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Contact: projects@libelium.com

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D4.1 SENSE Scenarios

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Lead Partner	LIBE	Lead Author	Juan Francisco Inglés
Contributors	Imascono (incoming partner) D&S	Reviewers	Katharina Volpp (KIELM) Arnaud Verstraete (OASC) Minu Tegethoff (D&S)

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Document Information

List of Contributors	
Name	Partner
Juan Francisco Inglés	Libelium Lab
WP4 front-end team	Imascono (incoming partner)
Oscar De Leon Salas	D&S

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Executive Summary

This deliverable (D4.1) is part of the SENSE project, funded by the European Union under the Digital Europe Programme (DIGITAL). It defines the use cases selected for the pilot cities of Cartagena and Kiel and describes the foundational models and enabling technologies that will be deployed to implement them, providing the basis for subsequent design, integration, and validation activities across the pilots.

This revised version updates the implementation approach adopted for the SENSE pilot scenarios and aligns the deliverable with the consolidated set of four use cases. Following a consortium restructuring, which is being formalised through an amendment to the Grant Agreement, the project use-case set has been consolidated from six use cases to four. Three scenarios are delivered through the common WP4 front-end approach described in Sections 2 to 4, while the fourth scenario, Kiel SEALEVEL, is specified in Section 5 and is implemented through a dedicated web-based architecture led by Drees & Sommer Digital Services. All four scenarios remain browser-accessible and are integrated with the SENSE data and service fabric, while allowing implementation technologies to be selected according to the needs of each use case. The four scenarios delivered by WP4 are documented in full, covering both operational and decision-support needs and public-facing engagement experiences:

- **Cartagena Smart Urban Mobility**, focused on real-time mobility and environmental awareness and on city management workflows, delivered as a web-native management application together with a lightweight, read-only public view.
- **Cartagena Public Space**, Environment and Quality of Life, extending the mobility foundations with neighbourhood profiling, composite quality-of-life indicators, and hotspot identification to support planning and equity-oriented analysis, delivered in this revision as a management tool.
- **Kiel Hidden World**, a cultural and heritage scenario that reveals historical layers of the contemporary city through a small set of points of interest combining 3D reconstructions and before/after comparisons, using pre-produced lightweight assets and a browser-based experience.
- **Kiel SEALEVEL**, a public-facing digital extension of the physical SEALEVEL exhibition that combines three-dimensional spatial exploration with curated texts, images, recorded audio and video, and, where suitable data is available, selected environmental information. Authorised professional users manage the digital stations, scenes and associated content through a content-management backend

Across the four scenarios, the deliverable uses a common logical framing based on three core elements: (A) the user-facing application, (B) a scenario-specific service and content layer, and (C) the data and knowledge resources connected to the SENSE Data Space. The concrete implementation differs where required by the scenario. The three scenarios specified in Sections 2 to 4 use the web-native geospatial stack described in those chapters, including CesiumJS, MapLibre GL and deck.gl. The SEALEVEL scenario uses a dedicated web implementation based on Next.js and Three.js/React Three Fiber for the user experience and

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3D environment, together with Strapi and Redis for content administration and caching and the SENSE Participant Agent for access to relevant Data Space resources. Both approaches retain client-side 3D rendering and browser-based access without requiring headset-based interaction.

To make the scenarios actionable for implementation, D4.1 provides representative user journeys and interaction flows describing the expected end-to-end behaviour from user action to content or data retrieval and visual presentation. The deliverable also describes the main datasets, content resources and underlying models required by each scenario. For SEALEVEL this includes the curated exhibition content, three-dimensional scene assets, CMS-managed digital stations and optional contextual environmental data.

The development approach is organised into parallel implementation tracks. Sections 2 to 4 follow the MVP, feature-completion and quality-assurance schedule described in Section 6 for the common WP4 front-end. The SEALEVEL implementation follows the dedicated D&S delivery sequence covering onboarding, core components and demonstration, professional content-administration functionality, public-facing adaptation and operational improvement. The agreed SEALEVEL milestones and the dependencies that govern both tracks are stated in Section 6.

Co-creation and user validation are embedded in implementation. At least one facilitated session will be held in Cartagena and one in Kiel, each using a working demo of at least one local use case with residents, visitors or other non-expert users, as appropriate. Each session will document who participated, what users found useful, unclear or difficult, and the resulting project response; that evidence will guide scenario refinement and will be reported as part of pilot validation.

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1. Introduction

1.1 Purpose of the Document

This deliverable (D4.1) defines and documents the SENSE pilot scenarios to be implemented in the two frontrunner cities, Cartagena (ES) and Kiel (DE). It describes the selected use cases and the foundational models and enabling technologies that will be used to deliver them, providing a shared reference point for subsequent design, integration, and validation activities across the pilots.

More specifically, the document aims to:

- Describe the scenario context and rationale, including the relevant urban and policy setting and the expected impacts for each use case.
- Identify stakeholders and user roles (for example, municipal professionals, operators, citizens and visitors, and content curators) and relate them to realistic tasks and needs.
- Define the functional scope of each scenario as a target solution (key features, interaction patterns, and the role of the 3D twin and thematic layers).
- Provide representative user journeys and interaction flows that guide requirements and prioritisation and help validate end-to-end behaviour.
- Outline the underlying models and data sources required to support the scenario logic and visualisations, and how these connect to the SENSE Data Space and scenario services.
- Set an incremental development plan describing how prototypes will evolve into a professional-grade MVP and later feature-complete pilots.

This revision of D4.1 also documents the evolution of the implementation approach adopted for the SENSE scenarios. For the three scenarios specified in Sections 2 to 4, the initial server-rendered approach has been replaced by a web-native architecture in which geometry and data are streamed to the browser and rendered on the client. The Kiel SEALEVEL scenario is likewise delivered as a browser-based experience, but uses a dedicated implementation optimised for curated exhibition content, with a Next.js application, Three.js/React Three Fiber 3D rendering, a Strapi content-management backend and caching services connected to the SENSE Data Space through the Participant Agent. The scenarios therefore share a common SENSE logical and data-integration framework without requiring an identical frontend technology stack.

Following a consortium restructuring, which is being formalised through an amendment to the Grant Agreement, the project use-case set has been consolidated from six use cases to four. The three scenarios delivered through the common WP4 front-end are specified in Sections 2 to 4, while Section 5 specifies the fourth consolidated scenario, Kiel SEALEVEL, which is implemented through the dedicated approach described in that chapter. Section 1.3 sets out how the consolidation was reached, what it delivers, what it gives up and how the resulting

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risks are managed. Until the amendment enters into force, the Description of the Action remains the contractual reference.

1.2 Structure of the Document

This deliverable is structured as follows:

- Section 1 introduces the document, including its purpose and structure, the consolidation of the scenario set, the way in which the use cases were defined and validated, and the technical contribution of this work and its integration with the SENSE data fabric, the objectives and their indicators, the role of artificial intelligence, and exploitation, adoption and continuity.
- Section 2 describes the Cartagena Smart Urban Mobility scenario, covering context, objectives, stakeholders, functional description, user journeys, and technical foundations.
- Section 3 describes the Cartagena Public Space, Environment and Quality of Life scenario, following the same scenario template (context, objectives, roles, functionality, journeys, technical foundations).
- Section 4 describes the Kiel Hidden World scenario, following the same scenario template (cultural context, objectives, stakeholders, functional description, user journeys, and technical foundations).
- Section 5 describes the Kiel SEALEVEL scenario, a public-facing digital extension of the physical SEALEVEL exhibition combining three-dimensional exploration, curated multimedia content and CMS-based content management, with optional environmental information provided through the SENSE data infrastructure where suitable data is available.
- Section 6 presents the development plan, outlining the phased approach from the MVP through feature completion to testing, quality assurance, and documentation.
- Section 7 concludes the deliverable and summarises the main outcomes and next steps implied by the scenario definitions.

1.3 Consolidation of the scenario set

The SENSE Grant Agreement described six use cases, defined in the Description of the Action and detailed at the project kick-off in February 2025: Cultural and Environmental, Societal Preparedness and Infrastructure Resilience, Historical and Technological, Fostering Community Engagement, Citizen Participation, and Smart Urban Mobility. That set has since been consolidated into four use cases, two in Cartagena and two in Kiel. The consolidation is being formalised through an amendment to the Grant Agreement. This section explains how the consolidation was reached, what it delivers, what it gives up, and how the resulting risks are managed.

How the four were formed. The reduction from six to four use cases resulted from a refocusing of the pilot scope around the type of experience to be demonstrated in each

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frontrunner city, while concentrating the available implementation effort on a smaller and more coherent set of scenarios. In Cartagena, the revised scope places greater emphasis on digital-twin-oriented applications, bringing together urban data, three-dimensional visualisation and decision-support capabilities for municipal professionals and, where applicable, citizens. In Kiel, the revised scope places greater emphasis on immersive and experience-oriented applications, with the selected scenarios focusing on cultural and historical exploration and on the digital extension of the SEALEVEL experience. The consolidation should therefore not be understood as a strict one-to-one merger of specific original use cases, but rather as a prioritisation and reorganisation of their main themes and objectives into four implementable scenarios. The resulting set comprises Smart Urban Mobility and Public Space, Environment and Quality of Life in Cartagena, and Hidden World and SEALEVEL in Kiel.

What the consolidation delivers. Four benefits, in order of weight. First, depth over breadth: each remaining use case can be specified, built and validated to an operational standard rather than demonstrated, which is what the project needs in order to be replicated by other cities. Second, a genuinely common technical base: the scenarios delivered here sit on the common technical framing described in this deliverable, built around the SENSE User Application, the Scenario Service Layer, and the Data and Knowledge Layer, rather than on separate applications, so effort spent on any one of them improves all of them, and that same framing is what follower cities receive. Third, the ability to incorporate generative production techniques that were not available when the original set was written, together with the analytical capabilities that the orchestration layer makes available as directions for a later phase, which the reassessment identified as a higher-value use of the remaining effort than an additional scenario. Fourth, a clearer division of responsibility, with a single partner accountable for the delivery of each use case.

Scope consolidation and implementation refocusing. The revised deliverable reflects adjustments resulting from changes in consortium capabilities and project priorities. The scenarios are delivered as browser-based 3D experiences accessible on standard devices, broadening access beyond headset-dependent virtual or augmented reality experiences. Gamification, engagement and game-theory considerations are integrated within scenario narratives, interaction design and validation instead of being reported as a standalone analysis. The thematic scope is consolidated from six subject areas into four municipal domains, concentrating delivery effort on a focused and implementable set while retaining engagement and narrative objectives within the scenarios.

Risks to impact, and how they are managed. The principal risk is to reach rather than to delivery. A smaller set of use cases addresses fewer municipal domains, which bears on the project indicator concerned with the diversity of use cases addressed. Three mitigations apply. The four use cases retained cover urban mobility, public space and social cohesion, cultural heritage, and coastal and environmental resilience, so the domains most relevant to the participating cities remain represented. Because the scenarios are built on one common technical framing rather than on separate applications, a follower city adopting that framing can configure an additional domain without new development, which converts thematic breadth from a delivery commitment into a replication property. And the shift to browser-based delivery removes the device barrier that immersive interfaces impose, so each remaining use case is reachable by a larger audience than any of the original six would have been, which offsets the

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reduction in number with an increase in the population that can be reached. A second risk is that removing the immersive components weakens the distinctiveness of the offer; this is addressed by the accuracy and provenance of the three-dimensional content itself, and by the data foundations behind it, rather than by the interface. It is also the reading the Description of the Action sets out, where interconnected virtual worlds, virtual and augmented reality and immersive environments are described as means used to achieve the objectives of the action rather than as the objectives themselves.

1.4 How the use cases were defined and validated

This section records how the four use cases were defined and how they have been validated since. The use cases were defined with the two frontrunner cities, which are beneficiaries of the project, and were detailed with them in structured sessions at the project kick-off. Validation then broadened beyond the partners: internal alignment and stakeholder mapping up to the end of 2025 were followed by the external sessions described below from February 2026 onwards. Co-creation continues through the definition sessions with the cities, the review of content and narrative with Kiel's local guides, and facilitated user validation during implementation. At least one working demo of a local use case will be tested with users in Cartagena and at least one in Kiel. Participants' feedback and the corresponding project response will be recorded, used to refine the scenarios and reported against the engagement and co-creation indicators in Section 1.6.

Definition. The initial set was detailed in facilitated sessions at the project kick-off in Kiel in February 2025, using a common template. Four completed templates covering the six use cases are held in the project repository, all dated 12 February 2025. The template captured the rationale, the intended activity, the resources and methods required, the barriers foreseen, the expected results and their impact, the technical prerequisites, the stakeholders to involve, the standards to apply, the route to replication in follower cities, and the next steps in four-week increments. One of the four entries records its participants by name and organisation, covering the coordinator, the City of Kiel and the strategic and technical partners; the other three do not record who took part. The completed templates are the origin of the scenario definitions carried into this deliverable in two ways. The barriers they identified, among them data protection requirements, technology adoption and the long-term funding of maintenance, are the origin of several of the constraints stated in the sections that follow. And the questions they left open, in particular the need to specify outputs and target groups more precisely, are part of what the specification work in this deliverable answers.

Validation in Cartagena. Five sessions were held between February and March 2026. Two on 24 February introduced the project and the Cartagena use cases to municipal technical staff. Two further sessions on 27 February broadened the audience to include the Polytechnic University of Cartagena and CETENMA, the regional technology centre for energy and the environment. A fifth session on 18 March presented the project and both cities' use cases to elected members of the municipal government, with particular attention to municipal governance. Attendance and photographic documentation are held in the project repository. These sessions established the institutional basis and gathered initial reactions. The next sequence deliberately broadens participation beyond institutional partners: it includes a

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facilitated working-demo session for residents and the wider public through the local development and employment agency, engagement with university users at the start of the academic year, sessions with additional municipal departments, and two online sessions in English. The public session will use at least one Cartagena use case to collect structured feedback on usefulness, clarity and usability, with the feedback and project response documented.

Validation in Kiel. For Hidden World, a meeting was held on 10 February 2026 with the manager of a city hotel to test the concept and the choice of points of interest, and a workshop on 24 April 2026 with Kiel-Marketing's local guides used a working prototype to gather feedback on the most compelling points of interest, routes and themes. Section 4 sets the number and type of curated points of interest; the production team selects them from available archival material, and Kiel-Marketing and the municipal heritage stakeholders validate historical accuracy. The city also ran a wider programme of validation for the coastal use case: three focus groups in May 2026; two questionnaire-based surveys with 35 and 24 participants covering residents, students, researchers, non-governmental organisations, businesses, tourists and public authorities; a session with 17 representatives of eight Baltic coastal municipalities and two federal states; and a workshop at a regional information technology fair. The findings inform the SEALEVEL specification in Section 5, especially simple visual communication, browser and mobile access, curated content, maintainability and preservation of exhibition material. During implementation, at least one further facilitated Kiel session will allow residents, visitors or other non-expert users to try a working Hidden World or SEALEVEL demo; accessibility, comprehension, relevance and user preferences will be recorded together with the resulting project response.

What the feedback confirmed and what it changed. The most consequential single comment came from the Kiel hotel manager, who advised against building a stand-alone application and recommended integrating the experience into surfaces people already use. That corroborates the delivery model adopted in this revision, in which the scenarios run in an ordinary browser and can be embedded in existing municipal and tourism channels rather than requiring an install. The survey findings point the same way and are reflected in specific commitments: a simple, visual and mobile-capable citizen view; plain language for non-expert readers; improved navigation and accessibility, addressed through the design guidance in this deliverable; historical data and the ability to compare change over time, addressed by the time control and the before/after comparison; and the validation and moderation of user-contributed material, addressed by the conditions that Section 6 attaches to it, since user-contributed material is not collected in this revision. Participants also raised the question of who maintains the tools after the project, which is one of the reasons the revised approach avoids a rendering infrastructure that would carry a recurring cost for each additional user.

Not every design decision recorded in this deliverable originated in these sessions; several were taken earlier on grounds of scope and cost. Where that is the case the feedback served to confirm the decision rather than to prompt it, and this section distinguishes the two so that the evidence is read for what it is.

Who the end users are. The stakeholder sections of each chapter list the groups involved. Stated as end users, and separated by what each one needs and by the decision each one

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takes, they are four. Municipal professionals in mobility, environment, planning and social services use the management views to see a situation they currently reconstruct from separate systems, and the decision they take is operational or budgetary: whether to activate an event configuration, where to place a small intervention, which area to prioritise. They work from a named account, in a small team, and they need the figures to be traceable to the source, because the decision has to be justified to someone else. Residents use the public views to understand a rule that affects them or a change in their neighbourhood, and the decision they take is personal and immediate: which route to take, whether a restriction applies to them today. They arrive without an account, often from a phone, and they need plain language and no prior knowledge. Visitors use the cultural experience during a short stay, and the decision they take is what to see in the time they have. They arrive from a link or a code, in a language that is not the local one, and they need the content to work without installing anything. Cultural and tourism professionals in Kiel bring and validate content, and the decision they take is editorial: which story is told and whether a reconstruction is faithful to the sources.

These four groups are not addressed to the same degree in this revision. The management views for municipal professionals, and the cultural experience for the visitors and residents of Kiel, are the groups this revision addresses within the scope stated at the start of each chapter. The resident side in Cartagena is delivered as a consultation view in the mobility scenario and depends on the deferred public portal in the public space scenario. That difference is stated here rather than left to be inferred, because the reach of the scenarios follows from it.

1.5 Technical contribution and integration with the SENSE data fabric

This section states how the scenarios connect to the data and service fabric built in the rest of the project, which standards that connection rests on, what is reused from the European framework for local digital twins, and what this work contributes that the underlying open-source components do not provide on their own.

The three-component framing used throughout this deliverable is a logical architecture rather than a requirement to use one identical technology stack in every scenario. Sections 2 to 4 share the web-native geospatial implementation developed for the common WP4 front-end. SEALEVEL follows the same separation between user application, scenario/content services and governed data access, but implements those functions with technologies selected for an exhibition-oriented experience: Next.js and Three.js/React Three Fiber in the browser, Strapi as the content-management and API layer, Redis/local caching for performance, and the SENSE Participant Agent as the integration point with the Data Space.

Integration with the WP2 and WP3 data fabric. The scenarios are not built on data collected for them. They consume the fabric established in WP2 and WP3: the city sources are onboarded, described and published in the SENSE Data Space catalogue, and the scenarios read from that catalogue rather than from bespoke extracts. For Cartagena this is already operational. Six near-real-time services covering air quality, weather, noise, traffic flow, crowd flow and parking are exposed through the FIWARE Orion Context Broker in NGSIv2 using FIWARE Smart Data Models, and together they aggregate 109 municipal sensors; alongside them, three static packages hold the city geospatial layers, the curated media and the socio-economic indicators. These are the Cartagena datasets listed for each scenario in Sections

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2.7.3 and 3.7.2. Four of them, namely air quality, noise, parking and weather, are already published with their terms and conditions in the project data space environment, so that access conditions travel with the data instead of being negotiated separately for each application, and further sources can be onboarded through the project onboarding process without any partner deploying infrastructure of its own. The remaining sources listed in Sections 2.7.3, 3.7.2 and 4.7.2, among them the static packages, are not yet published with their terms and conditions and follow the same onboarding process.

Data access, governance and federation. Access to data is federated rather than based on the centralisation of all source information in a single application repository. Each city and data provider retains ownership and operation of its own sources and publishes their descriptions and access conditions through the SENSE Data Space. The scenarios consume these resources through the integration mechanisms provided by the project, while scenario-specific service layers may process, transform or cache the information required for efficient delivery to the user application.

For the scenarios implemented through the common WP4 front-end, data is generally accessed through the SENSE Data Space connectors when it is required by the application. Where a scenario needs historical information, pre-computed indicators or derived results, these may be maintained as versioned thematic layers in the Data and Knowledge Layer rather than as independent copies of the municipal source systems. The SEALEVEL scenario follows the same governance principle but uses a slightly different technical pattern: relevant content and data can be retrieved through the SENSE Participant Agent by the scenario backend and managed through the Strapi content-management layer, with local and Redis-based caching used where appropriate to support efficient delivery to the public-facing application. This implementation difference does not change the governance conditions attached to the original source.

Open data is consumed under the conditions defined by the corresponding data provider. In Cartagena, this includes information available through municipal and national sources, such as the city geoportal and cartographic, orthophoto and terrain resources of the Instituto Geográfico Nacional, as well as the municipal data services integrated into the SENSE Data Space. For Kiel, relevant open and municipal resources include the available city geodata, building models, base maps, points of interest and other content made accessible through regional or municipal channels. In the case of SEALEVEL, exhibition-related material and any environmental information incorporated into the experience are accessed through the mechanisms agreed within the project and are subject to the availability, format and usage conditions of the corresponding source.

Where a source is subject to access restrictions, licensing conditions or other usage requirements, these conditions remain associated with the data and must be respected by the scenario services that consume it. The Scenario Service Layer, or the equivalent scenario-specific backend, is responsible for ensuring that information exposed to the user application is consistent with the applicable access conditions. In SEALEVEL, for example, the public-facing application accesses approved content through the CMS and does not require direct access to the underlying SENSE Data Space services.

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The scenarios are designed, as far as possible, to avoid unnecessary dependencies on data sources that are not under the control of the project partners. Core functionality is therefore based on sources and content that can reasonably be made available within the project framework, while additional municipal, operator, scientific or institutional sources can be incorporated as enrichment where they are available and their conditions permit their use. If an optional source is unavailable, the corresponding layer or information element can be omitted without affecting the remaining functionality of the scenario. For content that forms part of the core experience, such as the curated SEALEVEL exhibition material, availability and access through the agreed project mechanisms remain an implementation dependency and are addressed as part of the corresponding scenario delivery.

Semantics and standards. Interoperability is carried through the data models, access mechanisms and open exchange formats rather than through a mandatory rendering library. Context data in the common WP4 front-end follows FIWARE Smart Data Models in NGSIv2, with NGSI-LD available through the SENSE Data Space where linked-data semantics are required. Geometry in those scenarios uses standards such as OGC 3D Tiles, glTF and CityJSON. The SEALEVEL implementation primarily uses web-optimised glTF/GLB assets for its three-dimensional scenes and consumes structured content and, where available, environmental information through the Participant Agent and the scenario backend. This allows both implementation tracks to remain connected to the same SENSE data-governance framework while using formats appropriate to their respective user experience.

Alignment with the Minimal Interoperability Mechanisms. The Cartagena platform already adheres to MIM1, MIM2 and MIM6, as noted in Section 2.2. Two further mechanisms of that framework, as set out in the MIMs Plus specification, bear directly on the work specified in this deliverable and are adopted as its reference. MIM7, Geospatial Data, covers the geospatial dimension: it connects geospatial data, two- and three-dimensional representations, GIS and BIM resources, CityGML-compatible and OGC-compatible assets, and the persistent identifiers and coordinate reference systems that keep those assets joinable, which is precisely the interface between the city data and the scenarios. MIM8, Local Digital Twins, provides the basis for connecting data, models, simulations, visualisations and decision-support flows into a single operational whole. It should be said plainly that MIM8 does not by itself describe a CitiVerse: it already places visualisation, virtual reality included, among the functionalities of a local digital twin, but a CitiVerse adds multi-user environments on top of that, and that additional layer is part of what this project contributes to rather than something it can inherit from an existing mechanism. What this revision delivers towards that additional layer is the ground it rests on: a three-dimensional city environment that runs in an ordinary browser, on devices people already have, and that a municipal team can open from a link and pass to a colleague with the view it was left in. What it does not deliver is headset-based interaction, simulation, or real-time shared sessions between users, for the reasons set out in Section 1.3. The annotation of a shared view by professional users is described in the scenario chapters as the increment that follows this revision.

Reuse of the European framework for local digital twins. The EU Local Digital Twins (LDT) Toolbox is used in two directions. As a source, the project takes from it the standards-based approach described above, so that the scenarios are assembled from interoperable building blocks rather than from a bespoke stack: open geospatial formats, context information

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management, catalogue-based publication, and the alignment with the Minimal Interoperability Mechanisms just set out. As a destination, the project produces assets intended to re-enter that ecosystem: the scenario configuration templates, the client-side rendering profile with its levels of detail and scene budgets, selected objects of the city model published with data space metadata descriptions so that they can be discovered and reused, where the licence of the source material allows it, the content production pipeline for heritage reconstruction with documented provenance, and the onboarding checklists for new data sources. Those artefacts are how a follower city adopts a scenario without repeating the development, and they are the practical form that replicability takes in this project. There is no runtime dependency on the Toolbox itself: it is a catalogue of building blocks and guidance rather than a service in execution, so nothing in the scenarios calls it at request time. The runtime integration that does exist is internal and is the one described above, in which the scenarios resolve data through the data-space connectors at the moment of the request and the Scenario Service Layer exposes scenario logic, content orchestration and model results as endpoints that the client consumes.

What is distinctive in this contribution. The rendering libraries used here are open source and this project claims no credit for them, so the question of what the work adds beyond them deserves a direct answer. The value-added sits in five places. First, the mapping of heterogeneous municipal sources onto one scenario model, which is what allows a single interface to serve two cities with different data maturity, different languages and different priorities. Second, the Scenario Service Layer, which turns context data into decision-ready views by applying scenario rules, access rights and indicator composition, none of which a rendering library provides. Third, governed access through the data space, so that a scenario can use a restricted source under recorded conditions instead of requiring an unrestricted copy of it. Fourth, the three-dimensional content itself, including the heritage reconstructions whose accuracy is validated with the relevant cultural and municipal stakeholders and whose interpretative parts are labelled as such. Fifth, the engineering that keeps all this usable on an ordinary device and without a rendering farm, which is the difference between a demonstrator and something a city can operate once the project has ended.

What each scenario contributes that the others do not. Smart Urban Mobility contributes the integration pattern for near-real-time municipal streams, bringing multiple operational datasets and the rules of a regulated zone into a common management and consultation environment. Public Space, Environment and Quality of Life contributes the composite-indicator method, bringing heterogeneous zonal data onto a comparable base while keeping the drivers of each result visible. Hidden World contributes a heritage-production pipeline that turns archival sources into lightweight, labelled three-dimensional or comparative content suitable for browser delivery. SEALEVEL contributes a content-driven 3D exhibition pattern: three-dimensional scenes are combined with CMS-managed digital stations, multimedia learning content and optional Data Space information, allowing authorised city teams to update the public experience without requiring a software change for every content revision. Together these four patterns provide complementary building blocks for replication in other cities.

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1.6 Objectives, indicators and evaluation

The objectives of each use case are stated in Sections 2.3, 3.3, 4.3 and 5.3. This section is what makes them SMART: specific to a named scenario, measurable through the key performance indicators below, achievable within the resources available for the WP4 front-end, relevant to the project indicator families, and time-bound to the reporting periods in which they are counted. It sets out the indicator families they answer to, how each indicator is counted, and the minimum and the ambitious target for each. Nothing here introduces a new objective, and nothing here requires measurement that the scenarios do not already produce.

The indicator families. The project carries four families, and every use case objective answers to at least one of them: the increase of users, covering citizens, enterprises, cities, regions and communities; the diversity of use cases addressed; the expansion of local digital twins; and interoperability and openness, which carries a target of a twenty per cent increase in the adoption of standardised data formats and interfaces compatible with the MIM-Plus framework.

Where the reach target sits, and why it is not allocated here. The project target of engaged users derives from the residents and visitors of the two frontrunner cities and is stated in the Grant Agreement, together with the assumption behind it. An engaged user is defined across the project as a person who has seen information about the project, counted by number of views, which is the lowest rung of a continuum whose upper levels are interaction and collaboration. That figure is a project-level target, and this deliverable does not divide it between use cases, for three reasons worth stating. A person reached by both scenarios of the same city counts once at project level, so per-scenario figures are not additive. The target also covers audiences reached by other partners and by the dissemination and communication activities, which are not delivered by the scenarios specified here. And this revision does not add usage instrumentation to the scenarios: the front-end records no identifiers and no per-user behaviour, which is consistent with the data protection commitments stated in this deliverable, so views are counted through the channels the project already measures centrally rather than through instrumentation added to the scenarios. What the scenarios commit to is what they deliver and what that makes possible, which is what the indicators below state.

Indicators for the mobility scenario. For the visibility of rules and conditions (O1), the indicator is the regulated zone and its rules rendered and explained in the interface, together with the number of near-real-time thematic layers available from the sources listed in Section 2.7.3: the minimum is the regulated zone and the environmental layers already published with their terms and conditions, and the ambitious target is the full set of layers listed there. For informed mobility choices (O2), the indicator is the public consultation view published with the regulated zone and the available indicators legible and explained: the minimum is that view published in Spanish, and the ambitious target is the same view in both languages stated in the scope of that chapter. The comparison of route options depends on the deferred routing components, so the ranking of routes lies outside this revision and no target is set for it. For operational support (O3), the indicator is the number of municipal departments with at least one active account and the number of predefined event configurations available: the minimum is one department and one configuration, and the ambitious target is three departments and a configuration for each recurring event type the city identifies. For evidence-based planning and

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evaluation (O4), the indicator is the number of analyses that the city reports having produced with the tool and used in an internal process: the minimum is one, and the ambitious target is one per municipal service involved. The prior testing of policy scenarios depends on a simulation capability that this revision does not expose, so no target is set for it. For engagement and behaviour change (O5), the immediate feedback on the effect of a choice depends on the deferred routing components, so this revision addresses the objective through the legibility of the zone, its rules and the available indicators: the minimum is the zone and its rules explained in the public view, and the ambitious target adds the environmental indicators presented alongside them.

Indicators for the public space scenario. For the integrated visibility of conditions and inequalities (O1), the indicator is the number of indicator families rendered at zone level, which is four: socio-economic, public space, environmental exposure and proximity to services. The minimum is those four for the most recent year published by each source, and the ambitious target adds comparison across years for the families whose sources publish a series. For planning and investment decisions (O2), the indicator is the composite index delivered with its drivers exposed and the side-by-side comparison of two areas, together with the number of analyses the city reports having used to support a proposal: the minimum is one such analysis, and the ambitious target is one per district reviewed in the period. For support to social services and community programmes (O4), the indicator is documented use by a social services team: the minimum is one documented use, and the ambitious target is one per team involved. For transparency and citizen understanding (O3) and for citizen engagement and co-creation (O5), the professional visualisation and its outputs are used as input to facilitated citizen and stakeholder validation. The indicator is documented participation by residents or community organisations in at least one validation activity using SENSE visualisations, together with recorded feedback on the interpretation of indicators and/or local priorities and a record of the resulting project response. The minimum is one such activity in Cartagena; the ambitious target is one activity for each relevant audience identified in Section 1.4.

Indicators for the cultural scenario. For the visibility and accessibility of heritage (O1), the indicator is the number of points of interest published with content in German and English: the minimum is two, one with a three-dimensional reconstruction and one with a before-and-after comparison, and the ambitious target is the five specified in that chapter. The minimum is set at two because publication depends on archive material and image rights being confirmed. A point of interest published in English ahead of review of its German text counts once that review is added. For informed and meaningful cultural experiences (O2), the indicator is the narrative content delivered for each published point of interest: the minimum is a caption and short narrative for every point published, and the ambitious target adds grouping by theme and simple curator-defined route configuration; automatic route composition remains part of the deferred guided-tour platform. For community engagement and co-creation (O3), the indicators are documented sessions in which local guides, cultural organisations or municipal heritage stakeholders review content or narrative, and at least one pilot try-out with non-expert residents or visitors. One content workshop was held on 24 April 2026. The minimum over the remaining period is one additional content-review session and one non-expert user try-out in Kiel; the ambitious target is four engagement sessions in total, each with recorded feedback and project response.

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Indicators for the SEALEVEL scenario. For the digital extension of the SEALEVEL exhibition (O1), the indicator is the number of agreed scenes published with functional digital stations and curated content: the minimum target is the three scenes forming the agreed delivery scope, and the ambitious target is that all three combine multiple content formats and support thematic or guided entry points. For immersive 3D exploration (O2), the indicator is successful navigation and interaction with the three agreed scenes on standard web devices: the minimum is functional desktop and mobile access, and the ambitious target includes validated performance and usability across the commonly used target devices identified during testing. For accessible marine and climate communication (O3), the indicators are approved non-technical explanatory content for every published station and documented pilot testing with non-expert users covering accessibility, comprehension and relevance. The minimum is explanatory content for every station and one documented non-expert test; the ambitious target adds suitable environmental or sensor-based information where approved and a follow-up test confirming that identified issues were addressed. For content management and professional use (O4), the indicator is an authenticated CMS workflow through which authorised users can create, edit and maintain scenes, digital stations and associated media: the minimum is a functioning role-based content-management workflow, and the ambitious target is an end-to-end content update and publication carried out by the City Cultural Team without engineering intervention.

The other three families. For the diversity of use cases addressed, the minimum is the consolidated set of four, distinctly identified and specified to an operational standard; the ambitious target adds domains that a follower city configures on the shared technical framing without new development, which is how thematic breadth is recovered as a replication property rather than as a delivery commitment. For the expansion of local digital twins, the minimum is the two frontrunner twins extended with the scenario layers specified here, and the ambitious target adds the twin of a follower city configured on the same framing. For interoperability and openness, the contribution is assessed across both implementation tracks. The common WP4 front-end adopts NGSIv2 and, where required, NGSI-LD, FIWARE Smart Data Models, OGC 3D Tiles, glTF and CityJSON. SEALEVEL adds a scenario-specific implementation using structured web APIs, the SENSE Participant Agent and glTF/GLB 3D assets while remaining governed through the same Data Space principles. The objective is therefore interoperability at the data and interface level rather than uniformity of the rendering technology.

How the indicators are reported. Each is reported per reporting period, with the figure for the period and the cumulative figure. Content, configuration and interoperability indicators are established by inspection of what is published. Professional adoption comes from the account records held by the scenario services. Documented analyses and participation come from what the cities and the project record, not from instrumentation in the front-end. Where an indicator depends on a source or a confirmation that is not yet available, the dependency is reported rather than an estimate. These reporting rules are the evaluation criteria of this deliverable: an indicator counts as met when the artefact it names can be inspected, when the account records show the stated adoption, or when a city or the project records the documented use. The impact pathway of each scenario runs from the capability delivered, through the indicator stated here, to the expected impacts listed in the corresponding chapter, and from there to the project indicator family that those impacts answer to. The impacts described in those chapters

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as medium to long term fall outside the measurement window of the project; within it they are represented by the adoption and documented-use indicators above rather than by a measured outcome.

1.7 The role of artificial intelligence

Artificial intelligence appears in this work as a set of services that return data, as a production technique for content, and, where provided, as an information service reached from the interface and delivered outside the front-end specified here. It is not a rendering method, and it is not an autonomous decision-maker. This section states where it is applied in this revision, what it is not applied to, and the limits that apply in both cases.

Where the capability comes from. The scenario work does not build an artificial intelligence engine. The orchestration layer delivered in the data work packages provides model serving, and a scenario consumes it as a service that accepts a request and returns a result as data. That division is what keeps the front-end free of any model, keeps each scenario usable when a service is unavailable, and lets one capability serve every scenario instead of being rebuilt for each use case.

What the front-end applies it to in this revision. One application, and it is in production rather than in the analytical path: the heritage assets of the cultural scenario are produced with generative support from the archival sources, offline, as part of the content pipeline. Every reconstruction is derived from documented sources and checked against them, elements that cannot be documented are left out rather than reconstructed by assumption, and every element produced this way is labelled as interpretative in the interface and validated by the institutions responsible for historical accuracy. This is what makes heritage content feasible at the scale the scenario needs, and the labelling is the safeguard that keeps it honest. Set against the conventional alternative, which is the manual modelling of each past state from the same sources, the gain is in production capacity rather than in the result: it is what makes the number of reconstructions the scenario needs feasible within the project, at the same standard of documentation and with the same labelling.

What it is not applied to, and what is done instead. In the mobility and public space scenarios no artificial intelligence model takes part in the analytical path in this revision. The scenarios are designed to be operated through their own controls, and the requirement that a non-expert reader can understand what is shown is met in the interface itself: plain language, explicit values and labels alongside any indicator conveyed by colour, and an explanation of each rule next to the layer that displays it. Two further capabilities that the orchestration layer would make possible, the generation of plain-language readings of indicators at scale and the surfacing of anomalies across the monitoring streams, are recorded here as available directions rather than as functionality of this revision, so that the scenarios do not depend on the integration of that layer being complete. Measured against a data-driven or model-based alternative, the analytical path of this revision is deliberately conventional: indicators are computed by explicit rules and presented with their drivers exposed, because a municipal decision has to be justified to someone else and an inferred value cannot be traced back to the source in the way that a stated rule can. The value that artificial intelligence adds in this

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revision therefore sits in production, where it changes what is feasible, and not in the analytical path, where a conventional method answers the need better.

What is reached from the interface and delivered outside this specification. A conversational assistant answers questions from content and data that the front-end does not supply; the service that answers is delivered outside the front-end specified here and is informative only. It composes no indicator, is not a source for a municipal decision, and the scenarios remain usable when it is not provided or not available. Measured against a conventional alternative, what it adds is that published information can be asked for instead of navigated to; it adds nothing to the analytical path, where a stated rule remains the method. Where the assistant is presented, that point is part of the front-end and can be inspected: it carries a notice that the answers are generated and that the terms of the service providing them apply, and the front-end neither stores nor publishes what a user types into it.

The SEALEVEL baseline specified in Section 5 does not depend on artificial intelligence. Its core interaction is content- and data-driven: curated exhibition material is managed through the CMS, three-dimensional assets are prepared through the content-production workflow, and optional environmental information is retrieved through the SENSE data infrastructure where available. An AI-based service could be connected later through the common SENSE service layer, but it is not required for the functionality or delivery milestones defined for SEALEVEL in this revision.

Limits. Four, stated so that they can be checked. No model takes a decision, writes to a municipal system or alters the underlying data. No personal data is submitted to a model. Every content element produced with generative techniques for the scenarios is labelled as such. And where a model reaches the city data used by the scenarios, it does so through the Scenario Service Layer under the same governed access as any other consumer, so a restricted source stays restricted when a model is the one reading it.

1.8 Exploitation, adoption and continuity

This section states what happens to the scenarios after the project from a technical standpoint. The commercial and business model perspective is set out in the exploitation and dissemination activities of the project rather than here.

What it costs to keep running, and who can run it. The operational profile differs slightly between the two implementation tracks. The scenarios specified in Sections 2 to 4 rely primarily on browser-rendered static assets and a small set of service endpoints, avoiding a server-side rendering tier and its associated per-user GPU cost. SEALEVEL also renders its three-dimensional environment on the client but includes a conventional web application and content backend consisting of Next.js, Strapi and associated caching services. Its continued operation therefore requires hosting of the web application, CMS and cache in addition to the availability of the content and data sources it consumes. The D&S implementation is designed to be portable across suitable cloud or on-premises infrastructure. Production hosting and post-delivery managed services are not part of the implementation scope described here; the solution and documentation are intended to allow the City of Kiel or its representatives to manage and update the exhibition content independently after handover.

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What is transferable, and to whom. Five artefacts are produced for reuse: the scenario configuration templates, the client-side rendering profile with its levels of detail and scene budgets, selected objects of the city model published with data space metadata descriptions so that they can be discovered and reused, where the licence of the source material allows it, the content production pipeline for heritage reconstruction with documented provenance, and the onboarding checklists for new data sources. Their first versions are produced alongside the first scenario that uses them rather than at the end of the project, so that they are available to the technical guidelines work and to follower cities while the project is running. A follower city adopting the shared technical framing configures an additional domain from these artefacts instead of commissioning new development, which is the practical form that replication takes here. For SEALEVEL, the reusable artefacts additionally include the CMS content model for scenes and stations, the web-optimised 3D asset-production workflow, the integration pattern between the Participant Agent, scenario backend and public frontend, and the content-administration procedures required for independent maintenance by the city or its representatives.

Adoption within the pilot cities. Adoption is treated as a condition of continuity rather than as an outcome reported at the end. The management views are used by named municipal staff from the minimum viable product onwards, so use is visible during the project and not only after it. The public views are reachable from a link and can be embedded in the municipal and tourism channels the cities already operate, which is the route the validation sessions themselves recommended over a stand-alone application.

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2. Cartagena - Smart Urban Mobility

Scope of this revision

This revised deliverable adjusts the Smart Urban Mobility scenario to the resources available for the WP4 front-end and to a web-native delivery approach. The scenario is scoped as a minimum viable product (MVP) that preserves the operational core while deferring the most computationally intensive functionalities to a later stage.

In scope (MVP):

- A web-native management application for a small team of municipal professionals: selectable thematic layers, covering the low-emission zone and those of the mobility and environmental sources listed in Section 2.7.3 that are available to the project, monitoring of their current values with a time control over the history that each source exposes, configurable thresholds that are highlighted in the interface when they are crossed, an event view of predefined configurations, and export of the current view as an image and of the underlying tables as data files.
- A public, account-free citizen 2D application (MapLibre GL), in Spanish with English as a secondary language, showing the low-emission zone, whichever of the near-real-time air-quality and road-traffic indicators are available to the project, and, where the city or the transport operator can supply the corresponding layers, public transport lines and stops, for consultation only.

Deferred to future extensions:

- Multi-criteria route planning and route explanations for citizens and visitors.
- Microscopic and mesoscopic traffic simulation for professional what-if workflows.
- The citizen-facing routing and journey-planning engine.
- The full photorealistic 3D city twin as the primary interface; 3D content is limited to lightweight, purpose-specific assets.
- Observed real-time positions and punctuality for public transport vehicles, which depend on a real-time feed from the transport operator.

The citizen reporting and feedback channel, which requires write access to the municipal incident management system.

The NGSI data foundation, the SENSE Data Space connectors and the AI and analytics services remain part of the architecture; what this revision changes is the rendering layer (client-side, in the browser). The deferred items are documented as modular extensions for later phases. Traffic simulation is not included in the WP4 front-end in this revision: where a simulation capability is operated elsewhere in the project or by the city, it runs outside the user application and no integration with it is assumed here. The remainder of this chapter describes the scenario in its full target form, as established in version 1.0 of this deliverable; where a capability is identified above as deferred or optional, its description should be read as target behaviour for a later phase rather than as functionality delivered in this revision. The same

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applies to the objectives stated in this chapter: where an objective depends on a capability identified above as deferred, this revision addresses the part of it that does not.

2.1 Scenario overview

In Cartagena, the *Smart Urban Mobility* scenario can be illustrated through the daily routine of María, a 32-year-old nurse. Every morning before leaving home, she opens the SENSE city twin on her phone and sees an intuitive 3D view of the city displaying live traffic conditions, expected travel times, bus and commuter-rail arrivals, the low-emission zone clearly highlighted around the historic centre, and colour-coded air quality indicators along the main corridors she might use. Her usual car commute appears in red: the corridor is congested and the air quality panel warns of “poor” conditions for the next hour. The system automatically proposes an alternative, combining a short walk, a commuter-rail connection and a bus. This route is shown in green, with a brief explanation indicating that it has a similar travel time but significantly lower emissions and “moderate” air quality along most of the way. With a single tap, María inspects the multimodal route in 3D, identifying where she will board the train, where she will change from train to bus, and how crowded the main stops typically are at that time of day. Confident that she will arrive on time while avoiding the worst congestion, she chooses the cleaner option. The app confirms the expected arrival time at the hospital and displays a small “impact” summary showing the emissions avoided and the minutes saved compared to her usual car route.

Later that week, a local festival takes place in the city centre. In the evening, María again consults the SENSE twin, this time activating an “event” view in which temporary street closures and pedestrianised areas are clearly displayed, detours and recommended access routes are highlighted, and additional public transport services as well as extended operating hours appear directly on the 3D network. She quickly realises that her normal bus stop will be out of service during the festival, but that another stop, two blocks away, will offer reinforced service. She shares a link to the same 3D view with her friends so they can adjust their routes and meeting point accordingly. For María, the city suddenly feels easier to understand: it is clear where she can drive, when it makes sense to leave the car at home, and how the system is adapting to events.

This fictional story illustrates the intended role of the *Smart Urban Mobility* scenario in Cartagena. Through SENSE, the city will offer an interactive 3D digital twin that consolidates real-time information relevant to mobility, environmental quality and regulatory enforcement in one coherent environment. Citizens and visitors will be able to explore the city virtually, plan multimodal routes, consult public transport itineraries and immediately see where restrictions such as low-emission zones, pedestrian areas or temporary closures apply at any given moment. At the same time, city managers and operators will gain a shared operational picture of mobility and environmental conditions, allowing them to monitor patterns and key indicators in real time, anticipate pressure points such as rush-hour build-ups, cruise ship arrivals or large events, and prepare targeted measures in advance. The same platform supports direct, visual communication with the public, making guidance accessible and traceable to underlying data. The use case is therefore not limited to a static map or informational dashboard; it is conceived as an operational tool embedded in everyday mobility management and public communication. The expected impact is twofold: to improve understanding of and compliance with low-

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emission and traffic regulations by making them visible, contextualised and easy to interpret; and to promote a modal shift towards cleaner and more efficient transport options by making sustainable routes more discoverable, comparable and practically usable in citizens' daily routines.

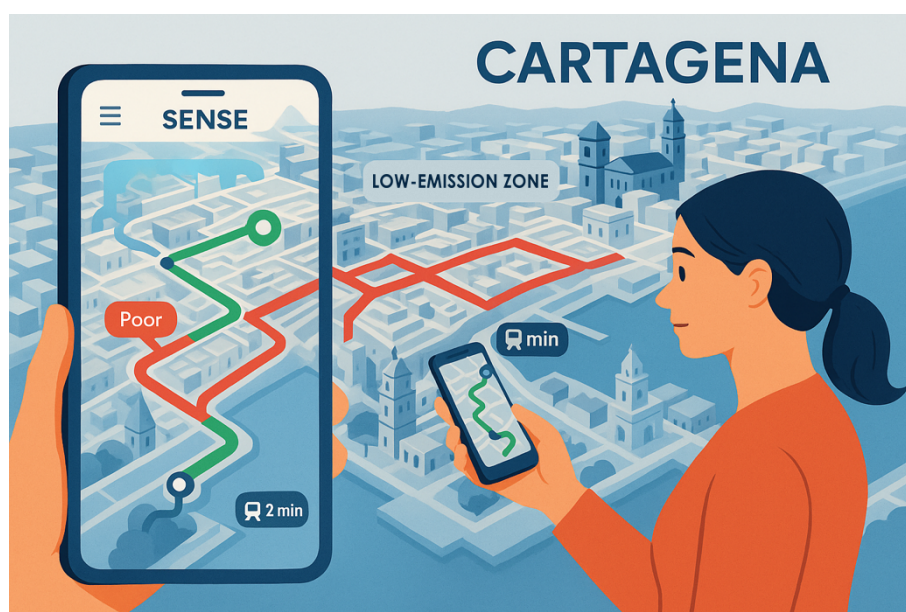


Figure 1. Cartagena - Smart Urban Mobility

2.2 Urban and policy context in Cartagena

Cartagena is a medium-sized coastal city in the Region of Murcia, in south-eastern Spain, with a population of around 215,000 inhabitants in the municipality and a wider metropolitan area that attracts many additional commuters and visitors. The city combines a major commercial and naval port, university and technology campuses, residential neighbourhoods and a highly valued historic centre characterised by narrow streets, heritage buildings and an active cultural life. Its Mediterranean climate, coastal setting and touristic appeal generate strong seasonal variations in population and mobility, while the presence of port, industrial and logistics activities adds further pressure on the transport network and on local environmental conditions.

In recent years, Cartagena has invested significantly in digital transformation and smart city initiatives. The city operates a FIWARE-based data platform that integrates information from multiple domains, including air quality indices, weather conditions, parking occupancy, people-counting systems and traffic data, as well as broader environmental datasets (temperature, humidity, noise, public affluence and data from green zones). The platform is designed for real-time data collection, storage and analysis, and is complemented by an open data portal that exposes selected datasets for public reuse. Interoperability is a core design principle, with the platform adhering to common standards and protocols (such as the OASC Minimal Interoperability Mechanisms MIM1, MIM2 and MIM6) and aligning with EU data space requirements on privacy, security and data governance. This provides a solid technical and policy foundation on which SENSE can build the *Smart Urban Mobility* scenario.

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Against this backdrop, Cartagena faces a set of mobility and environmental challenges that the scenario aims to address:

- **Congestion and unreliable travel times** on main access routes and within the inner city, especially at peak hours and during events.
- **Local air pollution** (e.g. NO₂, particulate matter) influenced by road traffic, port activities and industrial sources.
- **Need for a clear and understandable low-emission zone scheme (LEZ, or ZBE in Spanish)**, so that both residents and visitors know where and when restrictions apply, and on what basis.
- **Need for a more comprehensive and unified representation of mobility and environmental data**, so that users can easily access information from different sources and obtain a holistic, up-to-date view of conditions and available options.
- **Need for effective two-way communication channels**, where citizens can easily provide feedback, report issues and share their mobility experiences, and where the city can respond and incorporate this input into planning and operational decisions.

2.3 Objectives and expected impacts

The *Smart Urban Mobility* scenario pursues the following overarching objective:

To support safer, cleaner and more efficient urban mobility in Cartagena by providing an accessible, real-time 3D environment where citizens and city managers can understand, anticipate and influence mobility and environmental conditions.

This overarching objective is articulated into the following specific objectives:

O1. Visibility and transparency of rules and conditions

- Make low-emission zones, traffic regulations, parking rules and other mobility constraints clearly visible and understandable within a single 3D environment.
- Provide real-time views of traffic density, congestion and air quality at street level.

O2. Support for informed mobility choices

- Enable citizens and visitors to compare route options in terms of travel time, reliability, environmental impact, comfort and accessibility, and to base their travel decisions on this information.
- Promote multimodal journeys combining public transport, walking, cycling and shared mobility.

O3. Operational support for city managers

- Offer mobility and environment teams a unified situational picture that allows them to monitor current conditions, detect incidents and anticipate problems such as recurrent bottlenecks or event-related pressures.

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- Facilitate coordination between departments (mobility, environment, police, emergency services and others) during planned events and unplanned incidents by providing a common, data-driven visual reference.

O4. Evidence-based planning and evaluation

- Provide aggregated indicators and spatial analytics to evaluate the effects of measures such as LEZ deployment, new bus lanes, traffic-calming interventions or changes in signal plans.
- Support the iterative improvement of the Sustainable Urban Mobility Plan (SUMP) and climate action plans by making it easier to test, visualise and communicate different policy scenarios.

O5. Citizen engagement and behaviour change

- Use storytelling and narrative elements, together with immediate visual feedback on the effect of each choice, such as the emissions avoided or the minutes gained, to encourage more sustainable mobility choices and recurrent use of the platform. Game mechanics are not part of the revised scope: they depended on the immersive interface and on user accounts, and the public view has neither.
- Foster a sense of shared responsibility for air quality, climate and street safety by making the links between individual choices, collective patterns and environmental outcomes more visible.

The expected impacts of the scenario can be grouped into two broad categories:

Short-term operational impacts

- Improved incident detection and response, for example by more quickly identifying bottlenecks, diversions, abnormal congestion or emerging hot spots.
- Reduced information asymmetry between the city and citizens, leading to fewer misunderstandings about rules, restrictions and temporary measures.

Medium- to long-term behavioural and policy impacts

- Increased use of public transport and active modes for everyday journeys, supported by better information, improved perceived convenience and more attractive multimodal options.
- Increased compliance with LEZ and traffic regulations, as rules become more visible, understandable and easier to follow in practice.
- Stronger political and public backing for mobility and environmental measures, thanks to clear, shared visual evidence of existing problems and the benefits of implemented solutions.

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2.4 Stakeholders, user groups and roles

The scenario is designed around several primary user groups, each with distinct needs and usage patterns:

- **Citizens and commuters**

Daily users who require reliable information on travel times, congestion, parking availability and applicable restrictions. They typically interact with the platform via mobile devices or standard web browsers, in short sessions focused on pre-trip planning or quickly checking current conditions.

- **Visitors and tourists**

Occasional users with limited familiarity with local rules, geography and public transport options. They mainly need simple, intuitive visual cues showing where they can drive or park, how to reach key attractions, and which public transport lines or interchanges connect the places they want to visit.

- **Municipal mobility and traffic departments**

Professional users who operate the platform in a control-room or office environment, often on large screens or dashboards. They are responsible for traffic management, signal plans, event planning, parking policies and coordination with the police, and use the tool to obtain a unified operational picture.

- **Environmental and climate departments**

Users focusing on air quality, emissions and noise indicators, including long-term exposure patterns and regulatory compliance. They rely on the platform to correlate traffic and mobility measures with environmental impacts and to support reporting and communication.

- **Public transport operators and mobility service providers**

Bus and regional rail operators, shared mobility providers and taxi dispatch services. They use aggregated information on congestion, passenger flows and service reliability to adjust planning, optimise operations and communicate disruptions or changes to users.

- **Security forces and emergency services**

Police, emergency services and civil protection units that use the platform during incidents, evacuations or large events. They require clear visualisations of closures, recommended routes, priority corridors and safe gathering points to support decision-making under time pressure.

- **Technical teams and researchers**

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City IT departments, local SMEs, universities and research groups working with SENSE data, models and services. They use the scenario as a testbed to integrate new data sources, develop and validate analytics and optimisation algorithms, and explore innovative human–digital interfaces for urban mobility.

For each of these user groups, specific roles and permissions are defined:

- **Public users**

Users of the public views, which require no account, with access to the main 3D visualisation, route planning functions and a core set of indicators (e.g. traffic, air quality, basic service information).

- **Professional users (city staff and operators)**

Authenticated users from municipal departments and service operators with access to extended functionality, including operational dashboards, historical data exploration, configuration of alerts, and the ability to define and manage scenario views (e.g. event configurations).

- **Administrators**

Users responsible for creating the named accounts of the participants in the pilot, assigning their roles and adjusting their access rights, configuring the available data layers, and maintaining integrations with external systems and services, as described in Section 6.2.

2.5 Functional description of the use case

2.5.1 Interactive 3D digital twin

The core of the scenario can be conceived as an interactive 3D digital twin of Cartagena that acts as the main entry point for both citizens and professionals. Functionally, the 3D twin could include the following capabilities:

- **City coverage and performance:** it could cover the relevant urban area with sufficient detail to distinguish buildings, the street network, squares, parks, major port facilities and key landmarks, while maintaining good performance on standard devices.
- **Navigation and orientation:** it could provide intuitive navigation (pan, rotate and zoom), potentially complemented by “fly-through” or follow-the-route modes, and a simple minimap/overview for orientation and quick repositioning.
- **Time control:** it could include a time control allowing users to switch between the current situation, historical replay and, where available, short-term predictions, so they can see how conditions change during the day, during specific events or under different scenario configurations.

From a functional perspective, the 3D twin could support at least the following interactions:

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- **Layer switching:** users could toggle thematic layers on and off (e.g. LEZ boundaries, air quality, road traffic, pedestrian flows, public transport routes) to focus on the information most relevant to their task.
- **Contextual information on click/tap:** selecting a street segment, junction, parking area or point of interest could open an information panel showing key attributes such as current speed, typical travel time, applicable restrictions, emission levels or service status.
- **Bookmarks and perspectives:** preconfigured views (e.g. historic centre, main access corridors, port access, major interchanges) could be accessed with a single click, supporting rapid navigation for both citizens and operators.
- **Search and geocoding:** users could search for addresses or points of interest (POIs: schools, hospitals, stations, tourist attractions, public facilities) and automatically centre the view on the selected location.

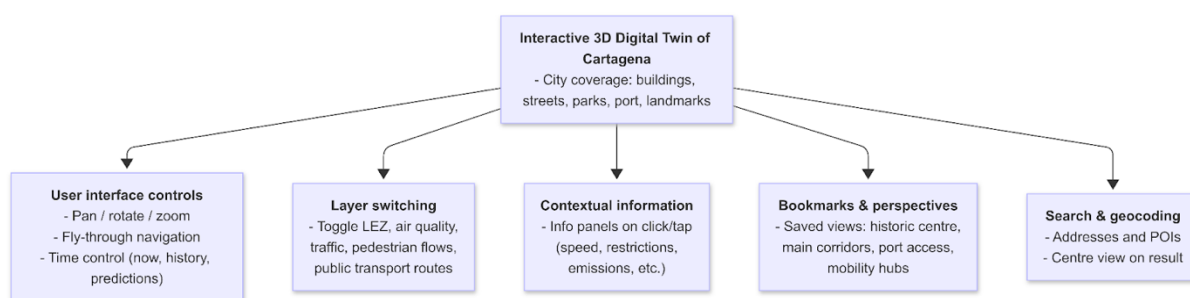


Figure 2. Basic features of the 3D digital twin of Cartagena

2.5.2 Real-time layers

The scenario will bring together a set of core data layers, some predominantly static and others dynamic or real-time. These could include:

Low-emission and restricted traffic zones

- **Static geometry** of LEZ/ZBE boundaries, pedestrian-only streets and restricted access areas (e.g. residents-only streets, time-limited loading zones).
- **Associated rules**, such as time windows, vehicle categories allowed, emission standards and permit requirements.
- **Visual representation** through coloured overlays on the 3D map, supplemented by clear legends and tooltips that explain the meaning of each colour and the applicable rule.

Road traffic conditions

- **Real-time or near-real-time traffic conditions** at the instrumented points of the network, including flow, average speed and a derived congestion level, aggregated by corridor where several sensors cover the same axis. Indicators for every street segment, among them level of service and segment travel time, require a wider source such as floating car data, which is a deferred extension.

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- **Data sources** such as fixed sensors (loop detectors, traffic cameras), floating car data or other city traffic data feeds.
- **Visual representation** via colour-coded corridors where sensor coverage allows (e.g. green–yellow–red), point markers at the instrumented locations, and, where appropriate, line thickness or glow effects to indicate intensity or volume.

Pedestrian flows and crowded spaces

- **Estimates of pedestrian densities** in key areas such as shopping streets, the waterfront, transport hubs and event venues.
- **Data sources** may include counting systems, Wi-Fi/Bluetooth probes or aggregated mobile positioning data. These sources reach the scenario already aggregated by the data holder, which remains the controller of the underlying personal data; the front-end consumes only counts and densities per area and time window, never individual traces.
- **Visual representation** via heatmaps or animated dots overlaying squares, pavements and other public spaces, making crowded or calm areas immediately visible.

Air quality and environmental indicators

- **Point measurements and spatial interpolations** of relevant pollutants (e.g. NO₂, PM₁₀, PM_{2.5}) and, where available, noise levels and other environmental indicators.
- **Temporal dimension**, providing current values, recent history (e.g. last 24 hours) and daily or hourly averages to support interpretation of trends.
- **Visual representation** using colour gradients, vertical extrusions (e.g. “pollution columns”) and contextual pop-up panels explaining levels, thresholds and health implications in accessible language.

Public transport and mobility services

- **Static layers** describing lines, stops, stations and timetables for buses, commuter rail and other relevant modes, as published by the city or the transport operator.
- **Scheduled positions** derived from the published timetables and labelled as scheduled, together with disruptions, planned detours and reinforcement services (e.g. additional buses during events). Observed vehicle positions and delays require a real-time feed from the transport operator: where such a feed is available they replace the scheduled positions, and where it is not, the interface states that the positions shown are scheduled rather than observed.
- **Visual representation** through moving icons for buses and trains, labelled according to whether the position shown is scheduled or observed, and clear highlighting of recommended interchanges and key nodes. Colour-coding of punctuality depends on the operator feed described above.

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2.5.3 Citizen/visitor functionalities

For citizens and visitors, the platform behaves as a 3D mobility assistant that supports everyday decision-making. The following are functionalities that could be considered in this scenario.

Route planning

Users specify origin and destination via address search, map click or “current location”. They can express preferences such as fastest, most reliable, least emissions, least walking or “avoid LEZ”. The system returns one or more route alternatives, each visualised as a highlighted path in 3D, with associated information including estimated travel time, distance, cost (if available), emissions estimate and expected comfort (e.g. a qualitative indication of crowding).

LEZ-aware routing

Users can indicate their vehicle type and emission class so that routing respects LEZ/ZBE rules. If a proposed route would enter a restricted zone in a non-compliant way, the interface explicitly warns the user, explains the relevant rule and offers alternative routes that respect the restrictions.

Contextual explanations and “why this route?”

For each recommended route, the system provides a short textual explanation, such as “Best trade-off between time and emissions”, “Avoids congested corridor X” or “Uses bus line Y with frequent service”. Users can explore the route step by step, viewing expected conditions along the path (e.g. typical congestion points, segments with higher pollution, interchanges and walking segments).

Exploration and learning

Users can explore the 3D twin without necessarily planning a specific trip, for example to check “What is the air quality in my neighbourhood?” or “Where are the busiest streets during rush hour?”. A time slider allows comparison between different times of day or days of the week, helping users understand temporal patterns and how their own choices interact with peak periods.

Two-way communication and feedback (deferred extension)

In its target form the platform also acts as an interaction channel between citizens and the city: users rate a route, report issues encountered on the network such as obstacles on pavements, malfunctioning traffic lights or missing signage, and comment on specific locations with geo-referenced notes, and the aggregated feedback reaches municipal teams as an input for planning and operational decisions. This channel is a deferred extension. Returning the status of a report requires write access to the municipal incident management system, which lies outside the front-end, and it involves personal data, whereas the public view delivered in this revision requires no account and is for consultation only. The equivalent functionality is deferred in the other two scenarios for the same reasons.

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Accessibility features

Information on restrictions and conditions is presented using simple, consistent icons and concise text written in plain language. The interface follows the contrast and text-size settings of the user's own system and browser rather than adding a separate set of display controls, and a reduced layer set is available for users on limited devices. Every indicator conveyed by colour is also given as an explicit value and label, so that regulatory and health-related information never depends on colour perception alone, and content is not placed behind hover-only interactions, so that the interface remains operable by keyboard and on touch devices. The two-dimensional views, panels and tables follow WCAG 2.1 AA as design guidance, and accessibility is checked during the quality assurance stage.

2.5.4 Municipal monitoring and decision-support features

For the municipality and other professional users, the platform could provide a “control-room” view that supports monitoring, coordination and evaluation.

Operational dashboards

Key performance indicators (e.g. congestion index by corridor, average travel times, bus punctuality where the transport operator publishes real-time vehicle positions, air quality indicators) are displayed in dashboard panels that are linked to the 3D view. Users can define configurable thresholds and alerts (for example, triggering a notification when congestion exceeds a given level on a critical corridor, or when pollution approaches regulatory limits in sensitive areas).

Scenario views for planned events

The system allows the predefinition of “event layers” for festivals, sports events, road works or demonstrations, including street closures, recommended routes, temporary parking areas and changes in public transport services. Operators can switch between “normal day” and “event day” configurations to check readiness, validate planned measures and communicate them consistently to the public and other stakeholders.

Historical analysis and evaluation

Professional users can access historical data for selected periods, enabling before/after comparisons (e.g. conditions before and after the introduction of an LEZ or new bus lane). The platform provides tools to generate maps, time series and summary charts that can be exported or embedded in reports, presentations and decision documents.

Collaboration and annotation

City staff can place annotations directly on the 3D map (e.g. “candidate location for new crossing”, “recurrent illegal parking area”, “potential public transport interchange improvement”) and attach comments, tags or links to external documents. These annotations can be shared across departments, forming a spatially organised knowledge layer that feeds into planning processes, internal coordination and future scenario refinement.

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2.6 User journeys

The user journeys described in this section represent the desired target behaviour of the *Smart Urban Mobility* scenario in Cartagena once the solution is fully matured and integrated into city operations. They are therefore intentionally ambitious and include functionalities that may extend beyond what can be implemented within the timeframe and resources of the SENSE project. Within the project, these narratives serve as a design compass: they guide requirements, prioritisation and technical choices. Therefore, the user stories should be read as aspirational target scenarios, not as a strict list of features guaranteed at project end.

2.6.1 Routing applications for citizens or visitors

Multi-criteria routing for citizens and visitors is a deferred extension in this revision, as noted in the scope statement at the start of this chapter. The user journeys below are retained as aspirational target patterns that illustrate the intended direction of the scenario, not as MVP features.

Daily commuter optimising the route

A citizen living in a residential neighbourhood and working near the city centre opens the SENSE mobility view on their phone before leaving home. In the search bar, they enter their home and work addresses, and the system immediately proposes a set of alternatives, for example a fastest car route and a multimodal route that combines a park-and-ride facility with a bus line. On the 3D map, the car route is highlighted in red, crossing a corridor with heavy congestion and poor air quality; the legend also indicates that part of the route passes through a low-emission zone where the vehicle is technically allowed but not particularly clean. The multimodal route appears in green and is annotated as slightly longer in time but substantially better in terms of emissions and reliability, while also avoiding the main congestion hot spots. A short explanation panel compares both options side by side in simple terms. The commuter decides to follow the recommended multimodal route and saves it as a favourite for future use. After completing the trip, they use the built-in feedback function to rate the route and briefly report, for instance, that one of the bus stops was more crowded than indicated, providing useful input for adjusting parameters and improving future guidance.

Visitor avoiding restricted areas and discovering public transport

A tourist arrives in Cartagena by car and wants to reach a hotel in the historic centre. On a hotel flyer and on the municipal tourism website there is a QR code linking directly to the SENSE mobility map. After scanning it, the visitor searches for the hotel name and the application centres the 3D view on the historic district, clearly showing the surrounding low-emission zone. From the main access road, the system proposes several options: driving as close as possible to the edge of the LEZ, parking in a peripheral car park and continuing on foot, or using a shuttle bus service. Because the visitor's car is older and does not meet the most stringent emission standards, SENSE flags that direct access to the central streets may be restricted and highlights the peripheral parking plus shuttle option as the most suitable and compliant route. The visitor can visualise the walking segment and bus route in 3D, including estimated travel times, stop locations and service frequency, which makes the multimodal option more understandable and less intimidating. After the trip, the visitor uses a simple

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feedback form in the app to confirm, for example, that the signage to the parking area was clear, providing a quick qualitative check that can be used by the city to refine information and signage.

2.6.2 Traffic planning and operations for city managers

Beyond individual routing, SENSE is intended to support municipal teams in planning, operating and communicating mobility and environmental measures at city scale. The following user journeys illustrate how traffic managers and environmental officers could use the platform for event preparation, day-to-day operations and policy communication. The simulation of expected flows and the interactive what-if visualisation are deferred extensions in this revision, as noted in the scope statement at the start of this chapter.

Mobility manager preparing for a large event

The city plans a large cultural event in the historic centre that is expected to attract many visitors. Several weeks in advance, the mobility team creates a dedicated “event configuration”: they define temporary street closures, extended pedestrian areas, priority corridors for public transport and emergency vehicles, additional bus services and recommended parking locations. Using the 3D twin, they simulate expected flows based on historical data from similar events, visually inspecting potential bottlenecks around key junctions and car parks. Once satisfied, they save this configuration as a named “event scenario” that can be activated with a single click.

On the day of the event, the control room displays the SENSE twin with the event scenario active and real-time data streaming in. Operators monitor congestion around access corridors and parking facilities and watch the evolution of pedestrian densities near the main venues. If a particular access route becomes saturated, they coordinate with communication teams to update public guidance, pushing alternative routes and parking suggestions through the city’s web channels, social media and, where possible, directly through the SENSE interface.

Environment officer explaining air quality

After several days with unusually high pollution levels, the environment department needs to explain the situation and the response measures to citizens and decision-makers. Staff open the SENSE twin and select the relevant period on the time slider. The map replays the evolution of traffic volumes and air quality indicators, allowing them to compare the high-pollution episodes with more typical days. They identify specific corridors and time windows where the combination of heavy traffic and unfavourable meteorological conditions led to peaks in NO₂ and particulate matter.

Using SENSE, they capture a series of illustrative views and short animations that overlay traffic patterns with pollution “plumes” over sensitive locations such as schools or health centres. These materials are used in public presentations, on the municipal website and in social media posts. During public meetings, the team uses the interactive “what-if” visualisation capabilities to show how different traffic management measures – such as restricting certain movements, strengthening public transport on key corridors or adjusting signal timings – could reduce exposure in targeted areas, helping citizens understand both the problems and the rationale for proposed interventions.

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2.7 Technical foundations

This section outlines technical aspects that may be considered for implementing the scenario. Some elements are generic and applicable across SENSE scenarios, while others may be adapted or extended to address scenario-specific requirements.

2.7.1 Core components

Conceptually, the SENSE scenario can be understood as a tailored configuration built on three core components, connected through a simple interaction and data chain that runs from A to B and from B to C.

A. SENSE User Application (Front-end) is the main entry point for both public and professional users. This layer hosts the user experience: exploring the 3D twin, enabling thematic layers, selecting points of interest, consulting indicators, and interacting with content (e.g. information panels, multimedia assets, or lightweight visualisations). Depending on the scenario, it may also include authentication and role-based views, so that different user groups are offered different features and levels of detail.

B. Scenario Service Layer (Scenario Back-end) represents the “scenario logic”. It acts as an intermediary that translates user actions into concrete services: it composes views and content, applies scenario-specific rules, manages access rights, and orchestrates access to data and results. Where scenarios require processing or computation (for example, indicator aggregation, advanced filtered queries, or the generation of scenario configurations), this layer coordinates those operations and ensures consistent behaviour aligned with the scenario objectives.

C. Data and Knowledge Layer (connected to the SENSE Data Space) groups persistence and governed access to information assets. It includes base datasets, metadata and catalogues, time series, multimedia resources, and pre-processed outputs or versioned thematic layers. The Data Space provides the framework to publish, discover and reuse data in a controlled manner, ensuring traceability, consistency and appropriate access conditions for different institutions and user types.

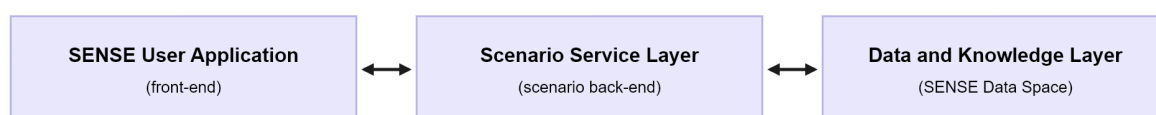


Figure 3. Scenario core components

2.7.2 Interaction flows

Overall, the interaction pattern is simple: the SENSE user application (A) communicates with the scenario service layer (B), which in turn reads from and writes to the data and knowledge layer (C). This separation lets the scenarios reuse a common foundation (front-end and Data Space) while each use case implements its specific logic, content and configuration in the scenario back-end. The sequence diagrams below illustrate this end-to-end behaviour for the professional interaction flows retained in the MVP, namely event preparation and air-quality communication. Some steps in these flows, in particular the interactive what-if visualisation used for public communication, belong to the deferred extensions identified at the start of this chapter and are shown here as target behaviour rather than as MVP functionality.

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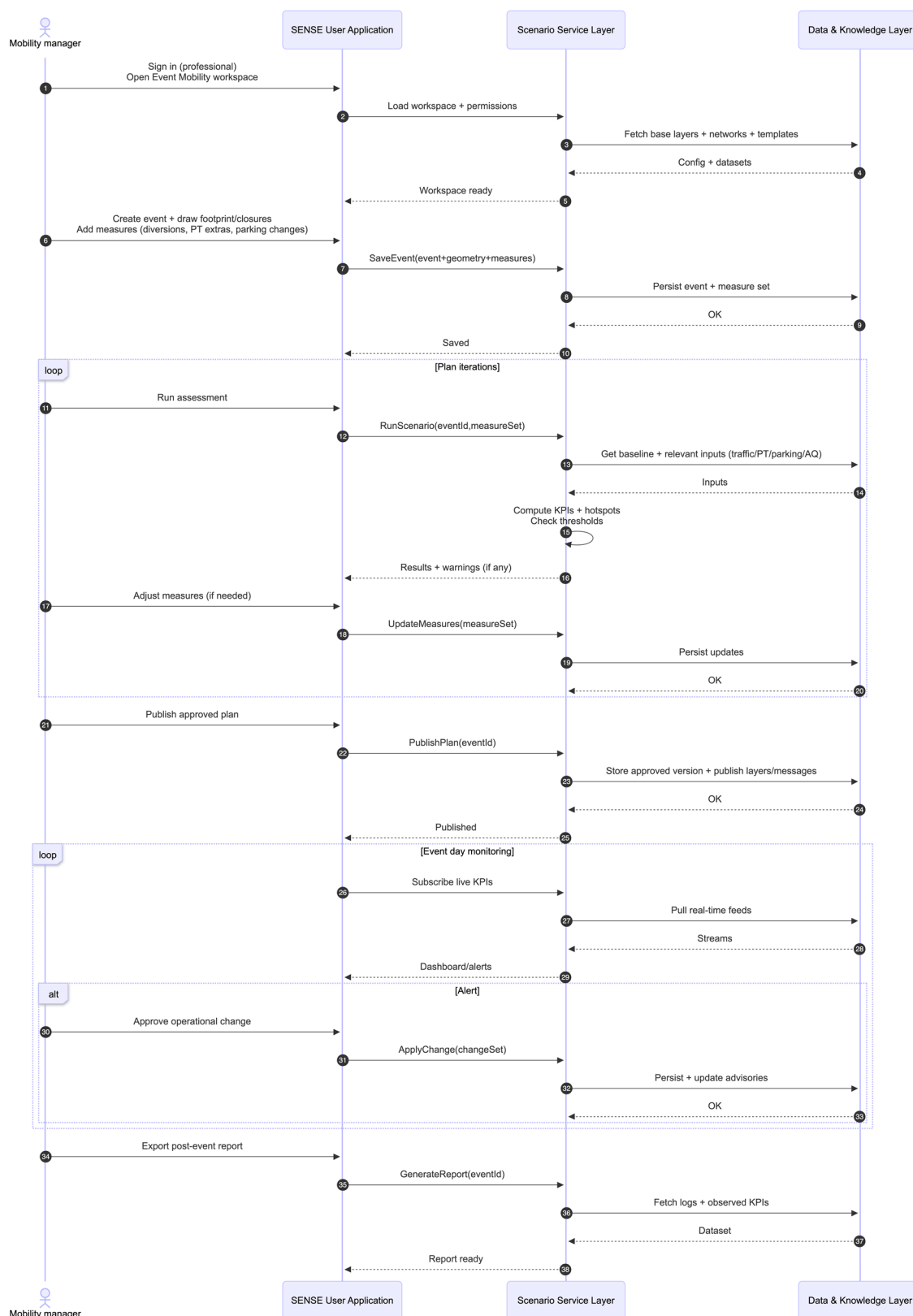


Figure 4. Sequence diagram for “Mobility manager preparing for a large event”

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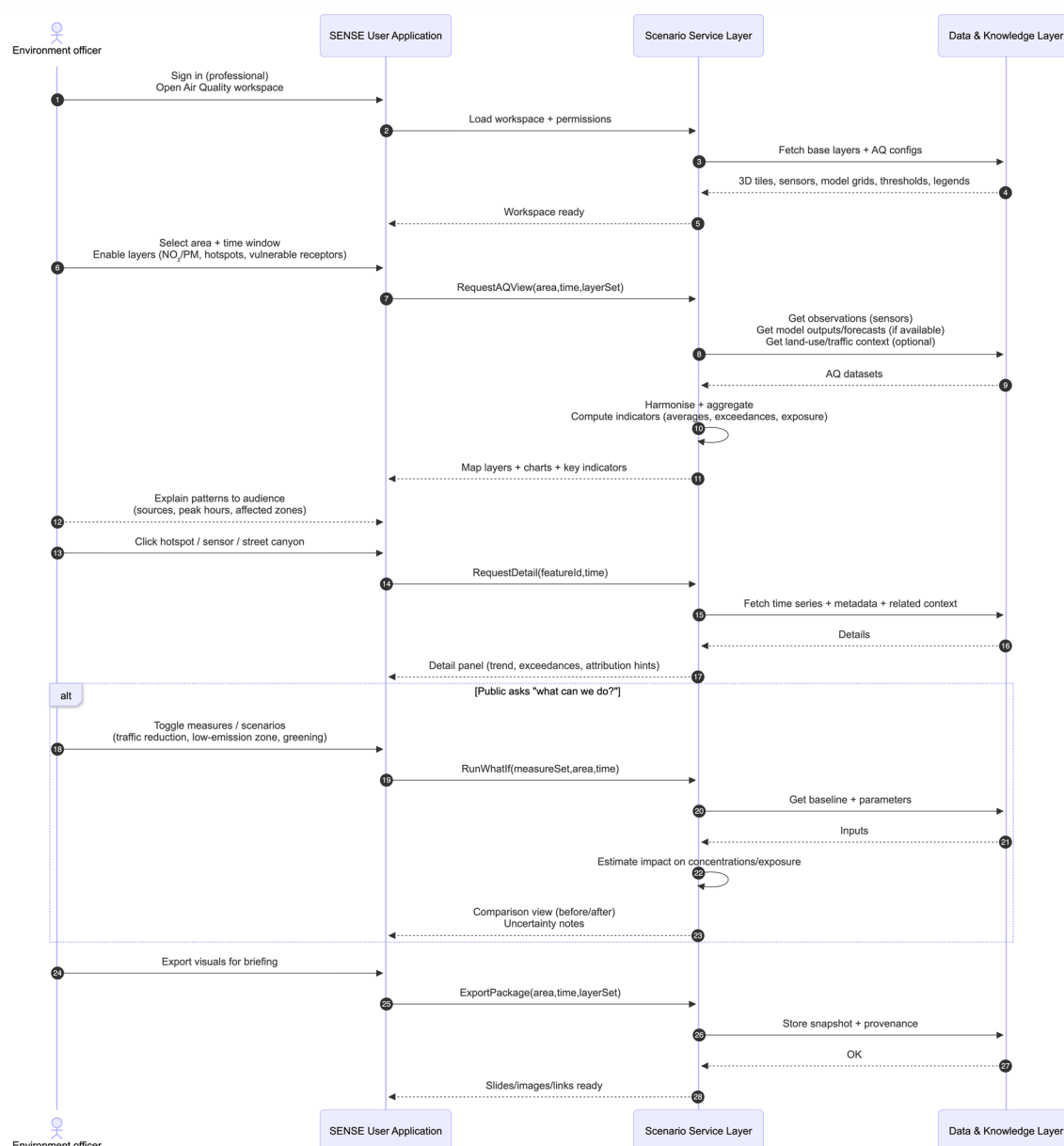


Figure 5. Sequence diagram for “Environment officer explaining air quality”

2.7.3 Input datasets

Below, we list the datasets that are registered in the SENSE Data Space and considered in the Smart Urban Mobility scenario. Together, they provide (1) the static geospatial context required to configure and render the scenario in the 3D twin, and (2) near real-time monitoring streams used to compute indicators, highlight hotspots and support routing and decision support. The context broker exposes the current state of each source, so the historical series used by the time control and by the before/after comparisons are those accumulated from the

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moment each source starts being recorded in the platform. Section 1.5 states which of them are already published with their terms and conditions and which are still being onboarded.

City of Cartagena Geospatial Data

- **Type:** OGC GeoPackage (static / periodically updated).
- **Content:** Reference and thematic geospatial layers for the City of Cartagena, including Points of Interest (aligned with the OGC POI standard), vegetation cover, the municipal tree inventory, public transport line, stop and timetable layers where the city or the transport operator can supply them, and additional GIS layers used by the scenario (e.g., administrative boundaries and mobility-related layers where available).
- **Use in the scenario:** Basemap/overlay layers for the 3D twin, POI discovery, and the configuration of routing contexts (e.g., districts, key destinations, thematic layers). It also provides the spatial “anchors” used to join monitoring streams to neighbourhoods, corridors, or points of interest.

City of Cartagena Media Data

- **Type:** Media package (static / curated).
- **Content:** Multimedia assets related to the city, including images and 3D models. This package complements the *City of Cartagena Geospatial Data* dataset, which may include references (e.g. within POIs) linking to the corresponding media resources.
- **Use in the scenario:** Enriches user-facing panels and visualisations with contextual content (e.g., landmark images, illustrative media, 3D representations of selected urban spaces), improving interpretability and engagement.

City of Cartagena Crowd Flow Data

- **Type:** Data service (FIWARE Orion Context Broker API, NGSIv2, FIWARE Smart Data Models).
- **Content:** Crowd/footfall measurements from 25 sensors in Cartagena.
- **Use in the scenario:** Supports the detection of crowding hotspots and temporal patterns (e.g., peak periods), and enables visitor/commuter guidance by indicating areas of high pedestrian pressure (as an operational signal and/or as a contextual indicator).

City of Cartagena Traffic Flow Data

- **Type:** Data service (FIWARE Orion Context Broker API, NGSIv2, FIWARE Smart Data Models).
- **Content:** Traffic flow observations from 13 sensors in Cartagena.
- **Use in the scenario:** Provides the operational basis for congestion-aware routing, corridor performance indicators (speed/flow trends), and the identification of mobility bottlenecks that may affect both commuters and event operations.

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City of Cartagena Weather Data

- **Type:** Data service (FIWARE Orion Context Broker API, NGSIv2, FIWARE Smart Data Models).
- **Content:** Weather observations from 5 sensors in Cartagena.
- **Use in the scenario:** Adds environmental context (e.g., temperature, humidity, wind) to interpret mobility and air-quality conditions, and supports user-facing explanations (e.g., why pollution peaks may coincide with specific meteorological conditions).

City of Cartagena Noise Levels Data

- **Type:** Data service (FIWARE Orion Context Broker API, NGSIv2, FIWARE Smart Data Models).
- **Content:** Noise level observations from 20 sensors in Cartagena.
- **Use in the scenario:** Enables noise exposure context for selected corridors/areas (useful for “quality-of-route” interpretation and for identifying potential nuisance hotspots relevant to urban mobility planning).

City of Cartagena Air Quality Data

- **Type:** Data service (FIWARE Orion Context Broker API, NGSIv2, FIWARE Smart Data Models).
- **Content:** Air quality observations from 26 sensors in Cartagena.
- **Use in the scenario:** Supports air-quality-aware mobility guidance (e.g., route comparison or corridor highlighting) and provides evidence for explaining LEZ-related goals and expected impacts using near real-time indicators and trends.

City of Cartagena Parking Sensor Data

- **Type:** Data service (FIWARE Orion Context Broker API, NGSIv2, FIWARE Smart Data Models).
- **Content:** Parking sensor observations from 20 sensors in Cartagena.
- **Use in the scenario:** Provides parking availability/occupancy signals to support parking search and demand management, and to contextualise mobility choices (e.g., encouraging park-and-ride or reducing cruising traffic where relevant).

2.7.4 Underlying models

In this section we list the main models that can be considered in the development of the *Smart Urban Mobility* scenario, covering (1) the 3D representation, (2) routing and optimisation, and (3) operational and analytical models.

- **Cartagena 3D City Model.** A web-native 3D representation of Cartagena, delivered as lightweight, level-of-detail OGC 3D Tiles and glTF/GLB meshes rendered client-side in the browser, with no server-side rendering. It provides the visual and spatial foundation for the scenario, supporting interactive navigation, layer switching and contextual inspection of streets, junctions, POIs and thematic layers within the 3D twin, while

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scene budgets and progressive loading keep performance predictable on mainstream devices. The model is assembled from open, official sources rather than from a dedicated survey. Building footprints come from the cadastral INSPIRE service, complemented by the municipal cartography where it is available; building heights are derived from the number of floors above ground recorded in the cadastre, with a documented default applied where that attribute is missing; the terrain comes from the national five-metre digital elevation model, since the municipal cartography is two-dimensional and carries no elevation values; the ground is textured with national orthoimagery published under a CC BY 4.0 licence; and street trees are placed from the municipal tree inventory. The resulting level of detail corresponds to CityGML LoD1: every building is present, correctly located and correctly proportioned in height, with flat roof surfaces and without modelled roof shapes or facade detail. That is the level of detail this scenario requires, as stated in Section 2.5.1, and it is reached with data that is available today, used under the terms of each service. Because the geometry is consumed as OGC 3D Tiles, a photogrammetric or laser survey of any part of the city, should one become available, replaces the corresponding tiles without any change to the application.

- **Cartagena street network model (deferred extension).** A graph-based representation of the mobility system, modelling streets and intersections and, where applicable, public-transport stops, lines and interchanges. It underpins the multi-criteria route planning described above and is therefore deferred to a later phase together with those routing functionalities; it is not part of the MVP for this revision.
- **Route planner and multi-criteria optimisation (deferred extension).** A routing model operating on the street graph with dynamic edge weights (for example congestion, crowding and environmental conditions) that would produce ranked route alternatives and short explanations of the trade-offs. It is documented here for completeness but is deferred to a future phase and is not implemented in the MVP.
- **Traffic simulation and scenario assessment model (deferred extension).** A mesoscopic or microscopic traffic simulation model intended for professional what-if workflows such as event preparation and testing closures or diversions. Given its computational profile it is deferred to a future phase and is not part of the MVP.
- **LEZ / restriction rule model.** A rules model describing LEZ/ZBE boundaries, pedestrian areas, restricted-access streets and temporary closures, including parameters such as time windows, vehicle categories, emission standards and permit requirements. In this revision the model drives the display of the zones and the explanation of the applicable rules; checking whether a route is compliant and generating compliant alternatives belong to the deferred routing functionalities.
- **Environmental exposure and impact estimation model.** A set of models translating environmental observations into route- and area-level indicators, e.g. (a) air-quality exposure along corridors (using point measurements and/or spatial interpolation), and (b) noise context where available. These models support both citizen-facing guidance (e.g., “avoid polluted corridor”) and professional interpretation/communication of impacts.

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3. Cartagena - Public Space, Environment and Quality of Life

Scope of this revision

Consistent with the resources available for the WP4 front-end and the web-native approach, this scenario is scoped for the present revision as a management-only tool. It preserves the analytical core (neighbourhood-scale assessment, composite indicators and hotspot detection) while deferring the public-facing portal and predictive functionalities.

In scope (MVP):

- A web-native professional (management) tool: neighbourhood and district navigation; thematic choropleth layers across the socio-economic, public-space, environmental and mobility-accessibility indicators; an interpretable composite index with explicit drivers and hotspot detection; side-by-side comparison of two areas; and export of the current view as an image and of the indicator tables as data files.

Deferred to future extensions:

- The public citizen-facing portal (neighbourhood profiles, city-wide comparison, story-guided views and citizen feedback).
- What-if and intervention-simulation tooling.

This scenario reuses the same data foundation as Section 2 and shares its 3D and basemap assets; the change relative to the original design is, again, the client-side rendering layer. The deferred items are documented as modular extensions for later phases. The remainder of this chapter describes the scenario in its full target form, as established in version 1.0 of this deliverable; where a capability is identified above as deferred or optional, its description should be read as target behaviour for a later phase rather than as functionality delivered in this revision. The same applies to the objectives stated in this chapter: where an objective depends on a capability identified above as deferred, this revision addresses the part of it that does not.

3.1 Scenario overview

In this scenario, the SENSE CitiVerse is used to understand how people live, move and interact in different neighbourhoods of Cartagena, and how public space, environment and social conditions combine to shape quality of life.

Imagine a resident opening the SENSE city twin and selecting their neighbourhood. On the 3D map, they see not only buildings and streets, but also a series of thematic layers: access to green areas and playgrounds, noise exposure from busy roads, proximity to schools and health centres, public transport stops, and basic socio-demographic indicators such as age structure and population density. By adjusting a set of simple filters, they can view how their area compares to others in terms of public space availability, environmental stress (e.g. noise, pollution proxies) and access to essential services.

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At the same time, a city planner uses the professional view of the same twin to examine a cluster of districts where complaints about lack of amenities and poor maintenance have been increasing. With a few clicks, they overlay indicators of unemployment, educational attainment and housing tenure with mobility accessibility and environmental indicators. Patterns emerge: some areas show a combination of limited green space, higher exposure to traffic-related impacts and lower socio-economic resilience. The planner uses these insights to prioritise small-scale interventions such as new shaded seating areas, improvements to pedestrian routes, renewal of playgrounds and better public transport stops, and to justify larger investments in public space.

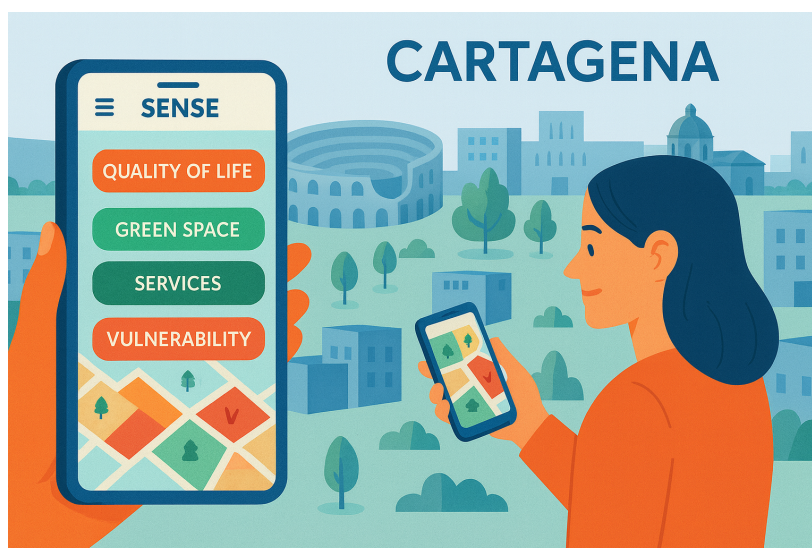


Figure 6. Cartagena - Public Space, Environment and Quality of Life

Social services teams can use the same environment to identify areas where socio-economic vulnerability and poor environmental conditions overlap, helping them focus outreach and community programmes. Citizen organisations and neighbourhood associations can use the public interface to communicate their experiences, validate or question the data and propose priorities. The overarching aim of this scenario is to make the spatial distribution of opportunities and stressors in Cartagena visible, understandable and discussable, in order to support more equitable, informed and participatory urban policy.

Overall, the scenario is designed to be used both internally (for evidence-based policy design, prioritisation and reporting) and externally (for communication and civic engagement), with the broader goal of supporting social cohesion and more equitable urban policy in Cartagena.

3.2 Urban and policy context in Cartagena

This use case aligns with Cartagena's broader strategic orientation towards a more environmentally, socially and economically sustainable city, as reflected in local frameworks such as the "Agenda Urbana" and the PACES (Sustainable Energy and Climate Action Plan) strategy for a sustainable city model. In this context, addressing inequalities and improving quality of life is not treated as a purely "social policy" topic, but as a cross-cutting urban challenge where mobility, environmental conditions, public space, access to services and neighbourhood investment interact.

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Cartagena is also positioned to build on an existing culture of digital innovation and data-driven approaches. The city has already engaged in multiple EU and national initiatives connected to sustainability, open data and urban transformation, such as BeOpen¹ (a Horizon Europe initiative aimed at developing an open-data framework to increase the availability and usability of high-value public sector datasets and enable new digital and AI-based services), as well as LIFE BAUHAUSING EUROPE² (a LIFE programme project that applies the New European Bauhaus approach to the renovation and reimagining of public buildings and neighbourhood spaces, with Cartagena included among the targeted municipalities). It is also involved in national investments and reforms linked to Spain's Plan de Recuperación, Transformación y Resiliencia (PRTR / NextGenerationEU)³. In SENSE, this scenario is framed as a cornerstone for community engagement and for strengthening the social fabric through more transparent, spatially grounded information about where disparities exist, how they intersect with environmental and accessibility factors, and how they evolve over time.

3.3 Objectives and expected impacts

This scenario pursues the following general objective:

To support more inclusive, evidence-based and transparent urban policy in Cartagena by providing an accessible 3D environment where socio-economic conditions, access to services, environmental stressors and public-space factors can be explored together at neighbourhood scale.

This objective is articulated into the following specific objectives:

O1. Integrated visibility of conditions and inequalities

- Provide an integrated view of socio-economic indicators, public space characteristics, environmental exposure and service accessibility at neighbourhood or district level.
- Make spatial inequalities and emerging vulnerabilities visible in a way that is understandable for both professionals and citizens.

O2. Support for planning and investment decisions

- Enable planners and policy makers to correlate socio-economic indicators with environmental stressors and accessibility gaps, helping them prioritise interventions and target resources where they are most needed.
- Provide empirical support for investment proposals (e.g. new parks, public space upgrades, service relocations), and for the evaluation of completed projects.

O3. Transparency and citizen understanding

- Offer a public interface where citizens can explore how their neighbourhood is evolving over time, understand the broader social fabric of the city and see how planned measures may affect them.

¹ BeOpen Project, <https://beopen-dep.eu>

² LIFE BAUHAUSING EUROPE, reference: LIFE22-ENV-ES-LIFEBauhausingEurope/101113886

³ https://serviciosociales.cartagena.es/proyectos_recuperacion.asp

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- Make underlying assumptions and limitations explicit, so that data and indicators are used as a basis for informed debate rather than as unquestionable “truths”.

O4. Support for social services and community programmes

- Help social services and community development teams identify areas where various forms of vulnerability overlap (e.g. high unemployment, low educational attainment, limited public space, higher environmental exposure).
- Support the planning and monitoring of outreach programmes, community initiatives and targeted support schemes.

O5. Citizen engagement and co-creation

- Provide a platform where neighbourhood associations, NGOs and citizens can leave structured feedback, identify places of concern or potential, and propose small-scale improvements in public spaces.
- Encourage co-creation of local priorities by combining data-driven insights with lived experience.

The expected impacts of the scenario can be grouped into two broad categories:

Short-term operational impacts

- Facilitate internal coordination between planning, environment, social services and mobility teams by providing a shared spatial reference.
- Improve the quality and clarity of communication materials used in public meetings and consultations.

Medium- to long-term impacts

- Contribute to a more balanced distribution of public investments in public space and services.
- Strengthen social cohesion by making inequalities visible and debatable in a constructive, evidence-based way.
- Support gradual improvements in environmental and quality-of-life indicators in the most vulnerable neighbourhoods.

3.4 Stakeholders, user groups and roles

The scenario is designed around several primary user groups, each with distinct needs and usage patterns:

Primary user groups

- **Municipal planning and urban regeneration teams:** use the platform to understand neighbourhood profiles, justify investment priorities, and support integrated planning decisions.
- **Social services and inclusion units:** use the scenario to identify vulnerability patterns, locate service gaps, and support targeted programmes.

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- **Public space / parks / neighbourhood management teams:** relate public-space provision and maintenance priorities to population needs and quality-of-life indicators.
- **Citizen associations and community organisations (e.g., federations of neighbourhood associations):** consult and validate whether the mapped patterns reflect lived experience, and contribute feedback during participatory processes.
- **Citizens (residents):** explore their neighbourhood context, understand city priorities, and follow how conditions change over time.

For each of these user groups, specific roles and permissions are defined:

- **Public users:** access an understandable subset of layers and explanations (with safeguards to avoid disclosure risks), and consult simple comparisons and time trends.
- **Professional users (city staff):** access extended functionality such as advanced indicator selection, comparison tools, dashboards, and internal notes/annotations for planning workflows.
- **Administrators / data stewards:** manage data publication rules, access control, indicator metadata, and update cycles, ensuring governance and privacy constraints are respected.

3.5 Functional description of the use case

3.5.1 Interactive 3D digital twin as an “urban cohesion lens”

This scenario reuses the same 3D digital twin of Cartagena as the mobility scenario, but focuses on neighbourhood-scale conditions rather than individual routes. Functionally, the 3D twin could include the following capabilities:

- **Comprehensive spatial coverage:** represent all urban districts with sufficient detail to distinguish buildings, blocks, streets, parks, plazas, waterfronts and major public facilities.
- **Intuitive navigation and context:** support smooth navigation (pan, rotate, zoom, “fly to district”) and offer a contextual overview map showing administrative units such as districts, neighbourhoods and census tracts.
- **Temporal exploration:** include time controls that allow users to move between different years or periods and compare the evolution of selected indicators (e.g. population change, increase in green space).

Key interaction features include:

- **Thematic layer selection:** users can activate thematic groups such as “Socio-economic profile”, “Public space and services”, “Environment and exposure”, “Mobility accessibility”.
- **Neighbourhood selection:** clicking on a district or neighbourhood boundary opens a summary card with selected indicators, while the map can shade all units according to a chosen indicator (e.g. unemployment rate).

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- **Comparison tools:** simple tools allow users to compare two neighbourhoods side-by-side, or to view distribution charts for the whole city.

3.5.2 Socio-economic, public space and environmental layers

The scenario could combine several thematic families of indicators, delivered as spatial layers.

Socio-economic and demographic indicators

- Population density and structure (age groups, dependency ratios).
- Household composition (e.g. share of single-person households, families with children).
- Educational attainment levels.
- Employment and unemployment rates, perhaps by broad sector.
- Housing characteristics (tenure, building age, basic conditions where available).

Public space, services and amenities

- Surface and accessibility of green spaces, playgrounds and sports facilities.
- Distribution of public services: schools, health centres, social services offices, cultural facilities, libraries, community centres.
- Basic indicators of public space quality, where available (e.g. presence of shade structures, benches, playground equipment, maintenance status).

Environmental and exposure indicators (linked to the *Smart Urban Mobility* scenario)

- Noise exposure proxies derived from traffic volumes and road classification or from measurement campaigns.
- Air quality indicators at neighbourhood level (e.g. long-term averages interpolated from monitoring stations or model results).
- Heat exposure indicators derived from land surface temperature and land cover (e.g. share of impervious surfaces, tree cover).

Mobility and accessibility indicators (linked to the *Smart Urban Mobility* scenario)

- Proximity to public transport, such as the distance to the nearest stop or station and the share of population within a given distance of one. Network-based accessibility, such as the number of jobs reachable within a given travel time, requires the street graph and the routing model and is therefore a deferred extension.
- Walkability indicators (e.g. pedestrian network density, barrier effects from major roads).
- Simple “proximity scores” for key services (e.g. proportion of population within a given distance of a park, a primary school, a health centre).

All these layers are rendered in a way that balances richness with readability, avoiding too many indicators at once and providing clear legends and explanations.

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3.5.3 Citizen-facing functionalities: exploration, transparency, feedback

For general users, the platform could focus on exploration and understanding:

- **Neighbourhood overview:** selecting “My neighbourhood” gives a concise overview card with a limited set of indicators (e.g. population, green space per inhabitant, access to services, generic socio-economic profile) and simple visual encodings (bars, icons).
- **City-wide comparison:** users can see where their neighbourhood sits in the city distribution for a given indicator (e.g. percentile rank for green space, unemployment).
- **Story-guided views:** for non-expert users, predefined “stories” lead them through a set of views, for example “Where are services located in Cartagena?” or “Understanding environmental exposure in your area”.
- **Feedback and local knowledge:** citizens can leave comments or structured feedback attached to specific locations or neighbourhoods, for example reporting under-used spaces and locations perceived as unsafe, or suggesting micro-interventions (more shade, benches, better lighting). This complements top-down indicators with bottom-up experience.

3.5.4 Professional functionalities: planning, analysis and scenario comparison

For planners, social services and environmental teams, the professional view could offer:

- **Configurable dashboards** showing key indicators for selected neighbourhoods or the whole city.
- **Multi-layer overlays**, allowing users to view combinations such as “low green space + high heat exposure + high share of elderly population”, or “high unemployment + poor public transport access”.
- **High-level indicator overlays for candidate interventions** (for example adding a pocket park or upgrading a square), showing at a glance how an area compares on accessibility or environmental-exposure indicators. Detailed what-if scenario simulation is a deferred extension and is not part of the MVP.
- **Export capabilities** for maps, indicator tables and charts that are used in reports, funding applications and public presentations.

3.6 User journeys

The user journeys below illustrate how different actors might interact with the scenario once fully operational. As in other scenarios, these narratives are aspirational and may include functionalities that go beyond what can be implemented within the SENSE project timeframe.

3.6.1 Social policy analyst identifying vulnerability hotspots

A municipal analyst responsible for inclusion policy opens the SENSE 3D twin and activates an “Urban Cohesion” workspace. She selects a set of indicators (e.g., unemployment distribution, population structure and proximity to essential services) and asks the platform to highlight districts that score above a chosen threshold. The map updates to show a small set

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of neighbourhoods where multiple risk factors overlap. She then toggles an environmental overlay (e.g., an air-quality or heat proxy layer, where available) to see whether exposure patterns intensify the social vulnerability profile.

She captures a set of annotated screenshots and exports a short “neighbourhood comparison card” that summarises key indicator differences for an internal coordination meeting with planning and public space teams.

3.6.2 Public space manager targeting improvements for quality of life

A public space manager is preparing next year’s maintenance and upgrade plan. Using SENSE, he selects a district and opens the contextual panel that summarises population density, age structure and proximity to parks and facilities.

By switching between layers, he identifies a set of streets and small squares where dense population coincides with low green access and poor service proximity. He places internal annotations (“candidate for pocket park”, “priority shading corridor”, “bench and lighting upgrade area”) and shares a link to the same view with colleagues in environment and social services to validate whether planned measures align with broader cohesion objectives.

3.6.3 Citizen exploring neighbourhood evolution and public priorities

A resident hears about a new municipal programme linked to neighbourhood regeneration. On the public-facing SENSE portal, she searches for her district and opens a “Neighbourhood profile” view showing a small set of accessible indicators and a brief explanation of what they mean.

She compares her area to the city average, then checks a “changes over time” slider (if available) to understand how key values have evolved. The platform also shows links to related municipal initiatives and offers an optional short questionnaire to capture perceived priorities (e.g., public space, services, environmental comfort), feeding into engagement processes planned for Cartagena.

3.7 Technical foundations

This section highlights the key technical aspects for implementing the scenario, including both common elements across SENSE scenarios and scenario-specific considerations.

3.7.1 Interaction flows

The sequence diagrams below define the interaction flows of the user journeys that this revision retains, illustrating the expected end-to-end behaviour of the scenario. The diagrams are based on the core components introduced in Section 2.7.1: (1) the SENSE User Application, (2) the Scenario Service Layer, and (3) the Data and Knowledge Layer. Some steps in these flows, in particular the testing of intervention options, belong to the deferred extensions identified at the start of this chapter and are shown here as target behaviour rather than as MVP functionality.

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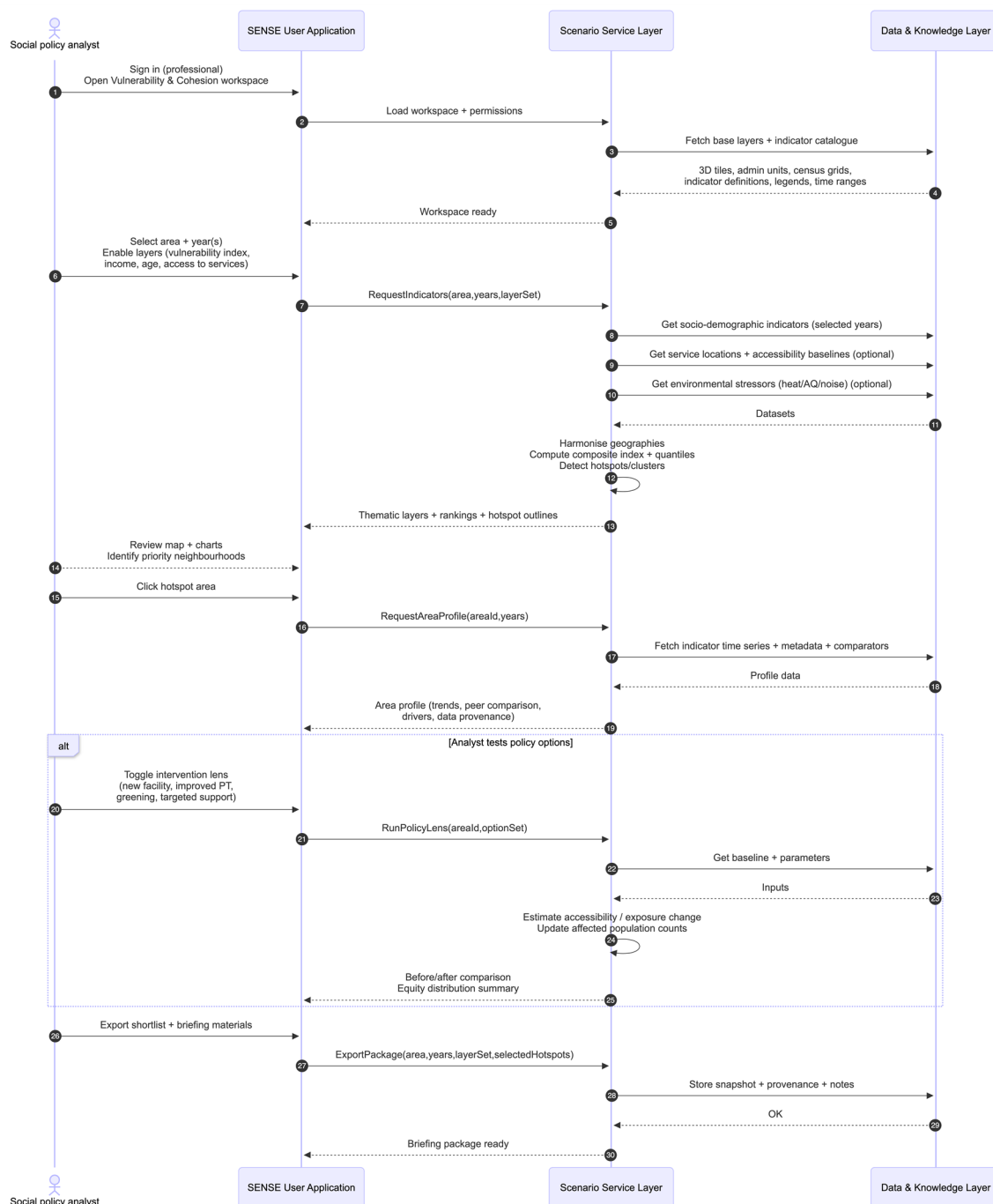


Figure 7. Sequence diagram for “Social policy analyst identifying vulnerability hotspots”

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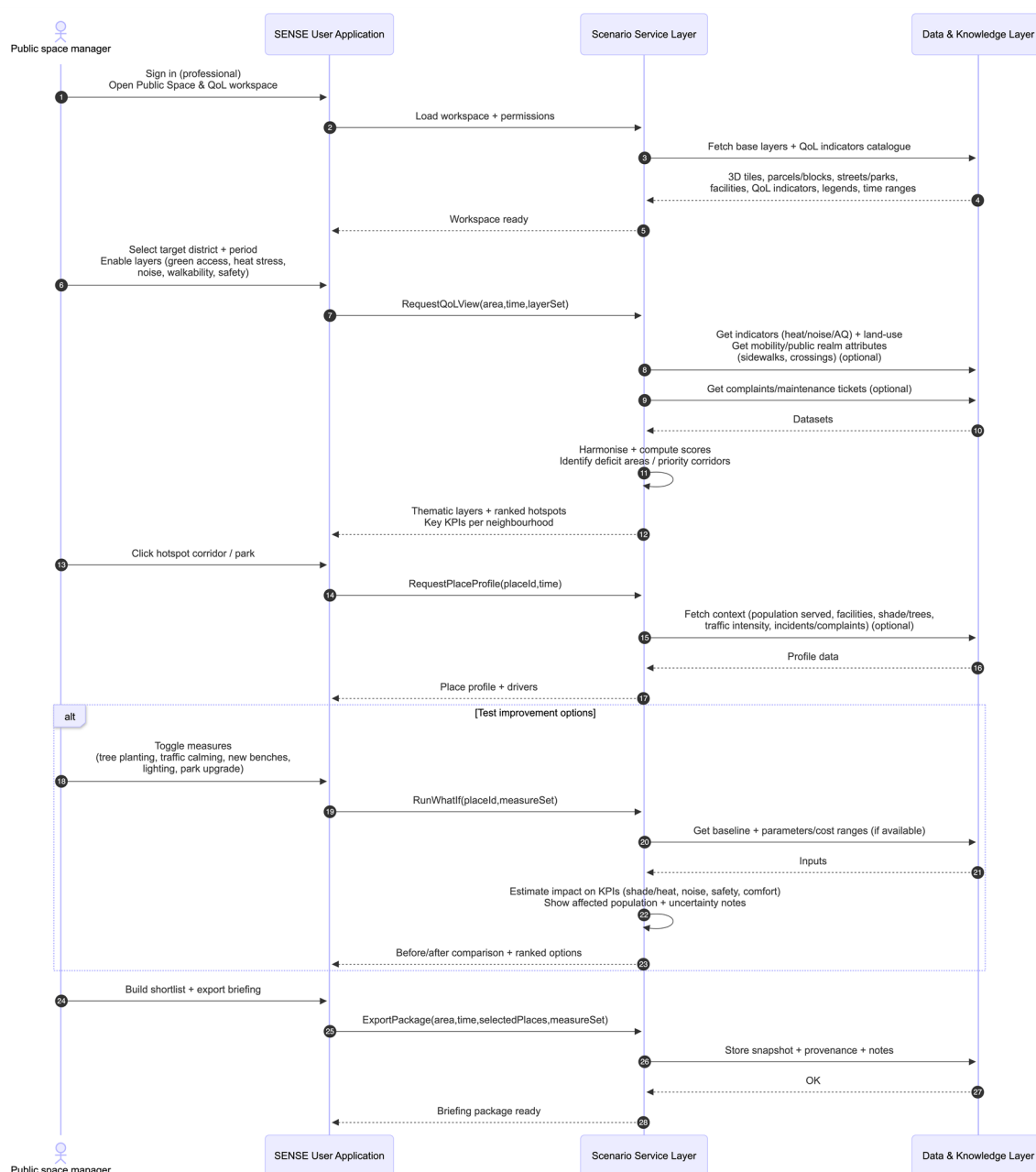


Figure 8. Sequence diagram for “Public space manager targeting improvements for quality of life”

3.7.2 Input datasets

Below, we list the datasets that are registered in the SENSE Data Space and considered in this scenario. Since *Public Space, Environment and Quality of Life* extends the *Smart Urban Mobility* scenario, several datasets are reused in both. Together, the datasets provide: (1) the static geospatial context required to configure and render the scenario in the 3D twin, (2) near real-time monitoring streams used to characterise environmental conditions and urban pressure, and (3) socio-economic indicators enabling neighbourhood comparisons and equity-

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oriented analysis. Section 1.5 states which of them are already published with their terms and conditions and which are still being onboarded.

City of Cartagena Geospatial Data

- **Type:** OGC GeoPackage (static / periodically updated).
- **Content:** Reference and thematic geospatial layers for Cartagena, including Points of Interest (aligned with the OGC POI standard), vegetation cover, the municipal tree inventory, public transport line, stop and timetable layers where the city or the transport operator can supply them, and additional GIS layers used by the scenario (e.g., administrative boundaries and mobility-related layers where available).
- **Use in the scenario:** Provides the spatial backbone for the 3D twin (basemap/overlays), supports POI discovery and public space exploration, and supplies the spatial anchors to aggregate and interpret monitoring streams (e.g., by neighbourhood, district, corridor or selected places).

City of Cartagena Media Data

- **Type:** Media package (static / curated).
- **Content:** Multimedia assets related to the city, including images and 3D models. This package complements the *City of Cartagena Geospatial Data* dataset, which may include references (e.g. within POIs) linking to the corresponding media resources.
- **Use in the scenario:** Enriches user-facing panels and story-like explanations with contextual content (e.g., parks, plazas, landmarks, before/after illustrations), improving interpretability for both public communication and professional briefings.

City of Cartagena Socio-Economic Data

- **Type:** Package of CSV files (static / curated), assembled for the scenario from the official sources that publish each variable, namely the national and regional statistical services and the municipal registers, at the smallest area unit and the most recent year at which each variable is published.
- **Content:**

Core/reference layers

- areas_geometry – geometries of areas (e.g., neighbourhoods, census tracts, districts).
- areas_metadata – metadata on these areas (administrative hierarchy, latest population, etc.).
- metadata_variables – variable dictionary with definitions, units, and scales.

Zonal socio-economic datasets (by area and year)

- demographics_zonal – population, age structure, households, migration.
- economy_employment_zonal – employment, unemployment, income, poverty, businesses.
- education_zonal – education level, illiteracy, education centres, accessibility.
- housing_zonal – housing stock, tenure, basic services, prices, vulnerability.

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- mobility_access_zonal – distance to the nearest transport nodes and key facilities, and the share of population within a given distance of them.
- environment_zonal – green areas, air quality, noise, climate risk.

Point/facilities datasets

- health_facilities – hospitals, health centres, clinics (point features).
- transport_nodes – bus stops, rail stations and other transport nodes (point features).
- **Use in the scenario:** Enables quality-of-life profiling and neighbourhood comparisons by combining environmental and social dimensions. It supports (1) identification of priority areas (e.g., places with lower green access and higher exposure/pressure), (2) trend analysis across years, (3) equity-sensitive interpretation (who is affected, where, and how), and (4) contextual explanations linking public space conditions to access to services, demographics and vulnerability patterns.

City of Cartagena Weather Data

- **Type:** Data service (FIWARE Orion Context Broker API, NGSIv2, FIWARE Smart Data Models).
- **Content:** Weather observations from 5 sensors in Cartagena.
- **Use in the scenario:** Provides environmental context (e.g., temperature, humidity, wind) to interpret outdoor comfort and the variability of air-quality/noise conditions. It can also support time-based narratives (e.g., seasonal differences) and contextual warnings during extreme conditions (e.g., hot periods affecting public space use).

City of Cartagena Noise Levels Data

- **Type:** Data service (FIWARE Orion Context Broker API, NGSIv2, FIWARE Smart Data Models).
- **Content:** Noise level observations from 20 sensors in Cartagena.
- **Use in the scenario:** Supports the identification of noise hotspots and time patterns (day/night), and helps assess the quality of public spaces and corridors. Combined with traffic/crowd indicators, it supports explanations of nuisance drivers and prioritisation of mitigation measures (e.g., traffic calming, reallocation of space, improved buffers).

City of Cartagena Air Quality Data

- **Type:** Data service (FIWARE Orion Context Broker API, NGSIv2, FIWARE Smart Data Models).
- **Content:** Air quality observations from 26 sensors in Cartagena.
- **Use in the scenario:** Enables the visualisation and communication of local air quality conditions and longer-term patterns. It supports exposure-aware interpretation of neighbourhood quality of life, helps relate environmental conditions to mobility/public space dynamics, and provides evidence for explaining interventions (e.g., greening, traffic reduction, LEZ-related effects).

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3.7.3 Underlying models

In this section we list the main models that can be considered in the development of the *Public Space, Environment and Quality of Life* scenario. As an extension of the *Smart Urban Mobility* scenario, it reuses part of the same foundational models (3D representation and environmental context), but shifts the analytical focus from routing and compliance towards (1) place-based assessment, (2) environmental quality and exposure, and (3) quality-of-life and equity-oriented hotspot detection.

- **Cartagena 3D City Model.** A web-native 3D representation of Cartagena, delivered as lightweight, level-of-detail OGC 3D Tiles and glTF/GLB meshes rendered client-side in the browser, with no server-side rendering. It provides the visual and spatial foundation for the scenario, supporting interactive navigation, layer switching and contextual inspection of streets, junctions, POIs and thematic layers within the 3D twin, while scene budgets and progressive loading keep performance predictable on mainstream devices. It is the same model as in Section 2.7.4, where its sources and level of detail are described.
- **Public space and green infrastructure model.** A spatial model representing public spaces and their attributes (e.g., parks, plazas, waterfront areas, pedestrian streets and urban green elements). Where available in the underlying GIS layers, the model can encode attributes relevant to use and comfort (e.g., area/extent, connectivity, proximity to key facilities, vegetation cover proxies). It supports place-based inspection (“what is here?”) and enables the computation of availability/access indicators (e.g., green access or public-space provision per neighbourhood).
- **Environmental conditions and exposure model.** A set of models translating environmental observations into area- and place-level indicators, combining sensor data (air quality, noise, weather) with spatial aggregation and, where appropriate, interpolation. Typical outputs include: (1) local air-quality context and exceedance patterns, (2) noise context by corridor/area, and (3) comfort-related contextualisation (e.g., meteorology supporting interpretation of outdoor conditions). This model underpins both professional interpretation and citizen-facing explanations.
- **Urban pressure and dynamics model.** A model layer that converts operational mobility signals (e.g., crowd flow and traffic flow) into pressure indicators for public space management. It supports detection of temporal peaks, identification of crowded hotspots, and contextual explanation of why specific areas experience recurring pressure (e.g., commuting peaks, event-driven dynamics, tourist concentrations).
- **Neighbourhood profiling and quality-of-life indicator model.** A modelling layer that integrates zonal socio-economic datasets with environmental and public-space indicators to create neighbourhood profiles (e.g., demographics, access to services, mobility accessibility, environmental stressors). This model supports comparisons across areas and across time, enabling “dashboard-style” summaries and transparent, explainable indicator definitions.
- **Composite index and hotspot detection model.** A multi-criteria analysis model that derives rankings and hotspot maps from multiple indicators (e.g., low green access +

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high noise + high crowding + vulnerable population). Methods are kept to normalisation, weighted aggregation and quantile classification, which keep every result traceable to the values behind it. The key requirement is interpretability: the model should expose drivers of the hotspot (which variables contribute most) to support decision-making and communication.

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4. Kiel - Hidden World

Scope of this revision

Following the consortium restructuring for the WP4 front-end and the move to a web-native delivery approach, the Hidden World scenario is delivered in a focused, MVP-first form. The experience runs entirely in the browser: geometry and content (glTF and OGC 3D Tiles, and 360-degree panoramas where geometry is uncertain) with lightweight metadata are streamed to the client and rendered on the device using an open web stack (CesiumJS self-hosted, with MapLibre GL and deck.gl), with no server-side render farm.

For the MVP, the scenario is built around five points of interest (POIs): two POIs with a 3D historical reconstruction and three POIs with a before/after comparator (archival photograph versus present-day view), each with a short caption and brief narrative. The specific POIs are selected by the production team from available archival material and are not fixed in advance. Tourism managers can arrange the five POIs into a simple curated route through the structured tour definition supplied to the production team. A complementary information panel can present up-to-date leisure and entertainment options from the Kiel Tourism database where access, freshness and usage conditions are confirmed. The design is modular and scalable: additional POIs can be added after the MVP as self-contained units without changing the underlying architecture.

Deferred to future extensions:

- The extended guided-tour platform: a catalogue of multiple tours, automatic composition of personalised routes from user preferences, and walking or public-transport guidance between stops. The MVP retains simple tourism-manager configuration of a curated route across the five POIs.
- The multilingual content-management layer and the in-app curator back-office: content authoring, review and publication workflows, usage analytics, and the in-app contribution of stories and media by residents and visitors.

Heritage assets are produced offline by the production team from the archival source material, with computer-assisted generation used as a production aid: each reconstruction is derived from documented sources and checked against them, and elements that cannot be documented are left out rather than reconstructed by assumption. The resulting assets are published as fixed, lightweight static files. Historical accuracy is validated with Kiel-Marketing (KIELM) and the relevant municipal heritage stakeholders; the production team is responsible for producing and integrating the validated assets. Source imagery is drawn from the historical photographic archive of the city (Stadtarchiv Kiel); the source and licence of each image are recorded and credited, and usage rights are confirmed before publication. The archive publishes under a Creative Commons licence and states the rights holder for each item individually, so the selection follows from that: the points of interest of this revision are drawn from items whose stated rights permit publication and derivative use, and where an item names a third-party rights holder or attaches a share-alike condition, either that condition is met in full for the published asset or the point of interest is selected from material that does not carry it.

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The two forms of use are distinguished in production, because a before and after comparison reproduces the archival photograph in the interface, while a three-dimensional reconstruction uses it as documentary reference and does not reproduce it. In the interface, reconstructions are presented as interpretive reconstructions based on archival sources rather than as historical photographs, and views produced with the support of generative techniques are labelled as such. The MVP content is delivered in German and English, in plain language, in line with the inclusion objectives of the project; the German text is reviewed with the Kiel partners before publication, on the same basis as the image usage rights, and a point of interest for which that review is not available in time is published in English first. A short audio narration is an optional addition. The remainder of this chapter describes the scenario in its full target form, as established in version 1.0 of this deliverable; where a capability is identified above as deferred or optional, its description should be read as target behaviour for a later phase rather than as functionality delivered in this revision. The same applies to the objectives stated in this chapter: where an objective depends on a capability identified above as deferred, this revision addresses the part of it that does not.

4.1 Scenario overview

The *Hidden World* scenario in Kiel will use SENSE to create a cultural and heritage experience that reveals stories, places and perspectives that are not immediately visible in the everyday cityscape. Through an interactive 3D model of Kiel, users can explore how the city has evolved over time, discover the traces of past events in today's urban fabric, and understand how maritime history, war destruction and post-war reconstruction have shaped the city's identity.

The scenario is built around a digital cultural tour concept. In a free-exploration mode, users can navigate the three-dimensional representation of Kiel, zooming in on emblematic buildings, squares, waterfront areas and neighbourhoods. Points of interest (POIs) attached to these locations provide contextual information such as historical descriptions, archival photographs, architectural reconstructions of earlier states and narrative explanations of each site's role in Kiel's development.

Beyond open exploration, the system can offer thematic guided tours focused on topics such as:

- Kiel as a maritime city (port development, shipyards, ferry links, Kieler Woche).
- War damage and post-war reconstruction.
- Everyday life in different historical periods.
- Religious, industrial or social heritage (e.g. former synagogue, fish market, workers' housing).

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Figure 9. Kiel - Hidden World

These tours can be experienced remotely or on site, with the 3D twin acting as a digital companion that complements the physical visit. Users can also create personalised tours by choosing a starting point, preferred walking duration and topics of interest; the application then composes a route and presents narrative stops along the way.

The scenario is multilingual and self-guided, allowing domestic and international visitors, day tourists and residents to engage with Kiel's history at any time of day and any season. The overarching aim is to strengthen residents' sense of belonging and to deepen visitors' understanding of the city, using SENSE as a bridge between digital storytelling and the lived urban environment.

4.2 Urban and cultural context in Kiel

Kiel is the capital of the German state of Schleswig-Holstein and a major Baltic Sea port. The city combines ferry and cruise terminals, shipyards and maritime industries with residential neighbourhoods, university campuses, cultural venues and recreational waterfront areas. Its location on the Kiel Fjord gives it a strong maritime character and makes it an attractive tourist destination, particularly for short stays.

Kiel records around one million overnight stays per year, with an average length of stay of about 2.1 days. Approximately 18% of visitors are international, driven largely by large events such as Kieler Woche, one of the world's largest sailing events, and by international ferry and cruise traffic.

This creates a significant demand for cultural offerings that are accessible, multilingual and suitable for short visits, while also providing deeper content for repeat visitors and residents.

Historically, Kiel has been a major naval and shipbuilding centre. During the Second World War, around 80% of the city was destroyed, and many historical structures disappeared or were radically transformed. As a result, much of the city's heritage is "hidden" in archives,

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memories and the underlying urban structure rather than in intact historical districts. The city's history is therefore harder to grasp through conventional sightseeing alone: visitors and even long-term residents may walk past sites of great historical importance without being aware of their stories.

At the same time, Kiel is actively positioning itself as a forward-looking, sustainable port city, investing in new waterfront developments, cultural institutions and climate-related initiatives. This creates an opportunity to present “yesterday’s and tomorrow’s Kiel” together: connecting the city’s maritime and wartime past with current urban development and future sustainability ambitions.

The *Hidden World* scenario responds to this context by:

- Making intangible or invisible heritage accessible through spatialised storytelling.
- Supporting short-stay and cruise tourism with flexible, self-guided cultural experiences.
- Offering residents and schools new ways to (re)discover their city and its neighbourhoods.

4.3 Objectives and expected impacts

The *Hidden World* scenario pursues the following overarching objective:

To reveal the “hidden” cultural and historical layers of Kiel and strengthen citizens’ and visitors’ sense of belonging by providing a self-guided cultural tour in the SENSE 3D twin, experienced as a three-dimensional model of the city that runs in an ordinary browser, delivered in German and English and written in plain language, and designed so that further language versions can be added as content packs in later phases.

This objective is articulated into the following specific objectives:

O1. Visibility and accessibility of heritage

- Make historically significant locations visible and understandable within a unified 3D environment, even where physical traces are limited or absent.
- Provide self-guided access to cultural content in German and English, written in plain language, for both international and domestic visitors, as well as residents.
- Integrate archival materials (images, documents, maps) directly into the spatial experience to give depth and authenticity to stories.

O2. Support for informed and meaningful cultural experiences

- Enable users to select themes, durations and difficulty levels (e.g. family-friendly, barrier-free routes) so that the experience fits their interests and constraints.
- Provide interpretive content that links individual sites into coherent narratives (e.g. a “reconstruction tour” or “maritime economy tour”).
- Combine historical information with practical, up-to-date information on leisure and entertainment options through a complementary panel using the Kiel Tourism database

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where available, with weather, opening hours and public transport connections added where suitable sources are confirmed.

O3. Community engagement and co-creation

- Involve local guides, shop owners, cultural organisations and citizens in co-creating stories, providing media content and validating narratives.
- Bring the contributions of local guides, businesses and cultural organisations into the published content through the production process, so that local knowledge reaches visitors even where the material is not held by the archive. In-app contribution channels for residents and visitors are a later extension.

The expected impacts of the scenario can be grouped into two broad categories:

Short-term impacts

- Enhanced visitor experience through interactive, memorable and shareable tours that can be accessed at any time.
- Increased visibility of lesser-known sites and neighbourhoods, potentially dispersing visitor flows beyond a few landmark locations.
- Stronger cooperation between the city archive, local guides, shop owners and tourism services around a common digital platform.

Medium- to long-term impacts

- Strengthened sense of belonging among residents, especially younger generations and newcomers who can discover their city's stories in accessible ways.
- Support for sustainable and inclusive tourism by promoting local businesses, reducing the need for resource-intensive printed materials, and offering more flexible, autonomous visits.
- A reusable digital infrastructure that can host additional tours, themes and collaborations, and potentially be replicated in other cities in future phases of SENSE.

4.4 Stakeholders, user groups and roles

The *Hidden World* scenario brings together several stakeholder groups with distinct interests, roles and levels of engagement. We can distinguish between primary users, enabling stakeholders and institutional partners. Engagement with these groups has already begun: a working prototype of the scenario was shown to the local guides of Kiel-Marketing on 24 April 2026, and their feedback on which points of interest, routes and themes were most compelling is the starting point for the content of this revision.

Primary user groups

- **Visitors and tourists**
 - *Profile:* International and domestic tourists, including cruise passengers and day visitors.

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- *Needs:* Easy-to-use, multilingual, self-guided tours that fit short stays and can be started at any time; engaging, visually rich content that is easy to share.
- *Role:* Core users of the digital tour; their numbers, satisfaction and word-of-mouth strongly influence impact.

- **Residents and local communities**

- *Profile:* Long-term residents, new residents, families, and individuals with an interest in local history and identity.
- *Needs:* Recognition of their own neighbourhoods, stories and perspectives; accessible content that does not assume prior historical knowledge; opportunities to contribute stories or feedback.
- *Role:* Both users and potential co-creators; their engagement is key to ensuring that the tour reflects diverse local voices.

Enabling stakeholders

- **Local guides**

- *Role:* Provide authentic insights, personal stories and contextual explanations that enrich the digital content.
- *Interest:* Deliver high-quality visitor experiences; strengthen their professional profile.
- *Influence:* High impact on narrative quality and tour attractiveness.

- **City of Kiel / City archive**

- *Role:* Key providers of historical photographs, documents and contextual information that underpin the narratives.
- *Interest:* Visibility of archival collections; public engagement with historical resources.
- *Influence:* Shapes the depth, authenticity and reliability of content.

- **Local shop owners and businesses**

- *Role:* Points of interest along routes, providing present-day “touchpoints” that connect historical narratives to current life; potential providers of stories and imagery.
- *Interest:* Increased footfall, visibility and economic benefit from tour participants.
- *Influence:* Can affect the “feel” of the experience and support sustainable, locally anchored tourism.

Institutional partners and internal stakeholders

- The city’s local tourism organisation (strategy, branding, coordination).
- Digital and IT departments (hosting, integration with SENSE platform and data space).
- Research partners (evaluation, user studies, content experimentation).

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For each of these groups, the platform can support differentiated access rights, from public users (no account required) to professional users (curators, city staff, teachers) and administrators managing content and roles, following the pattern established for other scenarios.

4.5 Functional description of the use case

4.5.1 Interactive 3D cultural twin of Kiel

The core of the scenario could be conceived as an interactive 3D representation of Kiel that serves as the entry point for cultural exploration, broadly analogous to the mobility twin developed for Cartagena (see Section 2.5.1) but tailored to heritage and storytelling content. Functionally, the 3D twin could include the following capabilities:

- **City coverage and performance:** it could cover the main urban area, waterfront and relevant neighbourhoods with sufficient detail to distinguish buildings, streets, port facilities and landmarks, while remaining usable on standard devices.
- **Intuitive navigation and orientation:** it could provide basic navigation controls (pan, rotate, zoom) and include a minimap or overview to support orientation and quick repositioning.
- **Semantic linking to heritage content:** it could support links between 3D objects (e.g. buildings, squares, waterfront segments) and associated heritage records, narratives and media assets.
- **Time-related views:** where relevant, it could offer basic temporal views, such as overlays of historical maps or simplified 3D reconstructions representing earlier building states.

From a functional perspective, the twin could also support:

- **Layer switching:** users could switch between cultural themes (e.g. “war damage and reconstruction”, “maritime economy”, “religious heritage”) and additional contextual layers (e.g. viewpoints, public transport stops).
- **Contextual information on selection:** clicking or tapping a point of interest could open an information panel with text, images, audio or short video clips; in some cases, this could include reconstructions or artistic renderings of past states.
- **Bookmarks and perspectives:** predefined camera positions (e.g. main squares, harbour viewpoints, former shipyard areas) could be made available for quick access with a single click.

4.5.2 Heritage and storytelling layers

The scenario could build several content layers on top of the 3D base model:

- **Points of interest (POIs):** georeferenced locations such as sights, restaurants, shops, former industrial sites and characteristic streets. Each POI is associated with metadata (name, category, time period, thematic tags) and one or more narratives.

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- **Narratives / storylines:** structured sequences of POIs forming a thematic tour (e.g. “From harbour to shipyard”, “Kiel in ruins and rebuilding”). Each narrative includes an introduction, per-stop content and a closing summary; content can be textual, audio-guided, visual or mixed.
- **Media assets:** archival photographs, historical maps, documents and audio recordings provided by the city archive and other partners. Contemporary photos and media contributed by local guides, businesses or citizens, subject to curation.
- **Operational context layers:** a complementary panel for up-to-date leisure and entertainment options from the Kiel Tourism database where access and usage conditions permit, with optional overlays for current weather, opening hours, public transport stops or walking times between POIs where suitable sources are available.

4.5.3 Visitor and citizen functionalities

For public users, the *Hidden World* scenario could behave as a “cultural tour companion” in 3D:

- **Free exploration:** users could move freely around the 3D city, select any POI and access its content. Filters allow restricting the view to certain themes, time periods or difficulty levels (e.g. family-friendly, “in-depth”).
- **Curated route and guided-tour extension.** In this revision, tourism managers can arrange the five curated POIs into a simple route by updating the structured tour definition supplied to the production team. The five POIs include two with a 3D historical reconstruction and three with a before/after comparator. A later phase may add a catalogue of multi-stop tours with estimated duration and distance, automatic personalisation, and step-by-step walking or public-transport guidance.
- **Personalised tours (deferred extension):** the automatic composition of custom routes from user preferences belongs to the deferred guided-tour platform and is not part of the MVP.
- **Multilingual support and accessibility:** content is available in German and English, reflecting the mix of international and domestic visitors, with further language versions as later content packs. The interface follows the contrast and text-size settings of the user’s own system and browser, and the content is written in plain language. A short audio narration is an optional addition.
- **Feedback and participation.** Facilitated pilot try-outs collect structured feedback from residents, visitors and other non-expert users on accessibility, comprehension, relevance and preferred stories or routes; the project records what changes in response. In-app surveys, ratings, open comments, story proposals and user media uploads remain part of the deferred contribution workflow.

4.5.4 Curatorial and management features

For professional users (city staff, archive curators and tourism organisations), content is authored offline and published as fixed web assets in this revision, with no in-app back-office. Tourism managers can nevertheless configure the order of the MVP’s five POIs through a

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simple structured route definition supplied to the production team. The fuller in-app management capabilities below remain future extensions:

- **Content authoring tools** to create and edit POIs, narratives and media bundles, and to define tours and thematic layers.
- **Workflow support** for reviewing and approving new or updated content, especially when submitted by external contributors (guides, businesses, citizens).
- **Analytics dashboards** summarising usage by tour, language, time of day and location, helping to understand which content resonates with which user groups.
- **Configuration of visibility rules** (e.g. experimental tours only visible to pilot groups) and integration with the broader SENSE Data Space and user management.

4.6 User journeys

The user journeys below illustrate how different actors might interact with the *Hidden World* scenario once fully operational. As in other scenarios, these narratives are aspirational and may include functionalities that go beyond what can be implemented within the SENSE project timeframe.

4.6.1 Visitor discovering the “hidden city behind the waterfront”

A couple visiting Kiel for a weekend disembarks from a cruise ship at the harbour. While checking tourist information, they see a QR code inviting them to “Explore Kiel’s *Hidden World* in 3D”. They scan it and the SENSE app opens directly in the Kiel cultural twin, centred on the waterfront.

The app proposes a 90-minute themed tour titled “Harbour stories: from shipyards to city life”, available in several languages. The couple selects their language, and the app shows the first stops along the quay, including the site of a former shipyard and a square rebuilt after the war. At each stop, they see archival photographs overlaid on the current 3D scene, listen to short audio clips and read concise explanations.

Between stops, the app guides them with simple arrows in the 3D view and an estimated walking time. When the tour passes a cluster of local shops identified as POIs, the app briefly highlights their specialities and invites the couple to discover them.

At the end of the tour, the couple rates the experience and leaves a brief comment about which stories they found most impactful. Their feedback is aggregated in the analytics dashboard for curators and city staff.

4.6.2 Resident reconnecting with their neighbourhood

A resident who has lived in Kiel for years hears about the SENSE tour from a local newspaper. At home, they open the web version of the cultural twin and search for their own neighbourhood.

They discover that nearby there was a former industrial site with an important role in the city’s labour history, and that their street was part of a post-war reconstruction plan. The app

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suggests a short “neighbourhood past and present” tour tailored to their location, with a duration of 30 minutes.

After completing the route, the resident notices that one of the stories mentions an event they remember from their childhood. Through the built-in participation features, they submit a short personal recollection and a family photo; the submission enters a review queue for the city archive, potentially enriching future versions of the tour.

4.6.3 Curator and tourism officer planning new content

This journey illustrates a deferred, future capability, namely in-app authoring and analytics; in this revision curators provide the source material and content is authored offline. A curator at the city archive and a tourism officer meet to review usage statistics from the last quarter. The analytics dashboard shows that a specific tour is popular among international visitors but has low engagement among locals, while another neighbourhood-focused tour is widely used by residents and school groups.

Based on this, they decide to:

- commission local guides and shop owners in an under-represented district to co-create new POIs;
- add an additional language to a high-performing tour; and
- test a pilot tour during Kieler Woche that links regatta locations with historical maritime sites.

They use the authoring tools to configure the new tour and schedule its publication, ensuring that all content is reviewed and approved according to agreed workflows.

As in the Cartagena scenario, these journeys can be decomposed into flows between the SENSE User Application, the Scenario Service Layer and the Data and Knowledge Layer connected to the SENSE Data Space: the User Application collects user inputs, the Scenario Service Layer composes the narrative sequence and delivers content, and the Data and Knowledge Layer provides harmonised access to 3D, heritage and contextual data.

4.7 Technical foundations

This section highlights the key technical aspects for implementing the scenario, including both common elements across SENSE scenarios and scenario-specific considerations.

4.7.1 Interaction flows

The sequence diagrams below define the interaction flows of the user journeys that this revision retains, illustrating the expected end-to-end behaviour of the scenario. The diagrams are based on the core components introduced in Section 2.7.1: (1) the SENSE User Application, (2) the Scenario Service Layer, and (3) the Data and Knowledge Layer. Some steps in these flows, in particular the guided story mode, the walking and public-transport guidance and the in-app contribution of content by residents, belong to the deferred extensions identified at the start of this chapter and are shown here as target behaviour rather than as MVP functionality.

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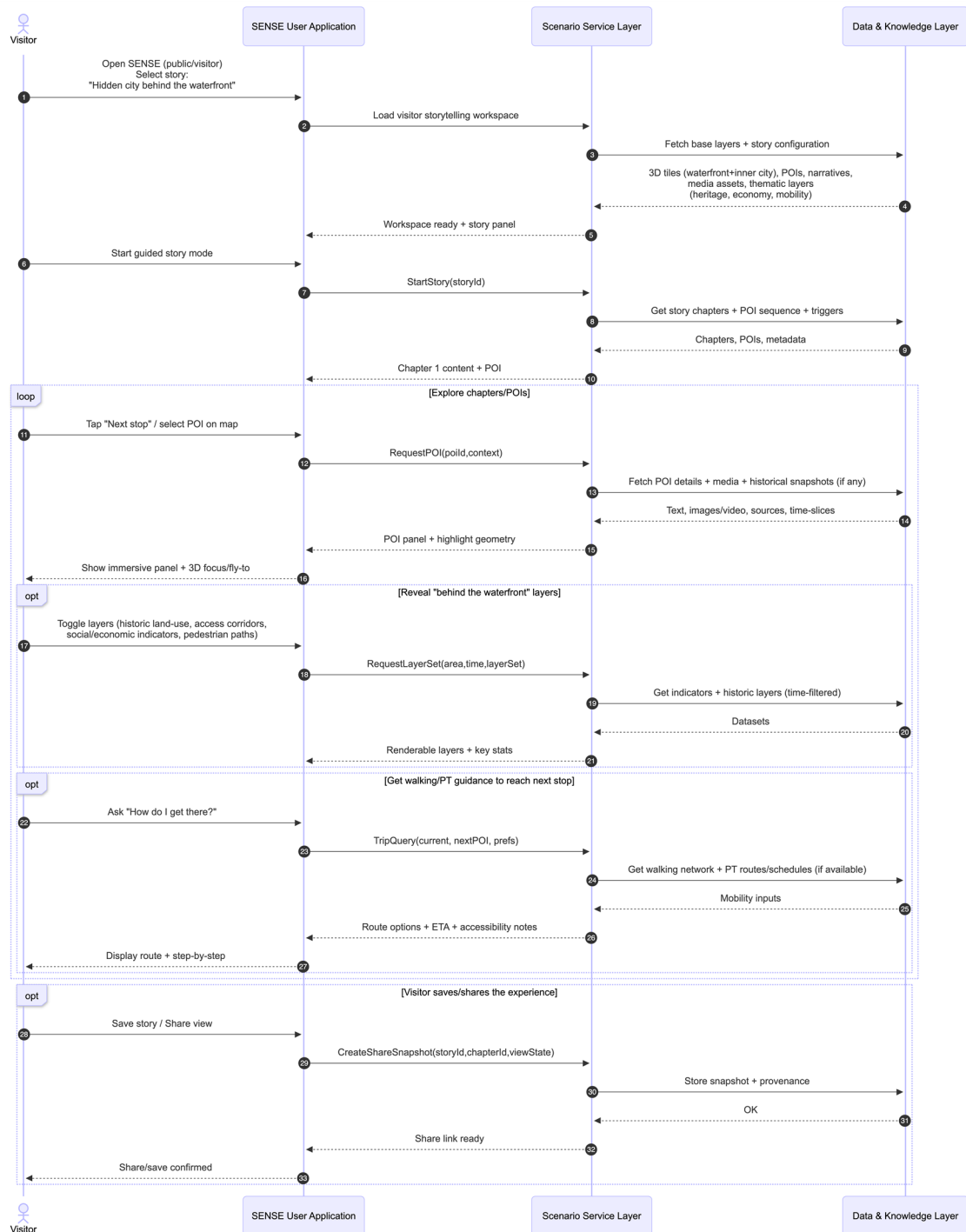


Figure 10. Sequence diagram for "Visitor discovering the "hidden city behind the waterfront""

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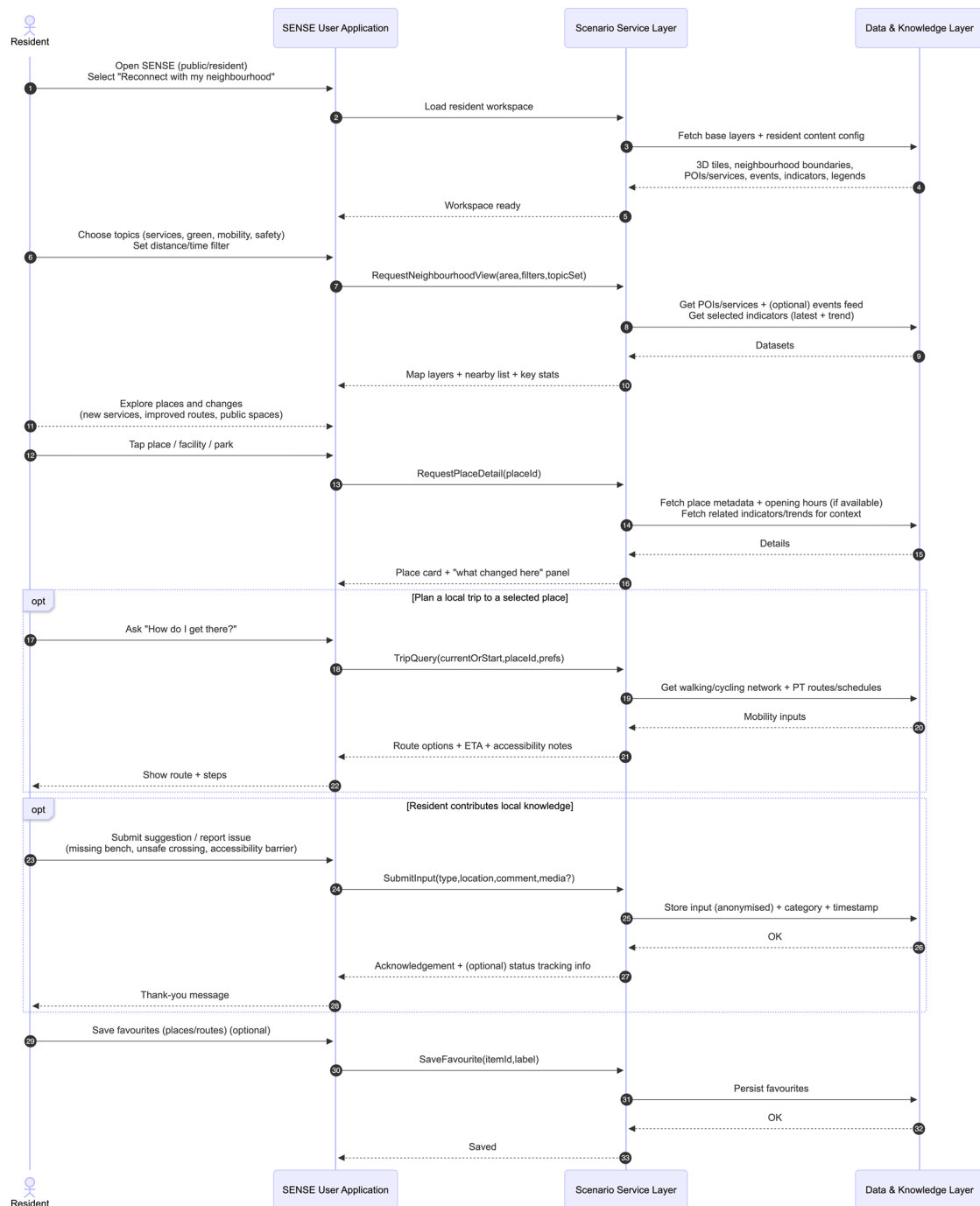


Figure 11. Sequence diagram for “Resident reconnecting with their neighbourhood”

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4.7.2 Input datasets

Below, we list the datasets that are registered in the SENSE Data Space and considered in the Kiel Hidden World scenario. Collectively, these datasets provide: (1) the geospatial and semantic context (POIs and reference layers) to anchor the experience in the digital twin, (2) curated multimedia assets to enrich the narrative, and (3) structured tour definitions that drive guided storytelling and self-paced exploration in the 3D environment. Section 1.5 states which of them are already published with their terms and conditions and which are still being onboarded.

City of Kiel Geospatial Data

- **Type:** OGC GeoPackage (static / periodically updated).
- **Content:** Reference and thematic geospatial layers for Kiel, including Points of Interest (aligned with the OGC POI standard) and additional GIS layers used by the scenario (e.g., districts/neighbourhoods, waterfront features, paths or other context layers where available).
- **Use in the scenario:** Provides the spatial backbone for the 3D twin (basemap/overlays), supports POI discovery and filtering (by theme, time period, category), and supplies the stable spatial anchors used by the narrative engine (e.g., “fly-to POI”, highlight geometry, define tour stops, and attach story chapters to locations).

City of Kiel Media Data

- **Type:** Media package (static / curated).
- **Content:** Multimedia assets related to Kiel, including images and 3D models. This package complements the *City of Kiel Geospatial Data* dataset, which may include references (e.g., within POI attributes) linking features to corresponding media resources.
- **Use in the scenario:** Enriches user-facing panels and story-like explanations with contextual content (e.g., landmark imagery, archival illustrations when available, 3D representations of key sites). Media assets improve engagement and comprehension by allowing the user to connect locations in the 3D twin with historically or culturally relevant material.

City of Kiel Tour Narratives

- **Type:** JSON (static / curated).
- **Content:** Structured narrative tour definitions designed to support guided and self-paced experiences in the SENSE platform. Each tour is represented as an ordered sequence of stops linked to specific locations and POIs. For every stop, the dataset typically provides:
 - Geospatial information (latitude/longitude) and/or references to the corresponding POI identifiers in the *Kiel GeoPackage*.

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- Narrative content (titles, descriptive text sections, optional “did you know?” facts, calls to action).
- Optional media references (e.g., image/3D model identifiers) to be presented in the 3D experience.
- Tour metadata such as theme(s), interaction mode (e.g., guided vs. free exploration), intended transport mode (e.g., walking), and indicative duration/distance.
- **Use in the scenario:** Acts as the experience script for the client application: it orchestrates chapter progression, triggers map actions (fly-to, highlight and focus), and binds story text and media to POIs. In this revision, the dataset carries the narrative content of the five curated POIs and provides the simple route definition through which tourism managers can set or revise their presentation order with the production team. The same structure can later support multiple thematic routes and the deferred multi-stop tour catalogue.

4.7.3 Underlying models

In this section we list the main models that can be considered in the development of the Kiel Hidden World scenario. The models focus on (1) the 3D representation and spatial anchoring of cultural content, (2) the narrative/tour orchestration logic that drives guided experiences, and (3) supporting models for discovery, personalisation and content lifecycle management.

- **Kiel 3D City Model.** A web-native 3D representation of Kiel, delivered as lightweight OGC 3D Tiles and glTF/GLB meshes and, where geometry is uncertain, 360-degree panoramas, all rendered client-side in the browser with no server-side rendering. It forms the spatial foundation of the experience, enabling navigation (pan, zoom, fly-to), viewpoint selection and the contextual rendering of POIs and of the historical reconstructions at selected hotspots. Its sources are the LoD1 and LoD2 building models published as open data by the regional mapping authority, complemented by municipal geodata where it is available, on the same principles as the Cartagena model described in Section 2.7.4. Where the geometry of a past state cannot be established from the archival sources, a 360-degree panorama is used in place of a reconstruction.
- **Kiel street network model (deferred extension).** A graph-based representation of streets and, where applicable, public-transport connections. It is only required for the multi-criteria route planning below and is therefore deferred together with those functionalities; it is not part of the MVP for this revision.
- **Route planner and multi-criteria optimisation (deferred extension).** A routing model operating on the street graph to compose walking itineraries between stops. It belongs to the full guided-tour platform, which is deferred to a future phase; the MVP presents a fixed set of five curated points of interest rather than computed routes.
- **POI and semantic place model (OGC POI-aligned).** A structured model representing Points of Interest with stable identifiers, categories, multilingual labels (where available), and links to geometry and media. This model provides the semantic layer

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that connects the 3D twin to cultural and tourism content, enabling filtering (theme/era/type), search, and consistent referencing from tours and story chapters.

- **Narrative tour model (chapter/stop orchestration).** A model describing each tour as an ordered sequence of stops/chapters with associated narrative content, media references and interaction metadata (e.g., guided vs. free exploration, intended transport mode, indicative duration). It orchestrates progression through the story and triggers map actions such as fly-to, highlight and focus at each stop.
- **View-state and interaction model (scene framing).** A lightweight model that binds narrative steps to the 3D environment through view parameters (camera position, orientation, zoom/tilt) and spatial targets (POI geometry, buffered highlight areas). This ensures each chapter reliably reproduces the intended “scene” and viewpoint, improving storytelling quality and consistency across devices.
- **Content curation and publication model (deferred extension).** A model supporting an in-app authoring and publication workflow (draft, review, published) with versioning and provenance. In this revision, content is authored offline and published as fixed web assets, so the in-app curator back-office is deferred to a future phase.

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5. Kiel - Sealevel

5.1 Scenario overview

The Kiel SEALEVEL scenario extends the physical SEALEVEL exhibition into an interactive online experience within the SENSE environment. The scenario is designed as a public-facing digital exhibit that combines three-dimensional spatial exploration with curated exhibition content, helping citizens, visitors and educational audiences understand marine ecosystems, climate-related changes and the local relevance of the Kiel Fjord.

Users can navigate selected waterfront and fjord environments in 3D and interact with digital stations or points of interest that present explanatory content in accessible formats. These stations may include short texts, images, recorded audio, video material and simple visual overlays derived from the SEALEVEL exhibition. The experience is intended to make complex marine and climate-related topics understandable for non-experts and to translate the exhibition narrative into a continuous digital format that can be accessed before, during or after a physical visit.

The digital experience focuses on three selected scenes. These scenes serve as spatial anchors for the digital exhibition and provide the basis for navigation, interactive content panels and guided exploration. Where relevant data is available through the SENSE Data Space, the platform may also display selected environmental indicators or sensor-based updates as contextual information.

Overall, the scenario should be understood primarily as an educational and communication-oriented online experience. Its core value lies in transforming curated exhibition content into an engaging, scalable and maintainable digital experience that can be updated by authorised content administrators.



Figure 12. Kiel – SEALEVEL Scenario

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5.2 Environmental and policy context in Kiel

Kiel provides a strong contextual basis for a digital SEALEVEL experience due to its close relationship with the Baltic Sea, the Kiel Fjord, maritime activities and public interest in marine protection. The existing SEALEVEL exhibition in Holstenstraße already communicates ocean-related topics through physical installations, interactive stations, films and curated educational material.

The SENSE SEALEVEL scenario builds on this exhibition context and translates selected content into a digital format. Instead of replacing the physical exhibition, the digital experience complements it by making selected narratives, media elements and explanatory content accessible through an interactive online platform. This allows users to engage with the exhibition remotely, revisit content after a physical visit or use the digital environment as preparation for a visit.

Scientific and educational content provided and validated by the relevant project and local stakeholders can be integrated into the platform as curated media and information panels. The focus is therefore on enabling clear, accessible and visually engaging public communication rather than on reproducing the complete physical exhibition or developing a scientific simulation environment.

5.3 Objectives and expected impacts

The SEALEVEL scenario pursues the following overarching objective:

To transform selected elements of Kiel's SEALEVEL exhibition into an interactive, web-based 3D experience that makes marine and climate-related content accessible, engaging and reusable for citizens, visitors and professional content teams.

This objective is articulated into the following specific objectives.

01. Digital extension of the SEALEVEL exhibition

- Translate selected exhibition content into digital stations, information panels and guided exploration elements.
- Enable users to access exhibition narratives remotely through a web-based application on desktop and mobile devices.
- Preserve the structure and educational character of the physical exhibition while adapting it to an interactive online format.
- Enable users to access exhibition content before, during and after a physical visit, including after the temporary physical exhibition is no longer in place.
- Provide a flexible platform that can subsequently be reused or extended in the context of future marine-visualisation activities.

02. Interactive 3D exploration of the Kiel waterfront and fjord

- Provide three selected 3D scenes representing relevant waterfront and fjord locations, including underwater environments where appropriate.

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- Allow users to navigate these scenes and access spatially anchored content through interactive hotspots or panels.
- Support intuitive exploration on desktop and mobile devices.

O3. Accessible marine and climate communication

- Present complex marine, ecological and climate-related topics in a clear and non-technical way.
- Use provided multimedia content such as text, images, recorded audio and video to support understanding.
- Where suitable information is available, provide selected environmental indicators or sensor-based information as contextual data layers.
- Validate the accessibility, comprehension and relevance of the digital experience with non-expert users during pilot testing, and document the feedback and resulting project response.

O4. Content management and professional use

- Enable authorised content administrators to create, update and manage exhibition-related content through a content management system.
- Support the curation of scenes, narratives, media assets and information panels without requiring engineering changes for every content update.
- Provide a maintainable platform structure that can be extended with additional content over time.

The expected impacts can be grouped into two categories.

Short-term impacts include a stronger and more durable impact of the SEALEVEL exhibition because key messages and material remain available digitally beyond the temporary physical setup; increased reach of marine-education content, including remote audiences and people who cannot visit the exhibition; and more attractive communication material for events, workshops and public meetings.

Medium- to long-term impacts include better-informed citizens and educational audiences with a clearer understanding of marine ecosystems, local environmental pressures and climate-related issues; a reusable platform for content-driven environmental communication; and a more flexible way for Kiel-related stakeholders to maintain and present exhibition material over time.

5.4 Stakeholders, user groups and roles

The SEALEVEL scenario builds on the stakeholder ecosystem created around the physical exhibition and extends it into the digital sphere.

Families and individual citizens explore the fjord and the exhibition content at home or on mobile devices, often in short sessions. They require intuitive and visually engaging interfaces that do not require prior specialist knowledge.

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Visitors and tourists may discover the digital exhibition through city-marketing channels or during a stay in Kiel and use it to gain orientation and contextual information about the waterfront, fjord and exhibition themes.

Educational audiences, including schools, students and informal learning groups, may use the experience as an accessible introduction to marine and climate-related topics through curated explanatory material.

City of Kiel professional users, particularly teams working in culture, education, environment, climate or city marketing, manage and curate the digital exhibition content through the CMS. Authorised users can maintain information panels and media assets, configure scenes and prepare curated narratives or thematic content.

Scientific and institutional partners may provide source material, scientific or educational content and validation input for digital stations. Their role is principally content contribution and validation rather than operation of the public platform.

The public-facing experience is read-only. Content-administration functions are available only through authenticated, role-based access.

5.5 Functional description of the use case

5.5.1 Marine 3D environment

The technical backbone of the scenario is a browser-based 3D environment representing selected areas of the Kiel waterfront and fjord. The environment acts as the spatial stage for the digital SEALEVEL experience and supports public exploration of curated exhibition content.

The experience focuses on three agreed scenes. Current candidates identified during technical planning include Kiel-Schilksee, Steiner Mole and Kieler Hafen; the final selection is confirmed with the project and city teams according to content availability, technical feasibility and the relevance of the associated exhibition narrative.

Users navigate the scenes through standard web interactions such as viewpoint selection, camera movement and object or hotspot selection. Interactive points of interest are positioned within the scenes and open information panels containing text, images, recorded audio, video or other approved media.

The environment prioritises performance and usability across commonly used desktop and mobile devices. Where relevant and technically feasible, selected environmental information may be presented as contextual overlays or information panels, provided that the required data is available and suitable for public communication.

5.5.2 Digital SEALEVEL exhibition layers

The physical SEALEVEL exhibition is translated into digital exhibition layers anchored in the three-dimensional scenes. These layers consist of stations, hotspots and information panels that organise exhibition material into a clear and accessible digital structure. Before publication, the relevant content owner reviews each station for accuracy and plain-language

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suitability; public media include captions, transcripts or alternative text as appropriate to the format.

Each digital station may include one or more modules such as explanatory texts, images, recorded audio, video clips or illustrative graphics. Stations can be organised according to themes reflecting the exhibition narrative, for example ecosystems, the fjord, marine life, human impact or climate-related change.

Content is managed through a CMS-based backend. Authorised users can update texts, media assets, metadata and station configurations without requiring redevelopment of the frontend for each change.

Where suitable data is available through the SENSE Data Space or associated approved sources, selected environmental indicators may also be integrated. They are presented as simple contextual information or lightweight overlays. Complex simulation, detailed scientific forecasting and policy-scenario modelling are not part of the core scope of the SEALEVEL implementation described in this revision unless separately agreed.

5.5.3 Citizen and visitor functionalities

For non-expert users, SEALEVEL behaves as a digital exhibition embedded in a 3D environment.

Users access the experience through a standard website on desktop or mobile devices. They can navigate the available scenes freely or begin from a thematic entry point that highlights relevant stations and content modules. Selecting a station opens an information panel containing curated media such as text, images, recorded audio or video.

The interaction is intentionally lightweight. Users can explore scenes, open content panels, switch between available themes and follow simple narrative paths through the exhibition material. The interface avoids unnecessary complexity and prioritises clarity for non-expert audiences.

Accessibility and readability are considered in the design of the interface and content structure. Where multilingual versions are supplied and approved by the project partners, the CMS structure supports presentation of the available language versions.

5.5.4 Professional and content-management functionality

For professional users, the scenario focuses on content administration and curated communication.

Authorised content administrators use the CMS backend to create, edit and maintain digital stations, information panels and media assets. This includes the management of text, images, recorded audio, video references and the configuration of the content presented to public users.

The professional interface uses role-based access so that administrative functionality is restricted to authorised users while the public-facing experience remains read-only. Administrators can prepare thematic narratives, update existing panels and coordinate publication of approved material without requiring direct changes to application code.

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5.6 User journeys

The following journeys illustrate representative interaction patterns for the SEALEVEL scenario. They describe the intended target experience while remaining subject to the final agreed content and technical scope.

5.6.1 Family exploring the fjord from home

A family living in or visiting Kiel hears about the SEALEVEL digital experience and opens the website on a tablet at home. From the landing view, they select a thematic entry point related to the Kiel Fjord and are guided into one of the available 3D scenes.

They navigate through the digital environment and discover interactive stations positioned in the waterfront or fjord scene. At each station they open concise information panels with explanatory text, images and recorded media taken from, or related to, the SEALEVEL exhibition. The material explains marine ecosystems, human impacts and climate-related changes in language suitable for non-experts.

Later, when the family visits the physical exhibition, the children recognise themes and visual material encountered in the digital experience. The online environment therefore acts both as an independent learning resource and as a complement to the physical visit.

5.6.2 City Cultural Team preparing a guided public presentation

A member of the City Cultural Team prepares a public information event related to SEALEVEL. Before the event, the user signs in to the CMS, reviews selected digital stations, updates explanatory text where required and verifies that the relevant images, recorded audio and video material are correctly associated with the stations.

During the event, the public experience is presented on a large screen. The presenter navigates through one of the selected waterfront or fjord scenes and opens a series of information panels. The audience sees how the physical exhibition content has been translated into a spatial online experience and how marine and climate-related topics are connected to recognisable places in Kiel.

After the event, the same approved material remains available through the public website, allowing participants and other users to revisit the stations independently.

5.6.3 Content administrator integrating partner-provided scientific content

A content administrator receives new educational material from a scientific or institutional partner, for example a short video, explanatory text and an illustrative diagram related to observations in the Kiel Fjord.

Using the CMS, the administrator creates or updates a digital station and links the material to an appropriate location in one of the agreed 3D scenes. The station is configured with a title, thematic category, descriptive text and associated media.

Once the material has been reviewed and approved according to the agreed content process, the updated station becomes available in the public-facing experience. Visitors can then

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discover the new material while exploring the scene, and authorised administrators can revise it later if updated information becomes available.

5.7 Technical foundations

5.7.1 Architecture and interaction flows

SEALEVEL follows the same high-level separation used by the other SENSE scenarios—user application, scenario/content service layer and governed data access—but implements these functions using a dedicated technology stack suited to an online exhibition.

The **application frontend** is based on Next.js. It provides the public web portal, routing, layouts, user-interface elements and integration with the backend APIs. Three-dimensional scenes are rendered on the client using Three.js and React Three Fiber, allowing cameras, lighting, underwater visual effects, object selection, navigation and inspection to run in the user's browser.

The **application backend and content layer** is based on Strapi. Strapi provides the headless CMS used by authorised content administrators to manage scenes, stations, explanatory texts, multimedia references, metadata and publication status. It exposes the required content through web APIs and enforces the roles and permissions associated with professional access.

Redis and local caching can be used alongside Strapi to improve response time and limit unnecessary repeated requests to external sources. This is particularly appropriate because most exhibition content is relatively static, while selected text-based environmental feeds may be refreshed more frequently.

The **SENSE Data Space integration** is provided through the Participant Agent. Where relevant content or contextual data is available through the Data Space, the backend requests it using the authorised connection, processes it as required for the scenario and exposes the relevant result to the frontend. The public browser therefore does not need to connect directly to governed Data Space services.

The principal interaction flows below also identify the three application surfaces used by the scenario: the public visitor application, the content-administration application and the backend Data Space integration.

- **Public visitor application.** A visitor opens the website; the Next.js application loads the relevant scene and requests the associated station and narrative content from Strapi. Three.js/React Three Fiber loads the required 3D assets and renders the environment on the client. When the visitor selects a station, the frontend displays its approved text and media.
- **Content-administration application.** An authorised administrator signs into the Strapi interface, creates or edits a station, assigns its media and metadata, completes the approval step and publishes the approved version. The public application receives updated content through the Strapi API without requiring frontend redevelopment.

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- **Backend Data Space integration.** Where contextual information is used, the backend retrieves approved structured data through the Participant Agent, applies the required caching or processing and makes the resulting information available to the public application.

5.7.2 Input data and content

The SEALEVEL implementation relies on several categories of input rather than on a single monolithic dataset.

SEALEVEL exhibition content consists of the explanatory texts, articles, images, recorded audio, video references, diagrams and other educational resources selected for the online experience. Content is structured in the CMS as reusable modules associated with digital stations and scenes.

Scene and asset data includes the three-dimensional geometry, textures and related metadata required to build the agreed waterfront and fjord environments. Assets are produced and optimised for real-time web delivery, principally in glTF/GLB-compatible form.

Scene configuration and metadata define viewpoints, hotspots, station positions, thematic categories and the relationships between spatial locations and narrative content.

Optional environmental information may include suitable text-based measurements or contextual information related to the fjord and marine environment. Such data is integrated only when it is available through the SENSE Data Space or another approved project source, when access rights permit its use and when it can be presented responsibly to a non-expert audience.

The implementation assumes that relevant Data Space information can be accessed through the Participant Agent using the authentication credentials and documentation provided by the project. Images and recorded media should be provided in standard web-compatible formats or through accessible URLs. Live streaming of audio or video is outside the current implementation scope.

5.7.3 Underlying models and technology components

Three-dimensional scene model. Each of the three agreed locations is represented as an optimised web scene containing the geometry, textures, environmental elements, viewpoints and interaction anchors needed for public exploration. The scenes are prepared with performance constraints appropriate to desktop and mobile browsers.

Digital station and narrative model. Exhibition content is represented as structured CMS entities linking a station to its title, description, thematic category, spatial anchor, media assets and publication metadata. This separates the narrative from the application code and allows authorised users to maintain the experience without engineering intervention.

Optional environmental-data model. Where suitable observations are available, the scenario backend maps the returned information onto simple presentation structures such as a current-condition panel, contextual value or lightweight visual overlay. This component provides context rather than scientific forecasting or simulation.

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Content and access model. Public users access only published material through the public application. Professional content users access an authenticated CMS interface with role-based permissions. This separates content authoring and publication from public consumption.

3D asset-production workflow. Blender is used to create and optimise the required scene assets, including geometry preparation, UV mapping, texture baking and real-time optimisation. Assets are exported in web-compatible formats such as glTF/GLB and integrated into the scene by the Three.js/React Three Fiber layer.

Deployment model. The software platform is designed to remain portable across suitable cloud or on-premises infrastructure. Production hosting is not part of the implementation scope described here. Post-delivery managed services are likewise outside the delivery scope; the platform, CMS functionality and associated documentation are intended to enable the City of Kiel or its representatives to manage and update the content after handover.

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6. Development plan

The development of the SENSE pilot scenarios will follow an incremental approach that balances (1) fast prototyping and technical feasibility checks, (2) high-quality “professional” pilot views that can support real operational workflows, and (3) a later adaptation towards public/citizen-facing access with higher scalability requirements. This staged approach reflects the common SENSE scenario structure (User Application, Scenario Service Layer and Data and Knowledge Layer connected to the Data Space) and supports reuse across the Cartagena and Kiel pilots. The phase descriptions in Sections 6.1 to 6.4 apply primarily to the three scenarios delivered through the common WP4 front-end. Kiel SEALEVEL follows a parallel delivery track led by Drees & Sommer Digital Services. Its stages correspond conceptually to the same progression, from technical baseline, through professional functionality and public-facing adaptation, to operational improvement, but use the dedicated architecture and delivery plan described in Section 5.7.

The scenarios are implemented with a web-native front-end that renders on the client, in the browser, rather than on a server rendering farm. Geometry and data (OGC 3D Tiles, glTF, CityJSON) are streamed to the client and drawn locally with open-source libraries, while AI capabilities are exposed as APIs that return results as data rather than as rendered imagery. This preserves the foundations that were already sound in SENSE, namely the NGSI data access, the Data Space connectors and the model-serving layer, and evolves the rendering layer, which was the main cost, scalability and replicability constraint. The main trade-off, client-side rendering being bounded by the capability of the user device, is mitigated through levels of detail, progressive loading, per-scene rendering budgets and pre-produced assets for the heaviest content.

The following phases are expressed as indicative project periods and may overlap where technical work and stakeholder validation can run in parallel; the corresponding dates are given at the end of this chapter. The phase descriptions below are generic and apply across the three scenarios delivered by the WP4 front-end. For each scenario, the functionality delivered is bounded by the scope stated at the start of the corresponding chapter: the capabilities identified there as deferred extensions are not part of the work planned in this schedule, even where a generic phase description mentions them.

6.1 Phase 1. First demos – tools and architecture design experimentation

The objective of Phase 1 is to put in place a working technical foundation for the SENSE pilots and to de-risk the most critical interactions early. The focus is therefore on feasibility and integration, rather than completeness: we aim to demonstrate that the full chain works (from user interaction to data access and visual output) with representative content for both cities.

Phase 1 establishes the technical baseline on which the minimum viable product described in Section 6.5 is built: the baseline architecture, the delivery pipeline and the first navigable web-native scenes for both cities, together with the integration experiments that validate the first end-to-end scenario flows.

During this phase, the expected scope and outcomes are:

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- **Baseline system architecture (v1).** Establish the initial separation between the SENSE User Application (front-end), the scenario service layer, and the connected Data and Knowledge Layer / Data Space. This includes practical conventions for scenario configuration (e.g., which layers and viewpoints are available), layer activation/deactivation, and view-state management (e.g., camera position, time slider state, selected POIs). Figure 13 presents a preliminary and simplified architecture illustrating the integration of data providers, the SENSE Data Space, and scenario services.
- **Development environment and delivery pipeline.** Set up shared repositories and baseline engineering workflows, including CI/CD (continuous integration and continuous delivery) building blocks, dev/staging deployments, and common asset pipelines for 3D content, basemaps and multimedia resources. The aim is to allow partners to iterate rapidly while keeping the builds reproducible and deployable.
- **3D twin “skeleton” for both cities.** Produce early, navigable 3D representations for Cartagena and Kiel with a minimal set of interactions (pan/zoom/rotate, “fly to” viewpoints, POI selection, and layer toggles). These initial models can include placeholders and simplified geometry: the key validation is performance, navigation usability, and consistency of interaction patterns. Early experiments stream OGC 3D Tiles and glTF meshes to the browser to test client-side rendering on mainstream devices; the reference devices and per-scene budgets are set in the Phase 1 test plan, with measured results reported there. Figure 14 and Figure 15 illustrate an example 3D visualisation of Cartagena and Kiel. The sources of that geometry and its level of detail are described in Sections 2.7.4 and 4.7.3.
- **Early data visualisation and integration spikes.** Connect a small number of representative sources (both static and dynamic) to validate: (1) ingestion and access patterns via the Data Space, (2) the required adapters/format conversions, and (3) how the data should be visualised in the 3D twin (e.g., overlays, markers, heatmaps, time-series panels). This work is aligned with the data integration architecture and Data Space approach defined in WP2 and WP3 deliverables.
- **Walkthrough demos aligned with user journeys.** Deliver end-to-end walkthroughs for at least one user journey per city to confirm that the complete loop works, from user action to scenario orchestration, data retrieval and visual rendering. Use a working demo from at least one local use case in a facilitated validation session in Cartagena and one in Kiel. Participants include residents, visitors or other non-expert users as appropriate, alongside relevant pilot stakeholders. The facilitator records what participants like, dislike, find unclear or find difficult; the team records the resulting decision or change and uses the evidence as the baseline for later refinements.

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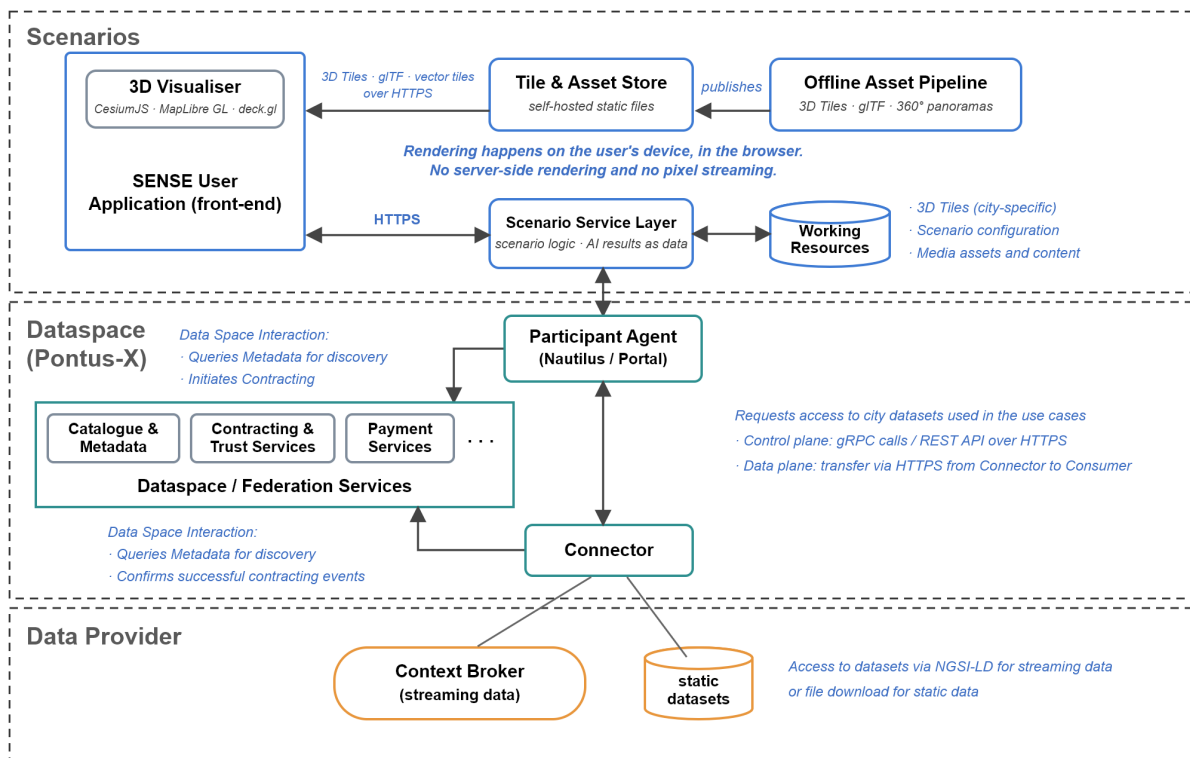


Figure 13. Simplified version of the SENSE architecture



Figure 14. Illustrative example of the 3D city view for Cartagena (web-native, client-side rendering)

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Figure 15. Illustrative example of the 3D city view for Kiel (web-native, client-side rendering)

6.2 Phase 2. Scenarios for professionals

The objective of Phase 2 is to evolve the initial technical prototype into a first operational pilot that supports professional users (e.g., city staff, operators, curators and technical teams). Building on the validated foundations from Phase 1, the focus shifts to delivering scenario-specific functionality, higher data fidelity, and workflows that can be used in realistic operational contexts.

While Phase 1 focuses on feasibility, Phase 2 focuses on usefulness: providing the capabilities required to complete professional tasks end-to-end (analysis, monitoring, reporting, content management), even if the system is not yet optimised for very large numbers of concurrent users.

During this phase, the expected scope and outcomes are:

- **Professional user workflows and features.** Implement the core features required by professional user journeys, such as advanced navigation and filtering, richer inspection panels, time controls (e.g., replay or comparison), and export or reporting capabilities where relevant.
- **Scenario-specific logic and orchestration.** Extend the scenario service layer so that each pilot can encode its specific business logic (e.g., how layers combine, which indicators are computed, what constitutes an event/alert, how narrative steps progress), while still reusing shared platform components.
- **Role-based access and administrative functions.** The management views of the two Cartagena scenarios are authenticated from the minimum viable product onwards, with the professional and administrator roles described in the corresponding chapters, while the public views require no account and expose only published, aggregated content. This phase extends that baseline with content and layer configuration,

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controlled publication, and internal-only views. The identity of professional users is held by the scenario services themselves: a small set of named accounts is created on request for the municipal staff taking part in the pilot, there is no self-registration, and the role attached to each account is applied by the Scenario Service Layer, which is where access rights are enforced in any case. This keeps the scenarios independent of any external identity infrastructure being available within the project timeframe, and it avoids a per-user subscription to an identity service, which would reintroduce the recurring cost per user that this delivery approach is designed to avoid. Where a city later offers its own identity provider, it can be connected as an additional way to sign in without changing the authorisation model.

- **Improved data integration and richer visualisations.** Expand the set of connected data sources and improve the quality of the visual representation (e.g., thematic overlays, time-series charts, interactive POIs, aggregated indicators), including more robust handling of updates and metadata.
- **Performance tuning for professional use.** Optimise the runtime for smooth interaction in professional environments (often fewer but more demanding users), including client-side performance tuning (levels of detail, progressive loading, tile caching and per-scene budgets) so that visual quality is preserved without any server-side rendering farm.

6.3 Phase 3. Adaptations for citizens, visitors and broader public access

The objective of Phase 3 is to adapt the pilots for public-facing access, ensuring that the experience remains intuitive, performant, and safe when opened to citizens and visitors. This phase prioritises scalability and simplicity: public users typically have shorter sessions, different devices (including mobile), and require clearer guidance and storytelling than professional users.

Compared to Phase 2, the key shift is from “feature richness” to accessible UX, controlled content, and higher concurrency readiness.

During this phase, the expected scope and outcomes are:

- **Public user experience (UX) and interaction simplification.** Provide a streamlined user experience with clear entry points (e.g., tours, recommended viewpoints, featured layers), simplified controls, and explanatory context for indicators and maps.
- **Scalable delivery modes.** Adapt technical choices to support more concurrent users (e.g., progressive loading, level-of-detail strategies, caching, simplified layer sets and reduced scene budgets for the public mode). Because rendering takes place on the client and static assets are cacheable and served as fixed files, the cost of serving an additional concurrent user remains low. The scenarios are delivered as static assets together with a small set of service endpoints, so they can be hosted on the project infrastructure or on a municipal web platform without a rendering tier; the hosting arrangement for each pilot is confirmed with the city and the coordinator during this phase.

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- **Narratives and curated content.** Strengthen the storytelling and interpretation layer, including curated POIs, curated narrative sequences at the selected points of interest, and consistent “why this matters” explanations.
- **Governance, privacy, and content safeguards.** Apply the protections required for public release, following the ALTAI-based approach adopted by the project: small-area socio-economic indicators are published only above a minimum population threshold and with reduced spatial precision, sensitive layers are withheld from the public views, and the front-end consumes pre-aggregated indicators rather than individual records. The holder of each source remains the controller of the personal data it processes and records the legal basis for it, so that the front-end works only with aggregated or anonymised outputs. The professional accounts described in Section 6.2 are the only personal data processed by the scenario services themselves: they are limited to the identity and the role needed to grant access, they are created only at the request of the participating city, which decides who is given access, and their retention is agreed with that city. User-contributed content is not collected in this revision; if it is introduced in a later phase it will require explicit consent, a confirmation of the rights over any image submitted, and a moderation and approval workflow before publication. Where a view is produced with the support of generative techniques, it is labelled as such in the interface.
- **Feedback and usability iteration.** Run facilitated try-outs in Cartagena and Kiel in which participants use the relevant scenario, explain what works or does not work, and identify content or interactions that are unclear. Record participant groups, the tasks attempted, feedback and observed usability issues, then maintain a response log showing whether each point was implemented, deferred or not adopted and why. Repeat targeted checks after material changes where practical, so iteration is based on documented user and stakeholder evaluation.

6.4 Phase 4. Operational improvements

The objective of Phase 4 is to harden the pilots into stable, maintainable services and to consolidate the results into assets that support longer-term operation and replication. This phase focuses on reliability, maintainability, and operational readiness, ensuring the solutions can run consistently and be managed efficiently over time.

During this phase, the expected scope and outcomes are:

- **Operational hardening and observability.** Improve monitoring, logging, error handling and alerting across the full chain (front-end, scenario services and data access), together with the operational notes needed to hand the scenarios over.
- **Data pipeline robustness.** Stabilise connectors and refresh cycles for dynamic sources, improve metadata quality, and formalise ingestion/update processes to reduce manual interventions.
- **Security and resilience.** Strengthen security measures (access control reviews, dependency management, secure deployment practices), and improve resilience (graceful degradation when a data source is unavailable, fallbacks for visual layers).

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- **Documentation and replication assets.** Produce reusable artefacts such as deployment guidance, scenario configuration templates, onboarding checklists for new data sources, and lessons learned to support replication beyond the initial pilot cities. The first versions of the configuration templates, of the client-side rendering profile and of the onboarding checklists are produced earlier, alongside the first scenario that uses them, so that they are available to the technical guidelines work and to follower cities during the project rather than only at its end; what this phase adds is their consolidation, the deployment guidance and the lessons learned.
- **Performance and cost optimisation.** Optimise runtime performance and operational footprint (e.g., caching strategies, resource sizing, deployment patterns) to ensure sustainable operation.

Figure 16 and Figure 17 present a conceptual mock-up illustrating how the SENSE interface could look at the end of the project. The underlying scene geometry is the one described in Sections 2.7.4 and 4.7.3.



Figure 16. Mock-up of the *Smart Urban Mobility* scenario in Cartagena

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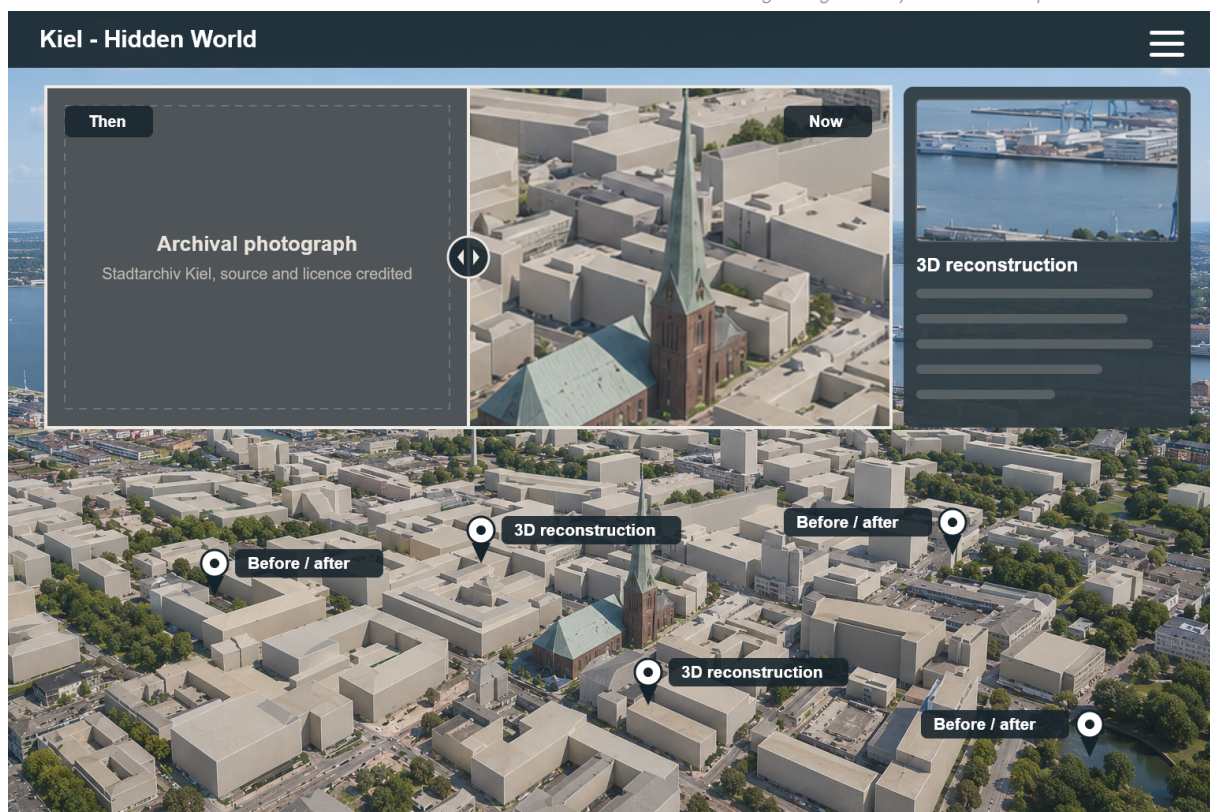


Figure 17. Mock-up of the *Hidden World* scenario in Kiel

6.5 Schedule and delivery milestones

The four phases above are mapped onto the remaining project schedule. The three scenarios delivered by the WP4 front-end are developed in parallel, each following the same sequence of working stages:

- **Revised deliverable.** This revised version of the WP4 scenario specification is issued in August 2026 and sets the baseline scope and schedule for the work described below.
- **Minimum viable product, end of October 2026.** A working minimum viable product for those three scenarios, available for validation with the pilot cities. For the two Cartagena scenarios it covers the outcomes of Phase 1 and the professional core of Phase 2, together with the read-only public view of the mobility scenario; for Kiel, whose experience is public-facing by nature, it covers those of the five curated points of interest whose archival material and image usage rights are confirmed by 30 September 2026, so the public-access work of Phase 3 is brought forward for that scenario.
- **Feature completion, November to December 2026.** Completion of the remaining professional functionality (Phase 2) and, for the scenarios where public-facing access is in scope in this revision, of the public-facing adaptations (Phase 3). The three scenarios are delivered complete, within the scope stated at the start of each chapter, at the end of this stage.

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- **Quality assurance and closeout, January 2027.** Testing, quality assurance, adjustments arising from validation, and user and operator documentation (Phase 4). This stage hardens, refines and documents what is already delivered rather than adding scenario functionality, and it feeds the replication and best-practice activities.

The stages run in parallel across those three scenarios and reuse the shared components described in this deliverable, which is what makes this schedule achievable with the resources available for the WP4 front-end. The dates are working targets for the front-end work and assume the entry into force of the amendment to the Grant Agreement, timely access to the city data sources, and access to the archive material for Kiel described in the preceding chapters. The assistant described in Section 1.7 is delivered outside the front-end specified here, and these dates do not depend on it. The scope described in this deliverable rests on that amendment as well: until it enters into force, the contractual reference remains the Description of the Action, with its original set of use cases and its immersive components.

SEALEVEL delivery track. The Drees & Sommer implementation plan follows four agreed delivery milestones: Phase 1 - Core components and demo by 27 November 2026; Phase 2 - Scenarios for professionals by 9 February 2027; Phase 3 - Public-facing adaptation by 4 March 2027; and Phase 4 - Operational improvements by 30 March 2027. Onboarding and familiarisation with the SENSE environment precede the first milestone. The principal dependencies are access to the Participant Agent, relevant SEALEVEL content and data, agreement on the three scenes, availability of the required media and 3D source material, and confirmation of the production-hosting arrangement.

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7. Conclusions

This deliverable defines the SENSE pilot scenarios for Cartagena and Kiel and describes the foundational models and enabling technologies that will be used to implement them, providing a shared basis for the subsequent design, integration and validation activities across the pilots.

The document specifies the four consolidated scenarios of the revised SENSE use-case set: (1) Smart Urban Mobility in Cartagena, focused on operational and analytical workflows for municipal mobility management complemented by a read-only public view; (2) Public Space, Environment and Quality of Life in Cartagena, providing a management tool based on neighbourhood indicators, hotspot identification and zone comparison; (3) Hidden World in Kiel, a public-facing cultural experience based on selected historical points of interest and lightweight three-dimensional or comparative content; and (4) SEALEVEL in Kiel, a public-facing digital extension of the SEALEVEL exhibition combining three-dimensional scenes, curated multimedia stations and CMS-based content management.

Across the four use cases, the document consistently frames each scenario through its context, objectives and expected impacts, stakeholders and users, functional scope, representative user journeys and technical foundations. This common structure allows the scenarios to be compared and reused while preserving the differences required by their respective operational, cultural and educational purposes.

On the technical side, the deliverable establishes a common logical relationship between the SENSE User Application, scenario-specific service and content functions, and the Data and Knowledge Layer connected to the SENSE Data Space. The implementation is deliberately not restricted to a single frontend library. The three scenarios delivered through the common WP4 front-end use the CesiumJS, MapLibre GL and deck.gl-based web-native approach described in Sections 2 to 4. SEALEVEL uses a dedicated Next.js and Three.js/React Three Fiber frontend with a Strapi and Redis-based content layer and integration with the SENSE Participant Agent. Both approaches render the user experience on standard browser devices and avoid dependence on headset-based interaction.

The development plan consequently comprises parallel but compatible implementation tracks. The three common WP4 front-end scenarios progress from their MVP to feature completion and quality assurance according to the schedule in Section 6, while SEALEVEL progresses through onboarding, core-platform demonstration, professional content-management functionality, public-facing adaptation and operational improvement according to its dedicated implementation plan. The next steps are to validate the remaining dependencies with the pilot cities and responsible partners, confirm the implementation schedules, complete the Grant Agreement amendment on which the consolidated use-case allocation depends, and proceed with implementation and validation of the four scenarios.

Finally, the deliverable outlines an incremental development approach organised in four phases and mapped to the project schedule set out in Section 6, moving from a minimum viable product covering those three scenarios, to the completion of scenario functionalities, and finally to testing, quality assurance and operational readiness. As next steps, the consortium will confirm the pending items identified in this document (including the entry into

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force of the amendment to the Grant Agreement, the Kiel points of interest, image usage rights, the validation of the German language content for Kiel, and the provision of the assistant described in Section 1.7), proceed with the MVP implementation of the three scenarios in coordination with the operational platform work, and consolidate the reusable configuration and deployment assets that support replication beyond the pilot cities.

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