Digital tools framework and architecture

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1. Executive summary

Deliverable 2.1 (D2.1) is the Month 08 (M08) **foundational framework specification for Digital Tools and eXtended Reality (XR)** required by the NEXTLOGIC Description of the Action. It establishes the initial architecture, interoperability, governance and evidence baseline for Work Package 2 (WP2): Task 2.1 (T2.1), "Digital Twins for urban space, mobility and logistics"; Task 2.2 (T2.2), "eXtended Reality (XR) for mobility systems"; Task 2.3 (T2.3), "Geospatial analytics and visualization for urban Digital Twins"; and Task 2.4 (T2.4), "Digital Toolbox Integration". At M08, D2.1 specifies roles, connection patterns, onboarding records and a staged validation pathway; it is **not an operational platform release** or evidence that all partner interfaces have already been implemented and validated.

The NEXTLOGIC Digital Platform is a **distributed decision-support ecosystem** for sustainable urban-logistics planning, testing and communication. The Digital Tools Hub is the common front door; the Task 2.4 Digital Toolbox Integration framework governs discovery, onboarding, composition, Sandbox testing and guided external integration. **The Toolbox unifies discovery, onboarding and integration—not ownership, hosting or execution.** Users can continue through iGuess® for geospatial discovery, analysis, processes, scenarios and 2D/3D exploration; the LIST LDT platform for selected context, telemetry and use-case views; authorised XR clients for co-design, guidance and feedback; or an authorised city, partner or specialist application.

The city experience connects "today" with "possible tomorrows". A City View Manifest loads a coherent baseline of authorised 2D/3D layers, observations and indicators. Scenario workflows branch that baseline into traceable Scenario Bundles that can be compared through linked maps and dashboards without overwriting the current state.

The implementable backbone is deliberately small and standards-led. A governed Capability Profile is the machine-readable source for each dataset, tool, service or workflow. OGC API – Records provides geospatial discovery; DCAT 3 and applicable European profiles support catalogue federation; a workflow configurator binds compatible inputs, processes and outputs; and OGC API – Processes submits and monitors distributed execution while providers retain operational control.

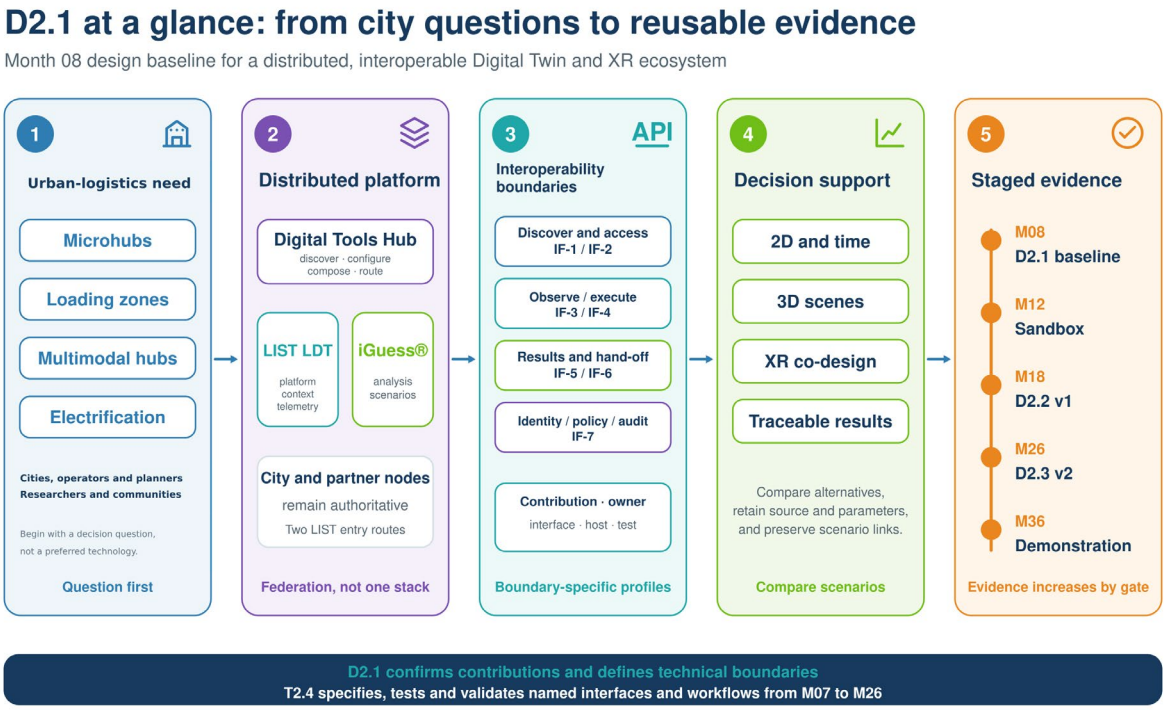
Authoritative city data, operational systems, partner models, services and XR environments remain with their owners. Partner responsibility and integration maturity are assessed separately: a contribution may be confirmed and an asset identified while its precise technical boundary remains pending. The current contributions of EXE, UniR1, MUV, MOV and WUEB are identified; the outstanding items concern interfaces, schemas, authentication, hosting, maintenance, testing and acceptance.

Each priority exchange has a bounded interface and responsibility record identifying its owner, inputs and outputs, interface or adapter, authentication, hosting, maintenance, maturity, evidence gate and contingency. Task 2.4, active from M07 to M26, governs this closure through partner-approved Tool Cards, Sandbox or equivalent testing and named acceptance results. Providers retain scientific and operational ownership; LIST supplies common profiles and agreed geospatial/interoperability support. Prospective Task 1.2 and European Mobility Data Space connections remain conditional external routes, not components delivered or validated by D2.1.

Interoperability is boundary-specific and extensible, not a single mandatory stack. OGC APIs suit geospatial resource and process boundaries; NGSI-LD may suit context management; SensorThings API supports observations; OpenAPI describes HTTP interfaces; OAuth 2.0/OpenID

Connect supports identity and authorisation; and AsyncAPI or another documented mechanism can support events. City-model, 3D-resource, catalogue and legacy profiles remain available where required. This envelope avoids narrowing the platform to one interface family or excluding complementary provider standards.

Figure 1 summarises the path from an urban-logistics question through the distributed platform and IF-1–IF-7 interoperability boundaries to configured solution workflows and traceable decision evidence. It distinguishes the contributions and assets identified at M08 from the technical boundaries that T2.4 will specify, test and validate through MS04, D2.2 and D2.3.



Defined contributions and identified assets enter a distributed Digital Twin and XR ecosystem; remaining technical boundaries are specified, tested and validated through T2.4's staged evidence gates.

Figure 1. Visual abstract of D2.1.

The four WP2 task frameworks use this architecture. T2.1 defines Digital Twin states, traceability, city/data readiness and distributed access. T2.2 defines XR scenario, resource and feedback boundaries, including Wrocław microhub co-design and the illustrative Dublin 3D-geofenced bicycle-parking guidance. T2.3 covers accessibility, routing, loading-zone, scenario-comparison, impact and site-screening services using DTU, UniR3 and Transcality patterns. T2.4, active from M07, manages Tool Cards, interface and responsibility records, owner-assigned closure gates, contingencies, Sandbox testing and guided external integration. Capabilities remain specified, planned or technical-boundary pending until implementation, hosting, maintenance and acceptance evidence exist for the named boundary.

The same capabilities configure the five WP3 solution templates and WP4 pilots without a monolithic platform for each city. Delivery is staged: Milestone 04 (MS04) at Month 12 provides first controlled Sandbox evidence; D2.2 at Month 18 provides integration v1; D2.3 at Month 26 provides extended integration v2; and Milestone 09 at Month 36 demonstrates the fully integrated and scalable platform. The controlled process moves each priority boundary from contribution confirmed and capability identified, through implementation, to integration validated. D2.1

therefore provides a coherent, open and testable implementation blueprint that preserves city control and provider ownership while making later evidence and fallback decisions explicit.

Keywords: Urban Digital Twins; Federated Geospatial Architecture; Digital Tools Hub; Digital Toolbox Integration; Composable Workflows; OGC APIs and NGSI-LD; Integration Governance; Sandbox Validation; Sustainable Urban Logistics.

2. Introduction

2.1 Purpose and scope of the document

NEXTLOGIC develops and tests innovative approaches to reduce the environmental and social impacts of urban freight while improving operational efficiency and the use of scarce public space. Work Package 2 (WP2), "Co-developing the NEXTLOGIC innovative technology platform", is led by the Luxembourg Institute of Science and Technology (LIST) and provides the digital framework that enables city data, models, analytical services, visualisation and XR tools to support this work.

The Grant Agreement names D2.1 "Digital tools framework and architecture". Its deliverable description specifies a "**Foundational framework specification** for Digital Tools and eXtended Reality", due at M08 and linked to Task 2.1 (T2.1), "Digital Twins for urban space, mobility and logistics", and Task 2.2 (T2.2), "eXtended Reality (XR) for mobility systems". This document answers that requirement by specifying the initial purpose, design principles, distributed architecture, component roles, interoperability approach and staged validation pathway for the NEXTLOGIC Digital Platform.

The Digital Twin and XR frameworks cannot be described usefully in isolation from the services they will consume and the mechanisms through which they will be integrated. D2.1 therefore also provides proportionate architectural context for Task 2.3 (T2.3), "Geospatial analytics and visualization for urban Digital Twins", and Task 2.4 (T2.4), "Digital Toolbox Integration". This wider context does not change the contractual scope of D2.1 or imply that the later task results are already available. It shows how the four WP2 tasks are intended to converge into one modular platform over the course of the project.

This specification does not require cities to transfer all data to a central repository, require partners to replace their internal technology stacks, or finalise every implementation-level endpoint before pilot data and partner interfaces are available. It defines **stable extension points and preferred integration patterns** so that those details can be agreed, implemented and tested at the appropriate stage.

2.2 Link with Work Package 2 tasks and objectives

WP2 comprises **four connected tasks**. The task boundaries describe responsibility for work; they **do not define four independent platforms**. Task leadership is assigned to Frankfurt University of Applied Sciences (FUAS) for T2.1, Delft University of Technology (TUD) for T2.2, and LIST for T2.3 and T2.4. The WP2 task boundary is summarised in Table 1.

Table 1. Work Package 2 task relationship and D2.1 treatment.

Task	Contractual focus	Lead	Treatment in D2.1
T2.1	Digital Twins for urban space, mobility and logistics	FUAS	Foundational functional and information framework; links to city data, models and decision support
T2.2	eXtended Reality (XR) for mobility systems	TUD	Foundational XR concept, user interaction, visualisation and Digital Twin integration logic

T2.3	Geospatial analytics and visualization for urban Digital Twins	LIST	Initial service portfolio and integration patterns needed to make the overall architecture implementable
T2.4	Digital Toolbox Integration	LIST	Initial tool registry, onboarding and interface-responsibility framework for later implementation

Task 2.4 is defined in the signed Description of the Action as the definition and implementation of a modular and compositional Digital Twin architecture that ensures compatibility across components and external applications. Its scope covers data ingestion, model execution, API integration and visualisation; provision of the Digital Toolbox to WP3 and WP4 so that stakeholders can define problems, connect relevant data sources and use simulation tools; Sandbox-based iterative testing; deployment guidance for seamless visualisation and city-specific demonstrators; and an operational environment for pilot testing and evaluation. D2.1 translates these commitments into a distributed target architecture and staged implementation baseline. Catalogue, onboarding and guidance are necessary T2.4 functions, but they do not constitute the complete contractual result, and D2.1 does not claim that the later implementation already exists.

The four WP2 objectives can be expressed as a **common outcome**: connect relevant city and partner resources; make them usable through interoperable analytical and visual interfaces; support workflows that link evidence to scenarios and stakeholder dialogue; and establish an open, modular basis that can be extended across cities. Sections 5 to 10 turn those objectives into an architectural specification. Annex A.3 distinguishes formal task contributors from identified component providers and from cross-WP data, domain and pilot contributors.

2.3 WP2 dependencies, solution interfaces and validation context

D2.1 remains a WP2 architecture deliverable. Other Work Packages are referenced only where they provide an input, define an external interface, consume a WP2 capability or supply the setting in which that capability will be tested. The resulting relationship is therefore not a general project workflow: WP1 establishes selected data and method inputs; WP2 specifies and integrates the enabling platform capabilities; Work Package 3 (WP3), “Co-developing solutions for climate neutral cities”, develops the five solution families; and Work Package 4 (WP4), “Piloting solutions in the NEXTLOGIC cities”, provides their deployment and validation context.

Task 1.2 (T1.2), “Data acquisition framework and management”, and Deliverable 1.3 (D1.3), “Data framework specifications”, are upstream dependencies for data requirements, recommended sources, processing and access arrangements. A prospective T1.2 data storage and access node may provide one authorised source for WP2 workflows. Its final ownership, hosting, datasets, interfaces and operational lifecycle are not yet fixed and are not designed or delivered by D2.1. WP2 instead specifies how the Digital Tools Hub, the LIST LDT platform route and iGuess® can discover or access such a node through an agreed dataset, catalogue and security interface once D1.3 and the responsible partners have confirmed it.

The T1.2 work may also enable participation in the common European mobility data space (EMDS). That connection remains conditional: neither the connector technology nor the eligible datasets, trust model or usage policies are assumed here. The Digital Tools Hub therefore retains a complementary NEXTLOGIC catalogue for tools, workflows, scenarios and datasets that cannot or should not be published through EMDS. Where several catalogues describe the same resource,

stable identifiers, an authoritative source-of-truth designation and controlled metadata harvesting or synchronisation should prevent conflicting records.

Task 1.3 (T1.3), "Impact evaluation framework", and Deliverable 1.2 (D1.2), "Methodological approach", define the project's impact-evaluation and indicator methodology. T2.3 may operationalise a suitable subset as reproducible geospatial processes when the formula, baseline, data and interpretation rules are available. The analytical service produces a traceable indicator result; responsibility for accepting the method and drawing project-level impact conclusions remains with the relevant evaluation work.

The direct WP3 consumers of WP2 capabilities are summarised in Table 2. The mapping identifies formal WP3 leadership and integration needs; it **does not transfer solution development or pilot ownership to WP2**.

Table 2. WP3 solution tasks as direct consumers of WP2 platform capabilities.

Task	Official WP3 solution and formal responsibility	Direct WP2 capability interface
T3.1	Integrated Mobile Microhubs — WUEB lead; LIST, WCG and DBINF key contributors	Data and tool discovery; demand, land-use and accessibility processes; scenario comparison; 2D/3D and optional XR views
T3.2	Smart Loading Zones for smart and dynamic curbside management — UniBG lead; PKUN, LIST and BUAS key contributors	Authorised observations; spatial-temporal indicators; operational views; curb scenarios and traceable before/after evidence
T3.3	15-minutes Multimodal Hubs — DTU lead; LIST and UniR1 key contributors	Network and service discovery; multimodal accessibility and service-gap processes; hub scenarios and visual comparison
T3.4	Incentive and Reward mechanisms — UniR1 lead; MUV and MOV key contributors	Tool onboarding; controlled behavioural or participation data exchange; dashboards, indicators and feedback records
T3.5	Electrification of Urban Logistics in the urban environment — UniLU lead; LIST key contributor	Fleet, charging and conditional grid-data access; location and coverage processes; scenario registration and comparison

WP4 pilots determine which configurations can be deployed and tested in each city. Later evaluation and replication activities may use the resulting WP2 evidence packages, but D2.1 does not define their methodologies. Section 5.6 expands the five solution interfaces into reusable platform patterns, while Sections 9 and 10 define how tools and workflows are onboarded and used.

2.4 Structure of the deliverable

Section 3 explains the platform's value and intended users for a wider audience. Section 4 positions the WP2 architecture against the state of the art and its persistent limitations. Section 5 provides the definitive overall framework and distributed architecture. Sections 6 to 9 describe the Digital Twin, XR, geospatial analytics and Digital Toolbox Integration frameworks without repeating the overall topology. Section 10 describes the end-to-end workflow, configurable WP3 solution composition, component interaction and illustrative Digital Tools Hub journey. Section 11 defines how the framework will be tested through the NEXTLOGIC pilots and releases. Section 12 addresses replication and transferability. Section 13 concludes and identifies the immediate next steps. Sections 14 and 15 provide the abbreviations and references; Annexes A.1–A.7 consolidate the registers and pilot-city baseline, Annex A.8 provides the detailed interoperability reference, and Annex A.9 provides the three role-based journey illustrations.

The report uses the **controlled maturity vocabulary** defined in Table 3.

Key platform terms. IF-1–IF-7 are the configurable interface ports defined in Sections 5.5 and Annex A.8. iGuess® is LIST's interoperable web-based geospatial Digital Twin framework for distributed data, analytical processes, scenarios and time-aware 2D/3D visualisation (iGuess® demonstration). The LIST LDT platform is the complementary NGSI-LD-oriented context and operational-view route described in Sections 3.4 and 5.3.

Table 3. Meaning of maturity terms used in D2.1.

Term	Meaning in this report
Existing baseline	A capability or asset already available to a partner before NEXTLOGIC integration; availability is not evidence of project integration.
Specified baseline	A principle, role or interface direction established by D2.1 for implementation planning.
Contribution confirmed	The partner's overall project contribution is established through WP/task coordination and is consistent with the agreed task descriptions; this does not by itself confirm an interface or deployment.
Asset or capability identified	A named tool, dataset, method, application or infrastructure asset is known and can be assessed for a defined workflow.
Technical integration boundary pending	The contribution and relevant asset are understood, while endpoint, schema, authentication, adapter, hosting, maintenance, test or acceptance details remain scheduled T2.4 work.
Proposed	A credible approach that still requires task-level or partner confirmation.
Planned	Work assigned to a later project stage or release, subject to stated prerequisites.
Open	A contribution, dependency or decision is genuinely unresolved and is recorded with an owner, evidence requirement, target gate and contingency.
Implemented	A named boundary has been configured or developed in a controlled environment, but has not necessarily passed the agreed acceptance test.

Integration validated	The named boundary has passed the recorded test and acceptance criteria for the stated release, version and operating conditions.

2.5 Progress against the Description of Action

D2.1 is the first step in a deliberately staged sequence. Its Month 08 purpose is to establish the **design baseline** early enough to guide the first integration and prototype work. The contractual milestones and deliverables make clear that implementation and operational evidence follow later. The contractual release sequence is set out in Table 4.

Table 4. Contractual staging relevant to the NEXTLOGIC Digital Platform.

Stage	Due	Contractual or project result	Evidence expected at that stage
D2.1	M08	Foundational framework specification for Digital Tools and XR	Coherent architecture, roles, candidate interfaces, open dependencies and validation pathway
MS04	M12	Digital Toolbox Sandbox accessible online and presented to the project team	Initial tool registration, test integrations and recorded exceptions in a controlled environment
D2.2	M18	First version of the modular platform, including Digital Twin integration and visualisation tools	Implemented interfaces, early pilot workflows and first integration evidence
D2.3	M26	Final version of the modular platform	Extended integration, consolidation, operational hardening and multi-use-case evidence
MS09	M36	Fully integrated and scalable platform demonstrated in the leading cities	Project-level demonstration and mature validation evidence

Accordingly, D2.1 establishes a solid and flexible baseline but does not claim that all partners have accepted identical interface profiles, that every adapter has been delivered, or that pilot workflows have been validated. Those items are routed to the release in which the necessary data, technical access and test setting are expected to exist. This **transparent staging** is a feature of the architecture and not a limitation of the deliverable.

The framework draws on the NEXTLOGIC Grant Agreement and Description of the Action, relevant WP1 inputs, partner technical material and iterative consortium co-development. A consolidated T2.4 whiteboard records three preliminary workshop sessions held in April 2026. Together with T2.1 and T2.3 workshops, monthly WP2 General Assembly discussions and the June 2026 Digital Twin architecture workshop in The Hague, these sessions shaped the architecture, candidate integration patterns and open dependencies without demonstrating formal acceptance, implementation or validation of every boundary.

Two survey routes serve different purposes. A consolidated FUAS-led T2.1 city-discovery comparison dated 3 August 2026, based on the March 2026 meetings and questionnaires, now refines the pilot-city implementation baseline. It remains a working synthesis rather than a city-

confirmed dataset-readiness assessment; access, publication, interface, update and ownership conditions remain subject to confirmation. The T2.4 conditional questionnaire describes a named tool, model, service or adapter for onboarding. The refined city baseline and confirmation status are summarised in Annex A.7.

The staged development and evidence pathway is shown in Figure 2.

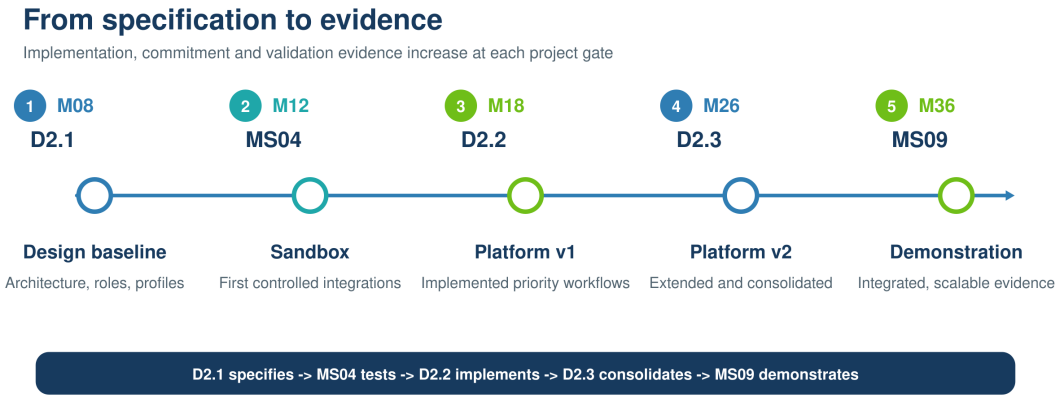


Figure 2. Staged development and evidence pathway from the D2.1 design baseline to the integrated NEXTLOGIC platform.

3. The NEXTLOGIC Digital Platform: what is it and why does it matter?

Cities must make urban-logistics choices under conditions of scarce space, fragmented information and competing interests. Decisions about Microhubs, loading and unloading areas, multimodal hubs, incentive measures or charging infrastructure affect public authorities, operators, businesses and residents, while the evidence needed to compare options remains distributed across organisations and varies in quality. Deliverable 1.1 (D1.1), "Urban logistic challenges", notes that even digitally advanced NEXTLOGIC cities do not yet have a freight-dedicated Digital Twin supported by sufficiently granular, real-time delivery data.

The NEXTLOGIC Digital Platform addresses this gap as a **common decision-support and co-design environment**. It combines Digital Twin capabilities, geospatial analytics and eXtended Reality (XR) to help cities and partners understand current conditions, examine alternatives and communicate the evidence behind urban-logistics decisions. Its value lies in connecting resources and users through a **traceable workflow**, not in concentrating every dataset or technology in one application.

3.1 Scope and vision

The platform is conceived as a digitally enabled **planning, analysis and co-design environment** for sustainable urban logistics. It connects spatial information, historical and real-time observations where available, analytical models, simulation results and interactive visualisation around a defined city question. Users can explore current conditions, formulate an intervention, configure an authorised analysis, compare likely effects and discuss the resulting evidence with affected stakeholders. Figure 3 in Section 3.4 shows how this coherent user route is combined with distributed ownership.

It is therefore a **decision-support ecosystem** rather than a single closed application. The Digital Twin relates relevant city objects, observations, models and scenarios to place and time. Analytical services produce indicators, forecasts, accessibility or suitability results and scenario comparisons. Maps, dashboards and 2D/3D views provide accessible routes to the evidence; XR can support selected spatial reviews when immersion adds value. The documented LIST LDT platform demonstrator and iGuess® provide complementary but non-equivalent routes, while authorised partner services can remain at provider nodes.

The distributed Digital Platform therefore combines the Digital Toolbox as the portfolio and integration framework for reusable assets, the Digital Tools Hub as its principal access, configuration and coordination layer, and the Sandbox as the controlled integration and validation environment. Together they provide a coherent user route while data, tools, computation and operational responsibility may remain distributed.

The Digital Tools Hub gives this federation an understandable front door. An individual **tool** is a registered technical capability; a **workflow** is a governed chain of tools and data; a **solution template** packages a reusable workflow for one solution family; a **configured scenario** adds a study area, time period, inputs, parameters and baseline; and a **result** is the traceable evidence produced by an execution. Keeping these objects distinct allows users to reuse a workflow without confusing a template with a completed or approved scenario.

This object model also supports continuity between planning, collaboration and later monitoring. A scenario reviewed in a workshop can retain the same identifier when its evidence is opened in a dashboard or XR view, while a later execution remains distinguishable from the earlier result.

The platform can therefore preserve a **reusable institutional record** of what was considered, on which evidence and under which assumptions.

A Microhub assessment, for example, may combine freight demand, a routable network, land-use constraints, cargo-bike catchments and stakeholder criteria, then compare locations and operating assumptions before scarce public resources are committed. The same platform pattern can support loading-zone utilisation, multimodal-hub accessibility, incentive feedback or charging-location screening by selecting different authorised inputs and processes. Users normally start from a guided goal or solution template; specialists can open the LIST LDT platform or iGuess®, or directly access or configure an individual registered tool where authorised.

The five solution families are treated as interventions in one wider urban system rather than isolated applications. Freight and passenger mobility, curb space, land use, energy, business operations and behaviour can influence the same location and stakeholders. A shared platform pattern makes those interactions visible while allowing each WP3 solution to retain its own method, data prerequisites and implementation responsibility.

No technology is sufficient on its own. A Digital Twin without analysis may reproduce conditions without helping users compare options; analytics without clear visualisation may remain inaccessible; and XR without a governed evidence base can create a persuasive but misleading scene. The platform therefore preserves inputs, assumptions, versions, limitations and scenario status as evidence moves between components.

The platform neither determines policy automatically nor imposes one level of digital maturity. Urban logistics choices involve values, distributional effects and priorities that cannot be reduced to one optimisation result; **final decisions remain with the competent authorities and responsible actors**. Cities can begin with reliable reference data, transparent indicators and map-based comparison, then add streaming data, detailed 3D content or more advanced services where the decision, evidence and operating capacity justify them. This graduated approach is important across the eight cities identified in D1.1, which differ in data availability, existing systems and institutional capacity.

3.2 Who will use it?

The platform serves several user groups with different responsibilities, expertise and access rights. It must therefore offer specialist analytical services, operational views, concise policy evidence and understandable participatory visualisations without exposing information beyond its authorised purpose. The Hub provides a recognisable starting point, while the depth of configuration, evidence and technical detail varies by role.

- **City authorities, urban and transport planners** use consistent spatial evidence, accessibility and scenario analysis to coordinate mobility, logistics, public space, climate, planning, permitting and enforcement decisions that would otherwise be examined in separate departmental settings.
- **Mobility agencies, traffic and public-space managers** examine how freight measures interact with traffic, active travel, public transport and competing curbside uses, including when loading demand occurs, how long space is occupied and which adjacent users may be affected.
- **Logistics operators, couriers and fleet managers** test operational consequences of locations, access rules, delivery windows, consolidation and vehicle choices, while

contributing practical requirements and authorised data that can expose unrealistic planning assumptions.

- **Businesses, site owners and infrastructure providers** assess servicing, access, demand and long-term operational feasibility where viable locations, investment decisions or business arrangements are needed beyond the funded pilot.
- **Policy makers and decision makers** compare concise indicator and scenario summaries, assumptions, uncertainty and effects on different groups against agreed objectives without treating a model output as an automatic recommendation.
- **Residents, workers and civil-society organisations** can engage through maps, workshops, surveys and selected XR experiences, contribute with local knowledge and compare revisions. Accessible non-immersive and non-digital alternatives remain necessary to avoid exclusion.
- **Researchers, technical experts and providers** develop or validate models, indicators, datasets and interfaces through described and reproducible records; platform administrators manage identity, configuration, data quality, integration status and lifecycle information.

These groups **will not use the same screen or see the same information**. Access follows legitimate responsibilities, confidentiality, data-protection requirements and data-sharing agreements, while public decisions should remain as transparent and traceable as those constraints permit.

3.3 What can users do better?

The platform should be judged by the decisions and collaborations it improves, not by the number of datasets or visual effects it contains. In practical terms, users should be able to:

- **Build a shared view** of present conditions from compatible assumptions, relate operator knowledge to public evidence and expose important data gaps before stakeholders debate solutions.
- **Screen potential interventions**, including Microhubs, loading areas, multimodal facilities, cargo-bike operations and charging locations, against spatial, operational, policy and stakeholder constraints.
- **Compare scenarios** for locations, designs, operating rules, delivery windows or scenario branches using consistent indicators and sensitivity tests.
- **Make trade-offs explicit**, including assumptions, uncertainty and distributional effects, before implementation without presenting modelled effects as guaranteed predictions.
- **Collaborate through shared views** in maps, dashboards, 3D or XR, use structured feedback to examine revisions and retain accessible alternatives.
- **Monitor and learn** against a named baseline, retaining reusable records of data, processes, parameters, status and results for later learning or transfer.

These functions help identify unsuitable options earlier, target pilot and investment effort more effectively, communicate proposals clearly and build institutional knowledge about which configurations work under which local conditions. They can also identify measures that need more evidence, regulatory preparation, operating agreements or stakeholder engagement before a pilot is justified. Where appropriate, a result can be exported or cited in a workshop or decision

record while retaining a link to its evidence package. The resulting record **supports professional and political judgement rather than replacing it**.

3.4 Main platform capabilities

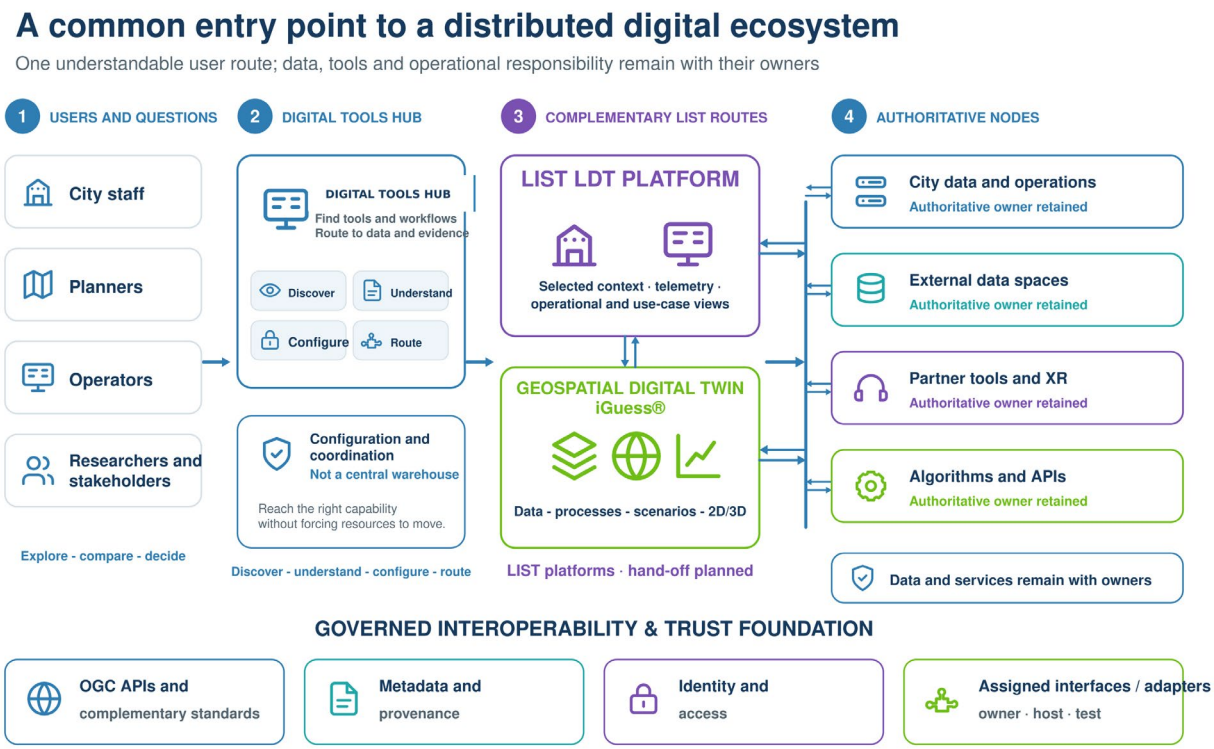
At a high level, the platform combines **three mutually reinforcing capability areas**: a Digital Twin, artificial-intelligence and advanced analytics, and XR-enabled visualisation and co-design. Common geospatial information, identities and interface records connect them while allowing each capability to evolve separately.

The Digital Twin provides the spatial and informational backbone. It relates streets, buildings, facilities, networks, observations and modelled or proposed states to a study area and time. Observed, reference, modelled and proposed conditions remain explicitly labelled so a convincing 3D scene is not confused with an approved or measured state. Required detail depends on the question: a planning workflow may use 2D networks and periodic data, while an operational case may justify streaming observations and detailed 3D context.

Analytics transform authorised data into decision-support evidence through accessibility and routing, demand estimation, site suitability, optimisation, simulation and indicators. Artificial intelligence is used only where it provides demonstrable value over transparent statistical, rule-based or optimisation methods. Inputs, parameters, validation status, uncertainty and limitations remain visible, with human review where incomplete data, bias or policy choices may materially affect the conclusion.

XR comprises virtual, augmented and related interactive 3D experiences. It can make scale, visibility, movement and relationships to familiar places easier to discuss, but it remains grounded in the same registered scenarios used elsewhere. XR is selected for a review task rather than treated as a default interface and complements maps, dashboards, physical workshops and other accessible formats.

Together, these capabilities support a continuous cycle: organise evidence, configure or select a scenario, run registered processes, compare results, facilitate review and connect later observations to the baseline. Figure 3 shows the common entry point and distributed ecosystem. Figure 16 in Section 10.4 translates that cycle into a guided Hub journey while retaining direct LIST LDT platform, iGuess® and authorised specialist access for experienced users.



The Digital Tools Hub supports discovery, guidance and routing to the complementary LIST LDT platform and iGuess® routes and to authorised specialist applications, while city, partner and external resources remain with their owners. Connections represent governed logical routes rather than completed Month 08 integrations.

Figure 3. Common entry point to the distributed NEXTLOGIC Digital Platform.

4. Digital Twins for cities: state of the art, limitations and intended advance

Urban Digital Twins combine geospatial information, context data, simulation, visualisation and participatory planning. The state of the art is therefore a set of complementary standards, platforms and practices rather than one complete reference stack. This section evaluates only the advances and **persistent limitations** that justify the WP2/D2.1 architecture. Each subsection follows the same logic: current state of the art, remaining limitation and the resulting WP2 design response.

4.1 Interoperability standards for urban Digital Twins

The Open Geospatial Consortium (OGC) provides web-oriented standards for features, maps, tiles, observations and processing. The OGC Urban Digital Twins Interoperability Pilot and related research show how modular APIs can connect 3D, sensor and other city resources without relying entirely on bespoke exchange [1] [2]. OGC API – Records – Part 1: Core, approved in 2025, now supplies a standard interface for discovering distributed geospatial datasets, services, processes and other resources [24]. Open & Agile Smart Cities & Communities (OASC) complements this technical view with city-oriented Minimal Interoperability Mechanisms [3]. For catalogue federation, DCAT-AP, GeoDCAT-AP and mobilityDCAT-AP provide complementary general, geospatial and mobility metadata profiles [25] [26] [27].

The limitation is that these specifications have different scopes, maturity and conformance rules. Geospatial APIs do not by themselves define identity, usage policy, workflow governance or every mobility-domain schema, while legacy and provider-specific services remain widespread. A generic claim of “OGC”, “OASC” or INSPIRE compliance would therefore conceal rather than resolve integration choices.

D2.1 responds with **reusable, version-controlled interoperability profiles** for relevant integration interfaces. A profile records the applicable standard and version, required metadata and schemas, authentication, status and error behaviour, provenance, adapter responsibility and test gate for a capability such as discovery, data access or process execution. It is not a different specification for every partner: reusable profiles are configured for the interfaces that genuinely differ, while documented adapters retain compatibility with established services. Annex A.2 separates core, conditional, compatibility and evaluation choices.

4.2 Local Digital Twins, context management and European data spaces

The European Commission presents Local Digital Twins as virtual representations that combine data and models to explore present conditions and future scenarios [4]. The EU Local Digital Twin Toolbox and Living-in.EU activities promote reusable building blocks [5], while DUET demonstrated both their decision-support potential and the integration effort created by different city baselines, models and subsystems [6] [7]. For dynamic context, ETSI NGSI-LD supports distributed entities, current and historic attributes, context-source discovery and subscriptions; the current API specification is version 1.9.1 [8] [28]. These capabilities complement rather than replace geospatial, processing and catalogue standards.

European mobility-data policy addresses a related scale of fragmentation. The Commission describes the mobility landscape as divided across ecosystems with difficult access and presents the common European mobility data space (EMDS) as a mean to facilitate access, pooling and sharing across existing and future sources [22]. The Data Spaces Support Centre (DSSC) Blueprint

v3.0 distinguishes data interoperability and exchange from participant identity, trust, access and usage-policy enforcement, provenance and catalogue functions [23]. Data-space participation therefore requires more than publishing an OGC data API.

The remaining limitation is that a city twin, context broker, catalogue or data-space connector does not automatically provide a coherent source of truth, accessible datasets or executable analytical workflows. D2.1 consequently treats the prospective T1.2 storage and access node, the complementary NEXTLOGIC catalogue and any EMDS connection as **separate interfaces**. Data remain authoritative at their owners; catalogue records use stable identifiers and controlled harvesting or synchronisation; and connector, trust, policy and dataset-eligibility choices remain conditional until WP1 and project governance confirm them.

4.3 Geospatial Digital Twins as the spatial backbone

Geospatial information supplies the common spatial and temporal reference for streets, buildings, facilities, networks, observations and model outputs. Research reviews emphasise that a convincing 3D visualisation alone does not constitute a usable, evolving twin, and case studies continue to identify semantics, standards and reuse as challenges [10] [11]. Research on Digital Twin descriptor services also explores dynamic urban-scene synthesis [9], but this remains distinct from a tested cross-platform solution workflow.

The persistent limitation is the assumption that interoperability requires one canonical database or 3D model. NEXTLOGIC instead requires each resource to expose or document **location, coordinate reference system, extent, time, owner, status and provenance**. A 2D network, observation stream, semantic city object, raster surface and simulation result may remain in different systems when their interfaces and relationships are sufficient for the workflow.

4.4 Urban logistics, last-mile delivery and curbside management

European urban-logistics roadmaps and projects such as URBANE and DISCO show the value of data and Digital Twins for scaling last-mile, freight and curb-management solutions [12] [13] [14]. Their use cases also illustrate a persistent transfer gap: platforms and models are frequently configured around one intervention, city or provider, with limited portability of data mappings, analytical steps, scenario lineage and operating responsibility.

WP2 addresses that limitation at the integration level. Microhub location, loading-zone utilisation, multimodal accessibility, incentive feedback and charging questions use different evidence, but they can share discovery, process onboarding, scenario, provenance and visualisation patterns. The five WP3 solutions therefore connect through **registered interfaces and workflows** rather than receiving five separate monolithic platform stacks.

4.5 XR for urban co-design

Extended Reality can improve understanding of scale, visibility, movement and trade-offs that are difficult to communicate through plans alone. Reviews report promising participation and planning applications, but also fragmented implementation, accessibility barriers and limited evidence about when immersion adds value [15] [16].

The D2.1 response is **selective and evidence-led**: XR uses the same registered scenario identifiers and source records as maps and dashboards, supports structured feedback, and retains

accessible non-immersive alternatives. It is a task-based review interface, not an ungoverned visual copy of a scenario or a technology deployed simply because it is available.

4.6 Synthesis of state-of-the-art limitations

The limitations material to the D2.1 architecture are consolidated in Table 5. The responses are **specified directions or proposed implementation patterns**; they are not claims that later integration and validation work is complete.

Table 5. State-of-the-art limitations and the corresponding WP2/D2.1 architectural response.

State-of-the-art area	Persistent limitation	WP2/D2.1 architectural response
Urban Digital Twin standards and APIs	Complementary specifications cover different functions, maturity levels and conformance scopes	Reusable, version-controlled profiles for relevant interfaces, with documented compatibility adapters
Context, geospatial and 3D systems	Dynamic context, detailed geometry, analytics and scenario status are not integrated automatically	Distinct LIST LDT platform and iGuess® routes linked through explicit identifiers, mappings and contracts
Catalogues and mobility data spaces	Discovery, data access, trust and usage policy are distinct; duplicate records can conflict	Prospective T1.2 node interface, complementary catalogue, optional EMDS federation and source-of-truth rules
Urban-logistics platforms and models	Tools and mappings are often use-case-specific and difficult to transfer	Tool Cards, explicitly assigned interfaces/adapters and reusable onboarding and workflow records across the five solutions
Models, indicators and XR	Scenario lineage, reproducibility, status and accessibility can be weak	Registered inputs, process versions, outputs, limitations and accessible 2D/3D/XR alternatives
Multi-city deployment	Cities differ in systems, data availability, governance and technical maturity	Modular adoption, conditional profiles, staged evidence and bounded replication configurations

4.7 NEXTLOGIC positioning and intended advance

NEXTLOGIC does not claim to invent OGC APIs, NGSI-LD, mobility data spaces, Urban Digital Twins or XR. Its intended WP2 advance is their **governed, profile-based and testable combination** for several urban-logistics solutions across heterogeneous cities. The architecture keeps resources with their authoritative owners, provides complementary operational and geospatial entry points through the LIST LDT platform and iGuess®, and uses the Digital Tools Hub to guide discovery, onboarding and workflow selection.

iGuess® provides an established OGC-oriented geospatial standards baseline, while the LIST LDT platform provides an NGSI-LD- and Smart Data Models-oriented context-management baseline. These strengths are complementary rather than exclusive: the applicable profile is selected for

each boundary and may combine OGC APIs, NGSI-LD and other standards according to the data, processing and interaction required.

Within NEXTLOGIC, the Digital Toolbox is the distributed portfolio of existing and project-developed tools, models, services, data interfaces, reusable workflows, applications, configuration schemas, adapters and integration records contributed across T2.1–T2.4. Assets may remain hosted and operated by their owners or, where feasible and agreed, be instantiated in the Sandbox. The Digital Tools Hub, to be specified and progressively implemented through T2.4, provides the principal WP2-level access, configuration, composition and coordination environment for this distributed Toolbox.

The strong interoperability focus follows directly from the implementation problem. NEXTLOGIC connects cities with different maturity, several technology and data providers, five WP3 solutions, static and streaming data, geospatial and semantic resources, models and user applications, plus a prospective T1.2 node and possible external data-space connection. **Replication beyond the pilots** requires these components to exchange evidence without imposing one vendor stack or transferring unlimited adapter responsibility to LIST.

The intended advance therefore combines explicit and reusable interface profiles; standards-based resource and process discovery; boundary-specific native interfaces or adapters with LIST integration support where agreed; visible provenance, uncertainty and scenario status; a questionnaire-driven Tool Card and Sandbox onboarding process; and **staged conformance and validation evidence**. European city examples remain useful illustrations of different Digital Twin approaches [17] [18] [19] [20] [21], but NEXTLOGIC's proposition will be judged by later evidence: whether it can connect freight-specific resources, reproduce and compare workflows, support understandable decisions and transfer bounded configurations between cities.

For NEXTLOGIC, machine-actionable catalogue federation provides the pathway from the initial questionnaire-based Tool Card onboarding towards searchable and reusable capability records. DCAT 3 supports dataset series, versioning and data-service descriptions, while OGC API – Records provides searchable geospatial resource records. STAC is relevant for spatio-temporal assets; OpenAPI and AsyncAPI describe synchronous and event interfaces; and NGSI-LD, SensorThings and OGC Connected Systems address contextual and observational resources. **NEXTLOGIC will apply these complementary standards at the appropriate architectural boundaries to support the progressive registration, discovery and federation of datasets, services, tools and observational resources through the Digital Toolbox and Digital Tools Hub** [24–28] [38–41].

Modern urban Digital Twins also require domain and presentation profiles. 3D Tiles and CityGML/CityJSON support streamed and semantic 3D city content; OpenXR provides a portable XR runtime interface; and OCPI/OCPP cover charging infrastructure and charging-point operation. NEXTLOGIC therefore adopts a profile-based approach rather than imposing one universal standard [42–45].

5. Overall framework specification

Section 5 is the definitive architectural reference for the task-specific frameworks in Sections 6 to 9. It moves from design principles and user-facing functions to the logical architecture, accountable components, interface profiles and solution configurations. Figure 4 is the central technical view: it brings the Digital Tools Hub, complementary execution and visualisation routes, authoritative owner domains, shared evidence and IF-1–IF-7 boundary contracts into one distributed federation.

5.1 Design principles

The following principles apply to the Month 08 baseline and guide implementation decisions in later releases. They are intentionally technology-aware but not tied to a single vendor stack. The resulting **design principles** are summarised in Table 6. Design principles for the NEXTLOGIC Digital Platform.

Table 6. Design principles for the NEXTLOGIC Digital Platform.

Principle	Architectural consequence
User and decision first	Data, models and visualisations are assembled around a planning or operational question, not around the desire to centralise technology
Distributed by design	City and partner systems remain authoritative; federation, discovery and invocation are preferred to mandatory replication
Open interfaces at boundaries	Each shared boundary is described by a machine-readable interface and an applicable interoperability profile
Profiles, not blanket compliance	Standards are selected per capability and dataset; conformance claims are made only after the named profile is implemented and tested
Modular extension	New data sources, processes and clients can connect through adapters without redesigning the full platform
Proportionate data movement	Processing may occur close to the source; only the data or derived result needed by a workflow is exchanged
Traceable evidence	Inputs, parameters, versions, provenance, uncertainty and result ownership remain visible through the workflow
Security and lawful access	Identity, authorisation, confidentiality, licensing and retention are treated as cross-cutting design requirements
Staged commitment	D2.1 fixes the common direction; implementation details are confirmed through MS04, D2.2 and D2.3 when evidence is available
Replication from the outset	Deployment profiles permit cities with different digital maturity and data availability to adopt useful subsets

These principles prevent Figure 4 from being read as a compulsory central stack. Detailed architecture decisions are recorded in Annex A.1 with the status specified, proposed or open. An item becomes binding for an implementation only when the relevant owner, boundary profile and release acceptance criteria have been confirmed.

5.2 Functional architecture

The platform supports a cycle that begins with a city question and ends with traceable evidence for a decision or co-design process. Its principal functions are to:

- Discover relevant datasets, services, tools and reusable workflows.
- Access or ingest authorised observations, reference data and model inputs.
- Create a geographically consistent view of the selected study area and time period.
- Execute partner or LIST analytical processes and simulations.
- Register outputs with their provenance, status and limitations.
- Visualise current conditions and scenarios in maps, dashboards, 3D scenes or XR.
- Compare alternatives using indicators aligned with the project impact framework.
- Capture user feedback, test evidence and configuration information for reuse.

The Digital Tools Hub provides the understandable first contact with these capabilities. It presents the complementary NEXTLOGIC catalogue, Tool Cards, solution and workflow records, user guidance and access routes. It may send a user to the LIST LDT platform, iGuess®, a partner application or a combined workflow. The catalogue can reference authorised datasets held by city, partner, public or prospective T1.2 sources; it is not the place where every dataset must be stored and the Hub is not a mandatory computation host.

The Hub supports three implementation modes. First, it can route a user to a capability's existing provider interface. Second, it can expose a shared, schema-guided configuration interface for a registered capability that has a callable boundary but no suitable user interface. Third, it can configure and coordinate a predefined solution workflow combining several registered tools or services. In all three modes, data, computation and operational responsibility may remain distributed; Hub coordination does not imply central computation.

Four recurrent interaction patterns make this functional architecture implementable without prescribing one data path for every case:

- **Federated access** retrieves or queries an authoritative city, partner or public resource without copying more content than the workflow requires.
- **Remote processing** sends authorised data references and parameters to a provider- or LIST-hosted process and returns status and result links.
- **Publish and reference** registers a derived dataset, scenario or indicator with its owner, provenance, access conditions and suitable map, feature, tile or 3D interface.
- **Composed workflow** combines several registered resources and processes while retaining a trace for every intermediate and final result.

The appropriate pattern is selected according to data sensitivity, volume, update frequency, performance, licensing, reproducibility and operating responsibility. A workflow may combine all four patterns; for example, it can query a city reference layer, invoke a partner model remotely, register only its authorised outputs and present them through iGuess®, the LIST LDT platform or XR. These four patterns are the interaction vocabulary for the routes and owner domains shown in Figure 4.

5.3 Logical architecture

Figure 4 is the definitive logical view of the Month 08 framework and should be read from top to bottom. It connects users and WP3 solution templates to the Digital Tools Hub, complementary routes, authoritative resource domains, shared evidence and IF-1–IF-7 boundaries. It is a target architecture and maturity baseline; no depicted NEXTLOGIC cross-component connection has yet been implemented or validated.

Common entry and solution layer. At the top of Figure 4, city experts, solution teams, providers, operators and administrators enter through a WP3 template or directly through the Hub. The Hub supports catalogues and stable identifiers, Tool Cards and readiness, guided goals and workflow or route selection. It coordinates navigation; it is neither a mandatory data store nor a universal execution engine.

Complementary routes, not a mandatory chain. Below the Hub, the LIST LDT platform route supplies selected city context, telemetry and use-case views; iGuess® supports geospatial processes, scenarios, results and 2D/3D exploration; and authorised specialist routes retain provider simulations, analytics, dashboards and XR clients. Routes can be used alone or composed. The planned LIST LDT platform–iGuess® hand-off uses IF-5/IF-6 and remains a proposed boundary; it has not been implemented or validated.

Owner-controlled domains and shared evidence. City, data, edge and partner capabilities remain authoritative with their owners. Sensors connect through an owned gateway; the prospective T1.2 node and external catalogue or data-space route remain conditional. The shared scenario and evidence record links identifiers for the workflow, study area, version, execution, parameters, outputs, provenance, quality, uncertainty, feedback and test or decision evidence. It does not copy every source dataset into a central store.

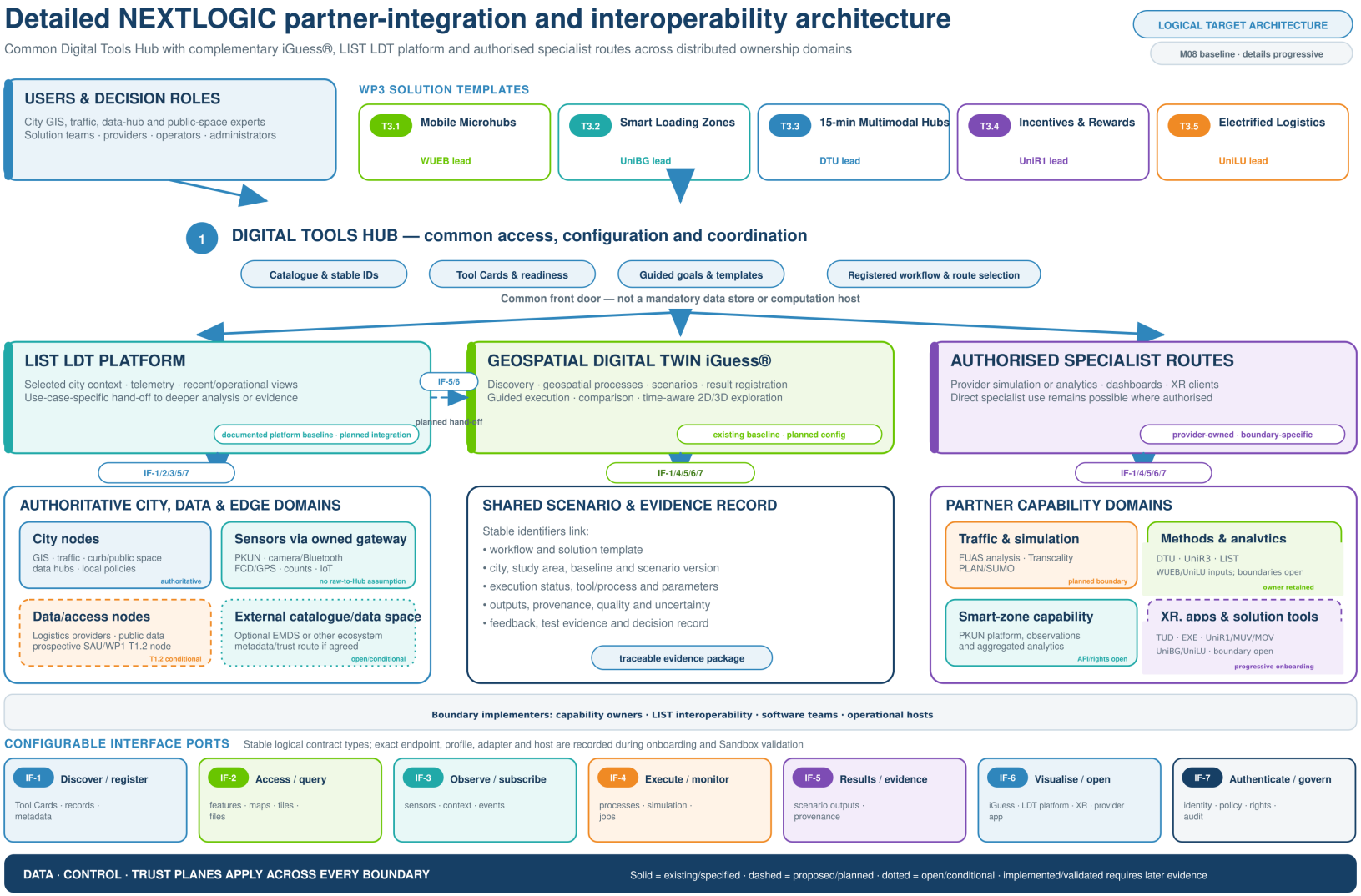
Distributed operation. Distribution is defined by ownership and interaction, not the number of front ends. Processing can remain with a provider, protected data with a city or T1.2 node, permitted reference layers can be cached, and XR can open an authorised scenario directly. Figure 4 neither sends every exchange through LIST nor requires a full installation in every city.

Configurable interfaces and visible maturity. IF-1–IF-7 cover register/discover, access/query, observe/subscribe, execute/monitor, results/evidence, visualise/open and authenticate/govern. A connection selects only the needed ports and records its owner, endpoint or profile, adapter, host, maintainer and test. Solid, dashed and dotted outlines distinguish existing/specified, proposed/planned and open/conditional elements; implemented or validated status requires later evidence.

Data, control and trust planes. These cross every boundary: data carries resources, parameters and outputs; control supports discovery, routing, job status, versions and monitoring; and trust covers identity, authorisation, policy, provenance, audit and sovereignty. Their separation prevents a data-access API from being mistaken for a complete data-space or governance arrangement.

Minimum boundary contract. Every priority connection records the capability and owner; interface and version; input and output schemas; identifiers and spatial or temporal reference; authentication and authorisation; expected status and error behaviour; operational limits; provenance requirements; adapter and maintenance responsibility; and the release and test in which the boundary will be accepted. Annex A.4 provides the initial assignments, while Annex A.8

defines the interface-port catalogue and generic boundary-record structure. This contract is deliberately smaller than the connected component's internal design, allowing an implementation to change without destabilising the agreed boundary.



The diagram defines the Month 08 logical framework and target architecture. Existing boxes identify available partner capabilities or documented baselines; no depicted NEXTLOGIC cross-component connection has yet been implemented or validated.

Figure 4. Detailed NEXTLOGIC partner-integration and interoperability architecture.

5.4 Platform components and responsibilities

Table 7 translates the principal boxes and responsibility boundaries in Figure 4 into accountable components. It distinguishes navigation, LIST and specialist routes, authoritative domains, adapters and shared evidence without treating every formal WP2 contributor as a software provider.

Table 7. Principal platform components and responsibilities.

Component	Primary role	Authority / proposed owner	What it is not
Digital Toolbox	Distributed portfolio of capabilities, workflows, schemas, adapters, Tool Cards, configurations, deployment guidance and integration evidence	Joint WP2/T2.4 contribution, with capability owners retaining their assets	One centrally hosted application or one LIST-owned software stack
Digital Tools Hub	User entry; catalogue and Tool Cards; readiness; guided tool/workflow configuration; predefined composition; execution routing/status; result and evidence access	Joint T2.4 implementation, coordinated by LIST task leadership with named component owners	Central database, universal source of truth or mandatory computation host
Sandbox	Local instantiation where feasible; remote-boundary testing; mixed end-to-end workflow testing and evidence collection	Joint T2.4 integration environment; operator and host to be assigned explicitly	Industrial production hosting or compulsory transfer of provider technology to LIST
LIST LDT platform	Context management, telemetry, monitoring, visualisation and agreed use-case coordination	LIST, with implementation boundaries assigned explicitly	Sole platform-wide orchestrator or front end to iGuess®

Geospatial Digital Twin iGuess®	Geospatial discovery, data integration, analytical process execution, scenario management, 2D/3D visualisation and result registration	LIST, with implementation boundaries assigned explicitly	A compulsory store for all city data, the sole platform-wide orchestrator or a front end to the LIST LDT platform
Authoritative city, data and edge domains	Municipal systems, sensors via owned gateways, public/logistics data and local policy sources	Respective city, data owner or authorised operator	Passive sources or unrestricted feeds required to surrender all data to the Hub
Partner capability domains and authorised specialist routes	Provider tools, models, analytical services, dashboards, applications and XR capabilities	Respective capability or technology provider	Components required to adopt LIST's internal stack or route every execution through LIST
Adapters	Translate a native interface, schema or protocol into an agreed NEXTLOGIC profile	Assigned boundary by boundary among the capability owner, LIST and any operational host	Unbounded custom integration maintained solely by LIST
Shared scenario and evidence record	Stable identifiers linking workflows, study areas, versions, execution status, parameters, outputs, provenance, quality, feedback and test evidence	WP2 coordination with the named data, capability and result owners	A central store for every source dataset or proof that a boundary has passed integration testing
Prospective T1.2 node	Authorised storage or access for selected project data, if confirmed through T1.2/D1.3	WP1/responsible data-node owner, to be confirmed	A component designed or delivered by D2.1
Optional external catalogue/data-space interface	Metadata federation and, where agreed, trusted policy-controlled exchange with EMDS or another ecosystem	Respective data-space participants and project governance, to be confirmed	A compulsory central database or an assumed production connector

Existing iGuess® capabilities and the documented LIST LDT platform demonstrator are

implementation assets for LIST, just as existing partner tools form assets for their providers. Their **scope and maturity are not assumed to be equivalent**. A capability is described as a **NEXTLOGIC integration** only after its project-specific interface, configuration and test evidence have been recorded.

Capability and method providers are expected to expose available native interfaces and contribute source semantics, requirements, constraints and tests. Where native support is unavailable, the adapter, hosting and maintenance responsibilities are assigned boundary by boundary with LIST and any operational owner. LIST can support interface profiles, reference patterns, reusable templates, mapping guidance, geospatial/interoperability implementation and Sandbox testing where agreed. Annex A.4 records the proposed assignments, confirmation status and release gates.

5.5 Data flows and interface profiles

Relationship between Figure 4 and Figure 5. Figure 4 identifies the logical IF port, owner and maturity of a boundary; Figure 5 identifies the standards families from which an appropriate technical profile can be selected. Port selection therefore precedes profile selection. The normal flow is to discover a resource, confirm access conditions, select or reference authorised input, invoke a process or retrieve a resource, register the returned result and provenance, present it through an appropriate interface, and retain the configuration and test outcome for reuse.

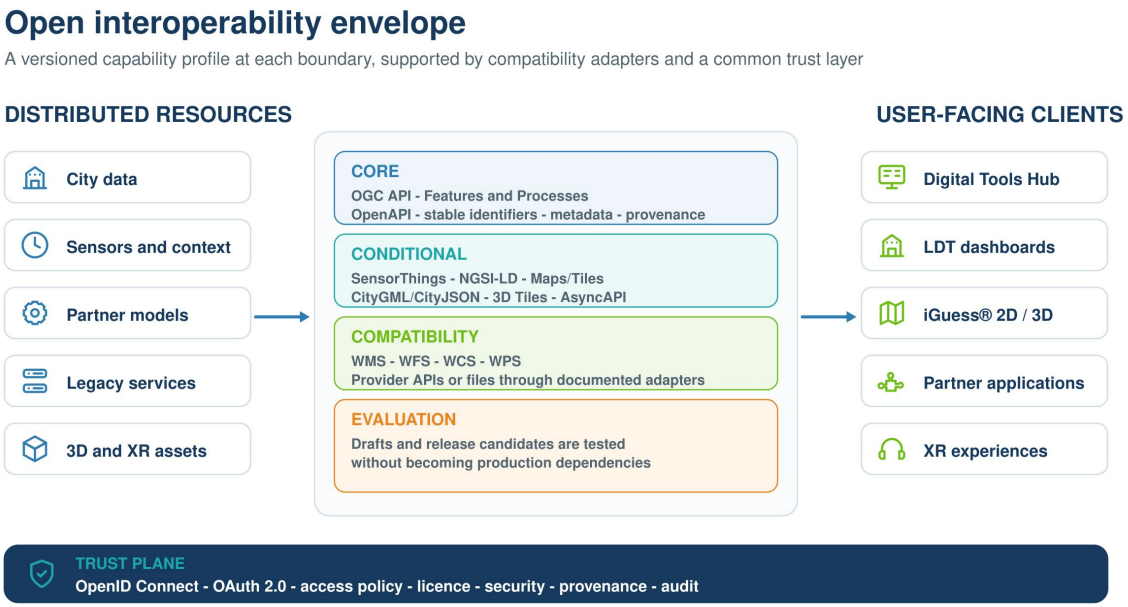


Figure 5. Open interoperability envelope for data, processes, visualisation, discovery and trust.

The interoperability envelope refines each applicable Figure 4 port through four profile levels:

1. **Core profiles** define capabilities that are expected at common geospatial and service boundaries, such as machine-readable API descriptions, stable identifiers, metadata, provenance and OGC API Features or OGC API Processes where applicable.
2. **Conditional profiles** are selected when the use case requires observations, context information, 3D content, city semantics or event exchange. Examples include SensorThings API, NGSI-LD, City Geography Markup Language (CityGML)/CityJSON, 3D Tiles and AsyncAPI.

3. **Compatibility profiles** allow established Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS), Web Processing Service (WPS), or partner-specific Representational State Transfer (REST) interfaces to remain usable through documented adapters.
4. **Evaluation profiles** cover draft or rapidly developing specifications that may be piloted without becoming a Month 08 production dependency.

OGC specifications are applied only where they fit the boundary. OpenAPI documents REST interfaces; OAuth 2.0 and OpenID Connect provide common authorisation and identity patterns; AsyncAPI can describe event interfaces; and deployment-specific monitoring and security controls remain necessary. Annex A.2 gives the initial version-aware standards register, while Annex A.8 relates selected profiles and ownership evidence to IF-1–IF-7.

Every exchanged result should carry, directly or by reference, the source and owner, observation or model time, spatial reference, process and software version, parameters, quality or uncertainty information, access conditions and the identifier of the workflow that produced it. This metadata permits a map, 3D scene or XR view to remain **traceable to the evidence behind it**.

Large or sensitive inputs should normally be passed by authorised reference or processed close to their source when the provider can support that pattern. Small public reference layers may be cached or replicated where this improves reliability and the licence permits it. The architecture therefore treats data movement as an **explicit workflow decision** rather than an automatic consequence of connecting a resource.

5.6 Integration with NEXTLOGIC solutions

The five WP3 solution templates across the top of Figure 4 —Mobile Microhubs, Smart Loading Zones, 15-minute Multimodal Hubs, Incentives and Reward mechanisms, and Electrification of Urban Logistics—reuse the same federation. Each solution selects only the data, processes, routes and IF ports it needs. Table 8. Illustrative platform patterns for the NEXTLOGIC solution areas summarises the corresponding platform patterns.

Table 8. Illustrative platform patterns for the NEXTLOGIC solution areas

Solution area	Typical data and services	Illustrative platform support
Mobile Microhubs	Demand, streets, land use, accessibility, operations and stakeholder constraints	Site screening, catchments, scenario comparison, 3D context and co-design
Smart Loading Zones	Location, occupancy, dwell time, enforcement and surrounding street activity	Operational monitoring, utilisation indicators, hotspot maps and curb scenarios
15-minute Multimodal Hubs	Networks, travel times, services, population and logistics demand	Multimodal accessibility, isochrones, service-gap analysis and hub comparison
Incentives and Reward mechanisms	Participation, behaviour, intervention and indicator data	Tool registration, controlled data exchange, dashboards and impact feedback

Electrification of Urban Logistics	Fleet demand, charging assets, grid information where available and land constraints	Charging-location screening, coverage analysis and conditional photovoltaic (PV) co-location assessment

No solution receives a separate monolithic architecture. The same discovery, access, process, visualisation and trust patterns are configured differently according to the question and the maturity of the pilot data. This common pattern is central to replication: a new city can begin with a small set of services and adopt additional capabilities later without changing the federation model.

6. Digital Twin framework

T2.1 develops the Digital Twin framework for urban space, mobility and logistics. In D2.1, the framework defines how relevant city objects, observations, models and scenarios can be related through a **geographically grounded information environment**. It does not prescribe a single complete city model or require every city to reach the same level of real-time detail.

6.1 Framework objectives

The framework creates a consistent inventory, describes each contribution's user purpose and technical boundaries, identifies any adapter needed, guides integration through the Sandbox and retains configuration and evidence for reuse. It must distinguish **provider information** from **reviewed interface information** and from **validated NEXTLOGIC integration evidence**.

- Establish a shared spatial and temporal frame for urban-logistics questions.
- Link authoritative city data, operational observations and partner model outputs without erasing their ownership.
- Support current-state, historical and scenario representations with clear status labels.
- Make data quality, provenance, uncertainty and access conditions visible.
- Expose reusable resources to analytics, dashboards, 3D visualisation and XR through the architecture in Section 5.

The term Digital Twin is used here for a **managed, evolving relationship** between relevant real-world entities and their digital representations. A static 3D city model can be one input, but it is not by itself the full Digital Twin. Conversely, a useful city workflow may begin with 2D reference data and a small number of observations when this is proportionate to the decision.

6.2 Digital Twin architecture

The Digital Twin framework separates authoritative sources, integrated views and scenarios. City and partner nodes remain the systems of record for the resources they own. The LIST LDT platform and iGuess® may federate, index, transform or cache authorised subsets to support a workflow. Each copy or derived representation must retain an identifier (ID) and provenance link to its source.

In this section, a state is a time- and provenance-qualified representation used within a Digital Twin scenario. The labels below describe representation roles rather than identical ontological categories, and distinguish how information entered the scenario and how it may be interpreted.

This usage is consistent with ETSI NGSI-LD, which represents the temporal evolution of entities through time-qualified attribute instances and explicitly covers historical evolution and future predictions [28]. The ETSI Digital Twin support report further distinguishes current state, history, predictive analytics and what-if simulation across design and operational stages [8]. The four roles below are therefore used as a D2.1 information-management classification; they are not presented as a taxonomy prescribed verbatim by either ETSI document.

1. **Observed state** represents measurements or recorded events and includes time, source or sensor, and quality information.
2. **Reference or baseline state** represents the authoritative or accepted context against which observations, models or proposals are interpreted, including its authority and effective date.

3. **Modelled state** represents an estimate, prediction or simulation and identifies the model, version, inputs, parameters and uncertainty.
4. **Proposed state** represents a planned intervention or design option and is clearly labelled to avoid confusion with observed or approved conditions.

This classification is especially important in 3D and XR, where a visually convincing proposed object can otherwise be **mistaken for an observed or approved condition**.

Figure 6 presents the information-management lifecycle of the Digital Twin. Authoritative resources are discovered and qualified; their representation roles are labelled; processing creates versioned derived information; results are published through suitable interfaces; and later observations or feedback extend rather than silently overwrite the evidence base. This lifecycle framing is consistent with the OGC Urban Digital Twins Discussion Paper, which envisages Urban Digital Twins as persistent data platforms supporting current and historical analysis, scenario evaluation, intervention planning, monitoring, feedback and evolving design information [37]. Figure 6 organises these information-management functions, whereas Figure 15 separately presents the user-facing decision-support workflow.



City Twin current-to-future state flow from distributed source discovery and qualification through explicit representation roles, versioned processing and derivation, publication, use and learning. This information-management view is distinct from the user-facing decision-support workflow in Figure 15.

Figure 6. City Twin current-to-future state flow.

The lifecycle starts by discovering and qualifying only the resources required by a decision question. Relevant identifiers, schemas, geometry and time references are then aligned sufficiently for the intended workflow. Observed, reference, modelled and proposed states are assembled into a scenario without losing their origin. Analytical processes may create further derived states, which are published through suitable interfaces and explored through the LIST LDT platform, iGuess®, dashboards or XR. Monitoring data and structured feedback can then create a new version or evidence record; they **do not silently overwrite the earlier baseline**.

City View Manifest: load a coherent current or baseline state. For a city or pilot, the layer tree and catalogue offer a reusable manifest referencing selected base maps, roads, buildings, land use and cover, infrastructure, sensors, demand surfaces, traffic, parking or loading occupancy and other authorised resources. Each entry retains its catalogue identifier, endpoint or asset link, spatial and temporal extent, coordinate reference system, selected time, style, order, visibility, access conditions and provenance. iGuess® or another authorised 2D/3D client can therefore load the view in one action without moving all data into one database.

The combined view remains a composition, not a flattened picture. OGC API Maps or WMS can provide a rendered overview, while queryable Features, Tiles, Coverages, SensorThings, NGSI-LD and 3D Tiles links remain available for analysis and interaction.

Scenario Bundle: branch the baseline into comparable future states. A parking management or other solution workflow binds the selected baseline, intervention parameters, datasets and services. Each run registers outputs, indicators, styles, limitations and provenance as a versioned Scenario Bundle, allowing scenarios A, B and C to reopen beside the baseline without overwriting one another.

Maps and dashboards are linked by identifiers and events, not by pixels. Map and chart selections exchange scenario/run, resource or feature identifiers and spatial-temporal filters, so a selected chart value highlights the map and a selected map location filters the dashboard. The same contract can serve 2D, 3D and XR clients.

6.3 Data management framework

T1.2 and D1.3 provide the upstream data-acquisition and management requirements; the relevant data owners remain authoritative. WP2 applies a **dataset-level readiness record** before a resource is used in a platform workflow. For each priority dataset, that record identifies authority, licence and lawful-access basis, spatial and temporal coverage, update frequency, coordinate reference system, schema, identifiers, quality limitations, sensitivity, retention, interface, owner, authoritative metadata source and target release. The Tool Card in Section 9 references this record rather than duplicating it.

Stable identifiers allow the same street segment, loading zone, vehicle class, scenario or indicator result to be related across services. Schema mappings should preserve source meaning and document any transformation. Where a full semantic mapping is not justified, a **smaller crosswalk for the fields actually used by a workflow** is preferable to an unsupported claim of complete harmonisation.

Real-time or event data are **integrated only when their value and operational prerequisites justify it**. Batch files, catalogue services and scheduled extracts remain valid patterns for many planning workflows. The choice between federation, caching and ingestion depends on source availability, performance, licensing, security and the need for reproducibility.

Temporal meaning must be explicit. Where applicable, a resource distinguishes the time at which a condition was valid, the time at which it was observed or an event occurred, the time at which a process produced a result, and the time at which that result was published. A “current” map therefore refers to a named observation or effective time rather than merely the most recently uploaded file. Historical snapshots and scenario branches remain addressable so that results can be reproduced after a source has changed.

Quality and uncertainty are also handled at the level at which they are known. Source completeness, positional or thematic accuracy, sampling bias and known gaps belong to the dataset record; modelling uncertainty and sensitivity belong to the process result; and limitations introduced by schema conversion or spatial aggregation belong to the transformation record. User interfaces should expose the limitations material to the decision through legends, labels, ranges or concise notes rather than hiding them in technical metadata alone.

Preliminary pilot-city baseline. A consolidated T2.1 comparison dated 3 August 2026 now provides a more systematic working view across the eight cities, ranging from reported models and data-preparation activities in Aarhus, The Hague and Frankfurt to higher-level pilot descriptions and pending inventories elsewhere. It remains a working synthesis rather than a city-confirmed readiness assessment: dataset availability, existing environments, interfaces, rights, update modes and ownership therefore remain separately qualified in Annex A.7.

6.4 AI and analytical components

The Digital Twin can consume statistical, optimisation, simulation and artificial-intelligence outputs, but **no method is privileged merely because it is labelled AI**. Analytical components must publish sufficient metadata for a user or reviewer to understand their purpose, inputs, parameters, output schema, limitations and validation status.

Where a model may materially influence a public decision, the workflow should expose uncertainty, sensitivity and important assumptions. **Human review remains necessary** for incomplete data, distributional effects and policy choices that cannot be reduced to a technical objective function. The T2.3 service portfolio in Section 8 therefore prioritises transparent geospatial methods and reproducible scenario comparison before data-intensive predictive functions.

6.5 Scenario modelling

A scenario is a **versioned package** containing a study area, baseline period, proposed intervention, selected datasets, process versions, parameter values, outputs and interpretation notes. Scenarios should be comparable without overwriting the baseline or one another. The framework supports branching—creating a new option from an existing configuration—and records who created or approved each version.

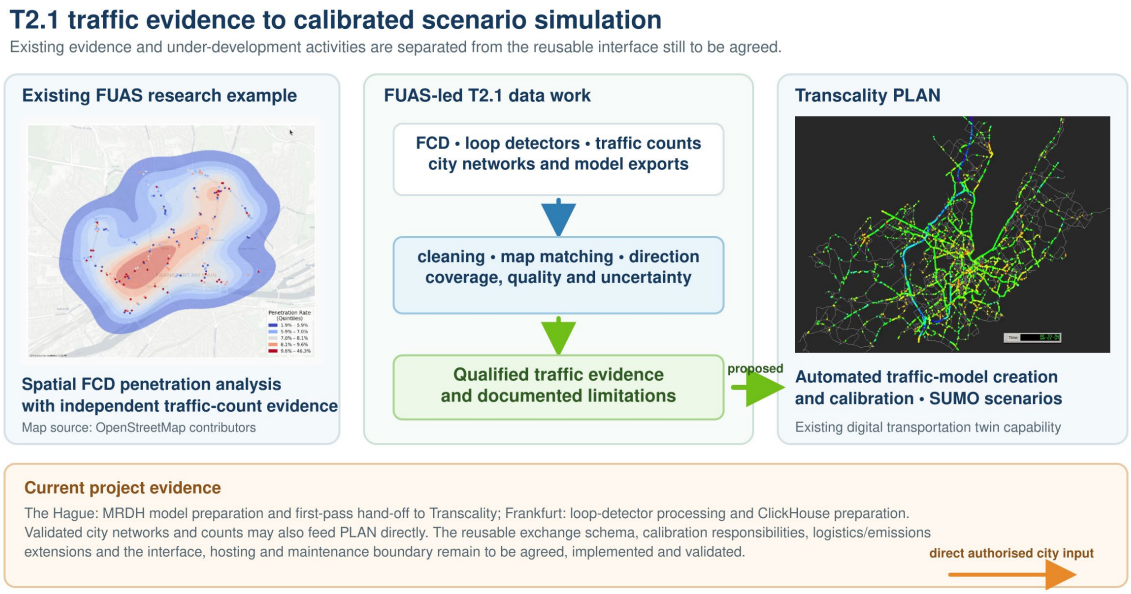
The framework distinguishes the **scenario definition**, an **execution record** and the resulting **evidence package**. The definition describes the intended inputs and parameters; an execution record captures the actual versions, status, messages and runtime context; and the evidence package links the outputs, indicators, visual styles and interpretation notes used in a review. This distinction permits a scenario to be rerun when data or models change without pretending that the new run is identical to the earlier evidence.

The scenario model is deliberately **neutral about the execution engine**. A scenario may invoke a LIST process, a partner-hosted simulation or a series of services. The shared requirement is that execution status and results can be traced and that a user can distinguish a completed run from a draft configuration, failed job or illustrative visualisation.

FUAS–Transcality analysis-to-simulation pattern. FUAS leads T2.1 and contributes with traffic-data inventory, cleaning, map matching, qualification and Digital Twin analysis, illustrated by the existing Frankfurt FCD/traffic-count research example [32]. The commercial Floating Car

Data (FCD) used for that historical study are no longer available to FUAS for NEXTLOGIC reuse; if city-specific commercial FCD are required, new access or procurement and the applicable licensing arrangements must be established for the relevant pilot. Current working evidence includes Frankfurt loop-detector preparation and a reported ClickHouse deployment on the T1.2 server for forthcoming traffic data, with ingestion, access and operational ownership still to confirm. The Hague has supplied an MRDH export to Transcality as a first-pass basis for SUMO integration; this remains a file-based exchange rather than an API. These activities demonstrate an evolving pipeline, not a reusable or validated partner interface.

Transcality PLAN is a SUMO-based digital transportation twin for automated traffic-model creation, calibration and scenario analysis [35]. Qualified FUAS outputs can support calibration or validation, while authorised city networks and counts may also enter PLAN directly. The exchange schema, calibration responsibilities, logistics and emissions extensions, interface, hosting and maintenance boundary remain to be agreed, implemented and validated. Figure 7 illustrates the proposed pattern.



The FUAS panel shows a historical research example concerning spatial Floating Car Data penetration and independent traffic counts; the underlying commercial FCD are not currently available for NEXTLOGIC reuse. The Transcality panel shows an existing SUMO-based simulation capability associated with PLAN. Current T2.1 work includes first-pass The Hague data hand-off and Frankfurt traffic-data preparation, while the reusable NEXTLOGIC exchange, calibration responsibilities and interface remain to be specified, implemented and validated. Sources: FUAS WCTR 2026 presentation [32], NEXTLOGIC T2.1 working material and Transcality [35].

Figure 7. Illustrative FUAS–Transcality analysis-to-simulation pattern.

6.6 Decision-support functionalities

Decision support **combines evidence rather than generating an automatic policy answer**. Core functions include filtering and exploration, baseline and scenario comparison, spatial and temporal indicators, sensitivity analysis, map and 3D presentation, export of results and recording of comments or decisions. Indicators originating from the T1.3 impact methodology are implemented in T2.3 only where the required data and computational rule are available; project impact conclusions remain the responsibility of the relevant impact-evaluation work.

A decision or workshop record **remains separate from the analytical output**. It can reference the scenarios reviewed, the evidence considered, material uncertainties, stakeholder comments and the responsible authority, but it does not convert a model result into an approved intervention

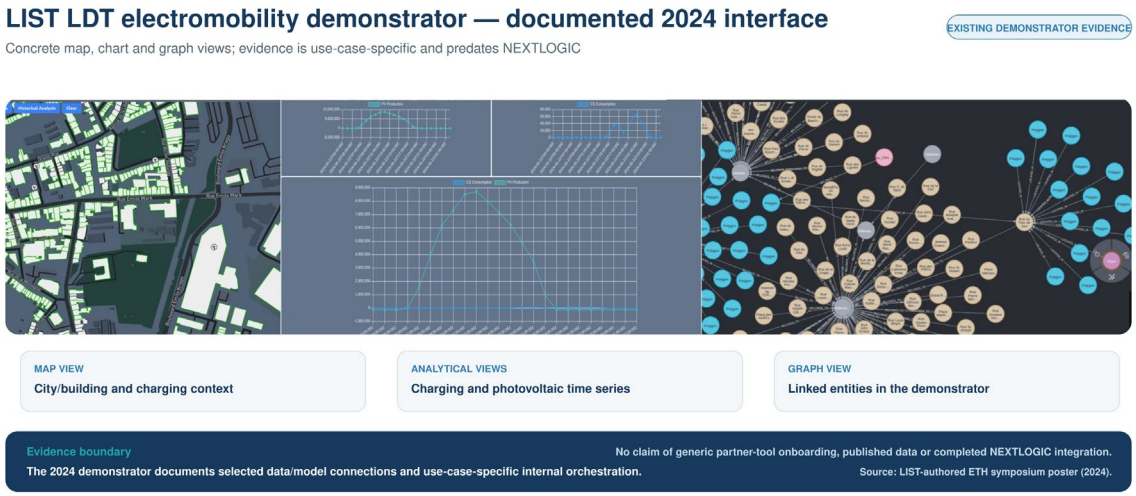
automatically. This separation supports transparency when different authorities legitimately reach different conclusions from the same technical evidence.

The Digital Twin framework prioritises traceability, provenance, temporal validity and fitness for purpose of representations used within decision-support workflows. Accordingly, users should be able to understand the origin, meaning, timeliness and applicability of information provided.

The 2024 LIST LDT platform electromobility demonstrator provides a concrete, use-case-specific implementation reference for T2.1. It combines selected city, building, charging and energy data with model-generated telemetry, map and chart views, a linked-entity graph and use-case-specific internal orchestration [29] [30].

The LIST LDT platform is being extended within CitCom.ai towards an open-source Local Digital Twin demonstrator aligned with NGSI-LD, Smart Data Models and applicable ETSI CIM guidance. The current CitCom.ai documentation [31] [36] describes an architecture combining context management, event streaming, analytics and visualisation components and structures its development around descriptive, predictive and prospective capabilities.

This material establishes a relevant technology and architecture baseline. Any NEXTLOGIC-specific endpoint, access conditions, configuration, operational status and integration-test evidence will be recorded through T2.4 when confirmed.



The interface, illustrating map-based Digital Twin entities, analytical views and linked entities, predates NEXTLOGIC and does not represent a completed generic tool integration or validated NEXTLOGIC implementation. Source: LIST-authored ETH symposium poster (2024) [29].

Figure 8. Existing 2024 LIST LDT platform electromobility demonstrator interface.

7. eXtended Reality framework

T2.2 develops XR approaches that help users experience, discuss and refine urban-mobility and logistics scenarios. The XR framework connects immersive and augmented interfaces to the same traceable scenario resources used by the wider Digital Platform. XR is therefore **one family of clients within the distributed architecture**, not a separate Digital Twin and not the default interface for every user.

7.1 Framework objectives

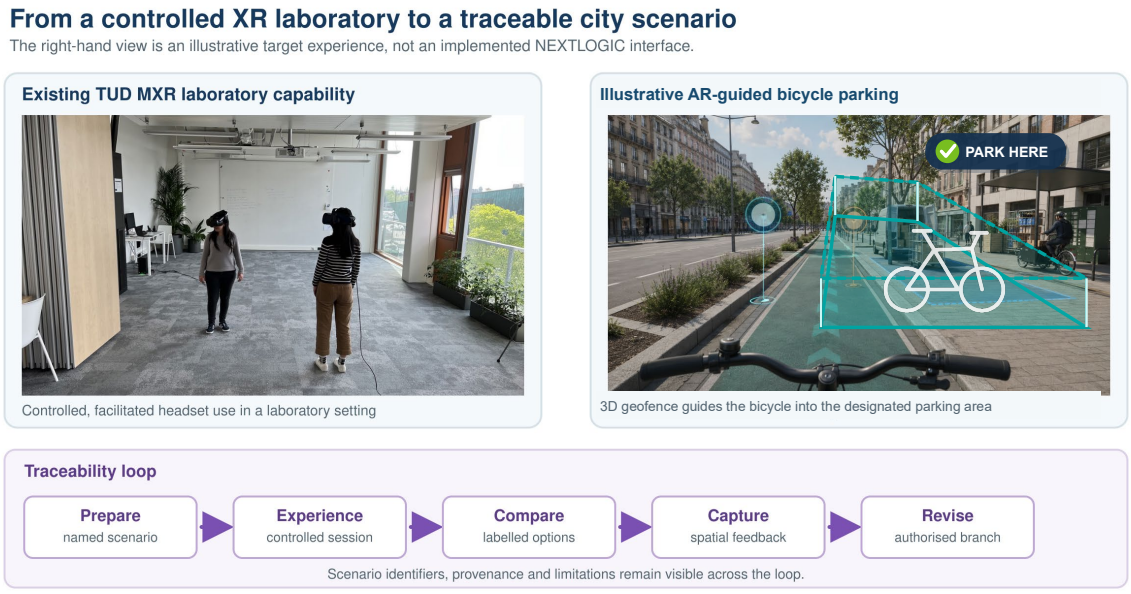
The framework aims to improve spatial understanding, enable task-based interaction with proposed interventions, support facilitated co-design and capture structured feedback. It also ensures that **non-immersive alternatives remain available** so that participation is not restricted by device access, physical ability, digital confidence or motion sensitivity.

7.2 XR concept and architecture

An **XR application or client software component** receives an **authorised scenario package** containing geometry or tiles, relevant attributes, coordinate and time information, interaction rules and provenance. A **registered scenario** is a versioned record with a stable identifier, study area, baseline, inputs, tool and model versions, parameters, outputs, provenance and access status. The **XR application** may retrieve authorised resources from iGuess®, the LIST LDT platform, a city service or a partner node. Feedback and selected interaction events may be returned through a documented interface where the use case and data-protection assessment permit it.

The framework **does not require a single rendering engine or headset**. Web-based 3D, virtual reality, augmented reality and simulator-based environments may coexist if they consume compatible scenario resources and preserve the meaning of the source data. Device-specific optimisation remains the responsibility of the XR provider.

Figure 9 grounds the controlled co-design loop in the existing TUD Mobility in eXtended Reality laboratory [33]. The right-hand panel shows an illustrative AR-guided bicycle-parking concept: a semi-transparent 3D geofence identifies the designated parking area and a positive placement cue guides the bicycle into the zone. It is not an implemented NEXTLOGIC interface and does not imply route navigation or enforcement. The traceability loop links the prepared scenario, controlled experience, labelled comparison, spatial feedback and any authorised revision.



The semi-transparent 3D geofence indicates the designated parking area; the right-hand view is a target concept, not an implemented NEXTLOGIC interface. Source: TU Delft MXR Lab [33]; illustrative AR-guided view generated for D2.1.

Figure 9. Existing TUD MXR laboratory capability paired with an illustrative AR-guided bicycle-parking view and a compact traceability loop.

This pattern can support different project settings without assuming identical interfaces. In Wrocław, the EXE-provided cargo-bike XR simulator and training environment may support operator/staff training and cargo-bike operational analysis in the T3.1 solution and T4.4 pilot context. In Dublin, an AR-supported bicycle-parking experience may visualise a designated parking area as a 3D geofence and guide users to place bicycles within it, with the aim of reducing undesired parking behaviour. TUD leads the applicable T2.2 XR methods; WUEB supplies the Mobile Microhub solution context and requirements; WCG leads the Wrocław T4.4 deployment. The exact scenario resources, device/client profile, simulator controls, facilitation and feedback interfaces remain implementation choices to be confirmed with EXE, TUD and the relevant solution and pilot partners.

7.3 User interaction

Every XR activity begins with a defined user, task and decision context. The initial use-case directions are: (1) EXE's cargo-bike XR simulator/training environment for simulator-supported assessment, operator or staff training and operational analysis in Wrocław; (2) TUD-led stakeholder co-design and assessment of future Microhub layouts in Wrocław; and (3) AR-guided bicycle placement within designated parking zones in Dublin. Other reusable tasks may include comparing named alternatives, checking visibility and access or discussing conflicts between freight, cycling and pedestrian space. Interaction design should favour a small number of meaningful controls over a technically impressive but confusing environment.

At minimum, users should be able to identify the scenario and date, move or view the scene safely, switch between clearly labelled alternatives, inspect important objects or indicators, and submit or record feedback. Facilitators should be able to reset the experience, explain limitations and provide an **accessible non-XR representation** of the same evidence.

Interaction requirements should be recorded **before the scene is built**. They include the participant group and task, the decisions or questions to be explored, the objects that may be

selected or changed, the indicators that must remain visible, the permitted feedback types, the session duration, the need for facilitation, and the accessible alternative. This prevents costly device-specific development from proceeding before the purpose of the activity is clear.

7.4 Visualisation environment

Visual fidelity must be **proportionate to the planning question**. Semantic 3D city content, 3D Tiles, textured models, point clouds or simpler extruded geometry can all be appropriate. Proposed objects and observed conditions use distinct visual styles so that proposal status is never mistaken for evidence certainty. Uncertainty in data, assumptions or model results is communicated separately through labels, legends, ranges or concise notes rather than hidden behind photorealism.

A **device delivery profile** records the target device, geometry complexity, texture resolution, network-bandwidth assumptions and any required fallbacks for a particular XR presentation route. D2.1 requires these configurations to be documented during implementation; it **does not claim measured device performance**.

7.5 Collaborative planning functionalities

XR sessions may support individual assessment, small-group design, public engagement or professional review. A **session plan** should specify the participant group, question, scenarios, facilitation method, feedback instrument, privacy conditions and criteria for determining whether XR added value compared with a map, dashboard or physical workshop.

Captured feedback should be associated with the scenario version and, where appropriate, a spatial location or object. Personal or behavioural data are collected only when necessary and with the applicable consent, access and retention controls.

A **minimum structured feedback record** may contain the scenario and version; participant role or anonymous session identifier; activity or question identifier where applicable; selected alternative; object, location or viewpoint where relevant; rating, category or comment; time; facilitator where relevant; and consent or privacy status. Free-text notes remain possible, but a small common structure is needed if feedback is to be compared across sessions or returned reliably to the Digital Twin workflow.

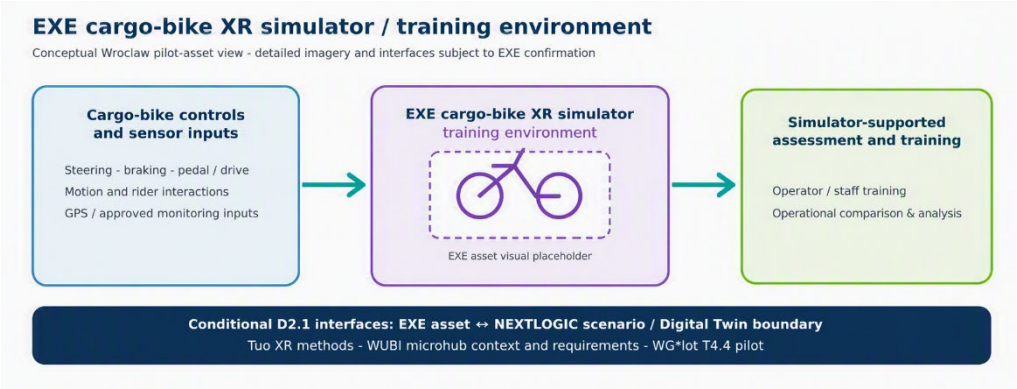
XR added value should be **assessed against the task, not against visual novelty**. Useful evidence can include whether participants understood spatial relationships more accurately, identified conflicts that were missed in a 2D review, completed the activity without unacceptable discomfort, and could explain the basis of their preference. Where a conventional map or facilitated workshop performs equally well with lower barriers, it remains the appropriate interface.

7.6 Integration with the Digital Twin

The integration boundary is the scenario package and its service interfaces, rather than direct access to the internal database of an LDT, iGuess® or a partner tool. TUD leads the applicable T2.2 XR methods and retains responsibility for its device-specific scientific and interaction choices. EXE is the provider and implementation partner for the Wrocław cargo-bike XR simulator/training environment and contributes Digital Twin applications and pilot-facing technology, including parking-occupancy camera hardware and data, cargo-bike GPS monitoring, integration support

and cloud storage for hosting Digital Twin applications for cargo-bike monitoring and bicycle-parking occupancy pilot solutions. WUEB supplies the T3.1 Mobile Microhub solution context and requirements, while WCG leads the T4.4 Wrocław deployment. These contributions are confirmed at M08; inclusion in a particular NEXTLOGIC workflow depends on the corresponding technical boundary and validation evidence.

EXE contribution. For D2.1, the cargo-bike XR simulator/training environment is treated as an EXE-provided, provider-operated Wrocław pilot asset and integration dependency, not as a core platform component. D2.1 defines only its scenario, Digital Twin, monitoring-data and XR boundaries; detailed construction, operation and pilot validation remain in the applicable implementation and pilot tasks.



The central asset panel may be replaced by an EXE-supplied image without changing the document layout. Source: EXE contribution and D2.1 conceptual integration view.

Figure 10. Conceptual EXE cargo-bike XR simulator/training environment and its conditional NEXTLOGIC integration boundary.



Figure 11. Existing EXE simulator environment.

T2.4 will specify and validate which camera, GPS and simulator inputs or outputs enter a scenario package; the role of each EXE Digital Twin, XR or client application; simulator controls, resource schemas, endpoints, access and authentication; hosting, maintenance and support; and the applicable test and acceptance evidence. LIST supports shared resource profiles, georeferencing, tile or layer publication and Sandbox or equivalent testing. TUD retains T2.2 XR-method leadership, WUEB contributes solution requirements and validation, and WCG and the Wrocław pilot authorities retain deployment and acceptance responsibilities. DEP-08, DEP-09 and DEP-14 in Table 19 record these boundary-level items for MS04/D2.2.

8. Geospatial analytics and visualisation framework

T2.3 converts relevant data, models and impact methods into **discoverable and reproducible geospatial services**, and makes their outputs understandable in 2D, 3D and time-aware interfaces. LIST leads the task with the key contributors UniR3, FUAS, Transcality and Parkunload (PKUN). Other partners may supply data, methods or use-case requirements without being described automatically as technology providers.

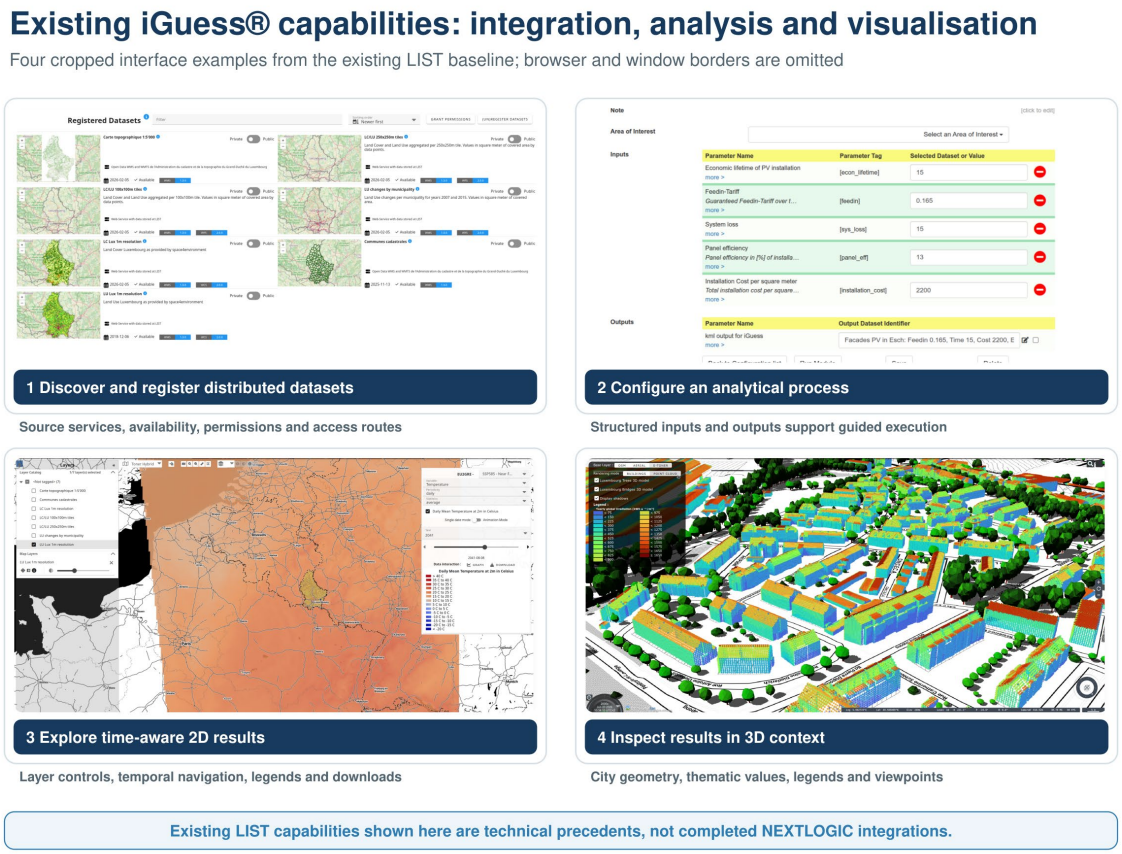
Within this collaboration, UniR3 contributes knowledge of logistics-modelling concepts and routing optimisation, while LIST supports the **geospatial implementation and integration of selected methods**. This support can cover routable-network and spatial input preparation, georeferenced outputs, open process exposure where appropriate, catalogue registration and 2D/3D visualisation. The exact algorithmic scope, interface, hosting and maintenance arrangements remain to be confirmed for the relevant release.

8.1 Framework objectives

The framework will:

- Expose analytical capabilities through documented process interfaces where proportionate.
- Make process parameters usable through generated or guided web forms.
- Support asynchronous execution, status, error handling and output registration for longer jobs.
- Visualise spatial and temporal results consistently in maps, charts and 3D scenes.
- Connect partner-hosted models without transferring their internal implementation to LIST.
- Implement selected geospatial indicators needed by the project impact framework while preserving responsibility boundaries.

Existing iGuess® capabilities provide a technical baseline for this work. They include registration of distributed OGC services, workspace and permission management, guided process configuration, execution monitoring, automatic output registration, temporal map animation, charts, downloads and interactive 3D presentation. Figure 12 shows these existing LIST assets in one consolidated, tightly cropped montage; it does **not claim that the depicted applications are already configured as NEXTLOGIC services**.



The screenshots show existing LIST capabilities, not completed NEXTLOGIC integrations, for distributed dataset registration, guided analytical-process configuration, time-aware 2D exploration and interactive 3D visualisation

Figure 12. Existing iGuess® baseline.

The NEXTLOGIC contribution is to connect priority partner and project processes through **open, recorded boundaries** and to configure these baseline capabilities for the named urban logistics workflows. The existing interface can therefore reduce repeated front-end development, while the **process provider remains responsible** for the scientific method, its implementation and its operating lifecycle.

8.2 Geospatial analytics and visualisation capabilities

The initial portfolio favours **useful, explainable functions** that can be implemented incrementally and reused across several solutions. The initial T2.3 portfolio is set out in Table 9.

Table 9. Prioritised initial T2.3 analytics and visualisation portfolio.

Capability	Typical output	Initial priority and dependency
Accessibility and isochrones	Walking, cycling, cargo-bike, road or multimodal catchments; population, services or demand covered	High; requires routable networks, speeds/impedances and destinations

Logistics routing and optimisation	Route alternatives, travel times, service areas and logistics-operation or fleet scenarios	High for selected use cases; UniR3 provides logistics-modelling knowledge and LIST supports geospatial implementation and integration; requires routable networks and operational constraints
Loading-zone utilisation	Occupancy, dwell time, turnover, exceedance and peak-period layers	High where authorised, time-stamped zone observations are available; PKUN is a T2.1/T2.3 contributor. Zone features, observation semantics, aggregation, privacy and the SensorThings/API-adapter boundary require confirmation.
Hotspot identification	Delivery, congestion, parking-search or loading-conflict clusters	High; transparent grid or density methods with documented parameters
Scenario comparison	Maps and charts of changes in flow, speed, delay, accessibility or emissions	High; depends on consistent baseline and scenario outputs
Spatial impact indicators	Vehicle-kilometres, delay, emissions, accessibility or public-space allocation by link or zone	High for selected T1.3 indicators with agreed methods and inputs
Microhub site screening	Ranked candidate areas and criterion maps	High; transparent multi-criteria analysis using demand, access, space and constraints
Charging-location screening	Demand coverage, proximity to logistics activity and access constraints	Medium; electricity-network evidence used only when available and authorised
Space-reallocation analysis	Area assigned to loading, parking, cycling, walking or other uses and scenario differences	Medium; requires comparable curb or street-space data
Service-gap analysis	Areas or groups insufficiently served by hubs, loading zones, charging or transport services	Medium; builds on accessibility functions
PV co-location screening	Conditional roof or canopy suitability near logistics and charging sites	Evaluation; included only where suitable building and solar data exist

Data-intensive forecasting, dynamic-pricing optimisation and AI-based traffic prediction remain **conditional later-stage activities**. They will be promoted only if a use case, adequate training and validation data, accountable ownership and a measurable advantage over simpler methods are established.

Visualisation is treated as **part of the analytical workflow**. A registered result should be presentable through default map styling, legends, time controls and comparison views without bespoke front-end development for every process. Where 3D adds meaningful context, output geometry or attributes can be published as appropriate 3D resources. Charts and downloadable data remain important for interpretation and verification.

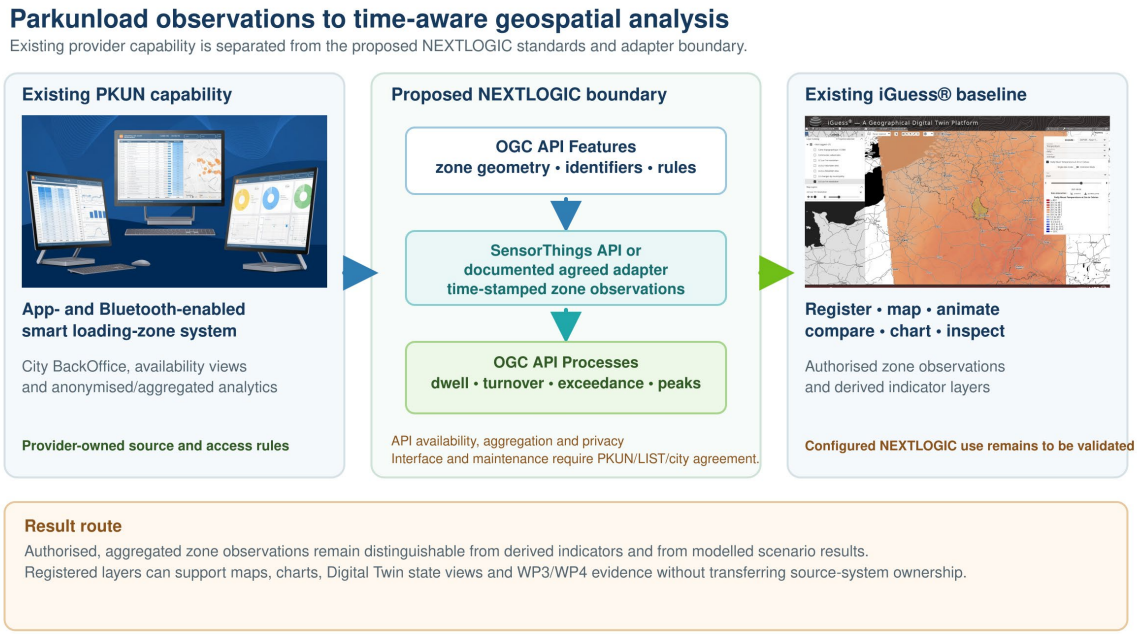
A process description should provide enough structure for a **safe and understandable guided interface**: identifier and version; purpose and limitations; input and output names, types and required status; defaults or permitted values where appropriate; spatial and temporal reference; data-by-value or data-by-reference options; expected execution mode; result lifetime; and useful error or status messages. Schema-driven generation does not prevent a task-specific interface from adding help text, grouped controls, map-based area selection or validated defaults. It provides a reusable baseline that can be refined when the generic form would not be understandable to the intended user.

Long-running or data-intensive services require **explicit job handling**. The interface should distinguish a draft configuration, accepted job, running job, completed result, failure and cancellation where supported. Large inputs and outputs should normally be exchanged by authorised reference rather than copied repeatedly through the browser. Execution quotas, timeouts, retention and retry behaviour are implementation details to be confirmed for each priority process and tested before an operational claim is made.

8.3 Integration of spatial observations and loading zone analytics

Parkunload (PKUN) is a named contributor to T2.1 and T2.3 and contributes an existing app- and Bluetooth-enabled Smart Loading Zone platform, city BackOffice and anonymised or aggregated analytics [34]. PKUN is also a T3.2 contributor but is not a named T2.4 contributor. Its resources are therefore treated as **provider-owned observations and analytics** to be onboarded through the common integration framework, not as T2.4-owned developments.

Proposed interface pattern. OGC API Features can expose authorised loading zone geometry, identifiers and rules; SensorThings API or a documented agreed adapter can expose time-stamped, zone-level observations; and OGC API Processes can publish agreed indicators such as dwell time, turnover, exceedance and peak periods. iGuess® can register, map, animate, compare and chart those resources. Public evidence does not establish native PKUN SensorThings support, so the API route, permissible aggregation, privacy conditions and the PKUN–LIST interface, hosting and maintenance boundary require partner and city confirmation. Figure 13 distinguishes existing capabilities from the proposed NEXTLOGIC route.



Existing PKUN smart-zone and analytics capabilities [34] and existing iGuess® functions are separated from the proposed OGC API Features, SensorThings API or documented-adapter, and OGC API Processes boundaries. Interface availability, privacy, aggregation and maintenance responsibilities remain to be confirmed and validated.

Figure 13. Proposed Parkunload observation-to-iGuess® integration pattern.

8.4 Integration with simulation and modelling tools

Three reference patterns make the proposed architecture concrete.

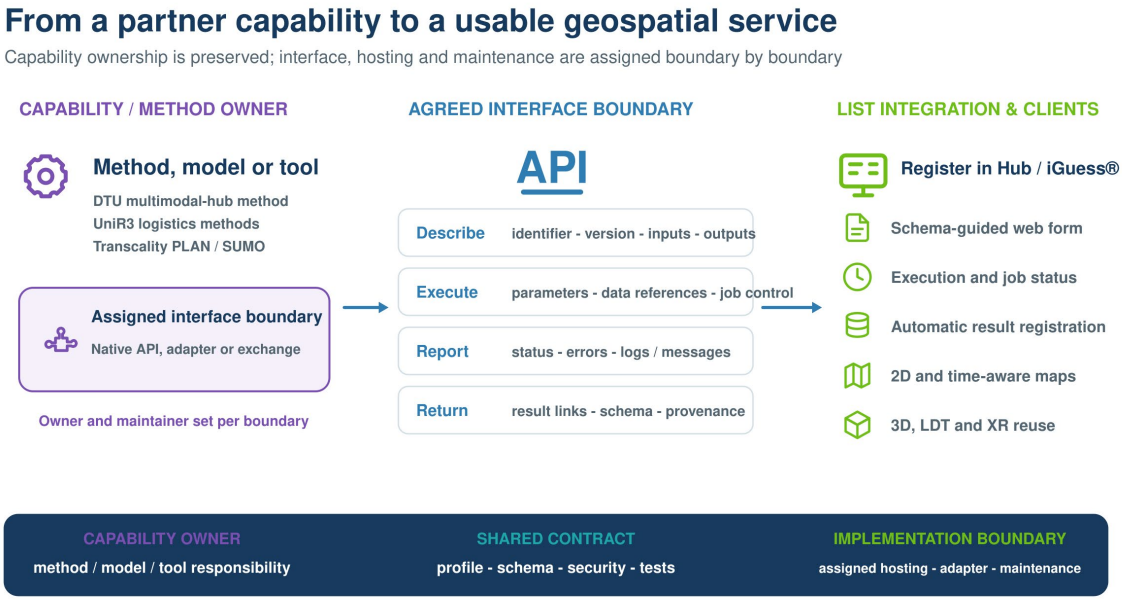
DTU-led 15-minute Multimodal Hub accessibility and siting method. DTU leads T3.3 and retains ownership and scientific responsibility for its accessibility, hub-location, GIS spatial-modelling and behavioural-analysis methods; LIST is a T3.3 key contributor and can support geospatial implementation and OGC API Processes integration. If an executable service is agreed, a machine-readable description can support schema-guided inputs, job status, result registration and 2D/3D visualisation in iGuess®. The precise method, executable status, interface, hosting and maintenance boundary require DTU–LIST confirmation.

Transcality PLAN and SUMO result integration. Transcality remains responsible for PLAN, its SUMO-based digital transportation twin, and for model creation, calibration, scenario semantics and scientific/technical validity. Section 6.5 describes the current FUAS-led data-analysis and qualification route, while authorised city networks and counts may also feed PLAN directly. LIST can support an agreed process or result profile, registration, styling, comparison and 2D/3D presentation in iGuess®. The NEXTLOGIC-specific scenario contract, priority inputs and outputs, logistics/emissions extensions, interface, hosting and maintenance boundary must be agreed with Transcality before the integration is described as implemented.

UniR3 logistics modelling and routing optimisation. UniR3 contributes the logistics-modelling concepts, routing-optimisation knowledge and scientific responsibility. LIST can support selected geospatial implementation and integration, including spatial and routable-network inputs, georeferenced schemas, open process exposure where appropriate, registration and 2D/3D visualisation. Whether the contribution is a conceptual method, executable model or operational

service—and the corresponding interface, hosting and maintenance boundary—must be agreed before the integration is described as implemented.

Figure 14 generalises these reference patterns. The capability or method owner retains ownership and scientific responsibility for the underlying method, model or tool. A native API, documented adapter, batch exchange or jointly implemented service can form the agreed interface boundary. LIST can then register the capability, generate or configure a guided user interface, monitor execution and register results for 2D, time-aware or 3D exploration where agreed. **The boundary—not the internal code**—is the object of the common NEXTLOGIC profile and integration test; interface, hosting and maintenance ownership is recorded separately for every integration.



Reference journey through an explicitly assigned interface boundary to registration, guided execution and 2D/3D result use in the NEXTLOGIC platform. Configuration may use a Hub-supported schema or the provider's native interface; the execution boundary is capability-specific.

Figure 14. Reference journey from a partner-owned method, model or tool.

For these patterns, the sustainable responsibility model is **boundary-specific**: the capability or method provider retains ownership and scientific responsibility, while native interface, adapter, hosting and maintenance responsibilities are assigned explicitly with LIST and any operational owner. MS04 or D2.2 must confirm input and output schemas, authentication, execution limits, error behaviour, versioning, hosting, maintenance owner and test cases before an integration is described as implemented.

8.5 Integration with the Digital Twin and XR frameworks

T2.3 reads authorised Digital Twin resources and publishes derived results back as versioned scenario or indicator layers. It **does not redefine the authoritative city data model**. Process outputs carry their input references, method and version so that they can be compared, reproduced and used in a dashboard, 3D scene or XR experience.

The **responsibility boundary with the impact framework is explicit**: T1.3 defines the indicator methodology, baselines and environmental, economic and societal interpretation; T2.3 implements suitable indicators as reproducible geospatial processes and produces spatial result

layers; and the relevant evaluation work in WP5 interprets pilot impacts and comparative results. This prevents analytical services from being mistaken for completed impact evaluation.

9. Digital Toolbox Integration framework

Within D2.1, the Digital Toolbox is the umbrella T2.4 integration result: a distributed portfolio of registered data resources, tools, models, services, reusable workflows and user applications, together with the interfaces, adapters, configuration schemas, composition records, deployment guidance and evidence needed to make them usable in solution workflows. The Digital Tools Hub is the Toolbox's principal user-facing access and coordination component. It supports discovery, readiness review, guided configuration of registered tools or workflows, composition of authorised solution templates, and routing or monitoring of execution and results. The Sandbox is the controlled environment for local instantiation where feasible and for remote-boundary and end-to-end integration testing. Provider tools, authoritative data and computation may remain owner-operated; a coherent user journey does not imply one central host, one runtime or one team implementing the complete platform.

At Month 08, T2.4 defines a questionnaire-supported onboarding and governance framework for tools, data services, models, reusable workflows and user applications. The three preliminary T2.4 workshop sessions held in April 2026 helped to define the main characteristics of this integration framework. Specific connectivity requirements, functions and design choices of the Digital Tools Hub will be specified and progressively implemented through T2.4. At M12, the DT Toolbox Sandbox must be accessible online and presented to the project team, in accordance with MS04.

9.1 Framework objectives

The framework aims to create a **consistent inventory**, describe each capability's purpose and technical boundaries, identify any adapter needed, guide suitable components through the Sandbox and provide guided external integration where central instantiation is inappropriate, and retain the resulting configuration and evidence for later reuse. It also ensures that a catalogue entry distinguishes an existing external capability from a capability that has been integrated and validated for a named NEXTLOGIC boundary or workflow.

9.2 Capability Profile, generated Tool Card and federated catalogue

A conditional questionnaire remains the easiest intake route, but it is not the catalogue architecture. A provider may complete the form, submit canonical JSON or YAML validated against the same NEXTLOGIC JSON Schema, expose a supported catalogue or service description for harvesting, or use an assisted route for a legacy contribution. All routes create or update one provisional machine-readable Capability Profile for a named contribution, version and boundary.

The Capability Profile is the governed source of truth for onboarding. It captures identity, purpose, owner, version, inputs and outputs, spatial and temporal semantics, access, policy, interface, deployment, lifecycle, workflow fit and evidence. The Tool Card is a generated readable view; the OGC record is a discovery view; DCAT supports European/data-space federation; and interface, deployment and workflow records add boundary-specific detail.

Table 10 sets out the initial minimum information to be captured in the Tool Card. Dataset-specific content remains in the Section 6.3 readiness record and boundary-specific content in the Section 10.3 interface record; the Tool Card links those records rather than attempting to replace them.

Table 10. Capability Profile fields and their generated Tool Card, catalogue and workflow uses.

Field group	Minimum Capability Profile content	Generated Tool Card, catalogue or workflow use
Identity and purpose	Name, contribution class, provider, version, user problem, intended users and WP2/solution relevance	Stable record, search and human-readable summary
Ownership and hosting	Technical and operational owner, hosting model, endpoint or access route, maintenance contact	Responsibility, routing and support
Inputs, outputs and interface	Input/output descriptions and schemas, interface type and version, example request/response or dataset	Profile selection, generated configuration and test preparation
Spatial, temporal and data links	Coverage, CRS, time semantics, update frequency, identifiers and links to dataset-readiness records	Compatibility and data-prerequisite checks
Access, legal and security	Authentication, authorisation, licence, sensitivity, privacy, retention and permitted purposes	Access warnings and deployment prerequisites
Integration and adapter	Native standards, required mapping or adapter, adapter owner, dependencies, limits and target release	Integration plan and responsibility record
Validation and evidence	Current maturity/status, named workflow, test cases, evidence links, known exceptions and limitations	Status label and bounded conformance claim
Lifecycle and support	Change notification, monitoring, service levels where applicable, version policy and deprecation route	Maintained or deprecated lifecycle record
Machine-readable description and projections	JSON Schema version; canonical JSON or YAML; native discovery links; OpenAPI, AsyncAPI, OGC API or other interface descriptions; OGC record and applicable DCAT mapping	Automated validation, catalogue publication, generated Tool Card, compatibility checks and workflow binding without re-entering the same information

Immediately after submission, the generated card carries the status "**Provider information submitted – not yet technically validated**". **Submission does not mean** that the contribution is integrated, endorsed for a pilot or suitable for every city.

Recommended catalogue service. NEXTLOGIC should expose OGC API – Records backed by a controlled metadata repository. The canonical model maps Capability Profiles to OGC records and to DCAT 3, DCAT-AP, GeoDCAT-AP or mobilityDCAT-AP where applicable. Stable identifiers and typed links connect resources, endpoints, owners, distributions, inputs/outputs, workflow roles, readiness, evidence and lifecycle.

Reference implementation candidate. pycsw with PostgreSQL/PostGIS is a strong first MS04/D2.2 evaluation candidate because it offers an open OGC catalogue implementation, spatial search and compatibility routes. Product choice remains an implementation decision; profile conformance, governance and tests are the acceptance criteria [46].

Semi-automatic onboarding adapters. Harvesters may inspect OGC API Records, DCAT, STAC, CSW/ISO, OGC API landing pages and process descriptions, OpenAPI/AsyncAPI, SensorThings/Connected Systems, NGSI-LD and legacy WMS/WFS/WCS/WMTS/WPS capabilities. Domain connectors may import OCPI resources. Unresolved ownership, access, hosting and lifecycle fields return to the provider for confirmation.

9.3 Multi-route onboarding, integration recipe and lifecycle

The questionnaire is the easy front door to the onboarding lifecycle; it does not remove technical review. The Sandbox supports three complementary modes: local instantiation of components that can lawfully and practically be deployed; controlled boundary testing against remote provider endpoints where licensing, hosting, computational, data or technical constraints prevent local deployment; and mixed end-to-end testing combining locally instantiated and remotely operated capabilities. The Sandbox is not the compulsory runtime or production home for every Toolbox asset. In each mode, agreed requests, responses, status and failure behaviour, configuration, responsibilities and test evidence must remain explicit.

1. Submit and classify the provider information for a named contribution and version, generating a provisional Tool Card and linked registry record.
2. Review completeness, ownership, access, licensing, privacy, security, data and hosting prerequisites and resolve material gaps.
3. Define the selected profile, schemas, native interface or adapter and assign interface, hosting, maintenance and test responsibilities.
4. Implement or configure the agreed boundary and prepare the Sandbox integration package with examples, prerequisites and expected results.
5. Test expected and failure paths; update maturity only when the evidence exists; then monitor, version, maintain and eventually deprecate the bounded catalogue entry.

For each priority component, the resulting **integration package** contains the current Tool Card; interface or adapter specification; example request, response or dataset; configuration and deployment notes; security and access prerequisites; tests and known exceptions; result styles or visualisation guidance; maintenance contact; and change-notification route. These records allow another partner or city to understand what was integrated without reconstructing the original development discussion.

D2.1 defines the template and status logic. Completed priority cards, confirmed interfaces and Sandbox test evidence belong to the T2.4 implementation cycle aligned with MS04 and D2.2. Until then, an existing provider capability can be listed as identified or described without being labelled NEXTLOGIC integrated.

9.4 Relationship to the platform architecture

The Digital Tools Hub presents catalogue and guidance records, but onboarded components are **not required to enter one execution environment**. Depending on purpose and interface, a registry record may route to the LIST LDT platform for selected context, telemetry, monitoring or

use-case views; to iGuess® for geospatial data integration, spatial/temporal analysis, process execution, scenario management and 2D/3D exploration; directly to an authorised city, prospective T1.2, partner or specialist application; or into a combined solution workflow. T2.4 coordinates discovery, metadata, onboarding, composition and routing across the federation; it neither centralises execution nor claims that the two LIST environments are interchangeable or already connected.

The responsibility model applies without imposing one universal adapter or platform owner. Technology and method providers retain ownership and scientific or operational responsibility for their capabilities; native interface, adapter, hosting and maintenance responsibilities are assigned for each boundary. LIST supplies common profiles, reference patterns, geospatial and interoperability implementation where agreed, integration assistance and the Sandbox test environment.

The Sandbox is a controlled integration and testing environment, not an industrial production-hosting environment. This does not remove the Description of the Action requirement for the wider Digital Toolbox to provide WP4 with an operational environment for pilot testing and evaluation.

The Digital Toolbox, Digital Tools Hub and Sandbox are joint WP2 and T2.4 implementation results. LIST task leadership coordinates the work, while Hub functions, registry and access management, Sandbox operation, iGuess®, LIST LDT platform interfaces, provider interfaces or adapters and solution-workflow configuration may have different implementers, hosts and maintainers. Each implementation boundary must identify those responsibilities and a named acceptance authority; no single LIST team is assigned responsibility for implementing or operating the complete distributed platform.

At M08, several records carry the status technical integration boundary pending. This status distinguishes a known contribution or identified capability from the interfaces, access, hosting, maintenance and acceptance details still to be specified and validated. T2.4 runs from M07 to M26 and provides the scheduled process for closing these boundary-level items.

Closure evidence. Every priority boundary requires a partner-approved Tool Card; a versioned interface and responsibility record; a representative request, response, dataset or resource package; named access/authentication, host and maintainer arrangements; Sandbox or equivalent test evidence; and a named acceptance authority and result. Status advances only for the named version and operating conditions covered by that evidence.

Evidence gates. MS04 at M12 supplies first controlled Sandbox evidence, D2.2 at M18 confirms priority implemented and tested boundaries, and D2.3 at M26 consolidates extended integration, lifecycle and operational evidence. Annex A.5 and Table 19 record the current owner, required evidence, gate, status and contingency for each item.

Contingency and escalation. If a technical boundary is not confirmed by its applicable gate, it remains outside the claimed integrated release. The affected workflow is narrowed, deferred or tested through an authorised provider-native, remote or controlled-exchange route; the underlying project contribution remains assigned. T2.4 records the impact and revised gate and escalates release-critical gaps through WP2 technical coordination to the relevant task, solution and pilot owners. No fallback may silently alter data authority, scientific ownership or acceptance responsibility.

Representative onboarding patterns are illustrated by the FUAS–Transcality data-to-simulation workflow in Section 6.5, TUD's XR capability in Section 7.2 and PKUN's smart zone observation route in Section 8.3. Through T2.4, these provider capabilities are registered, documented and progressively qualified through **Tool Cards and interface records**, enabling their discovery and routing while preserving their original task attribution and provider responsibility.

10. Platform integration

Platform integration turns the component model into **repeatable workflows**. It is successful when a user can move from a question to a **traceable result** without needing to understand which organisation hosts every component, while technical and legal responsibilities remain explicit behind the interface.

In D2.1, orchestration means the bounded and traceable coordination of registered inputs, parameters, service calls, execution status and result hand-offs across one or more authorised capabilities. Depending on the selected capability, the user may be directed to its native interface, use a Hub-supported configuration form where no suitable interface exists, or configure a predefined multi-tool solution workflow whose components execute in different owner-operated environments. This does not imply a universal drag-and-drop workflow editor, automatic deployment of every registered tool, one common computation host or one detailed results interface for every provider technology.

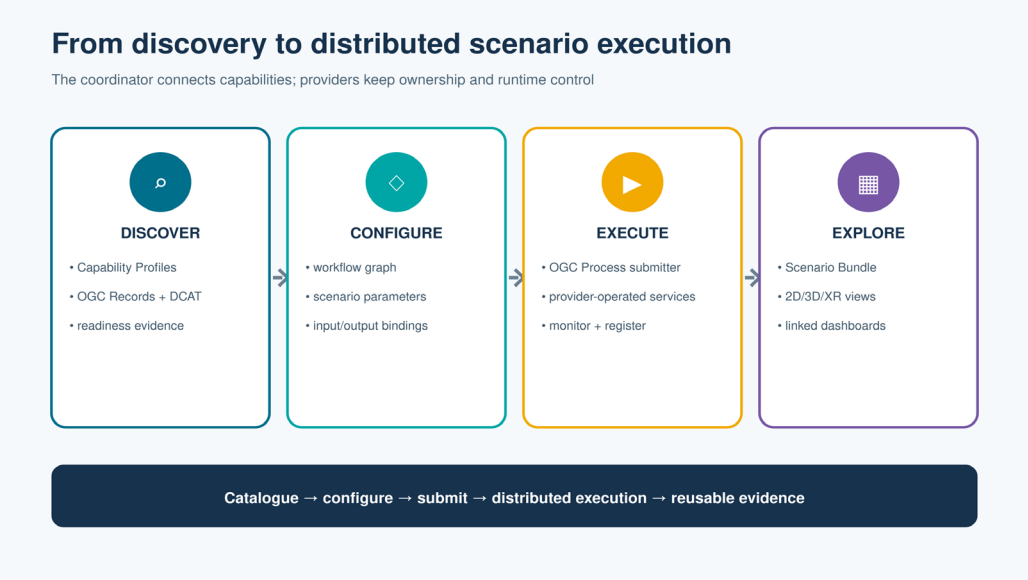
Catalogue, configurator and execution coordinator are separate responsibilities. The catalogue describes discoverable capabilities and compatibility metadata. The configurator creates a versioned directed acyclic graph of process steps, data bindings, parameters, credentials references, output routes and visualisation targets. The coordinator submits, monitors and records execution but does not become the runtime or owner of partner capabilities.

OGC API – Processes is the preferred geospatial submission boundary. The coordinator resolves the selected process description, validates inputs, submits a job, follows status and result links, and registers outputs and provenance. A workflow step may call a remote OGC process, SensorThings/NGSI-LD service, OCPI endpoint, legacy OGC service or another approved API through a tested adapter [47].

Execution remains distributed and provider-operated. The coordinating service triggers the chain and applies retry, timeout, cancellation, policy and evidence rules; the responsible partner or city continues to host and maintain each capability. OGC API – Processes Part 3 deploy/replace/undeploy operations may be evaluated for authorised environments, but are not assumed for every provider.

10.1 End-to-end workflow

Figure 15 presents the reference sequence. It is deliberately generic enough to support a Microhub, loading zone, multimodal hub or charging question.



The sequence may span the Hub, provider environments, the LIST LDT platform, iGuess®, the Sandbox and XR; it is not one Hub application.

Figure 15. Discovery-to-distributed-execution journey from a city question to traceable evidence.

1. **Define the decision context:** a city or project team records the question, study area, baseline, users and acceptance criteria.
2. **Select the user route:** the Digital Tools Hub guides the user from a goal or direct technical route to a registered workflow or solution template and identifies its data, tool, access and validation prerequisites.
3. **Reference authorised resources:** city, partner and public resources are referenced or accessed through the selected profiles.
4. **Invoke and monitor services:** the workflow calls one or more analytical or simulation services at LIST or partner nodes and monitors their execution.
5. **Register results and provenance:** results retain status, parameters, uncertainty and access conditions.
6. **Explore and compare evidence:** users work through iGuess®, the LIST LDT platform, a partner application, dashboards or XR to compare alternatives.
7. **Record feedback and decisions:** feedback, selected decisions and test results are linked to the workflow and scenario version.
8. **Monitor and learn:** later observations are compared with the baseline and expected effects to support refinement and replication.

For a Mobile Microhub, for example, the workflow may combine delivery-demand evidence, a routable network, land-use constraints, cargo-bike isochrones and a transparent multi-criteria process. Candidate locations can be compared in 2D and 3D, discussed with operators and city departments, and passed to XR only where immersive assessment adds value. The result is a **documented decision aid**, not an automatically selected site.

For a Smart Loading Zone, this is a conditional integration example rather than an existing end-to-end implementation. A reference location and authorised occupancy or event observations may be registered; an agreed T2.3 process may calculate dwell time, turnover, exceedance and peak-period indicators; the LIST LDT platform may provide a recent-conditions view if the required data and interfaces are available; and iGuess® may support spatial and temporal comparison or

exploration of a proposed curb configuration. These functions may execute in different owner-operated environments. The example does not claim that the Digital Tools Hub calculates the indicators or that a PKUN–LIST LDT platform connection already exists.

For a traffic, logistics routing or accessibility scenario, a user may configure an applicable registered DTU, UniR3 or Transcality capability through iGuess® where an executable boundary has been agreed. Computation may remain with the capability owner or run in an authorised LIST-supported environment according to the recorded hosting assignment. Link-, route-, zone- or catchment-level results can be registered with the scenario, mapped and compared, and made available to selected T1.3/WP5 indicators or an XR review. The workflow hides unnecessary hosting detail from the end user but keeps the capability owner, operational host, versions, parameters and limitations visible in the **evidence package**.

10.2 From digital tools to configurable WP3 solutions

The five WP3 solutions are not additional WP2 platform components. They are **predefined but configurable compositions** of registered WP2 capabilities. The consumer mapping in Table 2 in Section 2.3 and the platform patterns in Table 8 in Section 5.6 are translated here into one governed object chain.

Digital Twin states and authorised datasets → registered tools and processes → reusable workflow → **WP3 solution template** → configured pilot scenario → execution → maps, dashboards, 2D/3D views, indicators and insights. A solution template records the required capability roles, input and output contracts, allowed configuration points, evidence requirements and visualisation routes. A **pilot configuration** then binds the template to a city, study area, time period, baseline, authorised resources, parameters and responsible users.

Table 11 shows the intended composition at solution level. It is deliberately **capability-based**: the precise provider, service endpoint and city dataset are selected only when their Tool Cards, readiness records and interface evidence justify that configuration.

Table 11. Configurable WP3 solution templates as governed compositions of WP2 capabilities.

WP3 solution template	Configured capability chain	Representative result routes
T3.1 Integrated Mobile Microhubs	Delivery demand + land-use and network states → accessibility, suitability and optional traffic/logistics simulation; optional EXE simulator-supported staff training and operational-process monitoring	Candidate sites and catchments; comparison maps; dashboard; selected 3D/XR review; optional EXE simulator-supported assessment or training record
T3.2 Smart Loading Zones	Curb and zone reference state + authorised observations → dwell, turnover, utilisation and before/after workflow	Operational/context view where available; temporal maps; dashboard; scenario comparison
T3.3 15-minute Multimodal Hubs	Multimodal network and service states → accessibility, catchment and service-gap workflow	Catchment and service-gap maps; hub comparison; 2D/3D stakeholder views

T3.4 Incentive and Reward mechanisms	Authorised participation or behavioural inputs → rule, indicator and feedback workflow	Participation and distribution indicators; dashboards; traceable feedback and scenario records
T3.5 Electrification of Urban Logistics	Fleet, charging and conditional grid/context data → coverage, siting and applicable traffic/energy processes	Charging-coverage and siting maps; indicators; scenario dashboards and 2D/3D views

The **composition remains federated**. The Digital Tools Hub supports discovery, configuration and routing; iGuess® can execute and coordinate geospatial analytical processes; the current LIST LDT platform baseline can contribute selected context, telemetry, views and use-case-specific coordination; and partner-owned services can execute at their authoritative nodes. Results and provenance are assembled as **one scenario evidence package** without assigning the whole workflow to one platform.

This is the target NEXTLOGIC solution-composition pattern. WP2 supplies the integration and evidence pattern; WP3 develops and maintains the five solution templates; and WP4 configures and tests them with the pilots. End-to-end coordination across partner tools, the LIST LDT platform, iGuess® and the five solution workflows remains to be implemented and validated. The reference sequence is shown in Figure 15 in Section 10.1.

10.3 Interoperability between components

Each priority boundary is governed by an **interface record** stating capability, owner, standard and version, schema, authentication, error and status behaviour, operational constraints, adapter responsibility, target release and test. The initial register is in Annex A.4. The architecture permits multiple profiles where the capability genuinely differs—for example, SensorThings API for observations and NGSI-LD for context management—rather than forcing a premature universal choice.

Integration testing will include the **expected path and meaningful failures**: unavailable source, invalid geometry, unauthorised access, schema mismatch, long-running process, partial output, version change and expired result. These tests belong mainly to MS04, D2.2 and D2.3. D2.1 defines them as acceptance requirements but does not report results that do not yet exist.

10.4 User journeys

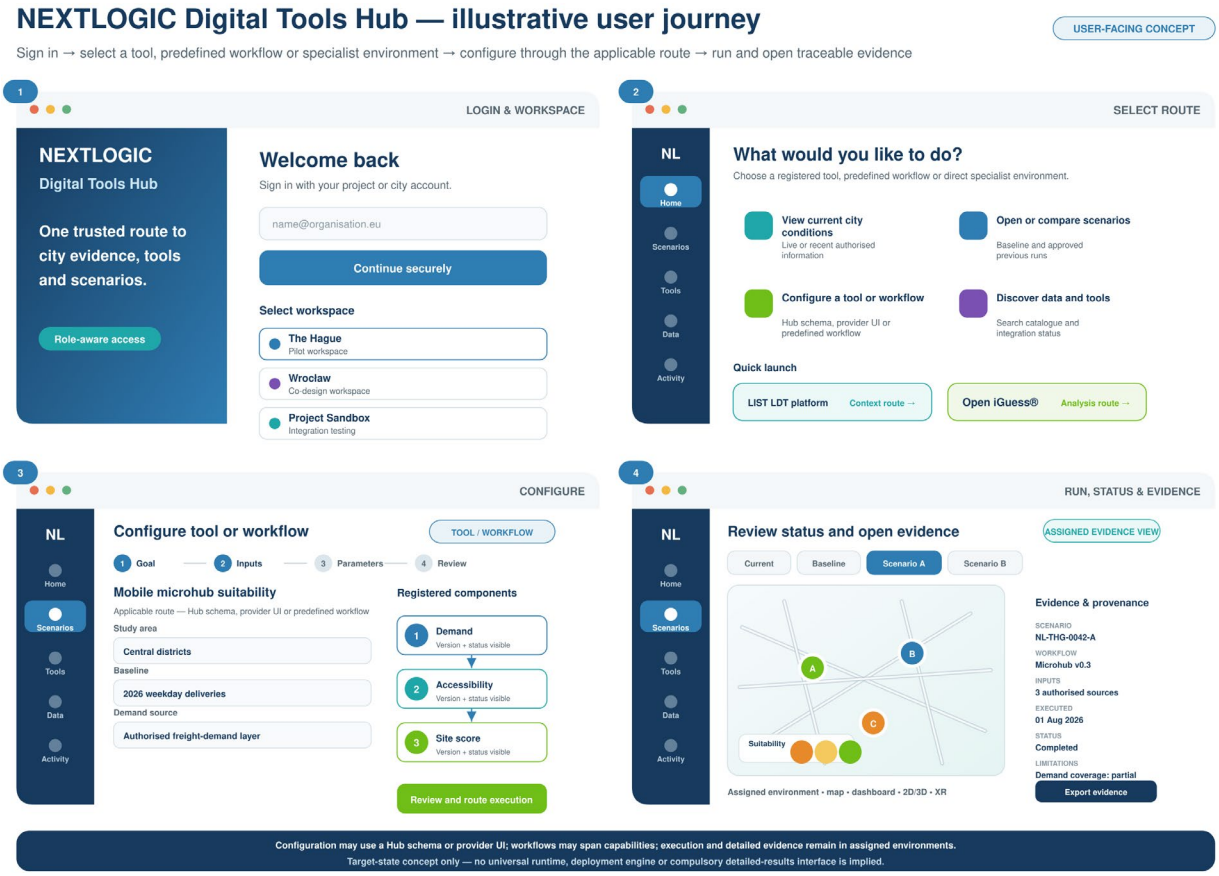
Three recurring journeys guide the user-facing concept. They share scenario identifiers, status and evidence, but they **do not require every user to operate the same screen**:

- **Planning and scenario comparison:** a planner chooses a goal or curated solution template, configures an authorised analysis in iGuess®, compares the baseline with one or more alternatives and exports a traceable evidence package.
- **Operational monitoring:** a city or operator opens an authorised LIST LDT platform or other monitoring view where current or recent data are actually available, investigates an alert or indicator and follows a stable link to the source, earlier state or deeper geospatial analysis.

- **Collaborative review:** a facilitator selects approved scenario versions or previously computed results, presents them through maps, dashboards, 3D or XR, records structured feedback and returns it to the scenario workflow.

The Digital Tools Hub should therefore offer goal-based guidance for most city users and direct "Open LIST LDT platform" or "Open iGuess®" routes for specialists. A guided route can configure an individual registered tool, using a Hub-supported schema or its provider interface, or a predefined multi-tool solution workflow. This bounded configuration and coordination does not imply a universal no-code drag-and-drop workflow editor.

Figure 16 translates the architecture and user-journey requirements into a high-level four-screen storyboard: sign in and select a role-aware workspace; choose a registered tool, predefined solution workflow or direct specialist environment; configure it through the applicable Hub-supported or provider-native route; and review execution status and open the assigned traceable evidence view.



The figure is a target-state concept, not implemented software or one compulsory execution environment. Includes: role-aware workspace access; selection of a registered tool, predefined solution workflow or direct specialist environment; guided configuration through the Hub or a provider interface; and execution/status routing to the appropriate traceable evidence view.

Figure 16. Illustrative Digital Tools Hub user-interface concept.

The concept supports three implementation modes: direct access to a provider environment; Hub-supported, schema-guided configuration of an individual registered capability without a suitable interface; and guided configuration and coordination of a predefined multi-tool solution workflow. The evidence view exposes the available input, version, parameter, owner, execution-status, limitation and provenance records. Detailed analysis and visualisation may remain in iGuess®, the LIST LDT platform, the Sandbox, XR or another provider-operated environment.

Figure 16 is an illustrative user-interface concept rather than completed software. Annex A.9 extends this compact view with three detailed role-based journeys for city and solution users, technology and tool providers, and city data and platform administrators. All three roles and the full readiness, interface, Sandbox-evidence and lifecycle responsibilities remain in scope. Final functions, visual language and interaction design remain subject to WP2 implementation, partner onboarding, access-control decisions and pilot co-design; not every depicted route is guaranteed in the same release.

11. Validation through NEXTLOGIC pilots

The pilots provide the settings in which the specified framework will be implemented, challenged and refined. **D2.1 defines the validation logic**; it **does not claim** that the architecture has already been validated by cities at Month 08.

11.1 Role of the pilot cities

The leading and replication cities contribute with use cases, data conditions, local governance constraints, users and acceptance authorities. Their differences are valuable: a framework that works only for the richest data environment would not meet the project's replication ambition. Pilot configuration must therefore record both what the platform can do and **which prerequisites were actually available** in each city.

Three T2.1-originated candidate Sandbox workflows have now been identified: a file-based MRDH-to-SUMO zero-emission/Smart Loading Zone scenario for The Hague; an authorised Frankfurt traffic-data/ClickHouse boundary supporting a Microhub-location or traffic-impact result; and a PTV Visum-based Hjortshøj accessibility/15-minute Hub scenario for Aarhus. These are cross-task candidates rather than confirmed T2.1-only implementations and remain conditional on dataset readiness, interface ownership, lawful access and named acceptance authorities. The M12 Sandbox should select the smallest tractable set and test a complete boundary, registered result and user review.

A priority Sandbox workflow should pass four progressive gates:

1. **Readiness gate:** owner, version, lawful access, sample inputs and expected outputs are recorded.
2. **Boundary gate:** the interface or adapter can be invoked with valid and invalid requests and returns documented status and errors.
3. **Workflow gate:** the result is registered with provenance and can be interpreted through the intended map, 3D, dashboard or XR route.
4. **User gate:** a named user group can complete the bounded task and identify the result's meaning, status and principal limitations.

Failure at a gate is useful evidence when it is recorded with an owner and corrective action. It is preferable to a nominal demonstration that bypasses the interface or relies on undocumented manual steps.

11.2 Mapping platform capabilities to pilot solutions

The initial city-facing validation focus is set out in Table 12. Initial validation focus by solution area.

Table 12. Initial validation focus by solution area.

Solution area	Candidate early evidence	Later evidence
Mobile Microhubs	Data-readiness assessment, catchment or site-screening workflow, scenario visualisation and optional EXE simulator-supported monitoring or training	Operational comparison and analysis, co-design or simulator-supported assessment results, and replication evidence
Smart Loading Zones	Sensor or observation interface, utilisation indicator and map	Reliability, operational use, before/after comparison and transfer conditions
15-minute Multimodal Hubs	DTU process profile, sample isochrone and generated web form	Multi-source accessibility, user validation and cross-city reuse
Incentives and Reward mechanisms	Tool card, indicator/data interface and privacy assessment	Integrated feedback loop and evaluated user response
Electrification of Urban Logistics	Initial demand/coverage workflow and data-gap assessment	Charging-location scenarios, relevant infrastructure constraints and measured use

This mapping is a **planning baseline**. It does not assign unconfirmed deliverables to individual partners or imply that every pilot will use every component.

11.3 Validation approach

Validation is organised at four levels:

1. **Component validation** checks that a data service, process, visualisation or client behaves as its owner specifies.
2. **Integration validation** checks interfaces, schemas, authentication, error behaviour, provenance and version compatibility across a boundary.
3. **Workflow validation** checks that an end-to-end scenario produces a traceable and understandable result under realistic data conditions.
4. **User and replication validation** checks whether intended users can complete priority tasks and whether another city can understand the prerequisites and reproduce the configuration.

Every test record should state scenario, version, prerequisites, input data, expected result, actual result, owner, date, exception and acceptance authority. Quantitative performance or accuracy targets are set only where the process and deployment context make them meaningful. Security, accessibility and data-protection checks are included according to applicability.

Validation labels must remain precise. A component test does not validate the full workflow; a successful technical integration does not establish policy effectiveness; and a positive workshop does not prove cross-city replicability. Later deliverables should therefore state the validation level, named workflow, deployment context and release whenever evidence is reported.

11.4 Expected refinements during implementation

MS04 is expected to reveal gaps in partner metadata, schemas, identity and hosting arrangements; differences in city data readiness; and usability needs for generated forms and visualisation. D2.2 will use this evidence to stabilise priority interfaces and deliver the first modular platform. D2.3 will extend the service portfolio, strengthen operations and lifecycle management, and consolidate multi-city evidence.

Changes to the Month 08 baseline should be **recorded as architecture decisions or interface-register updates**, with rationale and effects on other components. This keeps flexibility controlled and prevents local fixes from silently fragmenting the platform.

12. Replicability and transferability

Replicability is achieved by **separating reusable capability patterns from city-specific configuration**. The objective is not to reproduce an identical technical estate in every city, but to make the prerequisites, interfaces, effort and limitations of a useful workflow sufficiently explicit that another city can adopt or adapt it.

12.1 Design for replicability

The distributed architecture supports replication because it does not require a city to replace existing systems or deploy every NEXTLOGIC component. **Reusable assets** include interface profiles, tool cards, process descriptions, schema mappings, workflow configurations, visual styles, test cases, user guidance and evidence templates. **City-specific assets** include local datasets, identity arrangements, policies, thresholds, stakeholder roles and deployment operations.

Versioning and provenance are essential. A replication package must identify which releases of the process, interface and source data were used, any local transformation, and what evidence supports the claimed outcome. Open-source components can improve auditability and reuse, but open source alone does not remove hosting, skills, data or governance requirements.

A useful replication package should contain six bounded elements:

- The decision question, intended users, and institutional owner.
- The minimum and optional data requirements, including quality and access assumptions.
- The tool cards, interface profiles, mappings and adapter responsibilities.
- The workflow and scenario configuration, including visual styles and user guidance.
- The functional, integration and user evidence together with known failures or limitations.
- The hosting, skills, maintenance, cost categories and governance arrangements needed after the pilot.

Keeping these elements together prevents a technically reusable process from being presented as a transferable solution when the receiving city lacks the **institutional owner, data rights or operating capacity** required to use it.

12.2 Adapting the platform to other cities

Three deployment profiles, compared in Table 13, allow cities to start at an appropriate level:

Table 13. Indicative city deployment profiles.

Profile	Typical starting conditions	Useful initial capabilities	Additional prerequisites
Basic	Limited live data; reference geographic information system (GIS) files or public services; small technical team	Catalogue, map-based baseline, simple indicators, documented batch process and scenario export	Named data owner, repeatable update procedure and basic access control
Intermediate	Several APIs or scheduled feeds; routable networks; existing dashboards or 3D data	Federated access, OGC API Processes, time-aware results, scenario comparison and selected 3D views	Interface maintenance, identity integration, monitoring and quality procedures
Advanced	Operational systems, sensor streams, mature city model and dedicated platform team	Near-real-time context, multi-process workflows, immersive clients and stronger operational automation	Service levels, resilience, security operations and lifecycle governance

A city can move between profiles by adding capabilities without changing the overall federation. The choice should reflect the **decision value of the function**, not a maturity ranking pursued for its own sake.

The initial profile choice should be refined against the consolidated T2.1 city-discovery comparison in Annex A.7. Because that source is a working synthesis, each city and data owner must still confirm datasets, Digital Twin/GIS environments, software, interfaces, rights, update modes and capacity gaps before a deployment profile or adapter plan is treated as operationally feasible.

The adaptation process comprises six steps:

1. Define the local decision question, users and institutional owner.
2. Map required capabilities to available data and systems.
3. Complete the dataset and tool readiness assessment.
4. Select a deployment profile and identify adapters or gaps.
5. Configure and test a bounded workflow with local users.
6. Document operating responsibilities, costs, limitations and the route to further capabilities.

12.3 Supporting additional urban logistics solutions

New solutions can be added when they can be expressed through the common pattern of discovery, authorised data access, process or model invocation, result registration, visualisation and feedback. Examples might include consolidation policy, zero-emission-zone design, dynamic curb allocation or freight-aware street works. Each extension requires a **defined user question, owner, data basis and validation plan**; it does not require a new platform core.

The standards register is deliberately extensible. A new domain specification can be added as a conditional profile, while a legacy interface can remain accessible through an adapter. The extension is **documented at the boundary** so that it does not become an undocumented exception.

12.4 Opportunities for future extensions

Later work may examine cross-city service discovery, data-space connectivity, stronger workflow composition, streaming analytics, federated learning or additional XR devices. These opportunities should be **assessed against demonstrated needs**, legal and security feasibility, operating capacity and measurable benefit. Emerging standards may be piloted through evaluation profiles before they become production dependencies.

The final replication evidence should allow a follower city to answer **five practical questions**: what problem the workflow addresses; what data and skills are required; which components must be hosted or accessed; what implementation and operating effort is likely; and what limitations were observed in the original pilots.

13. Conclusion and next steps

D2.1 establishes the Month 08 design baseline for a distributed NEXTLOGIC Digital Platform. Its central architectural choice is a Digital Toolbox that combines registered capabilities and integration records, a common Digital Tools Hub for access, guided configuration, predefined composition and routing, the Sandbox for controlled integration and testing, complementary LIST LDT platform and iGuess® routes, and authoritative city and partner nodes. Extensible interface profiles and explicitly assigned native interfaces or adapters allow specialised technologies to connect without being absorbed into a monolithic LIST stack or one compulsory runtime.

The specification makes T2.1, T2.2, T2.3 and T2.4 actionable as connected contributions. It separates a confirmed contribution and identified asset from the technical boundary that T2.4 still has to implement and validate. This distinction clarifies the current EXE, UniR1, MUV, MOV and WUEB contributions without overstating integration maturity. For the Wrocław cargo-bike XR simulator/training environment, EXE is the provider and implementation partner; TUD leads the applicable T2.2 XR methods; WUEB supplies the T3.1 Mobile Microhub solution context and validation requirements; and WCG leads the T4.4 pilot deployment.

The immediate priority after D2.1 is to convert a small number of priority boundaries into controlled Sandbox or equivalent integration evidence. T2.4, which began at M07, will close the partner-approved Tool Cards, interface/responsibility records, examples, access, host/maintainer, tests and acceptance results needed at MS04, D2.2 and D2.3. Annex A.5 gives each item an owner, evidence gate and contingency so that delays narrow a release claim rather than reopening the architecture or silently shifting responsibility.

The first demonstrable backbone should connect four things end to end. A standards-based catalogue publishes validated Capability Profiles; a technical workflow configurator binds one representative WP3 solution; an OGC API – Processes coordinator submits and monitors distributed execution; and iGuess® or another approved client reopens the resulting Scenario Bundle as linked map and dashboard evidence. This provides a concrete, testable route to MS04 and later D2.2/D2.3 evidence.

The first post-D2.1 implementation cycle should therefore aim to produce a **compact evidence set** rather than broad but shallow coverage:

- Partner-approved Tool Cards and interface/responsibility records for the priority datasets, tools, owners and workflows, including the separate EXE Digital Twin/camera/GPS boundary under DEP-09 and EXE simulator boundary under DEP-14.
- One DTU-led 15-minute Multimodal Hub accessibility/siting or UniR3 logistics-method boundary prepared for possible OGC API Processes integration.
- One Transcality PLAN/SUMO scenario boundary with agreed priority inputs, outputs, calibration responsibilities and interface, hosting and maintenance ownership.
- At least one authorised city or partner data connection whose result can be registered and visualised.
- One TUD-led XR scenario-resource and feedback pattern, including the applicable EXE cargo-bike simulator boundary and WUEB/WCG requirements and acceptance roles.
- A repeatable MS04 test and exception record that can be reused for additional integrations.

These are implementation priorities and coordination targets, not claims that the named integrations have already been delivered. The contributions are defined at the level justified by current project coordination; the remaining technical and operational details will be confirmed with the responsible partners through the controlled T2.4 evidence and acceptance process.

Figure 2 in Section 2.5 protects the deliverable's credibility by reserving implementation, conformance and user-validation claims for the releases in which evidence exists.

14. List of Abbreviations and Acronyms

Term	Definition
2D	Two-dimensional
3D	Three-dimensional
AD	Architecture Decision
AI	Artificial Intelligence
AMQP	Advanced Message Queuing Protocol
API	Application Programming Interface
AR	Augmented Reality
AsyncAPI	Specification for describing asynchronous and event-driven APIs
BIM	Building Information Modelling
CDS	Curb Data Specification
CIM	Context Information Management
CityGML	City Geography Markup Language
CityJSON	JavaScript Object Notation (JSON) encoding for three-dimensional city models
CRS	Coordinate Reference System
CSV	Comma-Separated Values
D	Deliverable (used in identifiers such as D2.1)
DATEX II	European road-traffic and travel-data exchange standard
DCAT	Data Catalog Vocabulary
DCAT-AP	Data Catalogue Vocabulary Application Profile
DPO	Data Protection Officer
DSSC	Data Spaces Support Centre
FCD	Floating Car Data
DUET	Digital Urban European Twins for Smarter Decision Making
EDR	Environmental Data Retrieval
eFTI	Electronic Freight Transport Information
EMDS	Common European Mobility Data Space
EPSG	EPSG geodetic identifier register (originally European Petroleum Survey Group)
ETSI	European Telecommunications Standards Institute
FlatGeobuf	Binary geospatial feature encoding
GBFS	General Bikeshare Feed Specification
GeoDCAT-AP	Geospatial Data Catalogue Vocabulary Application Profile
GeoJSON	JavaScript Object Notation (JSON) format for encoding geographic data structures
GeoPackage	Open Geospatial Consortium (OGC) SQLite-based geospatial data container
GeoParquet	Columnar geospatial encoding based on Apache Parquet
GeoTIFF	Georeferenced Tagged Image File Format
GIS	Geographic Information System
GL	Graphics Library
glTF	GL Transmission Format

GR	ETSI Group Report
GTFS	General Transit Feed Specification
HTTPS	Hypertext Transfer Protocol Secure
ID	Identifier
IFC	Industry Foundation Classes
iGuess®	LIST geospatial Digital Twin environment (registered product name)
ISPRS	International Society for Photogrammetry and Remote Sensing
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
LCSA	Life Cycle Sustainability Assessment
LDT	Local Digital Twin
M	Month (used in schedule codes such as M08)
mobilityDCAT-AP	Mobility Data Catalogue Application Profile
MQTT	Message Queuing Telemetry Transport
MS	Milestone (used in identifiers such as MS04)
NGSI-LD	Next Generation Service Interfaces–Linked Data
NWE	North-West Europe
OASC	Open & Agile Smart Cities & Communities
OAuth	Open Authorization
OGC	Open Geospatial Consortium
OpenAPI	OpenAPI Specification
OpenID Connect	Identity layer based on the OAuth 2.0 protocol
PNG	Portable Network Graphics
PROV	World Wide Web Consortium Provenance Data Model
PU	Public
PV	Photovoltaic
R	Document/report deliverable type
REST	Representational State Transfer
SUMO	Simulation of Urban MObility
SVG	Scalable Vector Graphics
T	Task (used in identifiers such as T2.1)
T4R	Twin4Resilience
UI	User Interface
VR	Virtual Reality
W3C	World Wide Web Consortium
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service
WMTS	Web Map Tile Service
WP	Work Package (used in identifiers such as WP2)
WPS	Web Processing Service
XR	eXtended Reality

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Annex A: Technical reference

A.1 Architecture decision register

The following register controls the Month 08 architectural direction without presenting unconfirmed implementation choices as completed agreements. Specified decisions provide the common baseline for implementation planning; *proposed* decisions require task- or partner-level confirmation; and *open* items require evidence or a choice at the named release gate. The controlled architecture decisions are recorded in Table 14.

Table 14. Initial architecture decision register.

AD ID	Decision	D2.1 status	Consequence and next gate
AD-01	The platform is a distributed federation, not a central installation	Specified	City and partner nodes retain authority; verify one federated flow at MS04
AD-02	The Digital Tools Hub supports catalogue and Tool Cards, readiness, guided configuration of registered tools and predefined workflows, execution routing/status and access to traceable results.	Specified	It is not the mandatory data store, universal source of truth or computation host.
AD-03	The LIST LDT platform and iGuess® are distinct, complementary integration routes.	Specified	Define supported identity, metadata and hand-off patterns without assuming symmetric capability or a completed connection.
AD-04	Relevant integration interfaces use reusable, version-controlled interoperability profiles	Specified	Complete priority interface records and tests at MS04/D2.2; avoid a different profile for every partner
AD-05	Mature OGC APIs are preferred at relevant geospatial boundaries	Specified	Legacy and provider APIs remain connectable through documented adapters
AD-06	Each capability uses a boundary-specific assignment for native interface, adapter, hosting and maintenance	Proposed	Confirm the owner and maintainer for every priority boundary before integration
AD-07	Source, scenario and result status, provenance and uncertainty remain visible	Specified	Include required metadata in every priority workflow and user interface
AD-08	Data movement is proportionate and respects source access conditions	Specified	Choose federation, cache or ingestion per dataset and record the rationale
AD-09	Predefined workflow composition may use more than one execution environment when the interface and evidence contracts remain stable.	Proposed	Assign execution host, interface and responsibility per capability; do not assume unrestricted no-code chaining.
AD-10	Identity and authorisation use common web security patterns	Proposed	Confirm identity federation, roles and service-to-service access by D2.2
AD-11	Implementation claims require recorded test evidence	Specified	Store versioned component, integration, workflow and user-test records
AD-12	Replication uses basic, intermediate and advanced profiles	Specified	Validate prerequisites and effort in leading and replication cities
AD-13	The prospective T1.2 node and any EMDS connection are conditional external interfaces, not D2.1-delivered components	Specified boundary; implementation open	Confirm ownership, datasets, interfaces, connector, trust and usage-policy choices through WP1/project governance
AD-14	Federated metadata uses stable identifiers, an authoritative source-of-truth designation and controlled harvesting or synchronisation	Proposed	Define conflict, update and withdrawal behaviour before connecting multiple catalogues

AD-15	The T2.4 Digital Toolbox collectively covers catalogue and onboarding, configuration and composition, API and model integration, Sandbox validation, execution routing and visualisation access through the Hub and distributed runtimes.	Specified	No contractual function may be left unassigned or assumed to belong entirely to one LIST team.

A.2 Initial interoperability and standards register

This register identifies the preferred direction at Month 08. It is not a claim that every listed standard applies to every component or has already been implemented. Version and conformance details must be confirmed in the interface record for the boundary concerned. The initial standards choices are recorded in Table 15.

Table 15. Initial standards and interoperability register.

Capability / boundary	Preferred profile	Compatibility or alternative	D2.1 classification	Target confirmation
REST interface description	OpenAPI 3.1	Provider documentation plus adapter specification	Core	MS04/D2.2
Geospatial features	OGC API Features Part 1; applicable extensions per use case	Web Feature Service (WFS) 2.0 or documented REST/GeoJSON adapter	Core where feature access is shared	MS04/D2.2
Maps	OGC API Maps Part 1	Web Map Service (WMS) 1.3.0	Conditional	D2.2
Tiles	OGC API Tiles Part 1	Web Map Tile Service (WMTS) 1.0	Conditional	D2.2
Geospatial processing	OGC API Processes Part 1	Web Processing Service (WPS) 2.0 or provider REST adapter	Core for shared analytical services	MS04/D2.2
Process workflow/chaining	Stable Part 1 process contracts	Provider workflow engine behind the boundary	Evaluation for OGC API Processes Part 3	D2.3
Resource discovery	OGC API – Records – Part 1: Core 1.0; applicable DCAT profile	Catalogue harvesting or documented registry API	Core for shared catalogue resources	MS04/D2.2
Observations and sensors	OGC SensorThings API 1.1	Documented sensor/platform API	Conditional	MS04/D2.2
Connected systems	OGC API Connected Systems 1.0 for applicable system/resource relationships	SensorThings API or provider service	Evaluation/conditional; not a universal replacement	D2.2/D2.3
Context information	ETSI NGSI-LD API 1.9.1 or compatible implementation profile	Adapter to OGC/data interfaces	Conditional for context-broker use cases	D2.2
Coverage / raster access	Cloud Optimised GeoTIFF, OGC API Environmental Data Retrieval (EDR) or WCS 2.1 according to need	File transfer with documented metadata	Conditional; OGC API Coverages remains draft/evaluation	D2.2

Capability / boundary	Preferred profile	Compatibility or alternative	D2.1 classification	Target confirmation
Tabular geospatial exchange	GeoParquet 1.1.0	GeoPackage, FlatGeobuf or comma-separated values (CSV) plus schema and coordinate reference system (CRS)	Conditional	D2.2
3D city semantics	CityGML 3.0 and/or CityJSON 2.0 according to workflow	Documented source model and mapping	Conditional	D2.2
Streamable 3D presentation	OGC 3D Tiles 1.1	Graphics Library (GL) Transmission Format (glTF) or provider-specific delivery with conversion	Conditional; 2.0 evaluation only	D2.2/D2.3
Building information	Industry Foundation Classes (IFC) 4.3 where relevant	Source-native Building Information Modelling (BIM) plus documented georeferencing/mapping	Conditional	D2.2/D2.3
Coordinate reference systems	EPSG geodetic identifiers and OGC CRS handling	Explicit documented CRS and transformation	Core for spatial resources	MS04
Metadata catalogue	DCAT-AP 3.0.1; GeoDCAT-AP 3.1.0 where geospatial; mobilityDCAT-AP 1.1.0 where mobility-specific	Provider catalogue mapping with stable identifiers and source-of-truth rules	Conditional	D2.2
Transport schedules	General Transit Feed Specification (GTFS) and GTFS Realtime	Provider/transit API	Conditional	D2.2
Shared mobility	General Bikeshare Feed Specification (GBFS) 3.0; 2.3 supported as legacy	Provider API	Conditional; 3.1 release candidates evaluation only	D2.2
Curb and kerb data	Curb Data Specification (CDS) 1.1 where applicable	Local curb schema with documented mapping	Conditional; later major versions monitored	D2.2/D2.3
Road-network exchange	DATEX II European road-traffic and travel-data exchange or relevant national/municipal profile	SUMO/OpenStreetMap/source-specific mapping	Conditional	D2.2
Events and messaging	AsyncAPI with Message Queuing Telemetry Transport (MQTT), Advanced Message Queuing Protocol (AMQP) or Hypertext Transfer Protocol Secure (HTTPS) profile as selected	Provider webhook or message adapter	Conditional	D2.2
Identity	OpenID Connect	Existing federated identity system with mapping	Core for user-facing protected access	D2.2
API authorisation	OAuth 2.0 profiles; token scopes and roles	Controlled API key only for bounded tests	Core for protected APIs	MS04/D2.2
Provenance	World Wide Web Consortium (W3C) PROV concepts and project metadata profile	Equivalent explicit source/process metadata	Core	MS04/D2.2

Capability / boundary	Preferred profile	Compatibility or alternative	D2.1 classification	Target confirmation
Data-space trust	DSSC Blueprint v3.0 functions; selected connector/trust implementation only if EMDS participation is agreed	Bilateral controlled exchange without a data-space connector	Evaluation/conditional until use case, governance and eligible datasets are agreed	D2.3
Electronic Freight Transport Information (eFTI) interfaces	Applicable EU implementing specifications when final and relevant	Existing transport-document interfaces	Evaluation; do not describe unfinished specifications as deployed APIs	D2.3
Catalogue federation and metadata synchronisation	OGC API – Records and applicable DCAT profile; stable identifiers, source-of-truth and controlled harvesting rules	Documented metadata exchange or registry API	Core for connecting more than one catalogue	MS04/D2.2
Canonical Capability Profile	NEXTLOGIC JSON Schema; canonical JSON or YAML	Questionnaire or assisted entry	Core	MS04
Spatio-temporal asset catalogue	STAC API / STAC Item, Collection and Catalog	OGC API Records link/projection	Conditional	D2.2
Charging ecosystem data	OCPI 2.2.1/2.3 where applicable	Approved provider API	Conditional	WP3 boundary
Charging-point operation	OCPP 2.0.1 where applicable	Provider-managed integration	Conditional	WP3 boundary
XR runtime portability	OpenXR 1.x where applicable	Client-specific runtime	Conditional	T2.2 boundary

Conformance is claimed only at capability and dataset level. A component may be labelled *NEXTLOGIC conformant* only when it implements every applicable mandatory profile, publishes its machine-readable interface and schemas, passes the named conformance and project integration tests, records security/version/owner/operational metadata and has no undeclared deviation from this register.

A.3 WP2 contributors and technology landscape

The formal task roles identify leaders and key contributors, but they do not mean that every organisation supplies a software component. Table 17 therefore separates contribution confirmed, asset or capability identified, and technical integration boundary pending. The confirmation reflects current WP/task coordination and is checked for consistency with the agreed task descriptions; it is not reconstructed solely from contractual wording and does not claim an implemented interface. Remaining boundary details are controlled T2.4 work rather than generic partner uncertainty.

Table 16. Formal WP2 task leaders and key contributors from the Description of the Action.

Task	Lead	Named key contributors
T2.1	FUAS	LuxMobility (LuxM), UniR3, LIST, EXE, Transcality, Wroclaw University of Economics and Business (WUEB), PKUN, DTU, Metroselskabet I/S (CphM), UniR1, MUV, City of Wrocław (CoW) and ALICE

Task	Lead	Named key contributors
T2.2	TUD	LuxM, FUAS, EXE, Transcality, WUEB and CoW
T2.3	LIST	UniR3, FUAS, Transcality and PKUN
T2.4	LIST	TUD, UniR1, MUV and MOV

Additional WP2 effort is allocated in Part A to the University of Luxembourg (UniLU), École nationale des travaux publics de l'État (LAET), Škoda Auto University (SAU), WCG Sp. z o.o. (WCG), the University of Bergamo (UniBG), Copenhagen Business School (CBS), Dún Laoghaire–Rathdown County Council (DLR), Ville de Differdange (CoDiff), House of Logistics & Mobility GmbH (HOLM) and DB InfraGO AG (DBINF). Their precise contributions must be described according to actual work and not inferred solely from budget allocation. The initial technology and contribution map is provided in Table 17.

Table 17. Confirmed WP2 contributions, identified assets and remaining technical integration boundaries.

Organisation / group	Contribution now confirmed	Identified asset or capability	Current status and remaining technical boundary
LIST	WP2 lead; T2.3 and T2.4 lead; geospatial, interoperability and integration coordination.	Digital Tools Hub/catalogue and Tool Cards; LIST LDT platform demonstrator; iGuess®; geospatial analytics and visualisation assets.	Contribution confirmed; assets identified or existing baselines. Named endpoints, adapters, hosting, maintenance and tests remain boundary-specific; no single LIST team owns the complete platform.
FUAS	T2.1 lead; traffic-data/Digital Twin analysis and pilot-city technology/data baseline.	Multi-source traffic-data inventory, cleaning, map matching, qualification and the consolidated T2.1 city-discovery comparison.	Contribution confirmed; assets identified. Output interfaces, publication conditions and city/data-owner validation remain pending.
TUD	T2.2 lead and T2.4 contributor; XR methods, scenarios and interaction/feedback design.	XR environments and planned scenario-resource and structured-feedback capabilities.	Contribution confirmed; capability identified. Device/client profiles, resource and feedback interfaces, hosting, maintenance and acceptance remain technical-boundary items (DEP-08).
EXE	T2.1/T2.2 and Wrocław, Heidelberg, Frankfurt and Dublin pilot technology contributor; Digital Twin and simulator development, sensing, documentation and integration support.	Digital Twin applications; EXE-provided cargo-bike XR simulator/training environment; bicycle-parking occupancy camera hardware/data; cargo-bike GPS monitoring hardware; cloud storage for hosting Digital Twin applications for cargo-bike monitoring and bicycle-parking occupancy pilot solutions.	Contribution and simulator ownership confirmed; assets identified. Scenario/XR/client roles, simulator controls, schemas, endpoints, authentication, hosting/support and acceptance remain technical-boundary items under DEP-09 and DEP-14, not missing contributions.
Transcality	T2.1/T2.2/T2.3 contributor; traffic-model creation, calibration and scenario simulation.	Transcality PLAN and SUMO-based scenario capability; planned pilot integrations.	Contribution confirmed; capability identified. Logistics/emissions extensions, data/result schema, city-data route, hosting and maintenance remain pending (DEP-06).
PKUN	T2.1/T2.3 technology and data contributor and T3.2 contributor for smart loading zones.	Smart loading-zone platform, mobile/Bluetooth session observations, city BackOffice and aggregated analytics.	Contribution confirmed; capability identified. API/adapter, aggregation, privacy, access and maintenance boundary remain pending (DEP-07).

Organisation / group	Contribution now confirmed	Identified asset or capability	Current status and remaining technical boundary
DTU	T3.3 lead, with LIST and UniR1 as key contributors; multimodal accessibility and siting method owner.	15-minute Multimodal Hub GIS method and behavioural-analysis capability.	Contribution confirmed; method identified. Executable form, schemas, endpoint, hosting, limits, maintenance and acceptance remain pending with LIST (DEP-05).
UniR3	T2.3 method contributor; logistics modelling, routing optimisation and decision-support collaboration with LIST.	Logistics/routing methods and candidate analytical processes for geospatial implementation.	Contribution confirmed; methods identified. Executable scope, interface, hosting, lifecycle and acceptance remain pending (DEP-10).
UniR1	T2.4 contributor, T3.4 lead and T3.3 contributor; incentive/reward application, dashboard and backend development.	UniR1 application/backend and intended integration with the MUV SDK/system for incentive and reward workflows.	Contribution confirmed; capability identified. App/API boundary, measurement schema, privacy/access, hosting, maintenance and acceptance remain pending (DEP-11).
MUV	T2.1/T2.4 and T3.4 contributor; gamification, behavioural engagement and pilot application contribution.	MUV SDK/system and Smart Reward gamification application, including relevant Dublin and Bergamo pilot routes.	Contribution confirmed; assets identified. Version, SDK/API contract, behavioural-data flow, privacy controls, hosting/support and acceptance remain pending (DEP-12).
MOV	T2.4/T3.4 contributor; assessment and deployment expertise for loading zone, Microhub and related pilot requirements.	Existing assessment-tool capability to be extended for the selected NEXTLOGIC pilot requirements.	Contribution confirmed; capability identified. Exact tool/version, inputs/outputs, API or controlled-batch boundary, hosting, maintenance and acceptance remain pending (DEP-13).
WUEB	T2.1/T2.2 contributor and T3.1 lead; Mobile Microhub solution context, cargo-bike operational requirements and decision-support validation.	T3.1 Mobile Microhub solution concept; cargo-bike operational and placement requirements; Wrocław decision context; solution-level validation input.	Contribution confirmed. WUEB supplies solution requirements and validation; EXE supplies the simulator. The solution-to-simulator/Digital-Twin/XR boundary remains pending under DEP-14.
CphM	T2.1 domain and integration contributor for metro/public transport, sustainable urban planning and multimodal integration.	Relevant domain knowledge, city context and potential authorised data sources.	Contribution confirmed at domain/data level. Dataset and access boundary require confirmation; no software component is inferred from effort allocation.
SAU and WP1 data contributors	SAU-led T1.2 data-acquisition framework and D1.3 specifications; governance, readiness and possible storage/access-node arrangements.	Data-framework records and a prospective authorised storage/access route.	Contribution confirmed. Node ownership, hosting, datasets, interfaces and lifecycle remain conditional cross-WP items (DEP-19).
LIST LCSA team and T1.3/WP5 contributors	Impact methods, indicators and evaluation contributions.	Candidate formulas, baselines and interpretation/acceptance criteria for selected indicators.	Contribution confirmed at method/evaluation level; not automatically a software contribution. Computable specifications remain pending (DEP-16).
UniBG, BUAS, LuxM, CoW, ALICE, LAET and other city/domain partners	Solution, city, policy, pilot, domain-knowledge and replication contributions according to their assigned tasks.	Use cases, requirements, local data/context, validation and replication evidence.	Contributions confirmed at their respective task level. Technology or interface claims are made only when a named asset and boundary are separately evidenced.

A.4 Initial interface and responsibility register

The priority boundaries and proposed responsibilities are listed in Table 18.

Table 18. Priority integration boundaries and proposed responsibilities.

Boundary	Capability/method owner responsibility	LIST/interoperability responsibility	Initial profile	Target gate
DTU 15-minute Multimodal Hub method ↔ iGuess® or another authorised route	Method, scientific validity, requirements, constraints and acceptance criteria; contribute schemas and tests.	Geospatial implementation and OGC API Processes support; endpoint, hosting and maintenance assigned with DTU.	OGC API Processes Part 1; GeoJSON/feature or coverage outputs as applicable.	MS04/D2.2
Transcality PLAN/SUMO ↔ iGuess® or another authorised result route	Model creation/calibration, SUMO scenario semantics, execution limits and scientific/technical validity; contribute schemas and tests.	Profile guidance, registration, result styling, comparison and tests; interface, hosting and maintenance assigned with Transcality.	OGC API Processes or documented API/batch boundary; documented network, demand, scenario and result schemas.	D2.2
PKUN zone features/observations ↔ iGuess®, LIST LDT platform or authorised dashboard	Zone/source semantics, authorised access, permitted aggregation, privacy, change notice and source-system responsibility.	OGC profile, mapping, catalogue, visualisation and derived-process support; adapter, hosting and maintenance assigned with PKUN.	OGC API Features plus SensorThings API or documented adapter; OGC API Processes for agreed indicators.	MS04/D2.2
FUAS qualified traffic-data evidence ↔ Digital Twin / Transcality / analytics	Source inventory, cleaning and analysis definitions, granularity, quality/uncertainty, licence and update method.	Data/process profile, mapping, registration, visualisation and integration support with the relevant provider.	OGC API Features/Processes, database/API or file compatibility profile selected per output.	D2.2
TUD XR ↔ scenario services	XR capability, experience design, device/client requirements, interaction and feedback semantics.	Geospatial resources, identifiers, tiles/layers and tests; conversion, interface, hosting and maintenance assigned with TUD.	3D Tiles/glTF/feature or map services; OpenAPI or documented feedback interface.	D2.2
EXE Digital Twin applications, parking-camera/GPS outputs, cargo-bike XR simulator/training environment and pilot cloud-storage route ↔ scenario/XR/Digital Twin services	Confirm component/version, camera/GPS and simulator-control semantics, simulator/client role, access conditions, hosting/support and acceptance criteria.	Tool Cards, geospatial/profile selection, mapping, routing and Sandbox/equivalent tests with EXE, TUD and relevant solution/pilot owners.	Documented camera/GPS schema plus simulator API, file/message or event boundary; OpenAPI, GeoJSON, SensorThings or NGSI-LD selected only where appropriate.	MS04/D2.2
UniR3 logistics/routing analytics ↔ federation	Method, scientific validity, constraints, requirements and acceptance criteria.	Geospatial/network implementation and process-profile support; endpoint, hosting and maintenance assigned with UniR3.	OGC API Processes or documented batch/API profile, to be confirmed.	D2.2

Boundary	Capability/method owner responsibility	LIST/interoperability responsibility	Initial profile	Target gate
UniR1 incentive/reward application and backend ↔ Hub/MUV/authorised result route	Application/backend definition, measurements, privacy/access model, interface and maintenance.	Registry, onboarding, profile/mapping guidance and integration tests with UniR1/MUV.	Documented REST/OpenAPI, SDK or controlled data-exchange profile selected for the confirmed application version.	MS04/D2.2
MUV SDK/system and Smart Reward application ↔ UniR1/Hub	SDK/application version, behavioural-data semantics, lawful access, privacy, hosting/support and change notice.	Tool Card, identity/profile guidance, mapping and controlled tests with MUV/UniR1.	Native SDK/API contract plus documented authentication and data-exchange profile.	MS04/D2.2
MOV assessment tool ↔ Digital Tools Hub / solution workflow	Tool/version, assessment method, pilot inputs/outputs, operating limits, hosting and maintenance.	Onboarding, schema/profile guidance, routing and tests with MOV and the relevant solution/pilot owners.	Documented API or controlled batch/data-exchange profile selected per confirmed tool.	MS04/D2.2
WUEB T3.1 mobile-microhub requirements and validation ↔ EXE simulator / Digital Twin / XR route	Confirm solution questions, scenarios, operator/participant roles, expected outputs, constraints and acceptance criteria with WUEB and the Wrocław pilot.	Translate T3.1 requirements into the EXE/TUD interface profile, scenario package and validation plan; retain WCG-led T4.4 deployment responsibility.	Partner-approved requirements and validation record linked to the EXE simulator boundary; no WUEB ownership of the simulator or its API is implied.	MS04/D2.2
City data services ↔ Hub, LIST LDT platform, iGuess® or authorised workflow	Authoritative dataset, access conditions, schema, quality and change notice.	Readiness assessment, mapping, catalogue and integration support.	Dataset-specific OGC, NGSI-LD, file or REST profile.	MS04 onward
T1.3 indicator method ↔ T2.3 process	Method, formula, baseline/interpretation and acceptance criteria.	Reproducible geospatial implementation and result publication.	OGC API Processes or documented batch process.	D2.2/D2.3
Prospective T1.2 node ↔ Hub, LIST routes or authorised workflow	Authoritative datasets, lawful access, metadata source, schema, endpoint, quality, change notice and operational owner.	Readiness record, profile/mapping guidance, catalogue reference, workflow integration and tests.	Dataset-specific OGC/NGSI-LD/file/REST profile plus agreed authentication.	D1.3/MS04/ D2.2
NEXTLOGIC catalogue ↔ optional EMDS/external catalogue	Eligible metadata/datasets, participant obligations, connector/trust functions and authoritative-record lifecycle.	OGC API - Records/DCAT mapping, stable identifiers, harvesting/synchronisation and conflict tests.	OGC API - Records; applicable DCAT profile; DSSC-aligned trust only if participation is agreed.	Decision D2.2; evidence D2.3

A.5 Controlled dependency resolution and contingency register

Table 19 is the controlled T2.4 resolution register. It separates contribution-level certainty from boundary-level work and gives every item a stable identifier, current status, responsible owner, required closure evidence, target gate and explicit contingency. T2.4 updates the register as evidence is accepted; a missed gate changes the claimed release scope rather than silently transferring responsibility or implying integration.

Table 19. Controlled dependency resolution, evidence and contingency register.

ID / current status	Technical boundary and responsible owner	Required closure evidence	Target gate and contingency
DEP-01 Technical boundary pending	**Boundary:** Toolbox/Sandbox operational host, capacity, native-interface, adapter, hosting, maintenance and post-project lifecycle assignments. **Owner:** LIST/T2.4, WP2 lead, capability owners and infrastructure owner.	**Evidence:** Approved operating model; named host/maintainer; capacity/performance targets; interface and lifecycle records; acceptance authority.	**Gate:** Before MS04 commitments. **Contingency:** Limit MS04 to evidenced capacity/routes; record a revised gate and escalate release-critical gaps.
DEP-02 Planned	**Boundary:** Select priority Sandbox workflows, users and acceptance authorities from the The Hague, Frankfurt and Aarhus candidates. **Owner:** WP2/WP4 leads, relevant cities and capability owners.	**Evidence:** Approved shortlist; bounded workflow description; users; prerequisites; test and acceptance plan.	**Gate:** MS04 planning. **Contingency:** Narrow to the most tractable workflow; defer non-ready candidates without claiming coverage.
DEP-03 Planned	**Boundary:** Priority dataset readiness and lawful access. **Owner:** City/data owners with SAU/WP1 and WP2.	**Evidence:** Dataset card; authoritative owner; access/licence; schema; quality; update; privacy/security; sample or endpoint.	**Gate:** MS04/D2.2. **Contingency:** Use an authorised substitute/reference dataset or narrow the workflow; record limitations.
DEP-04 Asset identified; validation pending	**Boundary:** City confirmation of the consolidated T2.1 city-discovery baseline and corrected not-reported statuses. **Owner:** FUAS with pilot cities and data/model owners.	**Evidence:** Dated city/data-owner confirmation, restrictions, corrections and source-qualified readiness status.	**Gate:** D2.2. **Contingency:** Retain working-synthesis status and exclude unconfirmed assets from operational claims.
DEP-05 Contribution confirmed; boundary pending	**Boundary:** DTU 15-minute Multimodal Hub method executable form, schemas, hosting, authentication, limits and maintenance. **Owner:** DTU with LIST.	**Evidence:** Approved Tool Card; method/version; sample inputs/outputs; endpoint or batch package; host/maintainer; tests; DTU acceptance.	**Gate:** MS04/D2.2. **Contingency:** Test a documented reference/batch route or defer integrated status while retaining the method contribution.
DEP-06 Contribution confirmed; boundary pending	**Boundary:** Transcality PLAN/SUMO inputs/results, calibration, city-data route, hosting and interface maintenance. **Owner:** Transcality with LIST and relevant city owners.	**Evidence:** Tool Card; model/version; schemas; calibration responsibility; endpoint/batch route; host/maintainer; test and acceptance result.	**Gate:** D2.2. **Contingency:** Use the authorised provider-native route or a controlled exchange; defer unsupported extensions.
DEP-07 Contribution confirmed; boundary pending	**Boundary:** PKUN zone-feature/observation model, API/adapter, aggregation, privacy, access and maintenance. **Owner:** PKUN with city/data owners and LIST.	**Evidence:** Tool/data cards; schema and aggregation rules; privacy/access approval; interface example; host/maintainer; Sandbox test; acceptance.	**Gate:** MS04/D2.2. **Contingency:** Use authorised aggregate exports or a provider dashboard; exclude non-approved personal/behavioural data.

ID / current status	Technical boundary and responsible owner	Required closure evidence	Target gate and contingency
DEP-08 Contribution confirmed; boundary pending	**Boundary:** TUD XR device/client profiles, scenario resources, interaction and feedback interface, including the applicable EXE simulator route. **Owner**: TUD with LIST, EXE where relevant, WUEB for T3.1 requirements, WCG and pilot owners for deployment/acceptance.	**Evidence:** Tool Card; device profile; resource package; feedback schema/API; host/maintainer; usability/integration test; TUD/EXE/pilot acceptance as applicable.	**Gate:** D2.2. **Contingency:** Use a 2D/3D or provider-native route if the XR boundary is not ready; record the changed validation scope.
DEP-09 Contribution confirmed; boundary pending	**Boundary:** EXE Digital Twin applications, bicycle-parking camera and cargo-bike GPS outputs, pilot client route, cloud storage, schemas, authentication and support. **Owner**: EXE with TUD/LIST and relevant pilot/solution owners.	**Evidence:** Partner-approved Tool Cards; component/version list; camera/GPS samples and schemas; endpoint/access; host/maintainer; Sandbox/equivalent test; named acceptance result.	**Gate:** MS04/D2.2. **Contingency:** Use an authorised EXE-native/remote or controlled data route, or defer the affected workflow; never claim untested integration.
DEP-10 Contribution confirmed; boundary pending	**Boundary:** UniR3 logistics/routing method scope, executable form, interface, hosting and lifecycle. **Owner:** UniR3 with LIST.	**Evidence:** Method/version; inputs/outputs; executable/API/batch package; host/maintainer; scientific and integration acceptance criteria/results.	**Gate:** MS04/D2.2. **Contingency:** Use a documented offline/reference implementation or defer the integrated-service claim.
DEP-11 Contribution confirmed; boundary pending	**Boundary:** UniR1 application/backend, measurement schema, MUV integration, privacy/access, hosting and maintenance. **Owner:** UniR1 with MUV and LIST/T2.4.	**Evidence:** Tool Card; application/version; API/data model; lawful access/privacy controls; host/maintainer; tests; UniR1/T3.4 acceptance.	**Gate:** MS04/D2.2. **Contingency:** Use a bounded mock/reference exchange or defer the affected incentive workflow; record scope and new gate.
DEP-12 Contribution confirmed; boundary pending	**Boundary:** MUV SDK/system and Smart Reward version, SDK/API contract, behavioural-data flow, privacy, hosting and support. **Owner:** MUV with UniR1 and relevant pilot/data owners.	**Evidence:** Tool Card; versioned SDK/API documentation; data-flow/privacy approval; access credentials/process; host/support; test and acceptance result.	**Gate:** MS04/D2.2. **Contingency:** Retain provider-native use or a non-personal synthetic test; defer behavioural-data integration until approved.
DEP-13 Contribution confirmed; boundary pending	**Boundary:** MOV assessment tool/version, pilot inputs/outputs, API or controlled-batch route, hosting and maintenance. **Owner:** MOV with UniR1/T3.4 and relevant pilot owners.	**Evidence:** Tool Card; method/tool version; sample exchange; interface or batch specification; host/maintainer; pilot test and MOV/pilot acceptance.	**Gate:** MS04/D2.2. **Contingency:** Use a provider-operated assessment/export route or defer the affected assessment step.

ID / current status	Technical boundary and responsible owner	Required closure evidence	Target gate and contingency
DEP-14 Contribution confirmed; boundary pending	**Boundary:** EXE-provided Wrocław cargo-bike XR simulator/training environment, sensor/control formats, Digital Twin/XR interface and operating responsibility. **Owner:** EXE with TUD/LIST; WUEB supplies T3.1 solution requirements/validation; WCG and pilot owners retain deployment/acceptance roles.	**Evidence:** Tool Card; simulator/version; representative inputs/outputs; sensor/control schema; interface; host/maintainer; test and named acceptance result.	**Gate:** MS04/D2.2. **Contingency:** Use a recorded simulator export or standalone EXE session; defer unsupported live coupling.
DEP-15 Technical boundary pending	**Boundary:** Shared identity, roles and service-to-service authorisation. **Owner:** LIST and relevant providers/cities.	**Evidence:** Role/access matrix; identity provider and token flow; service accounts; revocation/audit; security test and acceptance.	**Gate:** D2.2. **Contingency:** Use bounded provider/city credentials for the test; exclude unsupported cross-service automation.
DEP-16 Method contribution confirmed; specification pending	**Boundary:** T1.3 indicator shortlist and computable specifications. **Owner:** T1.3 lead/contributors with T2.3.	**Evidence:** Formula, inputs, baseline, units, interpretation, uncertainty and acceptance criteria for each selected indicator.	**Gate:** D2.2. **Contingency:** Implement only approved indicators; label exploratory outputs and exclude them from formal evaluation claims.
DEP-17 Planned controls	**Boundary:** Accessibility, security, privacy and legal applicability assessments. **Owner:** Relevant task leads, DPO/security, data owners and pilot authorities.	**Evidence:** Applicable assessments, mitigations, approvals and residual-risk acceptance for the named workflow/release.	**Gate:** MS04 onward. **Contingency:** Restrict data/users/functions or postpone deployment until controls and approvals are adequate.
DEP-18 Technical boundary pending	**Boundary:** Interface change, monitoring, version and deprecation process. **Owner:** T2.4 and technology providers.	**Evidence:** Version policy; change notice; monitoring/contact; compatibility test; deprecation and replacement route.	**Gate:** D2.2/D2.3. **Contingency:** Pin the tested version and suspend affected workflow updates until compatibility is restored.
DEP-19 Conditional external route	**Boundary:** T1.2 storage/access node ownership, hosting, datasets, interfaces, metadata source and lifecycle. **Owner:** T1.2/D1.3 lead, SAU/WP1, data owners and WP2.	**Evidence:** Named operational owner; authorised datasets; interface/schema; metadata source; access controls; lifecycle and integration test.	**Gate:** D1.3/MS04/D2.2. **Contingency:** Reference authoritative source systems directly or use approved project storage; do not assume the node exists.
DEP-20 Conditional external route	**Boundary:** Whether/how NEXTLOGIC participates in EMDS, including connector, datasets, trust and usage-policy responsibilities. **Owner:** Project governance, T1.2/data owners, WP2 and relevant EMDS participants.	**Evidence:** Governance decision; eligible use case/datasets; participant roles; trust/connector design; policy and test evidence.	**Gate:** Decision D2.2; evidence D2.3. **Contingency:** Use bilateral controlled exchange/catalogue federation and retain EMDS as an unclaimed future option.

A.6 Staged verification and evidence

The following evidence allocation prevents Month 08 design statements from being confused with later implementation results. The recommended evidence gates are allocated in Table 20.

Table 20. Recommended evidence allocation by release.

Release	Minimum evidence package
D2.1	Scope traceability, architecture, roles, initial profiles, responsibility model, candidate workflows, standards register, open dependencies and validation plan
MS04 Sandbox	Deployed test resources, questionnaire-generated provisional and reviewed Tool Cards, endpoint/interface examples, mapping records, integration tests, exceptions and presentation to the project team
D2.2 Platform v1	Implemented priority interfaces, workflow evidence, initial city/user tests, security and performance observations, versioned configurations and support ownership
D2.3 Platform v2	Extended portfolio, operational hardening, lifecycle management, multi-city or multi-use-case validation, resilience and consolidated replication evidence
MS09 demonstration	Integrated and scalable demonstration in leading cities with project-level outcome and usability evidence

Three final gates apply to each release: the architecture and interface records must not contradict one another; every maturity claim must link to specification or evidence; and a reviewer must be able to identify what is available, what remains open, who owns it and when it will be verified.

A.7 Preliminary pilot-city digital and data baseline

Status and source boundary. A consolidated FUAS-led T2.1 city-discovery comparison dated 3 August 2026, based on the March 2026 meetings and questionnaires, is now available and has been used to refine Table 21. It remains a working synthesis rather than a city-confirmed dataset-readiness assessment: 'not reported' is not treated as 'not available', and access, publication, interface, update and ownership conditions remain subject to city and data-owner confirmation. The baseline remains distinct from the T2.4 Tool and Technology Onboarding Card and complementary to the SAU-led T1.2/D1.3 data framework.

Table 21. Preliminary pilot-city digital and data baseline and confirmation status.

City	Pilot context	Current traceable baseline	Confirmation and integration implication
Aarhus	Leading city; 15-minute Multimodal Hub	The 3 August 2026 T2.1 comparison reports PTV Visum, transferable model outputs, a 2016 baseline with an update in preparation, exploratory MATSim work, Open Cities Planner and an initial Hjortshøj study area. Travel-survey and possible traffic-count inputs are also reported.	Confirm model/output scope, the current baseline/update, data rights, interfaces, hosting and owner acceptance before using a bounded near-term accessibility/15-minute-hub Sandbox case.
Dublin (DLR)	Leading city; Smart Bike Parking Digital Twin and incentives	The working comparison reports a smart-bike-parking environment, SCATS, RealSim.ie/Bentley and bicycle-data sources. D2.1 also retains the TUD-reviewed illustrative AR-guided bicycle-parking use case in which a 3D geofence identifies the designated parking area and EXE-owned parking-occupancy Digital Twin and camera data for pilot site.	Confirm the authoritative parking-zone data, platform and AR boundaries, provider rights, privacy, update arrangements and permitted user feedback before implementation.

The Hague	Leading city; Smart Loading Zones	MRDH exchange is currently file/export-based rather than API-based. A 2026 export has been supplied to Transcality as a first-pass SUMO basis; a bounded study area and ZE/Smart Loading Zone scenarios are identifiable. Parkunload exports may be available, but their time-dependent curb-use meaning requires careful interpretation; current CBS output is insufficient for the intended validation and aggregated ANPR categories are expected later.	Treat the candidate as a controlled batch workflow. Confirm reusable schemas, lawful access, calibration and acceptance data, Parkunload interpretation, the PKUN boundary and operational/lifecycle owners.
Wrocław	Leading city; Mobile Microhubs, cargo bikes and XR	FCD acquisition and city/site inputs remain planned through WP4. A recent in-house PTV Visum model based on comprehensive travel surveys is reported, while the current TUD-reviewed XR contribution centres on microhub co-design; the wider GIS, Digital Twin, XR and software inventory is still incomplete.	Confirm data/model owners, access and publication conditions, interfaces, update modes and XR resources. Keep any Visum-to-SUMO sequence conditional until agreed by the responsible partners.
Frankfurt	Replicating city; Microhubs and logistics Digital Twin use cases	The working comparison reports loop-detector preparation, a ClickHouse deployment on the T1.2 server for forthcoming traffic data, VISUM/VISSIM, mainziel.de, DATEX II and coordination with DB InfraGO and HOLM. Actual ingestion, access, data rights and operational ownership of the ClickHouse boundary remain unconfirmed.	Confirm the authorised traffic inputs and ClickHouse owner/access route, output interfaces and update process before testing a bounded microhub-location or traffic-impact result; assign any optimisation or Transcality relationship explicitly.
Differdange	Replicating city; Smart Loading Zones and charging	The Grant Agreement notes advanced IT/data-visualisation capability and renewable-energy mapping. The working comparison reports a national MATSim model developed by UniLU and a real-time bus API covering 52 stops as potential inputs; suitability, access and publication conditions remain unconfirmed.	Confirm the platform/API inventory, data-owner approval and access conditions for MATSim and bus inputs, and the PKUN and charging-system boundaries.
Heidelberg	Replicating city; Smart Loading Zones and Mobile Microhubs	The working comparison reports a municipal VISUM model and the Offene Daten Heidelberg portal, while also identifying a logistics-demand evidence gap. Transcality is assigned to contribute to the pilot Digital Twin; other municipal systems and datasets are not yet consolidated.	Confirm model, portal and loading-zone resources, access and ownership. Use an OpenAPI-compatible documented boundary where applicable; keep any Visum-to-SUMO sequence conditional until formally agreed.
Bergamo	Replicating city; dynamic curb and Smart Loading Zones	No transport model or operational dataset was identified in the supplied working comparison; this means not reported in that source, not that none exists. The reported context includes the ZTL and possible ISPRA emissions information, while Transcality contribution and real-time monitoring remain planned.	Confirm curb, ZTL, emissions and monitoring resources, interfaces, ownership and update modes before selecting a workflow or inferring data availability.

A.8 Detailed partner and interoperability reference

Figure 4 is the common logical blueprint. For each confirmed integration, partners locate the resource or contribution, select only the applicable IF port or ports, and record the owner, native interface, adapter, operational host, maintainer and acceptance test.

Table 22 summarises the configurable interface-port catalogue; the selected technical profile remains boundary-specific.

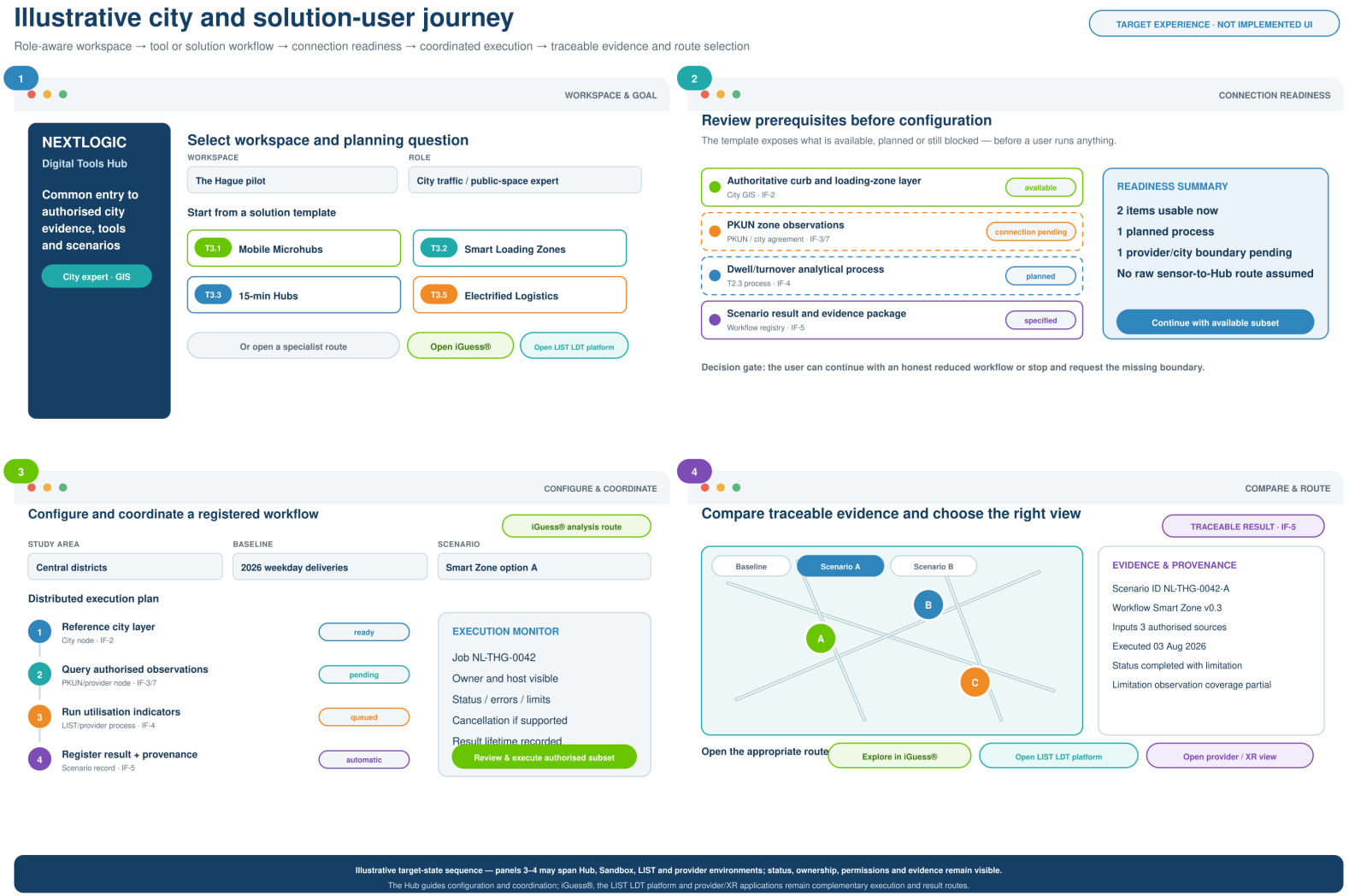
Table 22. Configurable IF-1–IF-7 interface-port catalogue and minimum evidence.

Port	Purpose	What crosses the boundary	Required record or evidence
IF-1	Register / discover	Tool Cards, metadata, catalogue records and stable identifiers	Owner, status, source of truth and catalogue route
IF-2	Access / query	Features, maps, tiles, files and other authorised resources	Rights, schema, CRS/time meaning, update mode and access test
IF-3	Observe / subscribe	Observations, context updates and events	Source semantics, gateway, privacy/aggregation and subscription behaviour
IF-4	Execute / monitor	Parameters, references, jobs, status and errors	Method owner, operational host, limits and expected/failure-path tests
IF-5	Results / evidence	Results, provenance, quality, uncertainty and scenario links	Result lifetime, version, status and traceable evidence package
IF-6	Visualise / open	Stable hand-off to iGuess®, LIST LDT platform, XR, dashboard or provider view	Identifiers, permissions, client/resource profile and feedback route
IF-7	Authenticate / govern	Identity, roles, policy, licence, privacy, retention and audit	Identity owner, scopes, lawful use, retention and audit evidence

Maturity labels are applied to the named boundary: existing baseline, specified baseline, proposed, planned, or open/conditional. 'Implemented' and 'validated' are reserved for later evidence. The minimum boundary record links the capability or data owner, native interface, adapter implementer, host, maintainer, release and acceptance test so that scientific ownership and operating responsibility remain distinguishable.

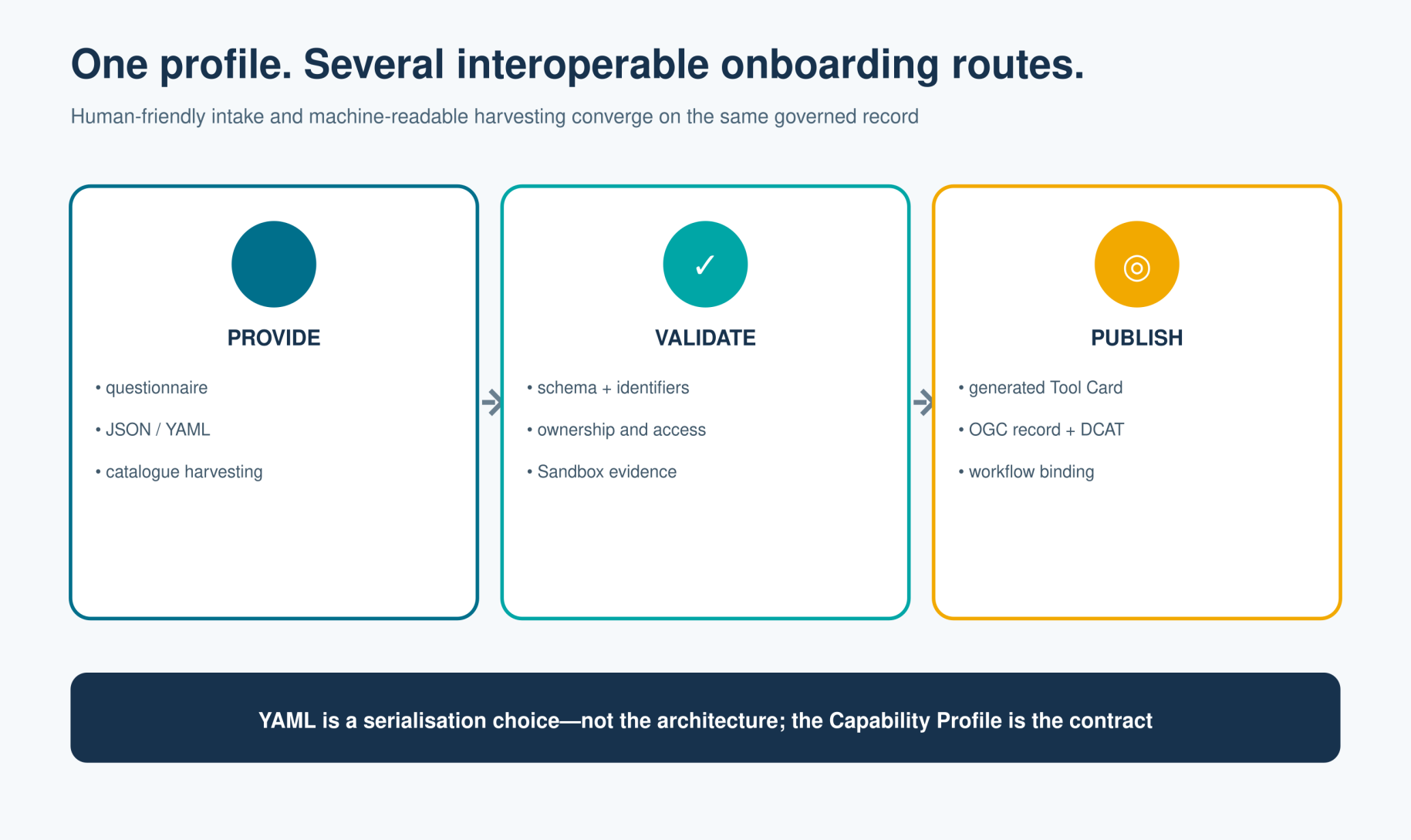
A.9 Illustrative role-based interaction journeys

The following target-state illustrations extend Figure 16 for three roles. They show intended readiness, ownership, permissions, evidence and lifecycle behaviour; they are not implemented screens or proof that every depicted route is available at Month 08.



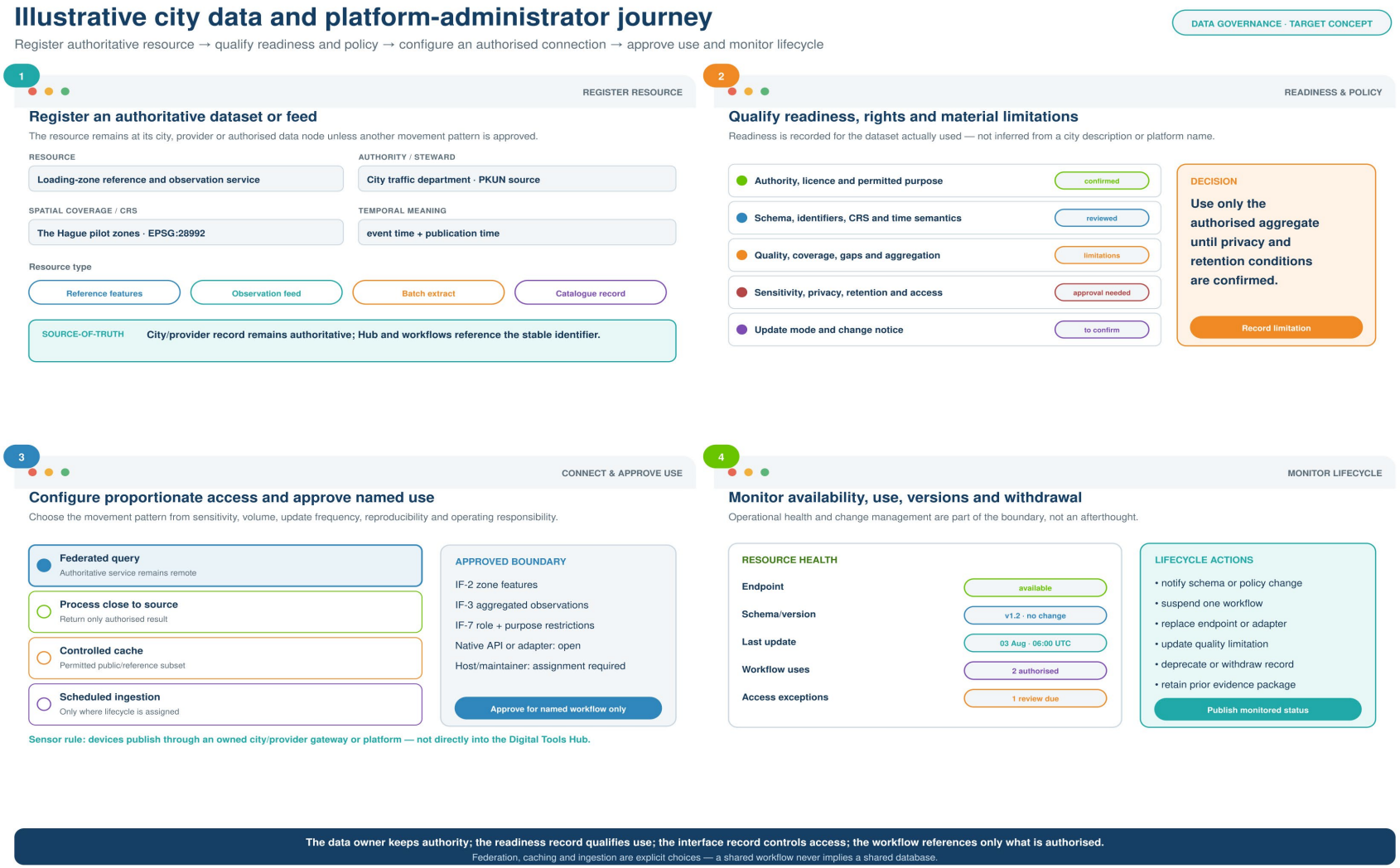
Illustrative city and solution-user journey from a role-aware workspace and question or solution selection through connection-readiness review and guided distributed execution to traceable comparison and route selection. Panels 3 and 4 may span Hub, provider, Sandbox, LIST LDT platform, iGuess® and XR environments. Ownership, maturity, permissions and evidence remain visible. The screens are target-state design concepts, not implemented software.

Figure 17. Illustrative city and solution-user journey



Standards-based provider-onboarding journey from a provisional Tool Card through interface and responsibility assignment, an optional Hub configuration schema or provider-native interface route, Sandbox integration-package testing, and bounded publication and lifecycle management. The Tool Card describes the capability, the interface record defines the boundary, and test evidence controls the maturity label.

Figure 18. Standards-based provider-onboarding journey.



Illustrative city data and platform-administrator journey from authoritative resource registration through readiness and policy qualification, proportionate access and named workflow approval to endpoint, version, use and withdrawal monitoring. Sensors publish through an owned city or provider gateway; a shared workflow does not imply a shared database.

Figure 19. Illustrative city data and platform-administrator journey.