. Historical data is updated periodically. c. Collect and analyse real-time and historical data. 3. Decision-Making Tools: a. Users can simulate the impact of decisions (e.g., adding/removing trees, adjusting environmental data). b. Simulations are visualised on the platform and include metrics like reduced urban heat index. 4. User Roles and Access Levels: a. Different roles (e.g., urban planners) have access to specific data and tools based on their permissions. b. Access is controlled through the platform's login functionality. 5. Urban Heating Index Inputs a. City tree stock b. Parks c. Urban planning zones d. Water bodies e. Soil sealing f. Building density g. Environmental data (air pollution, weather, wind)

ACADEMIA			
UHI-US4	Use collected data to create prediction models	As a researcher, I want to analyse collected data using AI algorithms, So that I can develop prediction models	1. Data Visualisation on Digital Twin Platform: a. The platform can be used to collect data. b. The platform uses TerriaMap to display prediction models. 2. Real-Time and Historical Data: a. Collect and analyse real-time and historical data. 3. Decision-Making Tools: a. Use AI algorithms to create decision-making tools. 4. Data Export: a. Export data (e.g., CSV, PDF) for further analysis.
UHI-US12	Open Data Access	As a student or hackathon participant, I want access to DT datasets and APIs, So that I can develop applications	1. Data Visualisation on Digital Twin Platform: a. The platform uses TerriaMap to display city infrastructures and related information on an interactive map. b. Users can view real-time utilization data (e.g., heatmaps, graphs) and predictive models. d. Users can view real-time data (e.g., UHI, heatmaps, graphs) and predictive models. f. The platform uses TerriaMap to display prediction models. 2. Real-Time and Historical Data: a. Real-time data is updated dynamically. b. Historical data is updated periodically. c. Collect and analyse real-time and historical data. 3. Decision-Making Tools: a. Users can simulate the impact of decisions (e.g., adding/removing trees, adjusting environmental data). b. Simulations are visualised on the platform and include metrics like reduced urban heat index. d. Use AI algorithms to create decision-making tools. 4. User Roles and Access Levels: a. Different roles (e.g., urban planners) have access to specific data and tools based on their permissions. b. Access is controlled through the platform's login functionality. 5. Data Export: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting.

			b. Simulated data and results can also be exported for use in decision-making processes.
INDUSTRY			
UHI-US13	Security and Privacy	As a system administrator or data protection officer, I want secure data management So that users information remains protected	1. Data Protection a. Personal data (location traces, payment details) is encrypted in transit and at rest. b. Access to personal data is restricted based on user roles and permissions. 2. User Control & Transparency a. Citizens can view what personal data is collected and how it is used. b. Users can manage consent and request deletion of their personal data. 3. Compliance & Security Monitoring a. The system complies with relevant data protection regulations (e.g., GDPR). b. Security events and unauthorized access attempts are logged and monitored.
UHI-US5	Sustainable design analysis	As an engineer, I want to assess environmental impact of developments	1. The Urban Heating index can be determined using: a. City tree stock b. Parks c. Urban Planning Zones d. Water Bodies e. Soil Sealing f. Building density g. Environmental data (Air pollution, Weather, Wind)
UHI-US15	AR/VR interaction	As an architect, I want to interact with the city in AR/VR	1. Data Visualisation on Digital Twin Platform: a. The platform uses TerriaMap to display city infrastructures and related information on an interactive map. b. Users can view real-time utilization data (e.g., heatmaps, graphs) and predictive models. d. Users can view real-time data (e.g., UHI, heatmaps, graphs) and predictive models. f. The platform uses TerriaMap to display prediction models.

TABLE 23: THE USER STORIES –USE CASE: SMART PARKING

This table provide the user stories developed from the Use Case Smart Parking

User Story ID	Title	User Story	Acceptance Criteria -Requirements
GOVERNMENT			
SP-US1	Analyzing Parking Data for Informed Decision-Making	As a government official, I want to access real-time and historical parking data, including capacity, utilization, demand, pricing, and restrictions, So that I can make data-driven decisions to improve parking infrastructure and urban living condition	1. Data Visualisation on Digital Twin Platform: - The platform uses TerriaMap to display parking locations, capacity, and related information on an interactive map. - Users can view real-time utilization data (e.g., heat maps, graphs) and predictive trends (e.g., hourly, daily, weekly updates). 2. Real-Time and Historical Data: - Real-time data (e.g., current utilization) is updated dynamically. -Historical data (e.g., trends, predictive models) is updated periodically (hourly, daily, or weekly). 3. Decision-Making Tools: - Users can simulate the impact of decisions (e.g., adding/removing parking spaces, adjusting pricing tiers). - Simulations are visualised on the platform and include metrics like projected utilization, revenue, and traffic impact. 4. User Roles and Access Levels: - Different roles (e.g., urban planners, traffic managers) have access to specific data and tools based on their permissions. - Access is controlled through the platform's login functionality 5. Pricing and Restrictions: - Users can view current pricing tiers and restrictions (e.g., time limits, vehicle types) for parking spaces. 6. Data Export: - Users can export data (e.g., CSV, PDF) for further analysis or reporting. - Simulated data and results can also be exported for use in decision-making processes.

			7. Alerts and Notifications: - Users receive alerts for critical issues (e.g., overutilization, underutilization) that require immediate attention.
SP-US2	Mobile application for finding affordable parking spots	As an Administrative Officer, I want a mobile application that allows me to easily find affordable parking spots for my car every morning.	1. Traffic and Navigation The app displays live congestion levels on the map. Traffic data updates dynamically based on external API sources. The app considers real-time traffic conditions when suggesting parking spots. Parking spots with easier access are prioritized in recommendations. Users can view congestion along their route to the parking spot. Alternative parking suggestions are provided if heavy traffic is detected near the chosen spot.

SP-US3	Planning Analytics: Parking & Traffic	As a city planner, I want to view aggregated parking and traffic data over time to identify areas that need improvement or new facilities.	1. Data Visualisation on Digital Twin Platform: - The platform uses TerriaMap to display parking locations, capacity, and related information on an interactive map. - Users can view real-time utilization data (e.g., heat maps, graphs) and predictive trends (e.g., hourly, daily, weekly updates). 2. Real-Time and Historical Data: - Real-time data (e.g., current utilization) is updated dynamically. -Historical data (e.g., trends, predictive models) is updated periodically (hourly, daily, or weekly). Temporal breakdowns (daily, weekly, seasonal trends) are supported." 3. Decision-Making Tools: - Users can simulate the impact of decisions (e.g., adding/removing parking spaces, adjusting pricing tiers). - Simulations are visualised on the platform and include metrics like projected utilization, revenue, and traffic impact. 4. Pricing and Restrictions: - Users can view current pricing tiers and restrictions (e.g., time limits, vehicle types) for parking spaces. 5. Data Export & Import: - Users can export data (e.g., CSV, PDF) for further analysis or reporting. - Simulated data and results can also be exported for use in decision-making processes. Visuals and datasets are exportable for planning reports. 6. Alerts and Notifications: - Users receive alerts for critical issues (e.g., overutilization, underutilization) that require immediate attention.

SP-US4	Environmental Impact Monitor	As an environmental officer, I want to monitor how parking and traffic affect air quality and noise, so that I can propose strategies (low-emission zones, cycling promotion, pricing policies) to reduce pollution.	1. Data Visualisation on Digital Twin Platform: Congestion and search time are correlated with air and noise sensor data. Real-time dashboards show emissions-related indicators by area. 2. Decision-Making Tools: The system estimates the impact of measures (e.g., reduced parking search time leads to CO2 decrease). 3. Alerts and Notifications: Alerts are raised on pollution spikes linked to traffic incidents or special events.
SP-US5	Smart Parking Sensor Placement and Connectivity	As a city operator, I want to evaluate and optimize the placement and connectivity of smart parking sensors across the city, so that the parking system delivers reliable real-time availability information with minimal data gaps and sensor failures.	1. Sensor Monitoring and System Performance - The system visualises sensor coverage, connectivity status, and data freshness across the city map. - Areas with poor coverage, frequent data gaps, or sensor outages are clearly highlighted. - The system provides metrics such as uptime, data latency, and failure rates per sensor or zone. - City operators are alerted when sensors fall below defined performance thresholds. - The system supports scenario analysis to evaluate alternative sensor placements or network configurations. - Operators can compare current vs. proposed setups based on coverage quality and re liability.

INDUSTRY			
SP-US6	Access and analyse parking data	As a parking owner, I want to have real-time information on parking occupancy, multiple payment options and insights of parking utilization, So that I can view real-time parking availability, provide a range of payment options, and anticipate demands.	1. Data Visualisation on Digital Twin Platform: -The platform uses TerriaMap to display parking capacity, and related information on an interactive map. - Users can view real-time utilization data and predictive trends (e.g., hourly, daily, weekly updates). 2. Real-Time and Historical Data: - Real-time data (e.g., current utilization) is updated dynamically. -Historical data (e.g., trends, predictive models) is updated periodically (hourly, daily, or weekly). 3. Decision-Making Tools: -Users can simulate the impact of decisions (e.g., adding/removing parking spaces, adjusting pricing tiers). -Simulations are visualised on the platform and include metrics like projected utilization, revenue, and traffic impact. 4. User Roles and Access Levels: - Different roles (e.g., parking owners, parking operators) have access to specific data and tools based on their permissions. -Access is controlled through the platform's login functionality. 5. Pricing and Restrictions: -Users can view current pricing tiers and restrictions (e.g., time limits, vehicle types) for parking spaces. 6. Alerts and Notifications: -Users receive alerts for critical issues (e.g., overutilization, underutilization) that require immediate attention.

SP-US7	Mobile payment system integrated to the smart parking app	As an industry stakeholder, I want a seamless mobile payment system to be integrated into the smart parking solution to enhance the overall user experience.	1.Payments and transactions -The system must support the widely used payment platforms Apple Pay, Google Pa or/and PayPal, other -Users should be able to complete a parking payment via mobile app without to switch to an external browser. -The user should receive notification and receipt within 5 seconds. -If a payment fails, the user must receive a clear error message and be given the option to retry or choose another method. -All transactions must comply with the security standards -Payment details must be encrypted
SP-US8	Digital Platform for Managing Parking Spaces, Reservations, and Dynamic Pricing	As a parking employee, I want to have the capability to manage parking availability and spaces through a digital platform, providing real-time information on parking availability and reservations.	1.User Roles and Access Levels: -The parking owners could have an account where they will be able to add authorized users in different levels (Owner, manager, editor) - Owner - Access to everything (Update prices, parking spaces, see reservations, do scenarios for changing prices, statistics, finance) - Manager - Update prices, parking spaces, see reservations - Operator - can view, approve, or cancel reservations." 2.Parking Management -The platform must allow authorized users to view and update parking space status and reservations in real-time. -Users can reserve parking spaces through the platform. -Admins can define and edit parking zones (e.g. disabled, VIP) and set availability per zone. 3. Pricing and Restrictions -Admins can set, update, and schedule parking prices by: time of day, day, special events etc. -Admins can define pricing rules (e.g., first hour free). -The system supports promotion codes -Users can see accurate, real-time prices before confirming a reservation or payment. -Alerts and Notifications:

			-Admins should receive alerts for errors -Admin should receive notification for reservations
SP-US9	Metacity	As an urban planner, I want to visualise parking behaviour, congestion, and citizen movement patterns inside a 3D Metaverse representation of the city, so that I can better understand urban dynamics and test alternative planning scenarios in an immersive environment.	Data Visualisation on Digital Twin Platform: - The system displays parking usage, congestion levels, and citizen movement patterns in a 3D city environment. - Data is synchronised with real or simulated time. - Users can navigate, zoom, and filter the 3D environment by time, location, or data layer. - Key indicators (occupancy, dwell time, traffic flow) are accessible within the immersive view. 2.Decision-Making Tools: - Urban planners can simulate alternative planning scenarios (e.g., new parking zones, reduced street parking, policy changes). - The system visualises the impact of each scenario on parking behaviour and congestion
ACADEMIA			
SP-US10	Environmental and Parking Prediction Models	As an academic, I want to analyse collected data using AI algorithms, So that I can develop prediction models for parking demands, optimising space usage and availability, and sustainable solutions.	1. Data Visualisation on Digital Twin Platform: - The platform uses TerriaMap to display the prediction models. 2. Real-Time and Historical Data: -Collect and analyse real-time and historical data. 3. Decision-Making Tools: - Use AI algorithms to create decision-making tools. -The system allows simulation" 4. Data Export: - Export data (e.g., CSV, PDF) for further analysis.

SP-US11	Integration of Smart Parking DT with other Digital Twins	As a researcher, I want to connect the parking Digital Twin with other urban twins (e.g., traffic flow, public transport)	1. Data Export & import: - Data Interoperability-The system must support standardised data exchange protocols 2. Real-Time and Historical Data: - Updates data in real time 3. Decision-Making Tools The system allows simulation 3. Data Visualisation on Digital Twin Platform - The platform uses TerriaMap to display prediction models. 4. Data Export and Data Access -The API will allow researchers to synchronise data from connected twins for custom analysis.
SP-US12	Open Mobility Data	As a university student or hackathon participant, I want open access to mobility and parking data, So that I can design, develop, and test applications that solve real urban challenges.	1.Data Export and Data Access -Clear documentation and examples for data usage. -Reasonable, low-friction access for non-commercial use. -Data freshness and quality indicators for each stream or dataset. -Public API or portal for real-time and historical datasets.
SP-US13	Access to historical and real-time mobility data for transportation research	As a scientist, I want access to both historical and real-time mobility data in usable format, So that I can analyse mobility trends and train algorithms under realistic conditions.	1. Real-Time and Historical Data: -Archival datasets spanning months or years for parking, traffic, accidents, and weather. 2. Data Export & import: -Standard formats (e.g., CSV, JSON) with bulk download options. 3. Privacy, Security and Data Protection: -Proper anonymisation and ethical safeguards for all published data.

CITIZENS			
SP-US14	Find Real-Time Available Parking Nearby	As a driver, I want to see real-time available parking spots near my destination, so that I can avoid circling the area looking for parking.	1. Data Visualisation on Digital Twin Platform: -Easy navigations -The map updates within 5 seconds to reflect changes in spot availability. -The platform uses TerriaMap to display parking locations, capacity, and related information on an interactive map. 2. Traffic and Navigation -Users specify the route to the parking spot based on their criteria (price, distance, accessibility etc.) - Alternative parking suggestions are provided in case of low availability 3. Alerts and Notifications: -Receive real-time notifications if my selected parking spot becomes unavailable or gets blocked, so I can reroute quickly
SP-US15	Book a Workplace Parking Spot in Advance via Mobile App	As an employee, I want to easily find and book a parking spot near my workplace through a mobile app, so that I can save time and avoid daily parking stress.	1. Traffic and Navigation -The app will suggest available parking spots on a map in the app. 2. Parking Management -Booking option with calendar and time selection -The booking process can be completed in a few taps, with clear confirmation. -The user can cancel or modify the reservation easily from the app.
SP-US16	Get Parking Expiry Alerts	As a visitor, I want to receive notifications when my parking time is about to expire, so that I can extend it or return in time.	1. Alerts and Notifications: - Notification 10 minutes before parking time ends, even if the app is not open 2. Parking Management -The user can cancel, modify or extend the reservation easily from the app.

SP-US17	Report Parking Issues Through the App	As a citizen, I want to report issues like blocked spots or malfunctioning sensors through the app, so that parking services can improve.	1.Parking Management -The user can report an issue from the map or from the report issue option -Report an issue per type (e.g. Wrong availability, closed permanently, dirty etc.) -The user can upload photos, comment and review Follow -up option -The user can check the status (e.g., Received,In Progress, Resolved) in the app. 2.Alerts and Notifications: -The user will receive notification for submission
SP-US18	Privacy & Security in Smart Parking	As a citizen, I want my parking behavior, location traces and payment information to remain private and secure, so that I can trust the system and use it without concerns about surveillance or data misuse.	**1. Privacy, Security and Data Protection** - Personal data (location traces, parking behavior, payment details) is encrypted in transit and at rest. - Access to personal data is restricted based on user roles and permissions. - Citizens can view what personal data is collected and how it is used. - Users can manage consent and request deletion of their personal data. - The system complies with relevant data protection regulations (e.g., GDPR). - Security events and unauthorized access attempts are logged and monitored.

Requirement Analysis Tables

This section consolidates and analyses the user requirements elicited through stakeholder workshops and user stories, translating them into functional and non-functional requirements per pilot.
The mapping ensures traceability between end-user needs, ODTF architectural components (as defined in D3.2), and pilot-specific KPIs.

TABLE 24: REQUIREMENT ANALYSIS-PATRAS SMART PARKING & SMART MOBILITY

GR UC1	**Patras Smart Parking & Smart Mobility**		
Acceptance Criteria / User Needs	**User story ID**	**Stakeholders / Users**	**Functional and Non-Functional Requirements**
1. Data Visualisation on the Digital Twin Platform:	GR.1, GR.3, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.26, GR.29, GR.32, GR.33, GR.42, GR.43, GR.53, GR.56, GR.57, GR.58, GR.61, GR.M01, GR.M02, GR.M03, GR.M04, GR.M05, GR.M06, GR.M07	Government, Citizens, Academia, Business	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-8: User-friendly interface F-RQ-T-13: Showing number of handicap-accessible parking spots F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform NF-RQ-T-3: Accessibility and usability for people with disabilities NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors NF-RQ-T-9: Mobile application interface for accessing the smart parking Digital Twin F-RQ-T-19: Ability to visualise simulation outputs through a 3D city interface, side analytics panel, expandable 2D views, impacted-street maps, and real-time or historical mobility layers.
a. The platform provides 3D Digital Twin and map visualisation for mobility, parking, traffic, curb-space and scenario data.	GR.5, GR.13, GR.24, GR.29, GR.43, GR.53, GR.56, GR.57, GR.58, GR.M01, GR.M05, GR.M07	Government, Citizens, Academia, Business	
b. Simulation outputs are displayed in a side analytics panel and can be expanded into a 2D analytical view.	GR.1, GR.3, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.26, GR.29, GR.32, GR.33, GR.42, GR.43, GR.53, GR.56, GR.61, GR.M02, GR.M03, GR.M07	Government, Citizens, Academia, Business	
c. Users can view before and after visualisations for proposed mobility interventions.	GR.5, GR.6, GR.13, GR.53, GR.56, GR.M01, GR.M02, GR.M07	Government, Citizens, Business	

d. Synchronised views and layer consistency are maintained during scenario comparison.	GR.3, GR.24, GR.57, GR.M03, GR.M05, GR.M07	Government, Citizens, Academia	
e. Users can view real-time and historical mobility layers, selected time windows and data gaps.	GR.1, GR.29, GR.56, GR.61, GR.M02, GR.M04	Government, Citizens, Academia, Business	
f. Users can visualise spatial impact maps and thematic layers for affected streets, zones and routes.	GR.5, GR.13, GR.M01, GR.M07	Government, Citizens, Business	
g. The platform supports 3D annotations and geo-anchored notes on published scenarios.	GR.M04, GR.M05, GR.M06	Citizens	
2. Scenario Configuration and Simulation Tools:	GR.1, GR.3, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.26, GR.29, GR.32, GR.33, GR.42, GR.43, GR.56, GR.61, GR.M01, GR.M02, GR.M03, GR.M04, GR.M07	Government, Citizens, Academia, Business	F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-3: Ability to work across different parking systems and providers F-RQ-T-4: Ability to work with multiple parking sensor vendors F-RQ-T-8: User-friendly interface F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors NF-RQ-T-5: Predicting parking demand and optimising space usage using AI algorithms
a. Users can define scenario areas, routes, corridors, street segments and time windows.	GR.1, GR.5, GR.13, GR.56, GR.M01, GR.M02, GR.M04, GR.M07	Government, Citizens, Business	
b. Users can edit mobility infrastructure, parking supply, curb-space allocation, bike infrastructure or pedestrian space.	GR.5, GR.6, GR.13, GR.M02	Government	

c. Users can configure park-and-ride sites and adoption assumptions.	GR.9, GR.11, GR.M07	Government, Citizens, Academia	F-RQ-T-18: Ability to configure and run what-if mobility scenarios by selecting areas, streets, corridors, time windows, intervention types, and scenario parameters.
d. Users can modify compliance, detection, behavioural, pricing, service or model parameters.	GR.1, GR.11, GR.M03	Government, Academia	
e. The system validates input values, geometry, attributes and scenario configurations before simulation.	GR.5, GR.9, GR.11, GR.29, GR.56, GR.61	Government, Citizens, Academia, Business	
f. Scenarios can be saved, duplicated, reloaded and persisted as scenario configurations.	GR.1, GR.M02	Government	
g. Users can execute simulations or what-if experiments for configured mobility scenarios.	GR.1, GR.3, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.26, GR.29, GR.32, GR.33, GR.42, GR.43, GR.56, GR.61, GR.M01, GR.M02, GR.M03	Government, Citizens, Academia, Business	
3. Decision-Making and Scenario Comparison Tools:	GR.1, GR.3, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.26, GR.43, GR.53, GR.56, GR.M01, GR.M02, GR.M03, GR.M07	Government, Citizens, Academia, Business	F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-7: Ability to receive navigation instructions to available parking spots F-RQ-T-8: User-friendly interface F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform NF-RQ-T-5: Predicting parking demand and optimizing space usage using AI algorithms
a. Users can compare baseline conditions with scenario results.	GR.1, GR.3, GR.5, GR.6, GR.M01, GR.M02, GR.M07	Government, Citizens, Academia, Business	
b. Users can compare two scenarios side by side.	GR.3, GR.5, GR.24, GR.M03, GR.M07	Government, Citizens, Academia	

c. The platform provides analytics and deltas for mobility impacts, including traffic, access, adoption, utilization and network effects.	GR.1, GR.3, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.43, GR.M02, GR.M03	Government, Academia	NF-RQ-T-10: Users must uniquely authenticate with the Digital Platform NF-RQ-T-11: Digital Platform must employ Role-Based Access Controls (RBAC) for logged-in users
d. Comparison snapshots can be shared or exported.	GR.3, GR.24, GR.M07	Government, Citizens, Academia	
e. Vetted scenarios can be published to the public portal by authorized municipal users.	GR.1, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.26, GR.53, GR.M02	Government, Citizens, Academia	
f. Published proposals can be filtered and discovered by users.	GR.53, GR.56	Citizens	
g. Users can assess route, commute and park-and-ride impacts.	GR.M07	Citizens	
4. Automated Data Retrieval, Data Integration, and Data Validation:	GR.3, GR.11, GR.32, GR.33, GR.42, GR.56, GR.61, GR.M01, GR.M03, GR.M06	Citizens, Academia, Business	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-3: Ability to work across different parking systems and providers F-RQ-T-4: Ability to work with multiple parking sensor vendors F-RQ-T-6: Ability to receive notifications about parking spot availability F-RQ-T-7: Ability to receive navigation instructions to available parking spots F-RQ-T-17: Capability to manage parking availability
a. The platform supports secure ingestion of parking, sensor, business and detector feeds.	GR.56, GR.61, GR.M01	Citizens, Business	
b. Ingested data are mapped to the correct spatial locations in the Digital Twin.	GR.M01	Business	
c. Real-time status, availability and event layers update when valid feeds are connected.	GR.61, GR.M01	Business	

d. Stale or invalid data are flagged and excluded from real-time displays.	GR.61	Business	and spaces through a digital platform NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors NF-RQ-T-6: Data encryption and protection for security and privacy NF-RQ-T-7: Data must be encrypted in transit and at-rest NF-RQ-T-8: All API endpoints must employ authentication and must mandate encryption
e. Aggregations update as data arrive, including counts, trends and feedback statistics.	GR.56, GR.M01, GR.M06	Citizens, Business	
f. Incoming data are validated through schema checks, range checks and time synchronisation.	GR.56	Citizens	
g. Integrated or observed data can be used as baseline or model input.	GR.3, GR.11, GR.32, GR.33, GR.42, GR.M01, GR.M03	Academia, Business	
5. Data Export, Reporting, Versioning, and Reproducibility:	GR.1, GR.3, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.26, GR.29, GR.32, GR.33, GR.42, GR.43, GR.53, GR.57, GR.61, GR.M01, GR.M02, GR.M03, GR.M04, GR.M07	Government, Citizens, Academia, Business	F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-12: Ability to view parking history and receipts F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform NF-RQ-T-8: All API endpoints must employ authentication and must mandate encryption NF-RQ-T-10: Users must uniquely authenticate with the Digital Platform NF-RQ-T-11: Digital Platform must employ Role-Based Access Controls (RBAC) for logged-in users
a. Users can export analytics and data outputs.	GR.1, GR.3, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.26, GR.29, GR.32, GR.33, GR.42, GR.43, GR.61, GR.M01, GR.M02, GR.M03, GR.M04	Government, Citizens, Academia, Business	
b. Users can export snapshots, run summaries, annotations or ingested time series.	GR.3, GR.24, GR.32, GR.33, GR.42, GR.61, GR.M03, GR.M07	Government, Citizens, Academia, Business	
c. Scenario and run configurations are versioned.	GR.1, GR.3, GR.5, GR.6, GR.9, GR.11, GR.13, GR.24, GR.26, GR.29, GR.32, GR.33, GR.42, GR.43, GR.53, GR.57,	Government, Citizens, Academia, Business	

	GR.61, GR.M01, GR.M02, GR.M03, GR.M04		
d. Results, logs, metrics, parameters and timestamps are saved.	GR.32, GR.33, GR.42, GR.M03	Academia	
e. Simulation and calibration runs are reproducible using saved seeds and parameter sets.	GR.3, GR.11, GR.29, GR.32, GR.33, GR.42, GR.43, GR.M03	Academia	
f. Runs can be cited through a run ID.	GR.3, GR.11, GR.29, GR.32, GR.33, GR.42, GR.43, GR.M03	Academia	
g. Share links are stable or versioned and restore selected view settings.	GR.57	Citizens	
6. Access Levels, Governance, and Role-Based Control:	GR.1, GR.5, GR.6, GR.9, GR.13, GR.24, GR.26, GR.53, GR.56, GR.57, GR.61, GR.M01, GR.M02, GR.M04, GR.M06	Government, Citizens, Business	NF-RQ-T-1: Privacy-preserving mechanism to safeguard drivers' information NF-RQ-T-2: Protection of personal and financial information NF-RQ-T-6: Data encryption and protection for security and privacy NF-RQ-T-7: Data must be encrypted in-transit and at-rest NF-RQ-T-8: All API endpoints must employ authentication and must mandate encryption NF-RQ-T-10: Users must uniquely authenticate with the Digital Platform
a. Only Governance users can publish scenarios to the public portal.	GR.1, GR.5, GR.6, GR.9, GR.13, GR.24, GR.26, GR.M02	Government	
b. Publishing actions are audit-logged.	GR.1, GR.5, GR.6, GR.9, GR.13, GR.24, GR.26, GR.53, GR.M02	Government, Citizens	
c. Business-submitted scenarios remain private by default unless shared with Governance for review.	GR.61	Business	

d. Raw or sensitive data access is controlled by user role.	GR.61, GR.M01, GR.M04, GR.M06	Citizens, Business	NF-RQ-T-11: Digital Platform must employ Role-Based Access Controls (RBAC) for logged-in users
e. Public views expose only aggregated and privacy-safe analytics.	GR.57, GR.M01, GR.M04, GR.M06	Citizens, Business	
f. Access-denied messages are clear and do not leak protected details.	GR.57	Citizens	
g. Feedback dashboards and sensitive data access follow role-based access control.	GR.56, GR.M06	Citizens	
7. Public Participation, Feedback, and Consultation:	GR.56, GR.M04, GR.M05, GR.M06	Citizens	F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-8: User-friendly interface NF-RQ-T-1: Privacy-preserving mechanism to safeguard drivers' information NF-RQ-T-2: Protection of personal and financial information NF-RQ-T-6: Data encryption and protection for security and privacy NF-RQ-T-7: Data must be encrypted in-transit and at-rest NF-RQ-T-9: Mobile application interface for accessing the smart parking Digital Twin NF-RQ-T-11: Digital Platform must employ Role-Based Access Controls (RBAC) for logged-in users
a. Users can submit structured feedback, acceptability scores, reason tags and text notes.	GR.56, GR.M04, GR.M06	Citizens	
b. Feedback can be submitted anonymously and does not require personally identifying information.	GR.56, GR.M04, GR.M06	Citizens	
c. Users can control the precision of their location before posting feedback.	GR.56, GR.M04, GR.M06	Citizens	
d. Geo-notes and annotations are tied to scenario, version and location.	GR.M04, GR.M05, GR.M06	Citizens	

e. Feedback aggregations are visible on scenario dashboards.	GR.56, GR.M06	Citizens	
f. Feedback and annotations can be filtered by area, time window or category.	GR.56, GR.M04, GR.M06	Citizens	
g. Feedback heatmaps and top-issue summaries are available for published proposals.	GR.56	Citizens	
h. Citizen feedback can be used as input to scenario refinement.			
8. Public Interface, Mobile Usability, Accessibility, and VR Interaction:	GR.43, GR.51, GR.53, GR.58, GR.M05, GR.M07	Citizens, Academia	F-RQ-T-7: Ability to receive navigation instructions to available parking spots F-RQ-T-8: User-friendly interface F-RQ-T-13: Showing number of handicap-accessible parking spots NF-RQ-T-1: Privacy-preserving mechanism to safeguard drivers' information NF-RQ-T-2: Protection of personal and financial information NF-RQ-T-3: Accessibility and usability for people with disabilities NF-RQ-T-6: Data encryption and protection for security and privacy NF-RQ-T-7: Data must be encrypted in-transit and at-rest NF-RQ-T-9: Mobile application interface for accessing the smart parking Digital Twin
a. The public interface is accessible through mobile browsers and touch-first controls.	GR.51	Citizens	
b. Core public functions, including view, filter, inspect and feedback submission, remain usable on mobile.	GR.51, GR.53	Citizens	
c. Accessibility basics are met for text size, contrast and tap targets.	GR.51	Citizens	
d. Accessibility settings apply immediately, persist and are consistent across views.	GR.43, GR.58	Citizens, Academia	

e. Labels and critical UI elements remain readable in 3D and VR views.	GR.43, GR.51, GR.58, GR.M05	Citizens, Academia	F-RQ-T-20: Ability to support VR walkthroughs of proposed mobility changes, including inspection of proposed interventions and issue flagging within the 3D environment.
f. A lightweight mode supports limited bandwidth conditions.	GR.51	Citizens	
g. Users can navigate and inspect proposed changes in VR with stable performance.	GR.M05	Citizens	
h. Users can flag issues and save markers during VR walkthroughs.	GR.M05	Citizens	
i. Exiting VR returns users to the same location and layer state.	GR.M05	Citizens	
j. Location permission can be granted, revoked and used only with opt-in storage.	GR.M07	Citizens	

TABLE 25: REQUIREMENT ANALYSIS -RENEWABLES (PV) POTENTIAL AND PERFORMANCE ANALYSIS TOOL

This section consolidates and analyses the user requirements elicited through stakeholder workshops and user stories, translating them into functional and non-functional requirements per pilot.
The mapping ensures traceability between end-user needs, ODTF architectural components (as defined in D3.2), and pilot-specific KPIs.

BG-UC1			
Requirement	**User story ID**	**Stakeholders / Users**	**Functional and non-Functional Code**
1. Data Visualisation on Digital Twin Platform: a. The platform uses GIS platform to display data on energy use of buildings.	BG-US1, BG-US2, BG-US3, BG-US4	Government, Citizens, Academia, Industry	F-RQ-E-2,F-RQ-E-3, F-RQ-E-5, F-RQ-E-7, F-RQ-E-8, F-RQ-E-10, F-RQ-E-12, F-RQ-E-14, NF-RQ-E-1, NF-RQ-E-4

b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and trends (e.g., monthly and annually).			
2.Decision-Making Tools: a. Users can analyse the trend of energy use b. Simulations are visualised on the platform and include metrics like projected energy use.	BG-US1, BG-US2, BG-US3, BG-US4	Government, Citizens, Academia, Industry	F-RQ-E-1, F-RQ-E-2, F-RQ-E-3, F-RQ-E-4, F-RQ-E-6, F-RQ-E-10, F-RQ-E-12, F-RQ-E-13, F-RQ-E-14, F-RQ-E-15, NF-RQ-4
3.Automated data retrieval	BG-US1, BG-US2, BG-US3, BG-US4	Government, Citizens, Academia, Industry	F-RQ-E-2, F-RQ-E-3, F-RQ-E-6, F-RQ-E-13, F-RQ-14, NF-RQ-E-3
4. Data Export: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.	BG-US1, BG-US2, BG-US3, BG-US4	Government, Citizens, Academia, Industry	F-RQ-E-2; F-RQ-E-9; F-RQ-E-10, F-RQ-E-12, F-RQ-E-14, NF-RQ-E-3

TABLE 26: REQUIREMENT ANALYSIS -BUILDINGS ENERGY PERFORMANCE ANALYSIS

BG-UC2			
Requirement	**User story ID**	**Stakeholders / Users**	**Functional and non Functional Code**
1.Data Visualisation on Digital Twin BIM Platform: a. The platform uses GIS and BIM platform to display data on energy use of buildings. b. Users can view historical and real-time data (e.g., heat, energy, water consumption graphs, spreadsheets, 3D visualisation of	BG-US5, BG-US6, BG-US7, BG-US8	Government, Citizens, Academia, Industry	F-RQ-E-2,F-RQ-E-3, F-RQ-E-5, F-RQ-E-8, F-RQ-E-10, F-RQ-E-12, NF-RQ-E-1, NF-RQ-E-4

installations and dashboards of different IoT devices) and predictive trends (e.g., daily, monthly and annually).			
2. Decision-Making Tools: a. Users can simulate the trend of energy use (e.g., changing energy use parameters or building parameters in the scope of assessment). b. Simulations are visualised on the BIM/GIS platform and include metrics.	BG-US5, BG-US6, BG-US7, BG-US8	Government, Citizens, Academia, Industry	F-RQ-E-1, F-RQ-E-2, F-RQ-E-3, F-RQ-E-4, F-RQ-E-5, F-RQ-E-6, F-RQ-E-8, F-RQ-E-10, F-RQ-E-11, F-RQ-E-12, F-RQ-E-14, F-RQ-E-15, NF-RQ-E-1, NF-RQ-E-2, NF-RQ-E-4
3. Access Levels and roles: a. Access after log in. b. Public interface: citizens, public organisations, external third parties. c. Internal municipal interface - Energy manager of the Municipality, municipal officer, public policy makers of municipality.	BG-US5, BG-US6, BG-US7, BG-US8	Government, Citizens, Academia, Industry	F-RQ-E-2, F-RQ-E-3, F-RQ-E-6, F-RQ-E-10, F-RQ-E-13, F-RQ-E-14, F-RQ-E-15, NF-RQ-E-1, NF-RQ-E-2, NF-RQ-E-3, NF-RQ-E-4
4. Data Export: a. Users can export data (e.g., CSV, PDF, EXCEL) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.	BG-US5, BG-US6, BG-US7, BG-US8	Government, Citizens, Academia, Industry	F-RQ-E-2; F-RQ-E-8, F-RQ-E-9; F-RQ-E-10, F-RQ-E-12, F-RQ-E-14, NF-RQ-E-1, NF-RQ-E-3

TABLE 27: REQUIREMENT ANALYSIS -BUDGET PLANNING FOR ENERGY USAGE AND BUILDINGS

BG-UC3			
Requirement	**User story ID**	**Stakeholders / Users**	**Functional and Non-Functional Code**
1. Data Visualisation on Digital Twin Platform: a. The platform uses GIS platform to display data on energy use of buildings. b. Users can view historical data (e.g., heatmaps, graphs, spreadsheets, maps of PV installations) and predictive trends (e.g., monthly and annually).	BG-US9, BG-US10, BG-US11	Government, Citizens, Academia	F-RQ-E-2, F-RQ-E-3, F-RQ-E-5, F-RQ-E-7, F-RQ-E-8, F-RQ-E-10, F-RQ-E-12, NF-RQ-E-1, NF-RQ-E-4
2. Decision-Making Tools: a. Users can simulate the trend of energy use (e.g., adding/removing energy use parameters or buildings in the scope of assessment). b. Simulations are visualised on the platform and include metrics like projected energy use.	BG-US9, BG-US10, BG-US12	Government, Citizens, Academia	F-RQ-E-1, F-RQ-E-2, F-RQ-E-3, F-RQ-E-4, F-RQ-E-7, F-RQ-E-8, F-RQ-E-10, F-RQ-E-12, F-RQ-E-15, NF-RQ-E-4
3. Access Levels: a. Access after log in.	BG-US9, BG-US10, BG-US12	Government, Citizens, Academia	F-RQ-E-3, F-RQ-E-7, F-RQ-E-10, F-RQ-E-13, F-RQ-E-14, F-RQ-E-15, NF-RQ-E-1, NF-RQ-E-2, NF-RQ-E-3, NF-RQ-E-4
4. Data Export: a. Users can export data (e.g., CSV, PDF) for further analysis or reporting. b. Simulated data and results can also be exported for use in decision-making processes.	BG-US9, BG-US10, BG-US12	Government, Citizens, Academia	F-RQ-E-2, F-RQ-E-7, F-RQ-E-9; F-RQ-E-10, F-RQ-E-12, F-RQ-E-14, NF-RQ-E-3,

TABLE 28: REQUIREMENT ANALYSIS -UHI REDUCTION

This section consolidates and analyses the user requirements elicited through stakeholder workshops and user stories, translating them into functional and non-functional requirements per pilot.
The mapping ensures traceability between end-user needs, ODTF architectural components (as defined in D3.2), and pilot-specific KPIs.

UHI Reduction			
Acceptance Criteria / Requirement	**User story ID**	**Stakeholders / Users**	**Functional and non-Functional Code**
1. **Data Visualisation on Digital Twin Platform:**			F-RQ-U-1: Real-time data such as traffic, weather, and air quality; F-RQ-U-2: Access to detailed data about the city's infrastructure, including roads, buildings, and utilities F-RQ-U-3: Ability to interact with a Digital Twin of the city and make changes F-RQ-U-5: Access to future projections about the city's infrastructure, such as population growth and economic development NF-RQ-U-4: Seamless integration of remote sensing and in-situ monitoring, utilizing IoT sensors for data collection F-RQ-U-13: Data updates on weekly/monthly basis F-RQ-U-7: Ability to view the Digital Twin of the city in virtual reality or augmented reality
a. The platform uses TerriaMap to display city infrastructures and related information on an interactive map.	UHI-US1,UHI-US2,UHI-US3,UHI-US7,UHI-US9,UHI-US11,UHI-US12,UHI-US15	Government,Citizens	
b. Users can view real-time utilization data (e.g., heatmaps, graphs) and predictive models.	UHI-US1,UHI-US2,UHI-US3,UHI-US7,UHI-US9,UHI-US11,UHI-US12,UHI-US15	Government,Citizens	
e. The platform can be used to collect data.	UHI-US4	Academia	
f. The platform uses TerriaMap to display the prediction models.	UHI-US4,UHI-US7,UHI-US9,UHI-US11,UHI-US12,UHI-US15	Academia, Government, Citizens	

2. Real-Time and Historical Data:			F-RQ-U-1: Real-time data such as traffic, weather, and air quality F-RQ-U-4: Access to historical data about the city's infrastructure F-RQ-U-13: Data updates on weekly/monthly basis
a. Real-time data is updated dynamically.	UHI-US1,UHI-US2,UHI-US3,UHI-US7,UHI-US9,UHI-US11,UHI-US12	Government,Citizens	
b. Historical data is updated periodically.	UHI-US1,UHI-US2,UHI-US3,UHI-US7,UHI-US9,UHI-US11,UHI-US12	Government,Citizens	
c. Collect and analyse real-time and historical data.	UHI-US4,UHI-US7,UHI-US9,UHI-US11,UHI-US12	Academia, Government, Citizens	
3. **Decision-Making Tools:**		Government	F-RQ-U-3: Ability to interact with a Digital Twin of the city and make changes F-RQ-U-5: Access to future projections about the city's infrastructure, such as population growth and economic development F-RQ-U-19 (new): AI algorithms for decision-making and scenario simulation
a. Users can simulate the impact of decisions (e.g., adding/removing trees, adjusting environmental data).	UHI-US1,UHI-US7,UHI-US11,UHI-US12	Government	
b. Simulations are visualised on the platform and include metrics like reduced urban heat index.	UHI-US1,UHI-US7,UHI-US11,UHI-US12	Government	
d. Use AI algorithms to create decision-making tools.	UHI-US4,UHI-US7,UHI-US11,UHI-US12	Academia, Government	

4. **User Roles and Access Levels:**			NF-RQ-U-11: Users must uniquely authenticate with the Digital Platform NF-RQ-U-12: Digital Platform must employ Role-Based Access Controls (RBAC) for logged-in users
a. Different roles (e.g., urban planners) have access to specific data and tools based on their permissions.	UHI-US1,UHI-US7,UHI-US11,UHI-US12	Government	
b. Access is controlled through the platform's login functionality.	UHI-US1,UHI-US7,UHI-US11,UHI-US12	Government	
5. **Data Export:**			F-RQ-U-20 (new): Ability to export data and simulation results for reporting and analysis
a. Users can export data (e.g., CSV, PDF) for further analysis or reporting.	UHI-US1, UHI-US4,UHI-US7,UHI-US12	Government, Academia	
b. Simulated data and results can also be exported for use in decision-making processes.	UHI-US1,UHI-US7,UHI-US11,UHI-US12	Government, Academia	
6. Targeted relevant alerts			F-RQ-U-21 (new): Configuration of spatial alert zones and threshold-based notifications
a. Configure alert zones and thresholds based on a region's risk strategy	UHI-US2,UHI-US7,UHI-US9	Government,Citizens	

7. Alerts and Notification:			F-RQ-U-22 (new): Alerts and notifications for critical environmental conditions
a. Users receive alerts for critical environmental warnings.	UHI-US3, UHI-US7,UHI-US9	Citizens,Government	
8. The Urban Heating index can be determined using:			F-RQ-U-1: Real-time data such as traffic, weather, and air quality F-RQ-U-23 (new): Data input sources for UHI index calculation (tree stock, parks, water bodies, soil sealing, building density, etc.)
a. City tree stock	UHI-US1,UHI-US5,UHI-US7,UHI-US11	Industry ,Government Citizens	
b. Parks	UHI-US1,UHI-US5,UHI-US7,UHI-US11	Industry ,Government Citizens	
c. Urban Planning Zones	UHI-US1,UHI-US5,UHI-US7,UHI-US11	Industry ,Government Citizens	
d. Water Bodies	UHI-US1,UHI-US5,UHI-US7,UHI-US11	Industry ,Government Citizens	
e. Soil Sealing	UHI-US1,UHI-US5,UHI-US7,UHI-US11	Industry ,Government Citizens	
f. Building density	UHI-US1,UHI-US5,UHI-US7,UHI-US11	Industry ,Government Citizens	
g. Environmental data (Air pollution, Weather, Wind)	UHI-US1,UHI-US5,UHI-US7,UHI-US11	Industry ,Government Citizens	
9. Data Protection			NF-RQ-U-2: Security and privacy measures to protect user data
a) Personal data (location traces, payment details) is encrypted in	UHI-US13	Industry	

transit and at rest.			
b) Access to personal data is restricted based on user roles and permissions.	UHI-US13	Industry	
10.User Control & Transparency			NF-RQ-U-2: Security and privacy measures to protect user data
a. Citizens can view what personal data is collected and how it is used.	UHI-US13	Industry	
b.Users can manage consent and request deletion of their personal data.	UHI-US13	Industry	
11. Compliance & Security Monitoring			NF-RQ-U-2: Security and privacy measures to protect user data
a. The system complies with relevant data protection regulations (e.g., GDPR).	UHI-US13	Industry	
b.Security events and unauthorized access attempts are logged and monitored.	UHI-US13	Industry	

TABLE 29:REQUIREMENT ANALYSIS -SMART PARKING

Smart Parking			
Requirement	**User story ID**	**Stakeholders / Users**	**Functional and Non-Functional Code**
1. Data Visualisation on Digital Twin Platform:			F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-3: Ability to work across different parking systems and providers F-RQ-T-8: User-friendly interface
The platform uses TerriaMap to display parking locations, capacity, and related information on an interactive map.	SP-US1,SP-US3,SP-US6, SP-US14	Government, Industry,Citizens	
Users can view real-time utilization data (e.g., heatmaps, graphs) and predictive trends (e.g., hourly, daily, weekly updates).	SP-US1,SP-US3	Government, Industry	
Congestion and search time are correlated with air and noise sensor data.	SP-US4	Government	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-3: Ability to work across different parking systems and providers F-RQ-T-8: User-friendly interface NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors

Real-time dashboards show emissions-related indicators by area.	SP-US4	Government	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
The platform uses TerriaMap to display the prediction models.	SP-US10,SP-US11	Academia	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-8: User-friendly interface
Users can view real-time utilisation data and predictive trends (e.g., hourly, daily, weekly updates).	SP-US1, SP-US3, SP-US6	Government, Industry	F-RQ-T-1: Real-time information on parking availability NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
The system displays parking usage, congestion levels, and citizen movement patterns in a 3D city environment.	SP-US8	Industry	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-3: Ability to work across different parking systems and providers F-RQ-T-8: User-friendly interface NF-RQ-T-4: Real-time parking availability monitoring using IoT

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			sensors NF-RQ-T-5: AI algorithms for predicting parking demand and optimizing space usage
Data is synchronised with real or simulated time.	SP-US9	Industry	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-3: Ability to work across different parking systems and providers F-RQ-T-8: User-friendly interface NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
Users can navigate, zoom, and filter the 3D environment by time, location, or data layer.	SP-US9	Industry	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-3: Ability to work across different parking systems and providers F-RQ-T-8: User-friendly interface NF-RQ-T-4: Real-time parking

			availability monitoring using IoT sensors
User-friendly interface APP withmap withh easy navigation	SP-US14	Citizens	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-8: User-friendly interface
The map updates within 5 seconds to reflect changes in spot availability.	SP-US14	Citzens	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-8: User-friendly interface
2. Real-Time and Historical Data:			NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors F-RQ-T-13: Showing number of handicap- accessible parking spots
Real-time data (e.g., current utilization) is updated dynamically.	SP-US1,SP-US3,SP-US6	Government, Industry	F-RQ-T-1: Real-time information on parking availability NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors

Historical data (e.g., trends, predictive models) is updated periodically (hourly, daily, or weekly).	SP-US1,SP-US3,SP-US6	Government, Industry	F-RQ-T-12: Ability to view parking history and receipts F-RQ-T-18: Access to historical data about parking and traffic
Collect and analyse real-time and historical data.	SP-US10	Academia	F-RQ-T-1: Real-time information on parking availability NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
Archival datasets spanning months or years for parking, traffic, accidents, and weather	SP-US13	Academia	F-RQ-T-18: Access to historical data about parking and traffic
Data freshness and quality indicators for each stream or dataset.	SP-US12	Academia	F-RQ-T-1: Real-time information on parking availability F-RQ-T-13: Showing number of handicap- accessible parking spots NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
Temporal breakdowns (daily, weekly, seasonal trends) are supported.	SP-US3	Government	F-RQ-T-18: Access to historical data about parking and traffic
Updates data in real time	SP-US11	Academia	F-RQ-T-1: Real-time information on parking availability NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors

3 Decision-Making Tools:			NF-RQ-T-5: AI algorithms for predicting parking demand and optimizing space usage
Users can simulate the impact of decisions (e.g., adding/removing parking spaces, adjusting pricing tiers).	SP-US1,SP-US6	Government, Industry	NF-RQ-T-1: Privacy - preserving mechanism to safeguard drivers' information
Simulations are visualised on the platform and include metrics like projected utilization, revenue, and traffic impact.	SP-US1,SP-US6	Government, Industry	NF-RQ-T-6: Data encryption and protection for security and privacy
The system estimates the impact of measures (e.g., reduced parking search time leads to CO2 decrease).	SP-US4	Government	F-RQ-T-19: Estimate environmental impact of parking and traffic management strategies
The system allows simulation	SP-US10,SP-US11	Academia	F-RQ-T-20: Support simulation of parking and urban mobility scenarios
Use AI algorithms to create decision-making tools.	SP-US10	Academia	NF-RQ-T-5: AI algorithms for predicting parking demand and optimizing space usage
Urban planners can simulate alternative planning scenarios (e.g., new parking zones, reduced street parking, policy changes).	SP-US9	Industry	NF-RQ-T-5: AI algorithms for predicting parking demand and optimizing space usage
The system visualises the impact of each scenario on parking behavior and congestion.	SP-US9	Industry	NF-RQ-T-5: AI algorithms for predicting parking demand and optimizing space usage

4. User Roles and Access Levels:			F-RQ-T-13: Showing number of handicap- accessible parking spots NF-RQ-T-3: Accessibility and usability for people with disabilities
Different roles (e.g., parking owners, parking operators, urban planners, traffic managers) have access to specific data and tools based on their permissions.	SP-US1,SP-US6	Government ,Industry	F-RQ-T-21: Provide role-based access control and user management
Access is controlled through the platform's login functionality.	SP-US1,SP-US6	Government ,Industry	F-RQ-T-21: Provide role-based access control and user management
The parking owners could have an account where they will be able to add authorized users in different levels (Owner, manager, editor) - Owner - Access to everything (Update prices, parkeing spaces, see reservations, do senarios for changing prices,statistics, finance) - Manager - Update prices, parkeing spaces, see reservations - Operator - can view, approve, or cancel reservations.	SP-US8	Industry	F-RQ-T-21: Provide role-based access control and user management
Data Interoperability-The Digital Twin system must support standardized data exchange protocols	SP-US11	Academia	NF-RQ-T-10: Ensure standardized data interoperability

5. Data Export & import:			
Users can export data (e.g., CSV, PDF) for further analysis or reporting.	SP-US1,SP-US3,SP-US10	Government ,Academia	F-RQ-T-22: Ability to export data and simulation results for reporting and analysis
Simulated data and results can also be exported for use in decision-making processes.	SP-US1,SP-US3	Government	F-RQ-T-22: Ability to export data and simulation results for reporting and analysis
Visuals and datasets are exportable for planning reports.	SP-US3	Government	F-RQ-T-22: Ability to export data and simulation results for reporting and analysis
Standard formats (e.g., CSV, JSON) with bulk download options.	SP-US13	Academia	F-RQ-T-22: Ability to export data and simulation results for reporting and analysis
Public API or portal for real-time and historical datasets.	SP-US12	Academia	F-RQ-T-1: Real-time information on parking availability F-RQ-T-13: Showing number of handicap- accessible parking spots NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
The API will allow to researchers to synchronized data from connected twins for custom analysis.	SP-US12	Academia	F-RQ-T-1: Real-time information on parking availability F-RQ-T-13: Showing number of handicap- accessible parking spots NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors

Clear documentation and examples for data usage.	SP-US12	Academia	F-RQ-T-1: Real-time information on parking availability F-RQ-T-13: Showing number of handicap- accessible parking spots NF-RQ-T-1: Privacy - preserving mechanism to safeguard drivers' information NF-RQ-T-2: Protection of personal and financial information NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors NF-RQ-T-5: AI algorithms for predicting parking demand and optimizing space usage
Reasonable, low-friction access for non-commercial use.	SP-US12	Academia	F-RQ-T-1: Real-time information on parking availability F-RQ-T-13: Showing number of handicap- accessible parking spots NF-RQ-T-1: Privacy - preserving mechanism to safeguard drivers' information NF-RQ-T-2: Protection of personal and financial information NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors NF-RQ-T-5: AI algorithms for predicting parking demand and optimizing space usage

			NF-RQ-T-6: Data encryption and protection for security and privacy
Data freshness and quality indicators for each stream or dataset.	SP-US12	Academia	F-RQ-T-1: Real-time information on parking availability F-RQ-T-13: Showing number of handicap- accessible parking spots NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
The Digital Twin system must support standardized data exchange protocols	SP-US11	Academia	NF-RQ-T-10: Ensure standardized data interoperability
Archival datasets spanning months or years for parking, traffic, accidents, and weather.	SP-US13	Academia	F-RQ-T-1: Real-time information on parking availability F-RQ-T-13: Showing number of handicap- accessible parking spots NF-RQ-T-1: Privacy - preserving mechanism to safeguard drivers' information NF-RQ-T-2: Protection of personal and financial information NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors NF-RQ-T-5: AI algorithms for

			predicting parking demand and optimizing space usage NF-RQ-T-6: Data encryption and protection for security and privacy
6. Alerts and Notifications:			
Users receive alerts for critical issues (e.g., overutilization, underutilization) that require immediate attention.	SP-US1,SP-US6	Government ,Industry	F-RQ-T-23: Provide alerts and notification management for system events
Alerts are raised on pollution spikes linked to traffic incidents or special events.	SP-US4	Government	F-RQ-T-23: Provide alerts and notification management for system events
Admins should receive alerts for errors.	SP-US8	Industry	F-RQ-T-23: Provide alerts and notification management for system events
Admin should receive notification for reservations.	SP-US8	Industry	F-RQ-T-23: Provide alerts and notification management for system events
Receive real-time notifications if my selected parking spot becomes unavailable or gets blocked, so I can reroute quickly.	SP-US14	Citizens	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors

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			F-RQ-T-23: Provide alerts and notification management for system events
Notification 10 minutes before parking time ends even if the app is not open.	SP-US16	Citizens	F-RQ-T-9: Reminders about parking time expiration F-RQ-T-11: Ability to extend parking time remotely F-RQ-T-23: Provide alerts and notification management for system events
The user will receive notifcation for submition (report issue or upload image)	SP-US17	Citizens	F-RQ-T-23: Provide alerts and notification management for system events
7. Pricing and Restrictions:			
Users can view current pricing tiers and restrictions (e.g., time limits, vehicle types) for parking spaces.	SP-US1,SP-US3,SP-US6	Government ,Industry	F-RQ-T-24: Manage parking pricing, rules, promotions, and restrictions
Admins can set, update, and schedule parking prices by: time of day, day, special events etc.	SP-US8	Industry	F-RQ-T-24: Manage parking pricing, rules, promotions, and restrictions
Admins can define pricing rules (e.g., first hour free).	SP-US8	Industry	F-RQ-T-24: Manage parking pricing, rules, promotions, and restrictions
The system supports promotion codes.	SP-US8	Industry	F-RQ-T-24: Manage parking pricing, rules, promotions, and restrictions
Users can see accurate, real-time prices before confirming a reservation or payment.	SP-US8	Industry	F-RQ-T-24: Manage parking pricing, rules, promotions, and restrictions

8. Payments and transactions			
a) The system must support the widly used payment platforms Apple Pay, Google Pa or/and PayPal,other	SP-US7	Industry	F-RQ-T-5: Ability to pay using different payment methods
b) Users should be able to complete a parking payment via mobile app without to switch to an external browser.	SP-US7	Industry	NF-RQ-T-9: Mobile application interface for accessing the smart parking Digital Twin
a) The user should received notification and receipt within 5 seconds.	SP-US7	Industry	F-RQ-T-23: Provide alerts and notification management for system events
b) If a payment fails, the user must receive a clear error message and be given the option to retry or choose another method.	SP-US7	Industry	F-RQ-T-23: Provide alerts and notification management for system events
a) All transactions must comply with the security standards	SP-US7	Industry	NF-RQ-T-2: Protection of personal and financial information
b) Payment details must be encrypted	SP-US7	Industry	NF-RQ-T-2: Protection of personal and financial information
9. Traffic and Navigation			
The app displays live congestion levels on the map.	SP-US2	Government	F-RQ-T-2: Integration with other transportation and urban planning systems
Traffic data updates dynamically based on external API sources.	SP-US2	Government	F-RQ-T-2: Integration with other transportation and urban planning systems F-RQ-T-3: Ability to work across

			different parking systems and providers
The app considers real-time traffic conditions when suggesting parking spots.	SP-US2	Government	F-RQ-T-2: Integration with other transportation and urban planning systems
Parking spots with easier access are prioritised in recommendations.	SP-US2	Government	F-RQ-T-2: Integration with other transportation and urban planning systems
Users can view congestion along their route to the parking spot.	SP-US2	Government	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
Alternative parking suggestions are provided if heavy traffic is detected near the chosen spot or low availiability	SP-US2	Government	NF-RQ-T-9: Mobile application interface for accessing the smart parking Digital Twin
Users specify the route to the parking spot based on their criteria (price, distance, accessibility, etc)	SP-US14	Citizens	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
The app will suggest available parking spots on a map in the app.	SP-US15	Citizens	F-RQ-T-1: Real-time information on parking availability F-RQ-T-2: Integration with other transportation and urban planning systems NF-RQ-T-4: Real-time parking

			availability monitoring using IoT sensors
The app considers real-time traffic conditions when suggesting parking spots.	SP-US2	Government	F-RQ-T-1: Real-time information on parking availability NF-RQ-T-5: AI algorithms for predicting parking demand and optimizing space usage F-RQ-T-6: Ability to receive notifications about parking spot availability NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
Parking spots with easier access are prioritized in recommendations.	SP-US2	Government	F-RQ-T-8: User-friendly interface F-RQ-T-16: Integration of mobile payment system F-RQ-T-6: Ability to receive notifications about parking spot availability NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
10.Sensor Monitoring and System Performance			

The system visualises sensor coverage, connectivity status, and data freshness across the city map.	SP-US5	Government	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
Areas with poor coverage, frequent data gaps, or sensor outages are clearly highlighted.	SP-US5	Government	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
The system provides metrics such as uptime, data latency, and failure rates per sensor or zone.	SP-US5	Government	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
City operators are alerted when sensors fall below defined performance thresholds.	SP-US5	Government	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
- The system supports scenario analysis to evaluate alternative sensor placements or network configurations.	SP-US5	Government	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
- Operators can compare current vs. proposed setups based on coverage quality and reliability.	SP-US5	Government	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
11.Parking Management			
Admins can define and edit parking zones (e.g. disabled, VIP) and set availability per zone.	SP-US8	Industry	F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform

Reservation system for parking spaces.	SP-US8, SP-US15	Industry, Citizens	F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform
Real-time parking dashboard.	SP-US8, SP-US15	Industry, Citizens	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
Parking availability management.	SP-US8, SP-US15	Industry, Citizens	NF-RQ-T-4: Real-time parking availability monitoring using IoT sensors
Booking option with calendar and times.	SP-US8, SP-US15	Industry, Citizens	F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform
The user can cancel,modify or extend the reservation easily from the app.	SP-US16	Citizens	F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform
The platform must allow authorized users to view and update parking space status and reservations in real-time.	SP-US8	Industry	F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform
Users can reserve parking spaces through the platform.	SP-US8	Industry	F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform
Booking option with calendar and time selection.	SP-US15	Citizens	
Admins can define and edit parking zones (e.g. disabled, VIP) and set availability per zone.	SP-US8	Industry	F-RQ-T-17: Capability to manage parking availability and spaces through a digital platform
The booking process can be completed in a few taps, with clear confirmation.	SP-US15	Citizens	F-RQ-T-8: User-friendly interface

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The user can cancel or modify the reservation easily from the app.	SP-US15	Citizens	F-RQ-T-11: Ability to extend parking time remotely
The user can rerport an issue from the map or from the report issue option	SP-US17	Citizens	F-RQ-T-25: Enable issue reporting, documentation, and follow-up
Report an issue per type (eg. Wrong availiability, closed permanently, dirty etc)	SP-US17	Citizens	F-RQ-T-25: Enable issue reporting, documentation, and follow-up
The user can upload photos, comment and review	SP-US17	Citizens	F-RQ-T-25: Enable issue reporting, documentation, and follow-up
Follow -up option -The user can check the status (e.g., “Received,” “In Progress,” “Resolved”) in the app.	SP-US17	Citizens	F-RQ-T-25: Enable issue reporting, documentation, and follow-up
12. Privacy, Security and Data Protection			
Personal data (location traces, parking behavior, payment details) is encrypted in transit and at rest.	SP-US18	Citizens	NF-RQ-T-2: Protection of personal and financial information
Access to personal data is restricted based on user roles and permissions.	SP-US18	Citizens	NF-RQ-T-6: Data encryption and protection for security and privacy
Citizens can view what personal data is collected and how it is used.	SP-US18	Citizens	NF-RQ-T-1: Privacy - preserving mechanism to safeguard drivers' information
Users can manage consent and request deletion of their personal data.	SP-US18	Citizens	NF-RQ-T-2: Protection of personal and financial information

The system complies with relevant data protection regulations (e.g., GDPR).	SP-US18	Citizens	NF-RQ-T-6: Data encryption and protection for security and privacy
Security events and unauthorized access attempts are logged and monitored.	SP-US18	Citizens	NF-RQ-T-6: Data encryption and protection for security and privacy
Proper anonymisation and ethical safeguards for all published data.	SP-US13	Academia	NF-RQ-T-6: Data encryption and protection for security and privacy

ANNEX 2: GAP ANALYSIS

This section presents the Gap Analysis Tables for each cluster. The analysis is structured around three main dimensions: (i) ICT systems and communication infrastructure, assessing the technological capabilities required to support the pilot implementation; (ii) data availability and access, evaluating the availability, quality, and accessibility of the required datasets; and (iii) operational and application aspects.

Gap Analysis Table of the GR Cluster

TABLE 30: GAP ANALYSIS TABLE OF THE GR CLUSTER

ICT Systems (3.2)				Communication Infrastructure Data (3.3)	Availability and Access (3.4)		Operational and Application Gaps (3.5)			
Requirement ID	**Required Component**	**Existing Technology / ICT System**	**Level of Modification**	**Communication Infrastructure**	**Data Availability**	**Access Type**	**Identified Gap**	**Proposed Action**	**Priority**	**Feasibility**

F-RQ-T-8	**3D Metaverse Services Engine**	**PlayCanvas.JS, DTDS, Earthatile**	**requireS developme nt and integration**	**NA**	**Available**	**Open Source**	A DTDS based system maps well on the METACITIES architecture while PlayCanvas offers maturity, open source software and both powerfull and versatile capabilities in visualisation, however a Digital Twin viewer adopting these will need to be developed.	Implementati on of the Viewer will be required	High	To be addressed within the project
-	**BlobStorag e**	**MinIO**	**used as-is**	**Available**	**Available**	**Open Source**	NA	NA	Low	NA
F-RQ-T-10 **F-RQ-T-12** **F-RQ-T-17**	**Digital Twin Analytics**	**Grafana, No available calculator but Python Based Frameworks exist**	**needs to be developed**	**NA**	**Not available**	**To be develope d**	Analytics calculation will need to be developed and integrated with storage and visualisation	A custom calculator will be developed to introduce aggregate re-calculable analytics and present them through Grafana	Mediu m	To be addressed within the project
F-RQ-T-11 **NF-RQ-T-10** **NF-RQ-T-11**	**DirectoryS ervices**	**Keycloak**	**used as-is**	**Available**	**Available**	**Open Source**	NA	NA	Low	NA
F-RQ-T-17	**Document Storage**	**MongoDB**	**used as-is**	**Available**	**Available**	**Free Distribut ion**	NA	NA	Low	NA
F-RQ-T-1 **F-RQ-T-3**	**EdgeEquip ment**	**Municipal & University**	**used as-is**		**Available**	**Municip al API,**	possibility of not full access to municipal	Evaluation of availability	Mediu m	To be addressed

F-RQ-T-4 **F-RQ-T-6** **F-RQ-T-13** **NF-RQ-T-4** **NF-RQ-T-7**		**sensor equipment**		**Available, LoRa & NB-IoT Based**		**Mobility Related Local Businesses APIs, University APIs and equipment**	equipment, will implement simulated devices based on observation data when not available.	and accurate simulator development		within the project
F-RQ-T-1 **F-RQ-T-14** **NF-RQ-T-7** **NF-RQ-T-8**	**EdgeProcessors**	**Will utilise the existing infrastructure of the business actor in the pilot**	**used as-is**	**Available**	**Available**	**Local Business APIs**	NA	NA	Low	NA
F-RQ-T-2 **F-RQ-T-7** **F-RQ-T-8** **F-RQ-T-15** **NF-RQ-T-1** **NF-RQ-T-2** **NF-RQ-T-6** **NF-RQ-T-7** **NF-RQ-T-8** **NF-RQ-T-9** **NF-RQ-T-10**	**Field-useapps**	**Will need to be developed**	**needs to be developed**	**Not Available**	**Not Available**	**Not Available**	To be developed and implemented within the realisation of the activities related to the pilot	develop PWA for the pulic application used for feedback	Medium	To be addressed within the project
F-RQ-T-16 **NF-RQ-T-8**	**Gateways**	**LoRaWAN**	**used as-is**	**Available**	**Available**	**APIs from Municipal,**	NA	NA	Low	NA

						University, Businesses				
F-RQ-T-5 **F-RQ-T-7** **F-RQ-T-10**	**GIS/BIMservices**	**OSM Networks, 3D Tiles**	**needs to be developed**	**Available**	**Licensed 3D Tiles Data**	**Google 3D Tiles API**	To be developed and implemented within the realisation of the activities related to the pilot	Implementaion of the required integration	Medium	To be addressed within the project
F-RQ-T-8	**GISData**	**Google 3D Tiles**	**used as-is**	**Available**	**Licensed 3D Tiles Data**	**Google 3D Tiles API**	NA	NA	Medium	NA
F-RQ-T-8	**MapData**	**OSM**	**used as-is**	**Available**	**Free Distribution**	**OSM Sources**	NA	NA	Medium	NA
F-RQ-T-17 **NF-RQ-T-1** **NF-RQ-T-11**	**Modeling& Simulation**	**SUMO**	**require minor modifications**	**Available**	**Available**	**Open Source**	Integration with the TraCI API is needed	Integrate with the TraCI API to the metacity data and scenario manager	High	To be addressed within the project
F-RQ-T-8 **NF-RQ-T-6** **NF-RQ-T-7**	**RelationalStorage**	**MySQL**	**used as-is**	**Available**	**Available**	**Free Distribution**	NA	NA	Low	NA
F-RQ-T-4 **F-RQ-T-9** **F-RQ-T-10** **NF-RQ-T-5**	**Rule Engines**	**Not Applicable to Use Case**	**NA**	**NA**	**NA**	**NA**	NA	NA	NA	NA

F-RQ-T-5	**Semantics Transform**	**Smart Data Models, DTDS**	**require minor modifications**	**Available**	**Available**	**Open Source**	appropriate translators need to be developed	appropriate translators will be required to encode raw data to smart data models and DTDS comforming ones or generate descriptive fields when required	Medium	To be addressed within the project
F-RQ-T-6										
F-RQ-T-2	**Simulators**	**Will need to be developed**	**needs to be developed**	**NA**	**NA**	**NA**	not existing simulators for this Use Case specifically	develop device simulators where real devices not present	Medium	To be addressed within the project
F-RQ-T-1	**Time-series Storage**	**InfluxDB**	**used as-is**	**Available**	**Available**	**Free Distribution**	NA	NA	Low	NA
NF-RQ-T-2										
NF-RQ-T-6										
NF-RQ-T-7										
F-RQ-T-1	**TrafficData**	**Google Maps API**	**require minor modifications**	**Available**	**Available**	**Maps API**	Information will need to be transformed since raw traffic rates are not available from all sources	Adapter needs to be developed	High	To be addressed within the project
NF-RQ-T-6										
NF-RQ-T-7										
F-RQ-T-8	**UserInputData**	**SenseCity API for road issue reports**	**used as-is**	**Available**	**Available**	**Sense.City API**	NA	NA	Low	NA
NF-RQ-T-3										

F-RQ-T-1	**WeatherData**	**Existing Weather APIs will be used (Open meteo)**	**NA**	**NA**	**NA**	**NA**	NA	NA	NA	NA

Gap Analysis Table of the BG Cluster

TABLE 31: GAP ANALYSIS TABLE OF THE BG CLUSTER

ICT Systems (3.2)				Communication Infrastructure Data (3.3)	Availability and Access (3.4)		Operational and Application Gaps (3.5)			
Requirement ID	**Required Component**	**Existing Technology / ICT System**	**Level of Modification**	**Communication Infrastructure**	**Data Availability**	**Access Type**	**Identified Gap**	**Proposed Action**	**Priority**	**Feasibility**
F-RQ-E-1:Real-time data such as energy consumption, CO2 levels in interior spaces, consumption of electricity, water and heat, level of lighting;	**Time-series Storage (Data Storage Layer – Software):** Captures environmental metrics over time to monitor urban heat stress patterns.	Available	need to be developed	Available	Available	Municipal Data	Real data flow per case	To follow the implementation plan	High	To be addressed within the project
F-RQ-E-2: Historical data										

representing time-line; F-RQ-E-3:data updates on daily/weekly basis which appropriate;										
F-RQ-E-4: Interoperability between renewable energy sources, smart lighting, ventilation and air conditioning	**APIs, Web and Mobile (Twin client Application Layer - Software)**	Not available	need to be developed	Available	Not available	Municipal Data	In order to complete this component we need completed components regarding to analysis and simulations	Required completed components regarding to analysis and simulations	Low	To be addressed within the project

F-RQ-E-5: Public buildings and residential buildings are in the focus of interest for the city Digital Twin	**Digital Twin Analytics (Service Layer – Software):** Analyses a real-time, data-driven model of the urban environment. Provides dynamic analysis of urban indexes by using pattern models and variable input data.	Not available	need to be developed	Not available	Not available	Municipal Data	To be developed and implemented within the realisation of the activities related to the pilot	To follow the implementation plan	Medium	To be addressed within the project
F-RQ-E-6:Real-time data such as PV energy production potential, weather, and air quality;	**Time-series Storage (Data Storage Layer – Software):** Captures environmental metrics over time to monitor urban heat stress patterns.	Available	need to be developed	Available	Available	Municipal Data	Real data flow per case	To follow the implementation plan	High	To be addressed within the project
F-RQ-E-8: Ability to interact with a Digital Twin of the city and make changes	**Document Storage (Data Storage Layer – Software):**	Available	need to be developed	Available	Available	Municipal Data/Public data	Almost completed in the testing phase	Waiting for results of testing phase	High	To be addressed within the project

F-RQ-E-9: Access to future projections about the city's infrastructure, such as PV installations on the buildings, energy management data	**Modelling & Simulation (Service Layer – Software):** Models the impact of different interventions by integrating different variables**.** Based on different input data making of simulation for energy efficiency and energy consumption predictions.	Not available	need to be developed	Available	Not available	Municipal Data/Public data	To be developed and implemented within the realisation of the activities related to the pilot	To follow the implementation plan	High	To be addressed within the project
F-RQ-E-10: Compatibility with other planning tools and software used by city officials and planners	**Semantic Transform (Service Layer – Software)**	Available	complete	Available	Available	Municipal Data/Public data	Ready to be connected with other components	NA	Low	To be addressed within the project
F-RQ-E-11: Ability to view the Digital Twin	**3D Metaverse services**	Available	complete	Available	Not available	Municipal Data/Public data	Ready to be connected with other components	NA	Low	To be addressed within the project

of the city in virtual reality	**Digital Twin Analytics (Service Layer – Software)**	Not available	need to be developed	Not available	Not available	Municipal Data	To be developed and implemented within the realisation of the activities related to the pilot	To follow the implementation plan	Medium	To be addressed within the project
	Modeling & Simulation (Service Layer – Software)	Not available	need to be developed	Available	Not available	Municipal Data/Public data	To be developed and implemented within the realisation of the activities related to the pilot	To follow the implementation plan	High	To be addressed within the project
F-RQ-E-12:Real-time data such as PV energy production potential, temperature, humidity, solar exposure	**Time-series Storage (Data Storage Layer – Software):** Captures environmental metrics over time to monitor urban heat stress patterns.	Available	need to be developed	Available	Available	Municipal Data	Real data flow per case	To follow the implementation plan	High	To be addressed within the project

F-RQ-E-13: Access to detailed data about the city's infrastructure, the buildings' energy performance, buildings insulation capacity at the roof level	**Relational Storage (Data Storage Layer – Software):** Storing structured historical data from building energy systems/ devices and processing data from lidar and satellite sources.	Available	used as-is	Available	Available	Municipal Data	Ready to be connected with other components	NA	Low	To be addressed within the project
F-RQ-E-14: Ability to interact with a Digital Twin of the city and make changes										
F-RQ-E-15: Access to future projections about the city`s infrastructure, such as buildings`energy performance /consumption, energy management data	**Semantic Transform (Service Layer – Software)**	Available	complete	Available	Available	Municipal Data/Public data	Ready to be connected with other components	NA	Low	To be addressed within the project

NF-RQ-E-1: Security and privacy measures to protect user data and the data of the city	**Directory Services (Service Layer – Software)**	Available	complete	Available	Available	Municipal Data/Public data	Ready to be connected with other components	NA	Low	To be addressed within the project
	APIs, Web and Mobile (Twin client Application Layer - Software)	Not available	need to be developed	Available	Not available	Municipal Data	In order to complete this component we need completed components regarding to analysis and simulations	Required completed components regarding to analysis and simulations	Low	To be addressed within the project

NF-RQ-E-2: User-friendliness of the platform, emphasizing visual representations and ease of use	**GIS Data (Data Acquisition Layer - Software):** Implements the GIS data that provides a foundation for mapping and analysis that are energy related and used for Green and Climate adaptive resource management to visualise information, to understand patterns and relationships and 3D mapping when applicable.	Available	used as-is	Available	Available	Municipal Data	Ready to be connected with other components	NA	Low	To be addressed within the project

	Map Data (Data Acquisition Layer – Software): This component supports the visualisation of the position and status of equipment and environmental features on to a map widget based on the needs of the Use Cases.	Available	complete	Available	Available	Municipal Data	Ready to be connected with other components	NA	Low	To be addressed within the project

	GIS/BIM services (Service Layer – Software): Provides geospatial analysis and visualisation of real building parameters using 3D models and detailed information from different data sources.	Available	complete	Available	Available	Municipal Data	Ready to be connected with other components	NA	Low	To be addressed within the project
	APIs, Web and Mobile (Twin client Application Layer - Software)	Not available	need to be developed	Available	Not available	Municipal Data	In order to complete this component we need completed components regarding to analysis and simulations	Required completed components regarding to analysis and simulations	Low	To be addressed within the project

NF-RQ-E-3: Data updates on daily/weekly basis which appropriate	**Edge Equipment (Device Layer - Hardware):** Provides values from IoT Devices for near to real time tracking of environmental conditions (internal and external).	Available	complete	Available	Available	Municipal Data	In order to complete this component we need completed components regarding to analysis and simulations	Required completed components regarding to analysis and simulations	Low	To be addressed within the project
	APIs, Web and Mobile (Twin client Application Layer - Software)	Not available	need to be developed	Available	Not available	Municipal Data	In order to complete this component we need completed components regarding to analysis and simulations	Required completed components regarding to analysis and simulations	Low	To be addressed within the project
NF-RQ-E-4: Processing of recuried data flows	**Edge Equipment (Device Layer - Hardware)**	Available	complete	Available	Available	Municipal Data	In order to complete this component we need completed components regarding to analysis and simulations	Required completed components regarding to analysis and simulations	Low	To be addressed within the project

Gap Analysis Table of the CY Cluster

TABLE 32: GAP ANALYSIS OF THE CY CLUSTER

ICT Systems (3.2)			Communication Infrastructure Data (3.3)	Availability and Access (3.4)			Operational and Application Gaps		
Required Component	**Existing Technology / ICT System**	**Level of Modification**	**Communication Infrastructure**	**Data Availability**	**Access Type**	**Identified Gap**	**Proposed Action**	**Priority**	**Feasibility**
Edge Equipment (Device Layer - Hardware)	Available	Not Applicable	APIs	Available	System	Not Applicable	Gather Smart City and public data using APIs	High	Large Scale Pilot
Simulator (Device Layer - Software)	Not Available	From Scratch	Mock data	Not available	System	New Component	Mock data sources	Medium	Small Scale Pilot
Gateways (Edge Computing Layer - Hardware)	Available	Not Applicable	APIs	Available	System	Not Applicable	Gather Smart City and public data using APIs	Low	Large Scale Pilot
Edge Processors (Edge Computing Layer - Hardware)	Available	Not Applicable	APIs	Available	System	Not Applicable	Gather Smart City and public data using APIs	Low	Large Scale Pilot
User Input Data (Data Acquisition Layer - Software)	Available	Major Modifications	User	Available	User	New Component	Implement new inputs as described	High	Small Scale Pilot
GIS Data (Data Acquisition Layer - Software)	Available	No Modifications	Public data	Available	System	Existing Component	Update data	High	Small Scale Pilot

Map Data (Data Acquisition Layer - Software)	Available	No Modifications	Public data	Available	System	Existing Component	Update data	High	Small Scale Pilot
Traffic Data (Data Acquisition Layer - Software)	Available	Minor Modifications	Public data	Available	System	Existing Component	Update data	Medium	Large Scale Pilot
Environmental Data (Data Acquisition Layer – Software)	Available	Major Modifications	Public data	Available	System	Existing Component	Update data	High	Small Scale Pilot
Blob Storage (Data Storage Layer – Software)	Not Available	From Scratch	Database	Not available	System	New Component	Implement as described	Medium	Large Scale Pilot
Relational Storage (Data Storage Layer – Software)	Available	Major Modifications	Database	Available	System	Existing Component	Enhance component	High	Small Scale Pilot
Time-series Storage (Data Storage Layer – Software)	Not Available	Not Applicable	Database	Not available	System	Not Applicable	No Action	Low	Large Scale Pilot
Document Storage (Data Storage Layer – Software)	Available	Major Modifications	Database	Available	System	Existing Component	Enhance component	High	Small Scale Pilot
Modeling & Simulation (Service Layer – Software)	Not Available	From Scratch	Scenario setup and processing	Available	User/System	New Component	Implement as described	High	Small Scale Pilot
Digital Twin Analytics (Service Layer – Software)	Available	Minor Modifications	Processing	Available	System	Existing Component	Enhance component	High	Small Scale Pilot
Semantics Transform (Service Layer – Software)	Not Available	From Scratch	Processing	Available	System	New Component	Implement as described	Medium	Large Scale Pilot

GIS/BIM services (Service Layer – Software)	Available	No Modifications	Processing	Available	System	Existing Component	Enhance component	High	Small Scale Pilot
Rule Engines Guided AI/ML (Service Layer – Software)	Not Available	From Scratch	Processing	Available	System	New Component	Implement as described	Medium	Large Scale Pilot
Directory Services (Service Layer – Software)	Available	Minor Modifications	Processing	Available	System	Existing Component	Enhance component	Medium	Large Scale Pilot
Digital Twin Platform (Application Layer - Software)	Available	Minor Modifications	Presentation	Available	User	Existing Component	Enhance component	High	Small Scale Pilot
Simulation Engine (Application Layer - Software)	Not Available	From Scratch	Processing	Available	System	New Component	Implement as described	High	Small Scale Pilot
Mobile App (Application Layer - Software)	Not Available	From Scratch	Presentation	Available	User	New Component	Implement as described	Low	Large Scale Pilot