European data space
for smart communities

Deliverable 3.1

DS4SSCC Deliverable 3.1 Interoperability between OUP and sectoral models and data model requirements

WP 3 – Model usage phase

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Abbreviations

Abbreviation	Definition	Abbreviation	Definition
DS4SSCC	European data space for smart communities (DS4SSCC)	DT-aCoGo	Digital Twinning as Common Good
OASC	Open & Agile Smart Cities & Communities	OUP	Open Urban Platform
WP	Work Package	PC	Pilot Coordinator
BIM	Building Information Modeling	WFS	Web Feature Service
OGC	Open Geospatial Consortium	ETL	Extract, Transform, Load
LOD	Level of Detail	UMG	Unreal Motion Graphics
REST	Representational State Transfer		

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1. Executive Summary

This deliverable presents the design, implementation, and evaluation of a timelapse slider functionality within Unreal Engine as part of the DT-aCoGo digital twin framework. The work builds directly upon the principles established in Deliverable 2.2, in which time is defined as an intrinsic property of urban data rather than a purely visual feature.

The primary objective of the timelapse slider is to enable users to explore urban environments across different moments in time, supporting both visualisation and analytical use cases. In the context of urban development, datasets representing the current state (e.g. 3D Tiles) and future developments (e.g. BIM models) inherently overlap. Without a consistent temporal mechanism, this leads to visual clutter, incorrect analytical results, and limited decision support.

The key design principle adopted in this work is the use of lifecycle-based filtering, where objects are enriched with temporal attributes (ValidFrom, ValidTo) during data preparation. This approach ensures that all applications interpret time consistently by applying the same simple filtering rule based on a selected time parameter.

Within Unreal Engine, this principle is implemented through a Blueprint-based timelapse slider widget, which acts as a user interface control for selecting a moment in time. The widget dynamically determines the temporal range based on available data, evaluates lifecycle attributes at runtime, and includes or excludes objects accordingly. Unlike visual masking techniques, this approach ensures that objects are not merely hidden, but structurally filtered out of the scene, avoiding issues with collisions, performance, and analytical inconsistencies.

The analysis presented in this deliverable demonstrates that visual masking approaches are insufficient, as they operate only at the rendering level and do not align with the data-driven architecture. In contrast, lifecycle-based filtering provides a robust, scalable and interoperable solution that can be consistently applied across visualisation environments (e.g. Unreal Engine, web viewers) and analytical services.

A key added value of the timelapse slider is its ability to ensure that analytical results are presented within the correct temporal context. By linking analysis models to the same time parameter, results such as heat stress simulations can be shown only when relevant to the selected moment. This prevents misinterpretation, for example by avoiding the display of future analysis results in the context of the current situation, and significantly improves the clarity and reliability of decision support.
The implementation in Unreal Engine confirms that lifecycle-based filtering can be realised in a real-time 3D environment through custom metadata parsing and runtime evaluation, despite limited native support for temporal semantics. The result is a reference implementation that demonstrates how the same mechanism can be applied consistently across different applications without modifying the underlying data.

In conclusion, the Unreal Engine timelapse slider is not a standalone feature, but a key component of a broader architectural approach in which time is embedded in the data and interpreted consistently across systems. This enables scalable reuse across cities and applications, supports interoperability within the DT-aCoGo ecosystem, and strengthens the integration between visualisation and analytical workflows.

2. Introduction

The DT-aCoGo project is developed within the European Data Space for Smart Communities (DS4SSCC) initiative and aims to establish a scalable and interoperable digital twin ecosystem for urban environments. Within this context, the Open Urban Platform (OUP) serves as the central data space, enabling stakeholders to publish, discover, and reuse data and services across domains and cities.

A key characteristic of the DT-aCoGo approach is the strict separation between data services, analytical platforms, and visualisation environments, as shown in figure 1. This separation ensures that data remains at its authoritative source while being accessible through standardised interfaces, supporting interoperability, reuse, and scalability across the ecosystem.

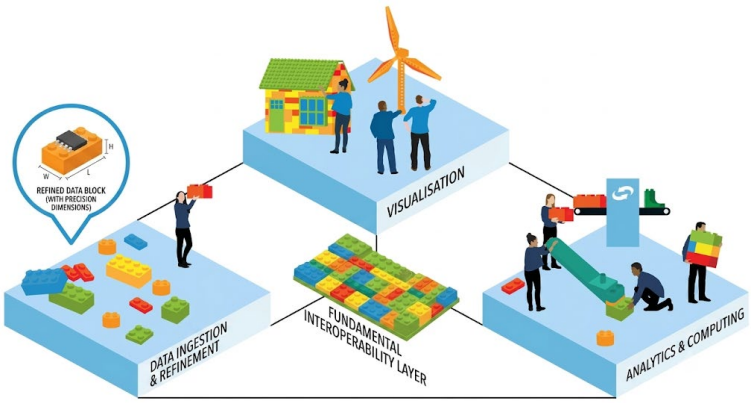


Figure 1: Schematic architecture DT-aCoGo

Within this architecture, multiple stakeholders—including municipalities, data providers, and model providers—collaborate through a federated hub structure. Each pilot city operates within its own governed environment while contributing to a shared data ecosystem. This enables cross-city collaboration while maintaining data sovereignty and control at the local level.

The primary objective of this deliverable is to describe how interoperability between the Open Urban Platform and sectoral analytical models is realised within this ecosystem. The deliverable focuses on enabling the integration of heterogeneous datasets and analytical models into a unified workflow, supported by a Common Information Model (CIM) and a semantic alignment layer.

In particular, the deliverable addresses the challenges posed by the diversity of data structures, formats, and semantics across cities and domains. It defines the approach for harmonising datasets and making them reusable across analytical models, thereby supporting cross-domain analysis and data-driven decision-making.

The scope of this deliverable includes:

- The integration of sectoral analytical models for water, traffic, and heat stress
- The definition and implementation of a Common Information Model for harmonised data usage
- The mapping of city-specific datasets to the CIM
- The description of interoperability workflows connecting data, models, and visualisation environments
- The documentation of data requirements in a format that supports replication across cities and use cases

Within this scope, Building Information Modelling (BIM) is not treated as a standalone analytical domain but as an essential data source representing future developments. BIM data is integrated into the ecosystem alongside datasets describing the current situation, enabling consistent analysis of future scenarios across all model domains.

The deliverable builds upon the architectural foundations established in earlier work, including the setup of OUP hubs and the definition of temporal data handling through lifecycle attributes. Together, these components provide a coherent framework in which data, models, and applications can operate consistently across domains and over time, supporting scalable and replicable digital twin implementations.

3. Problem Definition

The integration of analytical models within a digital twin ecosystem is fundamentally challenged by the lack of uniformity in both data structures and system capabilities.

Although municipalities increasingly adopt national standards for data management, significant differences remain in how these standards are implemented in practice. Data sources originating from different cities often rely on distinct information models, even when based on comparable national frameworks. Variations in interpretation, level of detail, and schema implementation result in datasets that are not directly interoperable.

When scaling this approach to a European context, these challenges become more pronounced. Differences in language, terminology, and national standards introduce additional complexity, making it difficult to align datasets across cities and countries. This creates semantic barriers that cannot be resolved through technical integration alone, requiring a harmonised approach to data modelling and interpretation.

In addition to differences in data structures, there is a lack of consistency in the availability and maturity of data services. Not all municipalities provide the same types of data access mechanisms, such as standardised web services or APIs. In some cases, required services must be created or adapted specifically for integration within the digital twin ecosystem. This variability limits the ability to establish a uniform integration workflow.

On the receiving side, analytical platforms also exhibit significant heterogeneity. Each model provider operates with its own information model, data requirements, and supported interfaces. Differences exist in:

- Required input data structures and semantics
- Supported data formats and service standards
- Level of automation in data ingestion and model configuration

As a result, data prepared for one analytical platform cannot be directly reused by another without transformation. This leads to increased integration effort and reduces scalability across domains.

A direct consequence of this lack of interoperability is that consistency between analytical models cannot be guaranteed. Each model may interpret input data differently or rely on differently structured datasets, leading to discrepancies in results across domains.
This lack of coherence is a critical limitation, as one of the key objectives of the DT-aCoGo ecosystem is to enable integrated, cross-domain analyses. To support effective decision-making, outputs from different analytical models must be aligned and comparable.

Furthermore, consistency must be ensured between analytical results and visualisation environments. In particular, the Unreal Engine-based digital twin requires that visual representations and analytical outcomes are synchronised at all times. If this alignment is not achieved, discrepancies arise between what users see and what is calculated.

Such inconsistencies directly impact user trust. Municipal users rely on the digital twin as a decision-support tool for day-to-day operations and long-term planning. If analysis results and visualisations are not coherent and synchronised, the outputs cannot be considered reliable. This undermines confidence in the system and prevents adoption in operational workflows.

Therefore, ensuring coherence across analytical models and visualisation environments is not only a technical requirement, but a fundamental condition for deploying the digital twin ecosystem as a fit-for-purpose solution within municipal contexts.

In addition to these challenges, temporal aspects of data introduce further complexity. Analytical models and visualisation environments require a consistent approach for distinguishing between current and future situations. However, datasets are often not structured to explicitly support time-based filtering, leading to inconsistencies between analysis results and visual representations.

Overall, these challenges highlight the need for:

- A harmonised data model that can bridge differences between source datasets
- A semantic alignment mechanism to address variations in terminology and structure
- A standardised approach to data services and APIs
- A consistent representation of temporal information across datasets
- Guaranteed coherence between analytical models and visualisation environments

Without such mechanisms, interoperability remains limited, and the potential for scalable, cross-domain digital twin ecosystems cannot be fully realised.

4. Sollution approach

To address the interoperability challenges identified in Chapter 3, the DT-aCoGo project implements a layered architecture based on the Open Urban Platform (OUP), complemented by a semantic interoperability layer provided by the Purple Polar Bear (PPB) platform and a shared Common Information Model (CIM).

This architecture is specifically designed to resolve the fragmentation of data sources, the heterogeneity of analytical models, and the lack of coherence between analysis and visualisation, thereby enabling a scalable and trustworthy digital twin ecosystem.

4.1 Architectural principles

The solution builds upon the core principles established in the DT-aCoGo ecosystem:

- Separation of data, applications, and visualisation layers
- Use of open, standardised data services
- Preservation of data at the authoritative source
- Federated governance through OUP hubs

Within this structure, the OUP functions as the central platform for publishing, discovering, and accessing data services, while PPB introduces a semantic layer that enables harmonisation and transformation of datasets across domains.

4.2 Addressing Heterogeneous Source Data

Problem addressed:
Different cities use varying information models, even when based on national standards, and additional barriers arise at European scale (language, semantics, implementation differences).
Solution:
The PPB platform introduces a semantic interoperability layer that translates heterogeneous source datasets into a unified Common Information Model (CIM).

Through explicit data mappings, source attributes are aligned to standardised CIM attributes. This ensures that datasets originating from different cities, countries, and standards can be interpreted consistently.

By separating source data structures from the CIM, the solution allows local data models to remain unchanged while enabling cross-city interoperability at the semantic level. This approach directly addresses differences in language, terminology, and schema implementation, making the solution scalable across European contexts.

4.3 Addressing Variability in Data Services and APIs

Problem addressed:
Not all municipalities provide the same types of APIs or services.

Solution:
The PPB layer also performs transformation of datasets into standardised data services, which are then published on the OUP.

This includes:

- Creating uniform API endpoints where none exist
- Converting datasets into standard formats (e.g. OGC-compliant services)
- Enriching data with required attributes (e.g. temporal metadata)

As a result, analytical models no longer depend on the native service capabilities of municipalities. Instead, they interact exclusively with standardised data services provided through the OUP, ensuring a consistent integration interface across all data providers.

4.4 Addressing Heterogeneity of Analytical Models

Problem addressed:
Different model providers require different data formats, structures, and services.

Solution:
The architecture decouples data provisioning from model-specific requirements by introducing the CIM as an intermediate layer.

Within this approach:

- Data is first harmonised into the CIM via PPB
- PPB then generates model-specific data services where required
- Analytical platforms consume only the data subsets and formats they require

This enables each model provider (Rana, DatMobility, Tygron) to operate using its own internal logic, while still relying on a shared and consistent data foundation.

By avoiding direct coupling between data providers and model providers, the solution reduces integration complexity and supports scalability across multiple analytical domains.

4.5 Ensuring Coherence Between Analytical Models

Problem addressed:
Lack of interoperability leads to inconsistent outputs across analytical models.

Solution:
By enforcing the use of a shared Common Information Model, all analytical models operate on harmonised and semantically aligned input data.

This ensures that:

- All models interpret core datasets consistently
- Differences in outputs are the result of model logic rather than data inconsistencies
- Cross-domain analyses can be compared and combined meaningfully

The CIM therefore acts as the single source of truth for data interpretation across the ecosystem.

4.6 Ensuring Consistency Between Analysis and Visualisation

Problem addressed:
Mismatch between analytical results and Unreal visualisation leads to loss of trust.

Solution:
The architecture ensures that both analytical models and visualisation environments consume the same underlying data services from the OUP.

In addition:

- Temporal consistency is enforced through lifecycle attributes (ValidFrom, ValidTo)
- These attributes are applied during data preparation in PPB
- Both analytical models and visualisation tools use the same filtering logic

This ensures that the state of the digital twin at a given moment in time is identical across:

- Analytical outputs
- Visual representations (e.g. Unreal Engine)

By aligning what is calculated with what is visualised, the system guarantees consistency and reliability of results, which is essential for user trust and operational adoption.

4.7 Conclusion

By combining the Open Urban Platform (OUP), the Purple Polar Bear (PPB) semantic interoperability layer, and the Common Information Model (CIM), the DT-aCoGo architecture provides a robust and coherent solution that not only resolves interoperability challenges but also ensures operational usability in real-world municipal contexts. Through the standardisation and harmonisation of data, coupled with transparent transformation processes and governed data sharing within the OUP, the ecosystem delivers a consistent and reliable data foundation for both analytical models and visualisation environments. This guarantees that all components operate on aligned datasets and identical temporal states, ensuring synchronisation between analytical results and visual representations. As a result, the system establishes a high level of trust among users, which is essential for adoption in day-to-day municipal workflows and decision-making processes. Furthermore, the architecture enables scalability and reuse across cities and domains by decoupling local data structures from their use in analytical applications, while maintaining a shared semantic layer as a single source of truth. In this way, the DT-aCoGo ecosystem moves beyond a technical integration solution and provides a scalable, interoperable, and trustworthy digital twin framework that is fit for purpose in supporting both operational and strategic urban decision-making.

5. Ecosystem configuration

Building on the architectural foundation described in Chapter 4, the DT-aCoGo ecosystem is operationalised through a structured configuration workflow that ensures the consistent integration of data sources, semantic harmonisation, analytical models, and visualisation environments. This workflow translates the conceptual interoperability approach—based on OUP, PPB, and the Common Information Model—into a practical implementation that can be deployed and reused across multiple cities and use cases.

The configuration of the ecosystem follows a series of logical steps, starting from the registration of source data and culminating in the execution and visualisation of analytical models within the Unreal Digital Twin environment.

The process is initiated by configuring an Open Urban Platform (OUP) hub for each participating city. Within the DT-aCoGo ecosystem, this results in separate, city-specific environments (e.g. for ’s-Hertogenbosch, Rotterdam, and Tampere), ensuring that data, services, and governance remain logically and technically separated. This hub-based approach aligns with the federated architecture of the OUP, where each city maintains control over its own datasets while enabling controlled sharing and reuse within the broader ecosystem.

During this step, differences in data policies between cities must be taken into account. For example, Den Bosch and Rotterdam primarily publish their datasets as open data, making them directly accessible through public services. In contrast, Tampere applies an authentication layer on top of its data services, requiring controlled access to datasets. The OUP hub configuration accommodates these differences by managing authentication, access rights, and service exposure at hub level, ensuring that each city’s data policies are respected while still enabling integration within the shared digital twin ecosystem.

Once the hubs are configured, source datasets are registered within the OUP. This includes both datasets representing the current situation and datasets describing future developments (e.g. BIM-based scenarios). At this stage, datasets may differ significantly in structure, terminology, and level of detail, reflecting the heterogeneity identified in Chapter 3.

The next step consists of semantic harmonisation through the Purple Polar Bear (PPB) platform. PPB retrieves the registered datasets from the OUP and applies mappings that translate city-specific data structures into the Common Information Model (CIM). This process includes the alignment of attributes, the enrichment of datasets with additional metadata (such as temporal attributes), and the transformation of data into a consistent structure that can be used across domains. The mapping definitions, as documented in the Mappingen.xlsx, form the basis for this transformation process and ensure that data from different cities is interpreted uniformly.

Following this harmonisation step, PPB publishes standardised data services back to the OUP. These services provide a uniform API layer, independent of the original data source or its underlying infrastructure. As a result, analytical models no longer directly interact with raw city datasets but instead consume CIM-based services via the OUP.

Subsequently, analytical model providers integrate their platforms with the OUP. This involves configuring their models to consume the standardised data services and to execute calculations based on the harmonised datasets. At this stage, two levels of interaction are distinguished:

- Configuration of the calculation model within the native environment of the model provider (expert mode)
- Exposure of the calculation model as an API-based service, enabling integration within the broader ecosystem and external environments such as Unreal Engine

Once configured, the analytical models—such as the Rana (water), DatMobility (traffic), and Tygron (heat stress) platforms—can retrieve data from the OUP, execute simulations, and publish their results back to the platform as standardised services.

A critical aspect of the ecosystem configuration is the correct linking between OUP hubs and visualisation environments. The Unreal Digital Twin is configured to connect to a specific OUP hub, ensuring that it retrieves data and analytical results from the correct city context. This hub-based routing mechanism prevents the mixing of datasets and model executions across cities. For example, calculations configured for Den Bosch are only executed using datasets from the Den Bosch hub, and cannot be unintentionally combined with datasets from Rotterdam or Tampere. This guarantees data integrity, avoids incorrect simulations, and reinforces trust in the system.

Finally, within the Unreal Digital Twin environment, analytical results are visualised in combination with the underlying datasets. Because both analysis and visualisation are based on the same CIM-aligned data services and temporal filtering logic, the outputs remain fully synchronised. This ensures that users always see a representation that accurately reflects the underlying analytical computations, enabling reliable interpretation and decision-making.
An oversight of the ecosystem is visualised in figure 2 below.

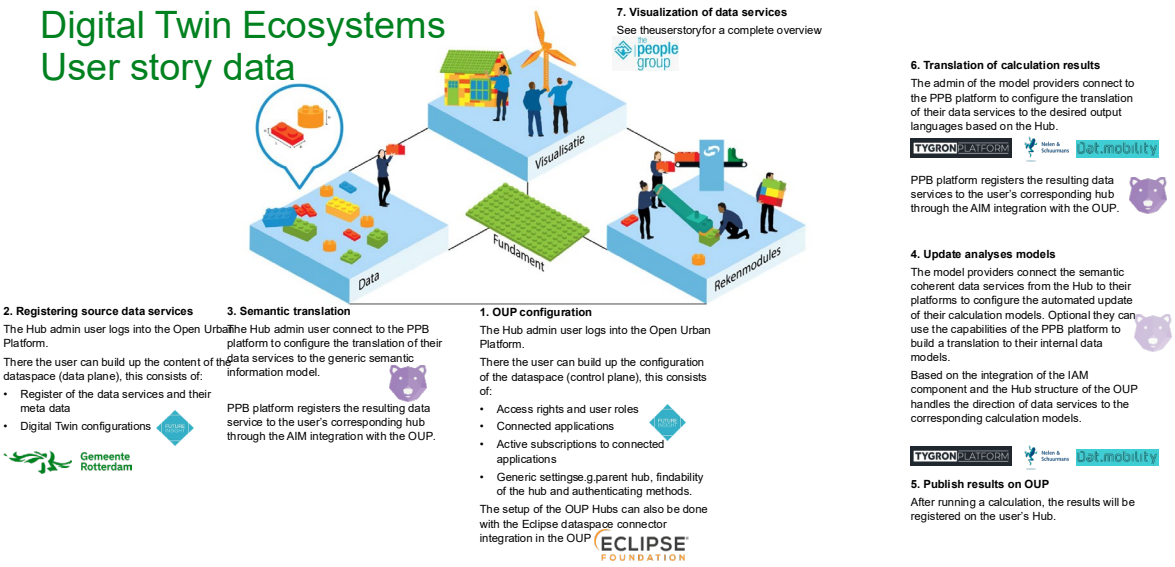


Figure 2: Digital Twin Ecosystem configuration

Through this structured workflow, the DT-aCoGo ecosystem translates the interoperability architecture into a practical and repeatable configuration process. By combining federated OUP hubs, semantic harmonisation via PPB, and model integration through standardised services, the ecosystem enables scalable deployment across cities while ensuring consistency, data integrity, and operational usability.

6. Common Information Model & Data Mapping

Following the ecosystem configuration workflow described in Chapter 5, the Common Information Model (CIM) forms the central backbone of interoperability within the DT-aCoGo ecosystem. While the OUP provides the infrastructure for data exchange and PPB performs the semantic transformation, the CIM defines the shared data structure that enables consistent interpretation across all analytical models and visualisation environments.

6.1 Concept

The CIM functions as an intermediate semantic layer that abstracts heterogeneous city datasets into a unified representation. Instead of replacing local data models, it allows each city to maintain its own data structures, while providing a harmonised view that can be used across domains and systems. This approach is essential within the federated OUP architecture, where multiple cities operate independently while contributing to a shared digital twin ecosystem.

The design of the CIM is driven by the combined data requirements of the sectoral models and the need for cross-domain consistency. Core domains include buildings, roads, vegetation, terrain, and environmental conditions. These domains are defined in a way that allows them to be reused across different analytical models, ensuring that all models operate on a consistent semantic foundation. This eliminates inconsistencies caused by differences in local schemas, naming conventions, or interpretations of national standards, as identified in Chapter 3

By acting as the single source of truth for data interpretation, the CIM ensures that analytical models and visualisation tools use the same underlying semantics. This is a critical requirement for maintaining coherence between analyses and the Unreal Digital Twin, ensuring that results are both consistent and trustworthy.

6.2 Data Mapping and Time-Based Filtering Approach

The transformation of city-specific datasets into the CIM is realised through a structured data mapping process, implemented within the PPB platform. This process translates heterogeneous datasets into a harmonised structure by defining explicit mappings between source attributes and CIM attributes. These mappings are documented in the Mappingen.xlsx, which serves as the central reference for semantic alignment across the ecosystem.

The mapping process consists of several steps. First, source datasets registered in the OUP are analysed to identify their structure, attributes, and semantics. Next, each source attribute is linked to an equivalent attribute in the CIM. This includes resolving differences in language, terminology, and classification schemes between cities. For example, attributes describing similar concepts—such as building usage, road type, or vegetation characteristics—may have different names or value sets in each city but are mapped to a single standardised CIM attribute.

A concrete example of this mapping approach is the representation of tree data across cities. In one dataset, tree height may be defined as “BOOMHOOGTE”, while in another it is defined as “HOOGTE”. Through the mapping process, both attributes are linked to the CIM attribute “treeHeight”, ensuring that analytical models interpret these values consistently regardless of their origin, see figure 3 for an mapping example on tree data.

City	Source	CM Service Nam	Source Attribute	CM Attribute	Definition
Den Bosch	2D Bomen	CM.Trees2d	BOOMHOOGTE	treeHeight	http://vocabs.lter-europe.net/EnvThes/22305
	2D Bomen	CM.Trees2d	DIAMETER	treeDiameter	http://vocabs.lter-europe.net/EnvThes/22303
	2D Bomen	CM.Trees2d	LATBOOMSOORT	scientificNam	http://rs.tdwg.org/dwc/terms/scientificName
	2D Bomen	CM.Trees2d	n/a	validFrom	http://inspire.ec.europa.eu/ont/base#validFrom
	2D Bomen	CM.Trees2d	n/a	validTo	http://inspire.ec.europa.eu/ont/base#validTo
Rotterdam	2D Bomen	CM.Trees2d	HOOGTE	treeHeight	http://vocabs.lter-europe.net/EnvThes/22305
	2D Bomen	CM.Trees2d	DIAMETER	treeDiameter	http://vocabs.lter-europe.net/EnvThes/22303
	2D Bomen	CM.Trees2d	BOOMSORTIMENT	scientificNam	http://rs.tdwg.org/dwc/terms/scientificName
	2D Bomen	CM.Trees2d	n/a	validFrom	http://inspire.ec.europa.eu/ont/base#validFrom
	2D Bomen	CM.Trees2d	n/a	validTo	http://inspire.ec.europa.eu/ont/base#validTo
Tampere	2D Bomen	CM.Trees2d	Pituusluokka	treeHeight	http://vocabs.lter-europe.net/EnvThes/22305
	2D Bomen	CM.Trees2d	Rungon_ymparys	treeDiameter	http://vocabs.lter-europe.net/EnvThes/22303
	2D Bomen	CM.Trees2d	Kasvilaji	scientificNam	http://rs.tdwg.org/dwc/terms/scientificName
	2D Bomen	CM.Trees2d	n/a	validFrom	http://inspire.ec.europa.eu/ont/base#validFrom
	2D Bomen	CM.Trees2d	n/a	validTo	http://inspire.ec.europa.eu/ont/base#validTo

Figure 3: Example of a mapping configuration

In addition to structural harmonisation, the mapping process introduces temporal consistency through the use of lifecycle attributes. Each object in the CIM is enriched with attributes such as “ValidFrom” and “ValidTo”, which define the temporal validity of the data. These attributes are used to distinguish between the current situation and future developments, enabling time-based filtering across both analytical models and visualisation environments.

This lifecycle-based approach ensures that at any given moment in time, both analysis and visualisation operate on the same subset of data. For example, when a future development is introduced through BIM data, the filtering mechanism ensures that existing objects are either excluded or replaced based on their temporal validity. This guarantees consistency between what is calculated by the analytical models and what is visualised in the digital twin.

Once the mapping and enrichment steps are completed, the transformed datasets are published as CIM-compliant data services. These services provide a consistent and standardised interface for all consuming applications, enabling reuse across models and domains.

6.3 Role of the PPB Platform

The Purple Polar Bear (PPB) platform plays a central role in operationalising the CIM and enabling semantic interoperability within the DT-aCoGo ecosystem. Positioned between the OUP and the analytical models, PPB acts as a semantic mediation layer that retrieves source datasets, applies mappings, and generates harmonised data services.

PPB performs several key functions within the architecture. First, it retrieves datasets from the OUP hubs and interprets their structure based on predefined mappings. Second, it transforms these

datasets into the CIM, aligning attributes, semantics, and classifications across cities. Third, it enriches datasets with additional information required for analysis, including temporal attributes that support lifecycle-based filtering. Finally, it publishes the resulting datasets as standardised services back to the OUP, making them available for consumption by analytical models and visualisation environments. A conceptual overview of the role and capabilities of the PPB platform is illustrated in figure 4 below.

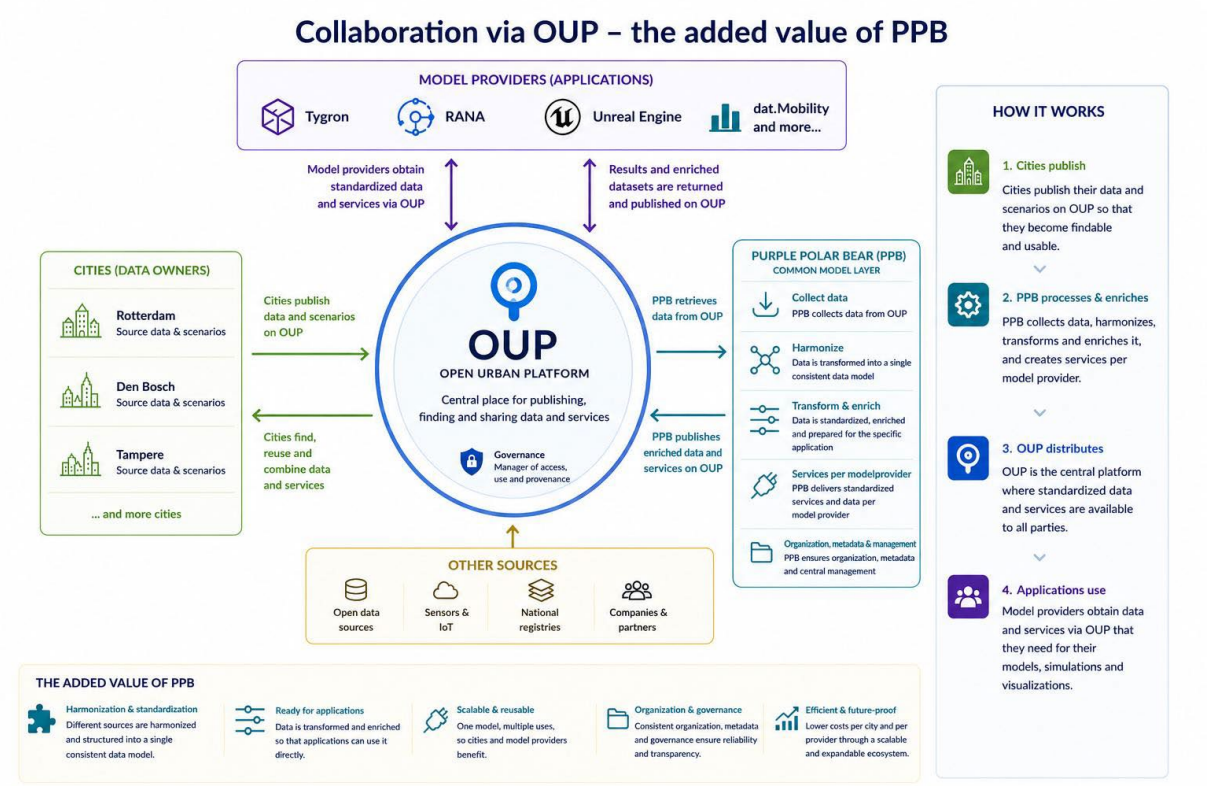


Figure 4: Overview of the capabilities and position of the PPB platform

An important characteristic of the PPB platform is that it decouples data providers from data consumers. Cities are not required to modify their datasets to conform to a common structure, and model providers do not need to adapt their internal data models to each individual data source. Instead, PPB dynamically translates between source data and model requirements, acting as a flexible intermediary that reduces integration complexity.

This decoupling also supports scalability. When new datasets, cities, or analytical models are added to the ecosystem, only the mapping definitions in PPB need to be updated. The overall architecture remains unchanged, allowing the ecosystem to grow without introducing additional integration overhead.

By centralising the mapping logic and managing semantic alignment within a single platform, PPB ensures consistency across the entire ecosystem. Combined with the CIM and the OUP, this enables a fully interoperable data environment in which all components operate on a shared semantic foundation, supporting coherent analysis, synchronised visualisation, and reliable decision-making.

7. Sectoral Model Implementations

Building on the architectural principles presented in Chapter 4, the ecosystem configuration workflow described in Chapter 5, and the semantic data harmonisation through the Common Information Model (CIM) in Chapter 6, this chapter focuses on the implementation of sectoral analytical models within the DT-aCoGo ecosystem.

The primary objective of this chapter is to demonstrate how different domain-specific models—covering water management, traffic, and heat stress—are integrated into a unified digital twin environment through the use of CIM-based data services and standardised interfaces. While each model operates with its own logic, data requirements, and computational methods, the use of the CIM ensures that all models are fed with consistent, harmonised input data, enabling cross-domain coherence and comparability of results.

The following sections provide an overview of the domain models implemented within the DT-aCoGo ecosystem, detailing how each model consumes harmonised data, which datasets and formats are used, and how the resulting analytical services are published and integrated within the broader digital twin framework.

7.1 Overview of domain models

Building on the interoperability architecture (Chapter 4), the ecosystem configuration workflow (Chapter 5), and the semantic data harmonisation through the CIM (Chapter 6), the DT-aCoGo ecosystem integrates multiple sectoral analytical models into a unified digital twin environment.

Within this framework, three primary analytical domains are implemented: water management, traffic modelling, and heat stress analysis. Each domain is represented by a dedicated model provider—Rana, DatMobility, and Tygron respectively. Despite their differences in modelling approaches, input requirements, and internal data structures, all models are integrated through the same architecture by consuming CIM-based data services provided via the OUP.

A key principle within this integration is that all models operate on the same harmonised datasets, ensuring consistency across domains. The current situation is derived from municipal asset management datasets, while future scenarios are based on BIM design data. Both datasets are aligned through the CIM and enriched with temporal attributes, allowing them to be filtered and combined using the timeslider logic. This ensures that all models operate on a consistent representation of reality at any given moment in time

The outputs of the analytical models are exposed as reusable services within the OUP, typically in the form of OGC-compliant APIs, including OGC API Processes. These services can be consumed by other applications, including the Unreal Digital Twin, enabling further integration, visualisation, and cross-domain analysis.

7.2 Water management models – Rana

The Rana platform is used for water management and hydrodynamic simulations within the DT-aCoGo ecosystem. Its primary purpose is to simulate rainfall events, surface water flows, and flooding scenarios based on the spatial characteristics of the urban environment.

The Rana model consumes CIM-based data services from the OUP, which include:
- Terrain elevation models (e.g. digital terrain model – DTM)
- Surface characteristics (e.g. impermeable vs permeable surfaces)
- Building footprints and volumes
- Drainage infrastructure (where available)

These datasets are derived from municipal asset management systems and harmonised via the CIM, ensuring that all relevant spatial properties are consistently defined across cities.

For future scenarios, BIM datasets are included in the simulation, allowing changes in terrain, buildings, and infrastructure to be assessed. Through the lifecycle-based filtering approach, the model dynamically distinguishes between current and future objects.

Rana retrieves its input data via standardised APIs exposed through the OUP and executes simulations based on these inputs. The resulting outputs—such as water depth, flow velocity, and flood extents—are published as geospatial services (e.g. WMS or OGC API services) and registered in the OUP.

These outputs can subsequently be consumed by the Unreal Digital Twin for visualisation or by other analytical tools, ensuring that water-related insights are fully integrated into the ecosystem.

7.3 Traffic Models – DatMobility

The DatMobility platform provides traffic modelling and mobility analysis within the DT-aCoGo ecosystem. Its primary function is to simulate traffic flows, analyse network performance, and evaluate the impact of infrastructure changes.

DatMobility consumes CIM-aligned data services, including:
- Road network structures
- Traffic infrastructure (e.g. intersections, lanes, signals)
- Mobility demand data (based on statistic data about eg of the area)
- Land use and activity-related data

These datasets originate from municipal asset management systems and are harmonised via the CIM, ensuring consistency in network representation and classification across cities.

In addition to current datasets, BIM-based developments are incorporated to simulate future mobility scenarios. For example, new roads or building developments can be included in the model to analyse their impact on traffic flows. Temporal filtering ensures that simulations reflect the correct scenario (current or future).

DatMobility accesses its input data via APIs exposed through the OUP and performs simulations within its own modelling environment. The results—such as traffic intensity, congestion levels, and travel times—are then published as standardised services in the OUP.

These services are made available as reusable APIs, including OGC API Processes, allowing them to be invoked from external applications such as the Unreal Digital Twin. This enables dynamic integration of traffic simulations into the broader digital twin environment.

7.4 Heat Stress Models – Tygron

The Tygron platform is used for environmental and heat stress analysis within the DT-aCoGo ecosystem. It provides simulations of urban heat stress based on environmental conditions and spatial characteristics.

Tygron consumes CIM-based datasets from the OUP, including:
- Building geometries and heights
- Vegetation and green infrastructure
- Surface materials and land use
- Meteorological inputs (e.g. temperature, wind, radiation)

These datasets are derived from municipal asset data and harmonised via the CIM, ensuring consistent representation of environmental and spatial parameters.

For future scenarios, BIM models are incorporated to assess the impact of new developments on heat stress conditions. Using lifecycle-based filtering, the model determines which objects are included in the simulation for a given time context.

The Tygron platform is integrated via a proxy API, which simplifies interaction with the OUP and provides a standardised interface for data exchange. Simulations are executed based on CIM-aligned input data, and the results—such as heat stress indicators (e.g. PET values)—are published as geospatial datasets or API services.

As with other models, the results are registered in the OUP and exposed as reusable services, including OGC API Processes. This allows them to be directly integrated into the Unreal Digital Twin, where heat stress results can be visualised in combination with other domain outputs.

8. Reflection on Model Integration and Platform Development

Following the implementation of the sectoral models as described in Chapter 7, this chapter reflects on the integration process of the analytical platforms within the DT-aCoGo ecosystem. While the architectural design—based on the Open Urban Platform (OUP), the Common Information Model (CIM), and the Purple Polar Bear (PPB) semantic interoperability layer—provides a consistent framework, the practical implementation revealed notable differences between the model providers in terms of platform maturity, flexibility, and development approach.

Despite these differences, all platforms were successfully integrated into the ecosystem by aligning their data consumption with the CIM-based services and exposing their outputs via standardised interfaces. This demonstrates that the interoperability approach is robust and adaptable, even in environments where underlying systems differ significantly in design and lifecycle.

8.1 Differences in Platform Development and Flexibility

A key observation during the integration process is the variation in development stage and flexibility of the analytical platforms. These differences had a direct impact on the level of integration that could be achieved and the amount of customisation required.

The Rana platform represents a relatively new solution that has been fully developed within the organisation, building on more than 30 years of experience in hydrodynamic modelling. One of its primary development goals was to simplify the setup of calculation models for end users, including enhanced functionality for data processing. As a result, the platform proved highly adaptable within the DT-aCoGo ecosystem. Because of its relatively recent development and smaller installed base, it was possible to directly influence the direction of the platform during the integration process, allowing for tight alignment with the OUP and CIM-based workflow.

In contrast, the Tygron platform presented a different integration profile. The software is built around a core system that cannot be modified, combined with a flexible layer that allows for extensions and configuration. While this flexible layer enabled integration with the OUP in terms of data consumption and result publication, limitations within the core system prevented full integration of the model-building process. As a result, certain configurations and data preparation steps had to be carried out manually within the platform.

The DatMobility platform showed the least flexibility in terms of direct user-driven model configuration. The creation and configuration of analytical models within DatMobility is typically performed by specialised consultants rather than end users. In addition, as a well-established product with a larger installed base, there are stricter constraints on introducing custom developments. This limited the degree to which the platform could be adapted to fully align with the automated workflows envisioned in the DT-aCoGo ecosystem.

8.2 Integration Across Heterogeneous Platforms

Despite the differences in flexibility, maturity, and development lifecycle across the platforms, all three models were successfully integrated into the DT-aCoGo ecosystem. This was achieved by focusing on alignment at the data and service level, rather than attempting to enforce uniform behaviour at the application level.

The use of the CIM and PPB ensured that all platforms could consume harmonised data services, regardless of their internal data structures or configuration models. By standardising the input data and exposing outputs via OGC-compliant APIs, each platform could be connected to the OUP without requiring fundamental changes to its internal architecture.

In practice, this meant that integration complexity was shifted from the model platforms themselves to the semantic interoperability layer. This approach proved effective in enabling interoperability while respecting the constraints of each platform. It also reinforced the principle that interoperability should be achieved through data alignment and service standardisation, rather than through direct modification of existing systems.

8.3 Alignment of Integration Mechanisms and Future Work

An important aspect of achieving this interoperability was the alignment of integration mechanisms across the different platforms. In particular, the integration of access, identity, and model invocation mechanisms (AIM integration) required coordination between the OUP and the model providers. Ensuring that all platforms could securely access data services, execute models, and publish results in a consistent way was essential for establishing a fully operational ecosystem.

This alignment is further elaborated in Deliverable D3.5, where the integration approach is detailed in terms of authentication, API usage, and service orchestration. The results from the DT-aCoGo pilot demonstrate that, although platforms may differ significantly in their internal architecture and development lifecycle, a common interoperability framework based on standardised data models and service interfaces can effectively bridge these differences.

Looking forward, the experience gained from this integration process highlights the importance of early alignment between platform providers, particularly in defining data requirements, service interfaces, and integration patterns. It also emphasises the value of a flexible semantic layer, such as the PPB platform, in accommodating differences between systems and enabling scalable, cross-domain digital twin ecosystems.

9. Replicable Recipe for Ecosystem Configuration

Building on the ecosystem configuration approach described in Chapter 5, the DT-aCoGo project formalises this process into a Replicable Recipe for Ecosystem Configuration. This recipe translates the conceptual architecture—based on the Open Urban Platform (OUP), the Common Information Model (CIM), and the Purple Polar Bear (PPB) semantic interoperability layer—into a structured and repeatable workflow that can be applied across cities and use cases.

The objective of this recipe is to ensure that digital twin ecosystems can be deployed in a consistent, scalable, and interoperable manner. By defining a sequence of standardised configuration steps, the recipe enables municipalities, model providers, and platform operators to reproduce the integration of heterogeneous datasets, analytical models, and visualisation environments without requiring bespoke system integration for each new implementation.
[1](https://cmhelmons.sharepoint.com/contentstorage/x8FNO-xtskuCRX2_fMTHLZA4RuMPK-ZEqvrzyPYZPo0/Documentbibliotheek/CopilotNotebooks/f8cdb2cb-7c4c-4904-8fa0-c736ac960a37_nb/Recipe.page)

The recipe is organised as a series of interconnected phases, each addressing a specific aspect of the ecosystem configuration. The process starts with the establishment of OUP hubs, where each city operates within its own governed environment, ensuring data sovereignty and separation of contexts. Within these hubs, datasets are registered and made available through standardised interfaces, forming the basis for further integration. [2](https://cmhelmons-my.sharepoint.com/personal/cm_helmons_hci-infra_nl/Documents/Microsoft%20Copilot%20Chat%20Files/Copilot%20Notebook%20Uploads/Pilot_G_DT-aCoGo_Deliverable_D2.1_Revised_V2.pdf?web=1)

Subsequently, semantic harmonisation is performed through the PPB platform, where mappings are applied to transform city-specific datasets into the Common Information Model. This step is critical for resolving differences in data structures, terminology, and semantics across cities and domains. The resulting CIM-aligned datasets are then published back to the OUP as standardised data services, creating a uniform interface for all consuming applications.

The next phase focuses on the integration of analytical models. Model providers connect their platforms to the OUP and configure their models to consume CIM-based data services. Despite differences in platform architecture and maturity, as described in Chapter 8, all models can be integrated through this standardised data layer. Once configured, models execute their analyses and publish their outputs as reusable services, typically through OGC-compliant APIs such as OGC API Processes.

These outputs are subsequently integrated into visualisation environments, most notably the Unreal Digital Twin. By linking the Unreal environment to a specific OUP hub, the ecosystem ensures that data and analyses remain consistent within a given city context. This hub-based routing mechanism prevents the mixing of datasets across cities and guarantees the integrity of simulations and visualisations.

Finally, the ecosystem ensures synchronisation and validation across all components by applying lifecycle-based filtering. Through the use of temporal attributes such as “ValidFrom” and “ValidTo”, datasets representing current and future scenarios are aligned and filtered consistently across

analytical models and visualisation environments. This ensures that what is calculated and what is visualised always represent the same state of reality at a given moment in time.

By structuring the ecosystem configuration into this replicable recipe, the DT-aCoGo project demonstrates that interoperability is not only achievable but can be standardised and reused across different contexts. The recipe abstracts complexity away from individual platforms and shifts it to a controlled, well-defined integration workflow. This enables cities to deploy digital twin solutions more efficiently, reduces implementation effort, and supports the scalability of the ecosystem.

As such, the Replicable Recipe for Ecosystem Configuration forms a key outcome of the project, providing a practical methodology for implementing interoperable digital twin ecosystems within the DS4SSCC framework and beyond.

9.1 Detailed recipe

The DT-aCoGo ecosystem configuration can be described using a Replicable Recipe Format, defining a structured and repeatable approach for deploying a digital twin environment. This recipe enables other cities and stakeholders to reproduce the integration of data, analytical models, and visualisation tools using the Open Urban Platform (OUP), the Purple Polar Bear (PPB) semantic layer, and the Common Information Model (CIM).

Each step in the recipe corresponds to a logical configuration action within the ecosystem, ensuring interoperability, scalability, and consistency across domains. In table 1 an overview is given of the steps involved for configuring the ecosystem.

Step	Phase	Objective	Component
1	OUP Hub Configuration	Set up city-specific data environments	OUP
2	Data Registration	Register datasets and services (current + future)	OUP
3	Semantic Harmonisation	Map datasets to Common Information Model	PPB + CIM
4	Service Standardisation	Publish harmonised APIs and datasets	PPB → OUP
5	Model Integration	Configure analytical models	Models + OUP
6	Model Execution & Publishing	Execute models and publish results	Models + OUP
7	Visualisation Integration	Connect Unreal Digital Twin	Unreal + OUP
8	Synchronisation & Validation	Ensure alignment between analysis and visualisation	OUP + PPB + CIM

9.2 Detailed Recipe Steps

Step 1 – OUP Hub Configuration
Objective:
Establish a federated structure where each city operates within its own environment.

Description:

- Create an OUP hub per participating city (e.g. Den Bosch, Rotterdam, Tampere)
- Configure governance, access rights, and authentication
- Define data ownership and sharing policies

Key consideration:

- Den Bosch and Rotterdam: open data services
- Tampere: authenticated data services

Result:

- Separation of digital twin contexts per city
- Controlled data access aligned with local policies

Step 2 – Data Registration
Objective:
Make datasets available within the ecosystem.

Description:

- Register source datasets in the OUP hub
- Include:
- Current state data (e.g. 3D city, sensors)
- Future state data (BIM models)
- Add metadata and service descriptions

Result:

- Datasets discoverable and accessible within OUP

Step 3 – Semantic Harmonisation
Objective:
Align heterogeneous datasets into a shared structure.

Description:

- PPB retrieves datasets from OUP
- Apply mappings (see Mappingen.xlsx)
- Transform:
- Attributes
- Terminology
- Data structures
- Enrich with lifecycle attributes (ValidFrom / ValidTo)

Result:

- All datasets available in a Common Information Model (CIM) format

Step 4 – Service Standardisation
Objective:
Provide uniform access to data across all systems.

Description:

- PPB publishes harmonised datasets as standardised services
- Generate consistent APIs (e.g. OGC services)
- Register these services back into the OUP

Result:

- Uniform interface for all data consumers
- No dependency on native municipal APIs

Step 5 – Model Integration
Objective:
Enable analytical models to consume harmonised data.

Description:

- Connect model providers (Rana, DatMobility, Tygron) to OUP
- Configure:
- Input datasets from CIM-based services
- Model parameters (expert mode)
- Ensure compatibility with API-based workflows

Result:

- Analytical models operate on shared, harmonised datasets

Step 6 – Model Execution and Publishing
Objective:
Run simulations and make results reusable.

Description:

- Execute models using OUP data services
- Publish outputs:
- As APIs
- As map layers (e.g. WMS, GeoJSON)
- Register results in OUP

Result:

- Analytical outputs available as reusable services

Step 7 – Visualisation Integration (Unreal Digital Twin)
Objective:
Integrate analysis results into the digital twin environment.

Description:

- Configure Unreal Digital Twin to connect to a specific OUP hub
- Retrieve:
- Base datasets
- Model outputs
- Ensure hub-specific routing

Key principle:

- Each Unreal instance uses one OUP hub → one city context

Result:

- No cross-city mixing of data or model execution

Example: Den Bosch models only run on Den Bosch data

Step 8 – Synchronisation and Validation
Objective:
Ensure consistent behaviour across the ecosystem.

Description:

- Apply lifecycle filtering (ValidFrom / ValidTo)
- Align:
- Analytical models
- Visualisation
- Validate outputs in Unreal

Result:
Full synchronisation between:

- What is computed
- What is visualised

Recipe Outcome
Following this recipe results in a fully operational digital twin ecosystem in which:
- Data from different cities is harmonised and reusable
- Analytical models operate on a shared semantic foundation
- Visualisation and analysis are fully synchronised
- City-specific contexts remain separated through OUP hubs
- The system can be scaled and replicated across new cities and domains

This Replicable Recipe Format provides a structured approach for deploying interoperable digital twin ecosystems within the DS4SSCC framework and beyond.

10. Conclusions

The DT-aCoGo project demonstrates that interoperability within digital twin ecosystems can be effectively achieved by combining a robust architectural foundation with a practical implementation approach. Central to this is the use of a Common Information Model (CIM), which provides a shared semantic layer for aligning heterogeneous datasets across cities and domains. By introducing the Purple Polar Bear (PPB) platform as a semantic interoperability layer, differences between local data structures, terminology, and service capabilities are resolved without requiring changes to the source systems.

The integration approach, based on standardised API-based data services within the Open Urban Platform (OUP), enables analytical models to consume harmonised datasets and expose their results in a reusable manner. This allows different sectoral models—such as water, traffic, and heat stress—to operate on a shared data foundation while maintaining their own internal logic and modelling approaches.

A key outcome of this approach is the ability to maintain coherence between analytical results and visualisation environments. By aligning current and future datasets through the CIM and enabling lifecycle-based filtering using temporal attributes, the ecosystem ensures that both analysis and visualisation operate on a consistent representation of reality. This is essential for building trust in the digital twin and enabling its use in operational decision-making processes.

Despite differences in platform maturity, flexibility, and integration capabilities among the model providers, the DT-aCoGo ecosystem successfully demonstrated that these can be overcome through data-level interoperability and service standardisation. By shifting the complexity to the semantic layer and maintaining a consistent integration framework, the ecosystem supports scalable and reusable digital twin implementations across cities and domains.

11. Recommendations

Based on the findings and experiences from the DT-aCoGo project, several recommendations can be made to further strengthen the interoperability and scalability of digital twin ecosystems.

First, further standardisation and formalisation of the Common Information Model (CIM) is essential. While the current implementation has proven effective, expanding and refining the CIM to cover additional domains and use cases will improve reuse and simplify onboarding of new cities and model providers.

Second, improvements to mapping and transformation tooling are recommended. Although the PPB platform provides a powerful semantic interoperability layer, the configuration and maintenance of mappings remain a complex process. Enhanced tooling, including better visualisation, validation, and automation of mappings, would reduce implementation effort and improve consistency across deployments.

Third, stronger support for temporal data management should be further developed. The use of lifecycle attributes and time-based filtering has proven to be a key enabler for aligning current and future scenarios. Expanding these capabilities—such as supporting more advanced temporal queries and scenario management—would further enhance the analytical capabilities of the ecosystem and improve decision support.

Finally, clearer and more standardised integration guidelines for model providers are recommended. As observed during the project, differences in platform maturity and flexibility can impact the ease of integration. Providing clear guidelines on data requirements, API standards, authentication mechanisms, and expected integration patterns will lower the barrier for onboarding new platforms and ensure more consistent implementations across the ecosystem.

Together, these recommendations support the continued development of a scalable, interoperable, and trustworthy digital twin ecosystem, capable of supporting municipalities in both operational and strategic decision-making processes.

11. Annexes

A1 CIM mappings
A2 DatMobility API description
A3 Rana API description
A4 Tygron API description

About the European Data Space for Smart Communities

The European Data Space for Smart Communities (DS4SSCC-DEP) initiative is a pivotal deployment following the preparatory action for a Data Space for Sustainable and Smart Cities and Communities (DS4SSCC). Emphasising sustainability aspects and diversity in communities, DS4SSCC developed a multi-stakeholder data governance scheme, created a blueprint for the European DS4SSCC, delivered priority datasets, and developed a roadmap towards a mature DS4SSCC.

DS4SSCC-DEP's vision revolves around creating a well-governed federated territorial, place-based data space for smart communities available for developers and infrastructure providers, aligning with the prospects outlined in Europe's Digital Decade objectives. This approach distinguishes itself from sectoral data spaces by encompassing diverse domains, and underpinning governance across all levels of society. The key objectives of the project are:

- **Objective 1: Establishing a Federated and Innovative Data Space**. This phase focuses on creating a large-scale data space controlled by public data holders, ensuring alignment with the Smart Middleware Platform and broader data space ecosystems. It also aims to offer middleware service solutions facilitating data sharing and management while refining the blueprint based on gained experience.
- **Objective 2: Pilots and Refinement of the Data Space Blueprint**. Through 10-12 cross-sectoral data pilots in various EU communities, this objective aims to validate and refine the data space blueprint. Using common high-value datasets, it seeks to create added value by combining data from various domains, contributing to the sustainability plan, and minimising infrastructure investment.
- **Objective 3: Fostering Innovation and Ecosystem Alignment**. Engaging stakeholders, compliance with sector-specific legislation, establishing links with Horizon Europe missions, creating services available via trusted application catalogues, and enhancing ethical considerations and AI-enabled local solutions constitute the focus of this objective.

DS4SSCC-DEP, building upon established European networks, aims to significantly contribute to the sustainability goals of European citizens. It emphasises co-creation, standardisation, business models, strategies for data spaces, and envisions a federated platform.

DS4SSCC-DEP consortium includes the following partners: