European data space
for smart communities

Deliverable 2.2 revised

DS4SSCC Deliverable 2.2 Timelapse viewing slider

WP 2 – Set-up 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 and implementation approach for a timelapse viewing slider within the DT-aCoGo digital twin, as part of the DS4SSCC initiative.

The purpose of the timelapse functionality is to enable users to explore urban environments across different moments in time, supporting both visualisation and analytical use cases. This is particularly relevant in the context of urban development, where existing city data and future design proposals inherently overlap.

The core design principle of the solution is to treat time not as a visual feature, but as an integral property of the data. This is realised by enriching datasets with lifecycle attributes (ValidFrom, ValidTo), allowing applications to filter objects consistently based on a selected moment in time.

A key enabler for this approach is the integration of Purple Polar Bear (PPB) as a common model layer within the Open Urban Platform (OUP). PPB ensures that:

- datasets from different cities are harmonised and semantically aligned,
- lifecycle attributes are consistently applied during data preparation, and
- standardised data services are delivered to both visualisation and analytical applications.

Temporal filtering itself is implemented within the applications, using a shared and simple rule based on lifecycle attributes. This distributed approach ensures consistency between what users see and what is computed, while maintaining a clear separation between data and applications.

The proposed solution avoids destructive data manipulation and instead supports non-destructive, project-based enrichment of datasets. This enables flexible handling of multiple overlapping development scenarios and supports scalable use across cities such as Rotterdam, ’s-Hertogenbosch and Tampere.

In addition to its implementation within the project, this approach contributes to the further development of open standards. The lifecycle-based timelapse concept will be brought forward within the Open Geospatial Consortium (OGC), specifically in relation to the evolution of 3D Tiles towards version 2.0, aligning temporal capabilities in 3D data with those already available in WFS and OGC APIs.

In conclusion, the approach provides a robust, scalable and interoperable foundation for time-aware digital twins, supporting consistent data-driven decision-making and enabling reuse across applications, domains and cities.

2. Introduction

Deliverable 2.2 is developed within the European Data Space for Smart Communities (DS4SSCC) project, as part of Pilot G: Digital Twin as a Common Good (DT-aCoGo). The pilot explores how digital twins can be used as shared urban infrastructures to support spatial planning, policy evaluation and cross-domain analysis.
Within the DT-aCoGo architecture, a strict separation is maintained between data services (e.g. WFS, GeoJSON and 3D Tiles), analysis platforms and visualisation clients. The functionality described in this deliverable must therefore operate consistently across all layers of the architecture.

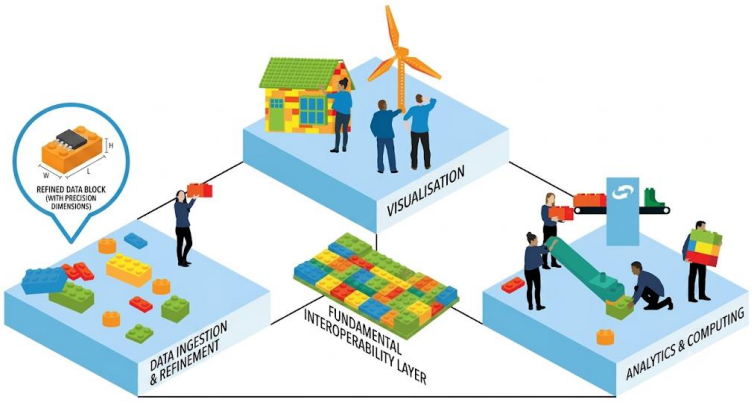


Figure 1: Schematic architecture DT-aCoGo

The Digital Twin in this pilot is composed of three primary data sources:

- 3D Tiles representing the existing situation
- BIM models representing future developments
- WFS / GEOJSON api's for analyses

In the context of area development, these datasets inherently overlap, as new developments are projected onto locations where existing buildings and infrastructure are still present. This creates a fundamental need for filtering mechanisms that allow the system to distinguish between current and future states.
A key requirement is that this filtering approach is not only applied at the visualisation level, but is equally applicable to the data used as input for analytical models, such as datasets provided via WFS or GeoJSON. Without a consistent approach across both visualisation and analysis, discrepancies arise between what users see and what is computed.
Furthermore, to ensure scalability and reuse across the DS4SSCC ecosystem, it is necessary to align underlying datasets in terms of data models, semantics and terminology. This enables data from different cities—such as Rotterdam, 's-Hertogenbosch and Tampere—to be used interchangeably as input for generic analysis and visualisation solutions.
The timelapse viewing slider presented in this deliverable addresses these challenges by introducing a time-based filtering mechanism that operates consistently across data services, analysis environments and visualisation tools, thereby supporting both local use cases and scalable cross-city applications.

3. Problem Definition

Current urban data services primarily describe the present situation. When future developments are introduced—typically through BIM models or design proposals—these are visualised alongside existing datasets. This leads to overlapping representations of buildings and public space in both 2D and 3D views.

For end users such as urban planners, policy makers and analysts, this has several consequences:

- Loss of visual clarity, making it difficult to interpret future scenarios;
- Incorrect analytical results, as simulations may process both existing and planned geometries simultaneously;
- Limited decision support, because users cannot explore how the city evolves over time.

Without a time-aware mechanism such as a timelapse slider, digital twins remain static snapshots and cannot fulfil their role as decision-support instruments for long-term urban planning.
The timelapse viewing slider enables users to:

- explore alternative futures,
- compare current and planned situations,
- and run analyses that are consistent with the selected point in time.

4. Investigated Methodologies

4.1 Introduction

To enable a timelapse viewing slider within the DT-aCoGo digital twin, several solution strategies were analysed. The objective was not only to support visualisation of time-dependent urban scenarios, but also to ensure consistency with analytical models and scalability across multiple cities.

A critical requirement is that the selected solution must operate consistently across:

- Visualisation environments (e.g. CesiumJS, Unreal Engine)
- Analytical data services (e.g. WFS, GeoJSON)
- Underlying data infrastructures

This section presents the analysed approaches, followed by the rationale for the selected design.

4.2 Solution Categories

Three main categories of solutions were identified:

1. Client-side visual filtering (visual layer)
2. Destructive data modification (data layer)
3. Lifecycle-based filtering (non-destructive data layer)

4.2.1 Client-Side Visual Filtering

This approach uses techniques such as clipping planes or bounding volumes in the visualisation client to hide existing objects where future developments are introduced.

Advantages:

- Fast to implement
- No changes required to underlying datasets
- Suitable for prototyping

Limitations:

- Only affects visualisation; underlying data remains unchanged
- Analytical services (e.g. WFS) still return outdated objects
- Leads to inconsistencies between visualisation and analysis
- Limited scalability for multiple projects and timelines

Assessment: This approach does not meet the requirement for consistent behaviour across visualisation and analytical environments.

4.2.2 Destructive Data Modification

This approach involves physically modifying datasets by removing or altering existing objects using tools such as FME or PostGIS.

Advantages:

- High geometric precision
- Consistent outputs across services

Limitations:

- Computationally expensive (re-tiling required)
- Loss of historical data (no “time travel”)
- Difficult to maintain for multiple concurrent scenarios
- Not flexible when project timelines change

Assessment: While technically robust, this approach conflicts with the need for flexibility, scalability and temporal analysis.

4.2.3 Lifecycle-Based Filtering (Recommended)

This approach introduces temporal attributes (e.g. **ValidFrom / ValidTo**) to objects, allowing filtering based on time without altering geometry.

Advantages:

- Non-destructive: original data remains intact
- Enables true temporal navigation (“time travel”)
- Consistent across visualisation and analysis
- Scales to multiple overlapping projects
- Supports dynamic updates when planning changes

Limitations:

- Requires extension of data models and pipelines
- Requires alignment across datasets and cities

Assessment: This approach is the only solution that meets all functional and architectural requirements.

4.3 Design Decision

Based on the analysis, the lifecycle-based filtering approach was selected as the foundation for the timelapse viewing slider.
The core design principle is:

Temporal logic is applied at the data-service level, not in the visualisation layer.

This ensures:

- A single source of truth
- Consistent interpretation across all applications
- Reuse of the same logic in visualisation and analytics

5. Architectural Integration

The integration of the timelapse functionality within the DT-aCoGo architecture is realised through collaboration with Purple Polar Bear (PPB) as a common model layer, in combination with the Open Urban Platform (OUP).

As illustrated in Figure 2, cities such as Rotterdam, 's-Hertogenbosch and Tampere publish their datasets and scenarios via OUP. These datasets include both existing conditions (e.g. 3D Tiles) and future developments (e.g. BIM-based models), which inherently overlap in the context of urban development.

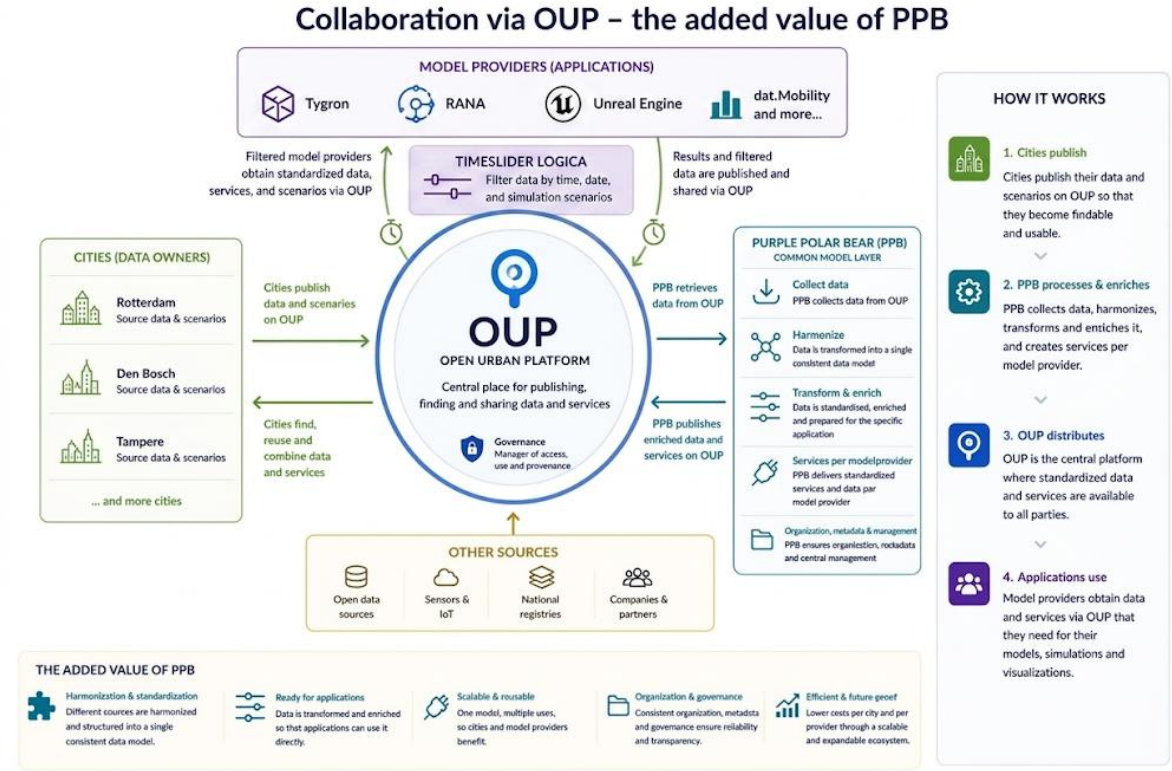


Figure 2: Integration of PPB as a solution

The PPB platform acts as an intermediate layer that:

- collects data from OUP,
- harmonises data models and semantics into a consistent structure, and
- enriches the datasets for use in applications.

This integration fulfils two essential architectural requirements.

5.1 Semantic alignment and interoperability

First, PPB ensures semantic alignment across cities and applications. By transforming heterogeneous datasets into a shared and standardised information model, it enables:

- consistent interpretation of data across different platforms,
- reuse of analytical models and visualisation components,
- interoperability between datasets from multiple cities.

This is a critical enabler for the DS4SSCC objective of a federated and scalable data space, where data from different sources can be used interchangeably without requiring application-specific adaptations.

5.2 Integration of lifecycle attributes

Second, the PPB layer provides the mechanism to introduce and manage lifecycle attributes within the data services.
During the transformation and enrichment process, attributes such as:

- ValidFrom
- ValidTo

can be added or normalised across datasets. As a result both 3D Tiles services (for visualisation), and WFS / GeoJSON services (for analytical use) expose consistent temporal metadata.

This ensures that all consuming applications operate on the same temporal structure, regardless of their specific implementation or technology stack.

5.3 Distributed filtering in applications

In line with the overall architecture, temporal filtering is not implemented as a central system component, but is instead realised within each consuming application.

Model providers and applications (e.g. visualisation engines such as Unreal Engine, or analytical tools) retrieve standardised and enriched datasets via OUP and PPB. Each application implements a generic filtering mechanism based on:

- the shared lifecycle attributes (ValidFrom, ValidTo), and
- a user-controlled time parameter (e.g. the timeslider).

This distributed approach ensures that:

- the same filtering logic is applied consistently across all applications,
- visualisation and analysis are always aligned,
- and no discrepancies arise between what is shown and what is computed.

The timeslider itself does not directly manipulate the underlying data, but provides a common input parameter that is interpreted by each application using the same rules.

5.4 Architectural benefits

By combining OUP and PPB with distributed filtering logic, the solution achieves:

- **Consistency**
  A shared data model and lifecycle attributes ensure alignment between visualisation and analytics.
- **Scalability**
  New cities and datasets can be integrated without changes to application logic.
- **Flexibility**
  Applications remain loosely coupled and independently implemented.
- **Reusability**
  Generic analysis and visualisation components can be applied across multiple cities.

The integration of Purple Polar Bear as a common model layer provides a robust foundation for implementing temporal functionality within the DS4SSCC architecture.

By combining semantic harmonisation with lifecycle attribute enrichment, and applying filtering logic consistently at the application level, the architecture enables a scalable and interoperable implementation of the timelapse viewing slider, without compromising the modular and federated nature of the system.

6. Data Preparation using Purple Polar Bear (PPB)

6.1 Introduction

To enable time-based functionality in the digital twin, datasets must be enriched with lifecycle information before they are consumed by applications. This preparation is carried out within the Purple Polar Bear (PPB) platform, which transforms source data into a harmonised and enriched Common Model.
Within this process, PPB converts heterogeneous city datasets into standardised data services that can be used directly by visualisation and analytical applications.

6.2 Lifecycle Enrichment Process

The preparation of datasets for the time slider is based on non-destructive enrichment of existing data. Rather than modifying or replacing base datasets, PPB adds lifecycle attributes that describe how objects evolve over time.

For each defined project area, the following minimal transformations are applied:
Unchanged objects
Objects that remain part of the urban environment are not modified. Their geometry and attributes remain intact.
Objects to be removed
Objects that cease to exist in future scenarios are assigned a ValidTo attribute, indicating until when they are valid.
New objects
Objects that are introduced in future developments are assigned a ValidFrom attribute, indicating from when they become valid.

This approach ensures that all relevant changes are captured through attributes, without requiring duplication or restructuring of datasets.

The lifecycle attributes are incorporated into the Common Model managed by PPB, where datasets from different sources are already harmonised into a consistent structure.
As part of the transformation process:

- source data is standardised into a uniform schema,
- lifecycle attributes are added in a consistent format,
- enriched datasets are published as reusable data services (e.g. 3D Tiles, WFS, GeoJSON).

This ensures that all downstream consumers work with datasets that share the same structure and temporal properties.

Lifecycle enrichment is applied selectively, based on the spatial scope of development projects.
This means that:

- only objects within a project area are enriched with lifecycle attributes,
- the remainder of the dataset remains unchanged,
- multiple project areas can coexist within the same dataset.

This approach supports incremental updates and avoids unnecessary processing of the full city model, see figure 3 for an conceptual example of a project area.

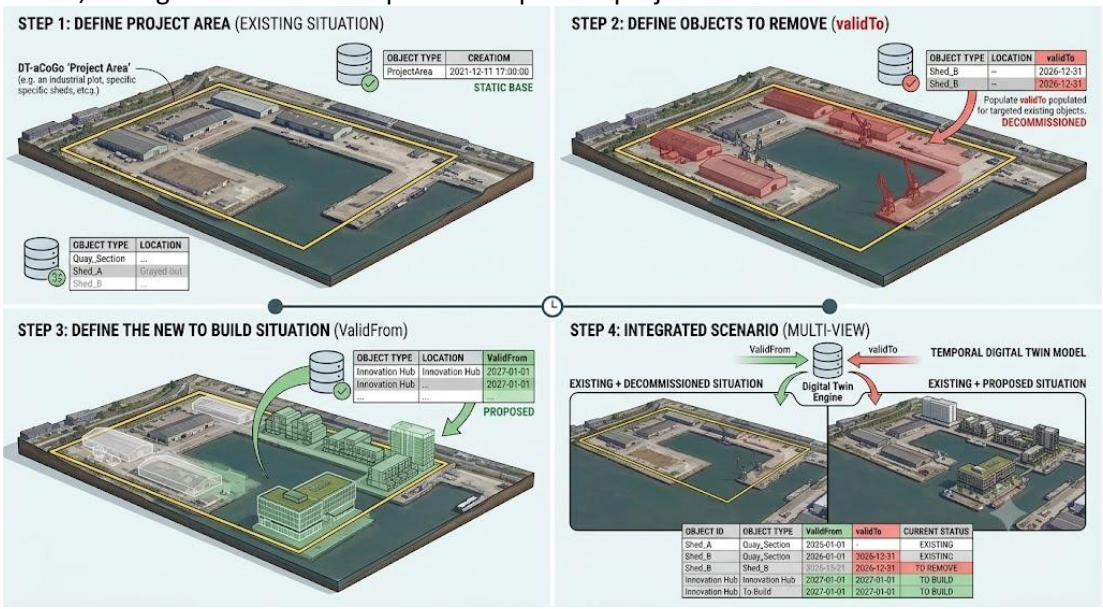


Figure 3Creating a timeslider scenario

6.3 Towards Scalable Dataset Management

The current workflow prepares datasets through project-specific transformations within PPB. To further improve scalability, future development will focus on supporting this process through a dedicated mutation application.

This application will enable:

- managing multiple development projects in parallel,
- defining lifecycle changes more efficiently,
- automatically generating enriched datasets based on project inputs.

This will allow city-scale datasets to be updated in a more efficient and maintainable way as development scenarios evolve.

6.4 Conclusion

By enriching datasets with lifecycle attributes within the PPB platform, the solution enables consistent time-based interpretation of urban data without altering the underlying datasets. This preparation step forms the foundation for applying generic filtering mechanisms in both visualisation and analytical applications.

7. Unreal Engine Timeslider concept

7.1 Introduction

Within the DT-aCoGo architecture, Unreal Engine acts as one of the visualisation environments consuming standardised datasets via the Open Urban Platform (OUP), enriched through the Purple Polar Bear (PPB) common model layer.

The implementation of the timeslider in Unreal Engine follows the general architectural principle described in Chapter 5:
Temporal filtering is implemented within the application itself, using shared lifecycle attributes (ValidFrom, ValidTo).

This ensures that Unreal Engine visualisations remain fully consistent with analytical applications and other model providers.

7.2 Conceptual Approach

The Unreal Engine timeslider does not directly modify datasets or geometry. Instead, it functions as a user interface control that provides a time parameter.
This time parameter is used within the Unreal application to evaluate which objects should be visible at a given moment.
Each object in the scene (e.g. buildings, infrastructure elements) contains lifecycle attributes:

ValidFrom: the moment the object becomes active
ValidTo: the moment the object is removed or replaced

The visibility of objects is determined by applying a simple and consistent rule:

An object is visible if:
ValidFrom ≤ selected_time < ValidTo

7.3 Data Integration in Unreal Engine

Datasets consumed by Unreal Engine (e.g. 3D Tiles streams or imported assets) already contain lifecycle attributes as part of the PPB enrichment process.

Within Unreal, these attributes are:

- stored as metadata per object (e.g. per building or mesh instance),
- accessible through the data structures used for rendering (e.g. metadata tables or object properties).

This allows Unreal Engine to evaluate temporal conditions without modifying geometry or requiring additional preprocessing.

7.4 Filtering Logic in the Visualisation Pipeline

The filtering logic is implemented in the Unreal visualisation pipeline as a runtime evaluation step. Conceptually, this works as follows:

1. The timeslider provides a selected time value
2. For each object in the scene:
    a. The lifecycle attributes (ValidFrom, ValidTo) are retrieved
    b. The temporal condition is evaluated
3. Based on the result:
    a. The object is either rendered (visible)
    b. or hidden / excluded from rendering

This filtering can be applied:

- at object level (entire building),
- or at finer granularity (if supported by the data structure).

7.5 Implementation Options in Unreal

Depending on the technical setup (e.g. Cesium for Unreal or custom pipelines), the filtering logic can be implemented in different ways:

A. Material-Based Filtering

- Lifecycle attributes passed to materials
- Visibility controlled via opacity or masking

B. Object Visibility Control

- Objects explicitly shown/hidden based on evaluation
- Most straightforward and efficient for discrete objects

C. Metadata-Informed Rendering (Preferred)

- Use metadata (e.g. from 3D Tiles Batch Table) directly
- Apply filtering before or during rendering
- Avoid unnecessary draw calls

The preferred approach depends on dataset size and performance requirements, but all approaches rely on the same underlying logic.

7.6 Relation to Timeslider Interaction

The timeslider acts as the central user interaction mechanism.
When the user adjusts the slider:

- The selected time value is updated
- The filtering logic is re-evaluated for all relevant objects
- The scene updates dynamically to reflect the chosen moment in time

This enables users to:

- explore current and future scenarios,
- understand phasing of developments,
- visually compare different time states.

7.7 Consistency with Analytical Applications

A key requirement of the DT-aCoGo architecture is that visualisation and analysis produce consistent results.

By using:

- the same lifecycle attributes
- and the same filtering rule

Unreal Engine ensures that:

- the visual representation matches analytical outputs,
- no discrepancies occur between what is shown and what is calculated.

This is essential for trustworthy decision support.

7.8 Scalability and Multi-City Use

Because lifecycle attributes are harmonised via PPB, the Unreal implementation does not depend on city-specific data structures.
This means that the same timeslider logic can be reused across the cities of Rotterdam, ’s-Hertogenbosch and Tampere. While no custom logic per dataset is required.

This supports scalable deployment across the DS4SSCC ecosystem.

7.9 Conclusion

The Unreal Engine timeslider is implemented as a lightweight, application-level filtering mechanism driven by lifecycle attributes.
By combining:

- a simple temporal rule,
- semantically aligned data via PPB,
- and a consistent interaction model,

the solution enables intuitive exploration of urban change over time, while remaining fully aligned with the broader architecture and design principles of the project.

8. Conclusion and next steps

This deliverable presents a coherent approach for enabling time-based functionality in urban digital twins through the implementation of a timelapse viewing slider.
The central design choice is to introduce lifecycle-based semantics into the data, rather than relying on application-specific or visual-only solutions. By enriching datasets with ValidFrom and ValidTo attributes, temporal behaviour can be interpreted consistently across both visualisation and analytical applications.
A key enabler for this approach is the integration of Purple Polar Bear (PPB) as a common model layer within the Open Urban Platform (OUP). PPB ensures that:

- datasets from different cities are harmonised and semantically aligned,
- lifecycle attributes are consistently integrated into data services, and
- standardised outputs can be distributed to multiple applications without additional transformation.

This combination of centralised semantic alignment (via PPB) and distributed filtering (in applications) allows the solution to:

- maintain a clear separation between data and applications,
- ensure consistency between visualisation and analysis,
- and support scalable reuse across multiple cities and use cases.

The approach explicitly avoids destructive data manipulation, enabling flexible handling of overlapping development scenarios and preserving the integrity of the underlying datasets.
Looking further then the scope of DT-aCoGo, future development will focus on improving the operational scalability of this workflow. In particular, the introduction of a mutation application will make it possible to:

- manage multiple development projects more efficiently,
- apply lifecycle changes in a structured manner, and
- maintain up-to-date city-wide datasets as projects evolve over time.

By combining semantic harmonisation, lifecycle enrichment and generic application-level filtering, the solution provides a robust and extensible foundation for exploring urban development scenarios over time, fully aligned with the objectives of the DS4SSCC initiative.

9. Appendix — Notes on Standards & Interoperability

An important outcome of this work is that the proposed approach is not only applied within the project context, but is also intended to contribute to the further development of open standards. The lifecycle-based timelapse functionality will be brought forward within the Open Geospatial Consortium (OGC), specifically in relation to the evolution of the 3D Tiles specification towards version 2.0.

While temporal attributes and filtering mechanisms are already supported in standards such as:

- OGC Web Feature Service (WFS), and
- emerging OGC API standards,

equivalent functionality is not yet uniformly embedded in 3D Tiles in a way that ensures full interoperability across platforms.

By proposing the integration of lifecycle semantics (ValidFrom, ValidTo) into the 3D Tiles ecosystem, this work contributes to:

- aligning 3D visualisation standards with existing OGC temporal capabilities,
- enabling application-independent time filtering,
- supporting consistent behaviour across 2D and 3D data services,
- and promoting standardised, reusable implementations across different engines and platforms.

This step is essential to ensure that time-based functionality in digital twins becomes a standard capability, rather than a project-specific custom solution.

10. Retrospective

The challenge was not limited to visualizing differences between current and future states. Integrating future plans into analytical platforms required a solution at the data-service level, not just in the viewer. Our architecture enforces a strict separation between data services, analytics platforms, and visualization layers. Therefore, differentiation between current and future situations must occur within the data services, so that all connected systems can filter consistently.

A uniform methodology for both 2D and 3D services is essential. While WFS manipulation options are already available, adapting 3D Tiles services proved more complex. As we scale to multiple projects across the city, flexibility in handling object start and end dates becomes critical because project timelines frequently change. Limiting the time slider to fixed scenarios (e.g., Current, 2030, 2040) is insufficient for long-term needs. Future solutions must support dynamic temporal filtering to accommodate evolving schedules and maintain analytical accuracy.

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: