Advancing National Spatial Data Infrastructure for Sustained Digital Twin

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Key words: Digital Twin, SDI, 3D modelling, spatial analytics

SUMMARY

This paper aims to describe the collaborative research efforts in designing a modern framework for a national spatial data infrastructure as the basis for a modern geospatial digital twin. Motivation of the work stems from recent advancements in remote sensing technologies and available nationwide datasets, as well as advancements in 3D topographic modelling. The approach is based on upgrading of current national geospatial datasets and programs, including cyclical Photogrammetric and LiDAR data collection campaigns done by the National Surveying and Mapping Authority of the Republic of Slovenia (GURS), by developing a systematic and automated production pipeline of 3D topographic mapping that can serve as the backbone of a modern 3D geospatial digital twin environment. Procedures for establishing such a modelling pipeline are explained in detail. Furthermore, the research work expands upon the critical aspects of geoprocessing, real-time data integration, simulation, visualisation and data distribution functionalities as core components of digital twin architecture. These functionalities are based on the topographic system's modelled environment and explore their core features required for downstream applications. The paper presents fundamental concepts by explaining the technological aspects and data architecture that enable the development of a national digital twin. The methodology of a national topographic 3D modelling based on cyclical nationwide remote sensing data is presented in detail. It outlines core features of such approach which includes automated production pipeline, data homogeneity, CityGML standard compatibility, approaches to dataset updates for sustained up-to-date representation and management of spatio-temporal dynamics. Furthermore, main digital twin functional components for downstream applications and user interactions are presented, foreseen as the most relevant for development of a national geospatial digital twin for Slovenia.

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1 INTRODUCTION

Geospatial information has become a core component of modern digital infrastructures. Among other functions, it enables integration of diverse datasets that contain spatial dimensions or location-based properties. The value of such information for informed spatial decision-making, both strategic and operational, has been widely recognised, given that many societal, environmental, political, and economic decisions are directly or indirectly linked to spatial information. Over the past decades, many countries have invested heavily in the development of national geospatial information infrastructures. In many countries, this infrastructure now constitutes a key element of digital transformation across various sectors, including e-government, e-services, and e-business (UN-GGIM, 2023). This commitment is also evident in international frameworks such as the European INSPIRE Directive, which emphasises the importance of interoperable and accessible spatial data. With growing expectations for spatial intelligence, digital infrastructures increasingly demand high-quality three-dimensional (3D) and dynamic (4D) representations of the natural and built environment. These are not only required to visualise complex spatial structures but also to support advanced spatial analytics capable of monitoring, modelling, and simulating spatial processes in real time. Real-time, data-driven spatial analytics is becoming particularly relevant in addressing challenges related to environmental change and climate adaptation, infrastructure management, and urban development all of which are linked to several UN Sustainable Development Goals.

The concept of the geospatial digital twin is emerging as a key paradigm to meet these demands. It can be understood as an enriched, dynamic digital replica of a physical environment that can represent past, present, and simulate potential future states. It aims to support spatial decision-making, scenario simulation, and location-based services (Ellul et al., 2022, Ellul et al., 2024). Although the broader idea of a digital twin is well established, particularly in engineering and manufacturing, its application in the geospatial domain raises conceptual, technical, and governance challenges. Since 2016, the term has been used more frequently in geoinformatics literature, often in the context of smart cities (Hämäläinen, 2020), yet both conceptual clarity and practical implementation remain major challenges (Jeddoub et al., 2023). International discussions and literature reviews highlight a lack of unified understanding of what a geospatial digital twin represents, what functional capabilities it should provide, and how it should integrate with existing national spatial data infrastructures (Metcalfe et al., 2024; Stoter et al. 2021).

Transferring the concept of digital twin to the geoinformation domain is difficult due to the complexity of modelling real-world environments across large spatial and temporal scales. Standardisation, therefore, represents a key factor for developing interoperable solutions. This is largely driven by the Open Geospatial Consortium (OGC), particularly through the CityGML standard, which provides a framework for complex 3D urban and landscape modelling (Kolbe et al., 2021). Recent work highlights the growing need for semantically rich models incorporating geometry, topology, and descriptive attributes (Biljecki et al., 2015), reflected in CityGML 3.0, which integrates temporal data and versioned states of the models. This represents an important step toward dynamic geospatial digital twins (Kutzner et al., 2020).

Importantly, geospatial digital twins are understood as more than detailed 3D spatial models. They typically integrate real-time sensor observations, live data infrastructures, and user-oriented interfaces for spatio-temporal analytics and simulation (Jeddoub et al., 2023). Current pilot projects demonstrate increasing adoption across built and natural environments, yet interoperability and integration across systems remain key drivers of research. This has led to a “system of systems” perspective, requiring ecosystem-level development for larger-scale implementations such as national digital twins (Ellul et al., 2024). Such integration requires addressing physical, cyber, and locational interdependencies as well as overlapping thematic and spatial scopes (Sharma et al., 2022). Persistent challenges include real-time data management (Errami et al., 2023), data accessibility (Bill et al., 2022), governance, ethics, and security (Goodchild et al., 2022). Lei et al. (2023) published a comprehensive systematic literature review of urban geospatial digital twins. The papers were collected using the following keywords: 3D city model, digital twin, city information model, and smart city. Among the technological challenges, the reviewed papers primarily highlighted data quality, data standards, interoperability, data integration, data complexity, software, hardware, updating and version storage. Among the non-technological challenges, the reviewed articles primarily emphasised sensitivity, collaboration, ownership, reliability, participation, funding, human capacities, and understanding. The authors included internationally recognised experts in 3D geospatial modelling, who assessed the significance of these challenges for the development of geospatial digital twins. Among the technological challenges, the most prominent were interoperability, data connectivity/integration, data sources, and human capacities.

Considering the presented developments and challenges, there is a growing need to explore how a national geospatial digital twin can be designed, developed, and operationalised in a way that aligns it with state-of-the-art technologies and international best practices. This article responds to that need by presenting the outcomes of a research and development project focused on conceptualising a national geospatial digital twin for Slovenia.

2 NATIONAL DIGITAL TWIN INITIATIVES

Understanding the role and added value of geospatial digital twins is essential for modern national geospatial information infrastructure. Recent literature reports many pilot twins, typically targeting traffic management, logistics, energy, precision agriculture, and broader uses in smart cities, autonomous vehicles, and disaster management (Metcalfe et al., 2024). In mapping agencies, the driver is that traditional 2.5D topographic models no longer adequately support decision-making in complex built and natural environments. Countries are adopting advanced 3D, time-enabled data models for time-aware analysis, change detection, and simulation of past and future scenarios. At European level, workshops have explored geospatial modelling and national geospatial digital twins, notably those jointly organised by EuroSDR and AGILE, which underline the importance of social aspects in such twins (Bucher et al., 2023; Ellul et al., 2024). The Centre for Digital Built Britain (CDBB, 2026) defines a national geospatial digital twin as an ecosystem of connected digital twins, originally aimed at infrastructure management but now extended to the natural environment. A 2025 IGN France workshop reviewed the state of the art and key challenges (EuroSDR, 2025). National agencies focus on optimising 3D city and landscape models, yet pilots and operational national geospatial digital twins are emerging, with mapping agencies providing shared platforms for integration, analytics, and simulation.

3 3D SPATIO-TEMPORAL MODELLING IN SLOVENIA

In this chapter, we identify, present and analyse Slovenian national spatial data infrastructure (NSDI) components that are relevant in the context of geospatial digital twins. NSDI can be considered as a data backbone on top of which other components of digital twins can be developed. We look beyond NSDI and identify potentially useful datasets that can complement official nationwide datasets. Next, we focus on the current ongoing 3D building modelling initiative in Slovenia and finish with the analysis of approaches for long-term management and maintenance of the 3D building models.

3.1 Data sources

3.1.1 Official cadastral databases

The Real Estate Cadastre is a fundamental official register of the Republic of Slovenia, containing detailed information on parcels, buildings, and parts of buildings. Data collected or updated in recent decades generally reflects real-world conditions accurately and ensures higher precision of the records. However, challenges arise with older datasets, which were not surveyed using modern methods and may therefore be outdated, often deviating from the actual situation on the ground. Among building-related datasets, the most useful layer is the building footprint layer, which represents buildings with cadastral registration. Well-defined building footprints are an important source of information for the creation of 3D building models. The limitation is that only around 20 percent of buildings in Slovenia have a cadastral registration with new surveying data and floor plans, since the detailed building data have been introduced into the cadastre from 2000. While not directly useful for 3D modelling, it is crucial for the national digital twin to be integrated with the cadastral data, as it provides links to many connected datasets and therefore widens the scope of digital twin applicability.

3.1.2 Topographic database

The national topographic dataset in Slovenia provides both graphical and attribute-based information on topographic features. Geometric data acquisition was carried out primarily using

Cyclic Aerial Photography of Slovenia. Attribute information is interpreted from stereo pairs, while additional attributes are also integrated from other official registers and thematic sources. Topographic information is organised into eight thematic object domains: buildings (including houses, other structures, and installations), transport networks (roads, road surfaces, railways, and cableways), utilities and public services (e.g., power lines), hydrography, land cover, areas of special use, relief (contours and elevation points), and the state border. The systematic collection of digital data began in 2002. In 2015, the Surveying and Mapping Authority of the Republic of Slovenia introduced a new topographic model aligned with the INSPIRE Directive, enhancing interoperability and harmonisation with European spatial data infrastructure standards. Nationwide data capture was completed in 2021, covering the entire territory of Slovenia. From 2022 onwards, the dataset entered a phase of systematic maintenance. The usability of the national topographic dataset is highest in areas that have been captured or updated in recent years, as these records more accurately reflect current real-world conditions. Most relevant thematic layers are buildings, transport networks, hydrography, and land cover, as these provide a reliable basis for spatial analysis and further processing workflows. In the context of building modelling, certain objects are particularly important (underground structures, and ruins) as these elements are often not detectable through automated extraction methods based on laser point clouds or orthophotos.

3.1.3 Aerial laser scanning

Aerial LiDAR (Light Detection and Ranging) data enable high-quality 3D spatial modelling by capturing dense and accurate point clouds that represent detailed geometries of buildings, infrastructure, and natural surfaces. In Slovenia, two cycles of nationwide data acquisition have been completed (Figure 1). The first was conducted from 2011 to 2015, and the second just recently (2023–2025) as part of a newly established CLSS (Cyclic Laser Scanning of Slovenia) program.

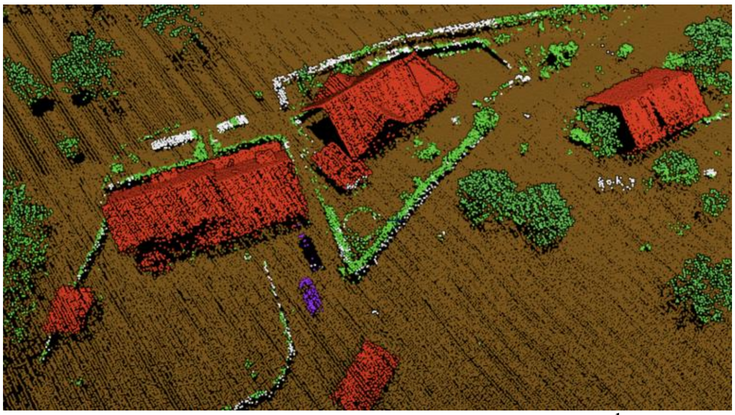

Figure 1: Slovenian nationwide classified point cloud (2^{nd} acquisition cycle)

The 1^{st} acquisition cycle was conducted at the point density of 5 points/m², while 2^{nd} acquisition cycle was conducted at the density of 10 points/m², which enables more detailed and efficient 3D modelling and realistic representations. State-of-the-art automated point cloud classification supports precise separation of object classes, improving both 3D modelling accuracy and analytical efficiency. For instance, correct roof classification greatly facilitates 3D roof reconstruction which represents a main process in 3D building modelling. Vegetation classification allows mapping of forest areas, individual trees, and biodiversity assessment. Automated detection is also effective for linear infrastructure (e.g. wires, poles), renewable energy installations (wind turbines, solar panels), and dynamic objects such as vehicles. Additionally, the laser return intensity attribute can support differentiation of material properties and surface reflectance. Overall, laser scanning point clouds are a central dataset for 3D spatial modelling, advanced analytics, and diverse applications within geospatial digital twins. LiDAR data can also be integrated with complementary sources such as mobile laser scanning and photogrammetric imagery. Such multi-source integration increases the usefulness of spatial digital twins by enabling more accurate and versatile digital representations.

3.1.4 Mobile laser scanning

Mobile laser scanning (MLS) enables the acquisition of very dense, high-resolution point clouds that serve as critical input for detailed 3D spatial modelling. MLS is particularly well-suited for capturing the geometry of low-level features such as road infrastructure, sidewalks, curbs, traffic signs, traffic lights, railway tracks, and other infrastructural elements that are often difficult to detect using aerial laser scanning (Figure 2). However, the resulting data volumes also create significant challenges for storage, management, and computational processing.

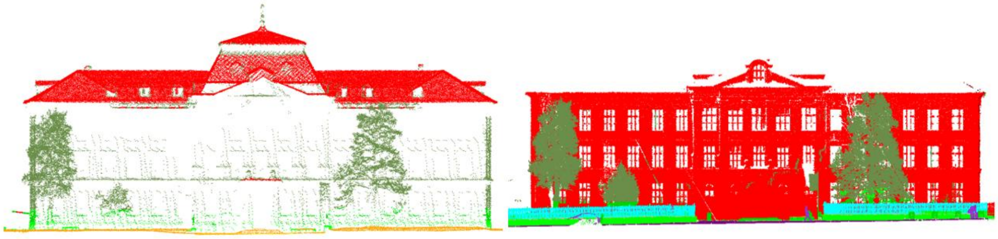

Figure 2: Comparison of aerial (left) and mobile (right) laser scanning point clouds.

In Slovenia, several MLS datasets exist, but they are generally not publicly accessible. They are most commonly commissioned by municipalities or infrastructure operators, primarily to update their road databases and to support detailed assessments of road damage. In addition, the entire Slovenian motorway network has also been captured using MLS for comprehensive monitoring of motorway infrastructure and overall asset management. Combining point clouds acquired through MLS and airborne scanning offers clear synergistic benefits. While airborne data effectively covers large areas and captures surfaces visible from above, MLS enriches the dataset with detailed ground-level information such as façades and curbs. This integrated approach improves the completeness and realism of 3D representations and strengthens their suitability for advanced applications within geospatial digital twins.

3.1.5 Aerial photogrammetric surveying

In Slovenia, the Cyclic Aerial Photography of Slovenia (CAS) was introduced in the 1970s and has been conducted in three-year cycles, with approximately one third of the national territory captured each year. The current CAS cycle (CAS2023–25) is nearing completion, and national coverage includes RGB orthophotos at 25 cm ground sampling distance (GSD), as well as NIR orthophotos at 50 cm GSD. Due to their spatial resolution and geometric quality, orthophoto products represent a core dataset for smart city development, urban planning, and environmental analysis. Orthophoto time series are particularly valuable for change detection and long-term spatial monitoring, while high-resolution georeferenced imagery increasingly supports automated extraction of roads, parking areas, and markings via machine-learning-based semantic segmentation and subsequent vectorisation. A major advancement for digital twin applications is the true orthophoto which is generated using a Digital Surface Model rather than only a Digital Terrain Model. This approach corrects displacement effects caused by building lean and object tilt, yielding geometrically accurate representations of buildings, bridges, and other infrastructure elements (Kosmatin Fras et al., 2021). True orthophotos therefore enable more reliable extraction of building footprints, which is critical for automated 3D city modelling workflows where precise planimetric outlines are required. Within the CLSS program, a pilot true orthophoto was produced at 16 cm resolution. Comparative analyses demonstrate that classical orthophotos can be acceptable for low-rise buildings (displacements up to ~0.5 m) but are unsuitable for high-rise structures where roof outline shifts may reach several meters (up to ~5 m), making true orthophotos essential in dense urban contexts (Figure 3).

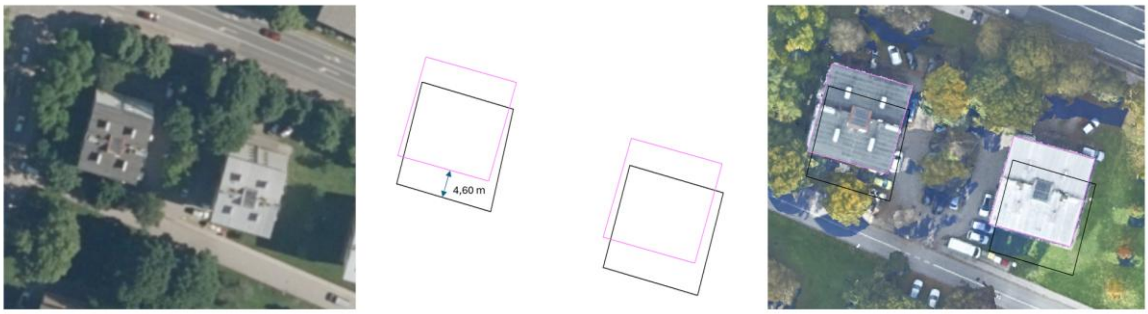

Figure 3: Comparing the building outlines of tall buildings between classic (left) and true (right) orthophoto.

Oblique aerial photography represents yet another upgrade from classical orthophotos. It provides façade-level information not visible in vertical imagery and supports the generation of textured 3D meshes for visualisation and simulation applications, including flood modelling and wind-flow analysis, thereby improving planning and risk management. However, a key limitation is that mesh models represent the environment as a continuous surface rather than an object-oriented structure. In 2022, the Surveying and Mapping Authority of the Republic of Slovenia supported a pilot project on oblique aerial photography, implemented across three geographically distinct test areas: Ljubljana, Murska Sobota, and Bled. The project aimed to acquire oblique aerial imagery at multiple geometric resolutions in order to evaluate its suitability for a range of geodetic and spatial analysis applications (Švab Lenarčič et al., 2024).

3.1.6 GeoBIM

GeoBIM refers to the integration of Building Information Modelling (BIM) with geospatial information systems (GIS). BIM datasets provide detailed building models primarily used for design, construction, and facility management, whereas GIS models typically operate at broader spatial scales and differ in modelling approaches, levels of detail, and georeferencing practices. In the context of geospatial digital twins, BIM data can therefore be used to capture especially planned and newly built buildings and infrastructure, rather than provide large-scale coverage. A major barrier to BIM–GIS integration for 3D built-environment modelling is that BIM data are often proprietary and protected by copyright, limiting their public availability. Effective integration, therefore requires careful alignment of differing data models, while major challenges include mismatched model resolutions and the limited practical adoption of consistent standards (Noardo et al., 2020).

3.2 3D building modelling

Within the national research project (V2-24073), and in parallel with the partners' research activities, we primarily investigated approaches to 3D building modelling and tested several widely used software solutions (Tekavec et al., 2025). This report phase, therefore, focuses on building reconstruction, as buildings represent the most common and arguably most important entities in urban environments. The evaluation framework followed the extended Level of Detail (LOD) specification proposed by Biljecki et al. (2016), with a particular emphasis on achieving LOD2.2. For each tool, we assessed the attainable LOD level, input data requirements, available reconstruction methods, and support for export formats essential for interoperability and long-term use in national 3D data infrastructures. Key formats considered included CityGML 2.0/3.0 and CityJSON for semantically rich LOD-structured models, OBJ for geometric visualisation, 3D Tiles for web-based delivery, and DXF/DWG and IFC for integration with GIS, CAD, and BIM workflows. The results of the test are summarised in Table 1.

3.2.1 Terrasolid

Terrasolid/TerraScan is a commercial point-cloud processing suite that supports automated 3D building vectorisation, typically achieving LOD2.2 by deriving roof planes and vertical walls from classified LiDAR points. The workflow is efficient and generally reliable for large areas, but performance is highly dependent on the accurate classification of the point cloud. Errors frequently arise when roof classes contain outliers or incorrectly labelled points, leading to over-segmentation, unwanted polygons, and imperfect ridge alignment. While Terrasolid handles large point clouds effectively, its export is largely limited to geometric formats (e.g., DGN, DXF, OBJ, Collada) without semantic structure, limiting its direct suitability for CityGML/CityJSON-compliant national datasets.

3.2.2 Virtual City Systems

Virtual City Systems is a commercial environment specialised in semantic 3D city modelling, with strong support for CityGML 2.0/3.0 and CityJSON. Its BuildingReconstruction module can automatically generate LOD2.0 models, which can be refined to LOD2.2 through manual editing. However, our tests indicated that achieving a consistent LOD2.2 specification requires substantial manual interventions, primarily due to generalised roof structures. Despite this, the platform is highly scalable and has demonstrated the ability to process large datasets, while also offering robust identifier management and standardised export, making it a viable candidate for national-scale implementations where manual refinement resources are available.

3.2.3 Roofer

Roofer is an open-source automated reconstruction pipeline that combines building footprints with LiDAR and photogrammetric sources and consistently produces LOD2.2 models with a high degree of automation. The tool is well-suited to large-scale production workflows, as demonstrated by its operational use in the Dutch 3DBAG initiative. Our evaluation confirmed strong performance across extensive areas, but also highlighted sensitivity to low-density point clouds, with recommended densities of at least ~15 points/m², and occasional omissions for low-reflectance roofs (e.g., very dark surfaces). A major advantage is robustness to limited point classification, as roofs, chimneys, and walls may remain within the same class without significantly degrading results. Export to CityJSON facilitates integration into modern 3D platforms, and the combination of open-source availability, scalability, and semantic output makes Roofer particularly suitable for national building model production, provided that input LiDAR quality and density are sufficient.

3.2.4 ArcGIS Pro

ArcGIS Pro provides a mature ecosystem for 3D visualisation, procedural modelling, and 3D content management, but its ability to achieve LOD2.2 building reconstruction is limited. Generated roof structures are typically over-generalised, and the platform lacks robust automated workflows that tightly integrate footprints and LiDAR point clouds into semantically consistent building models. Supported exports (e.g., Multipatch, OBJ, FBX, Collada, 3D Tiles, IFC) are largely oriented toward visualisation and interoperability within Esri ecosystems, while CityGML/CityJSON workflows generally require additional conversion. Based on our tests, ArcGIS Pro is best suited for inspection, visualisation, analysis, and demonstration of 3D building models rather than as a primary solution for national-scale automated LOD2.2 reconstruction.

Table 1: Summary of the tested software for 3D building modelling.

Tool	LOD 2.2	Export	Scalability
Terrasolid	YES	COLLADA/OBJ	Limited
Virtual City Systems	PARTLY	CityGML 2.0/ CityJSON	YES
Roofer	YES	CityJSON	YES
ArcGIS Pro	PARTLY	Multipatch/COLLADA/OBJ	NO

3.3 Maintenance and temporal dynamics

The data is generally most useful if it is up to date. In Slovenia, the LiDAR acquisition campaigns are now designed to be cyclic. This brings challenges to the long-term data management strategy for 3D buildings. The easiest way is to change the entire dataset when the new models are modelled using the latest LiDAR data and put the whole old dataset in the archive. This approach treats the 3D building dataset as a package. This way, we obtain more than one model of the same building that is at least slightly different each time. This can cause several issues for data users and even more if the dataset is integrated into national SDI. An alternative approach is to manage the buildings within the dataset individually and use a versioning approach to document the changes. This type of data management does not exclude campaign updates; they are just executed differently. Such a dataset is more consistent and more suitable in the context of digital twins, where each object is supposed to have a temporal dimension (life span), which is especially important for simulation applications.

The next level of maintenance is the integration with other complementary data sources mentioned in chapter 3.1. In this regard, official cadastral and BIM data can be used to provide data on the buildings and infrastructure when the building is registered or even not yet existing (planned). Another important complementary source is satellite imagery: regularly acquired, high-resolution optical and radar (SAR) satellite data can support systematic monitoring of construction activity, demolition, roof changes, and land cover transitions. Combined with machine-learning algorithms for automatic change detection and object extraction, satellite imagery can provide scalable, near real-time indicators of change, which can then trigger targeted updates of the 3D building dataset (for example, prioritising areas for LiDAR reprocessing, photogrammetric reconstruction, or field verification).

4 NATIONAL DIGITAL TWIN COMPONENTS

On top of properly structured spatial data, several components that constitute a digital twin can be developed. In this chapter, the main digital twin functional components for downstream applications and user interactions are presented (Figure 4). These components have been foreseen as the most relevant for development of a national digital twin for Slovenia.

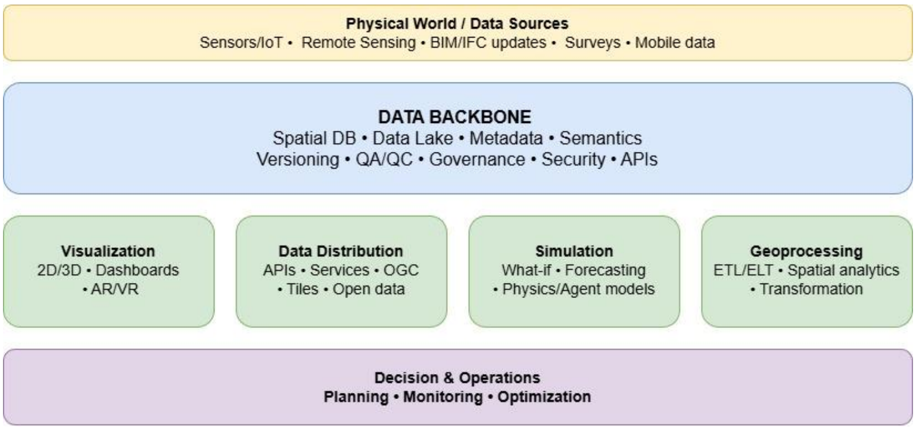

Figure 4: Main digital twin functional components (green) within national digital twin architecture

4.1 Visualisation

Visualisation's primary role is to serve as the enabling interface between users and the underlying functions and outputs of a geospatial digital twin. It supports transparent access to complex analyses and simulation results. In practice, 3D visualisation is not merely an aesthetic enhancement because it allows spatial relationships, scale, and dynamic interactions to be perceived in a way that is difficult or sometimes impossible to achieve through tabular or 2D representations. This becomes particularly important in real-time digital twin applications, where large volumes of sensor-derived data would otherwise impose a high cognitive load and hinder rapid situational judgment; visualisation is therefore treated as an essential “interface technology” that turns continuous data collection and modelling into actionable insight. For indoor or building-interior applications, careful control of transparency is required, since excessive translucency can create occlusion artefacts and depth ambiguities that reduce interpretability. Research on digital-twin-based augmented reality and city-scale visualisation (Kikuchi et al., 2022) similarly highlights the necessity of occlusion-aware rendering to preserve spatial clarity when multiple layers and objects overlap. Overall, effective visualisation must prioritise comprehension over visual richness, ensuring that even complex digital twin outputs are presented in a clear form that supports communication, collaboration, and evidence-based decisions.

4.2 Data Distribution

Digital twin data can be provided through dedicated services that expose either selected entities (e.g., a single attribute, observation, or geometry) or packaged datasets for broader downstream use. This service-oriented access supports interoperability and reuse by enabling task-specific, selective retrieval. In geospatial and urban digital twins, standards-based service interfaces are crucial for efficient data integration across organisations and software ecosystems. The temporal dimension is especially important because many datasets evolve over time, with validity depending on observation time, update frequency, and synchronisation between physical and digital domains. Therefore, data should include metadata on lineage, versioning, and update rules so users can choose the appropriate dataset version. Recent literature emphasises that metadata and quality indicators are key for assessing fitness-for-purpose when digital twin data are used outside the original platform (Correia et al., 2023), enabling cross-system integration, benchmarking, and secondary analytics.

4.3 Simulation

The simulation component of a geospatial digital twin is responsible for transforming structured spatio-temporal data into explanatory and predictive models that support both retrospective analysis and scenario exploration. When the underlying spatial data backbone is organised to preserve temporal continuity and spatial consistency, the digital twin environment can be used to analyse historical patterns and long-term trends. Satellite Earth observation data provides a clear example, because their multi-decadal time series enable the detection of gradual change, seasonal variability, and anomalies across multiple spatial scales, creating an empirical basis for understanding system dynamics and calibrating models. Beyond retrospective analytics, simulations enable “what-if” reasoning by allowing users to modify selected parameters or entity attributes and, with geoprocessing support, generate alternative states. This capability is frequently emphasised as the most valuable function of digital twins, because it supports decision-making under uncertainty in applications such as crisis management, urban growth, climate adaptation, security assessment, and spatial planning. Simulation environments may therefore include predefined models with exposed parameters for common use cases, while more advanced implementations can provide a simulation sandbox that supports custom model execution through programmable interfaces, interactive visualisation, and standardised mechanisms for distributing results to external systems.

4.4 Geoprocessing

The geoprocessing component of a geospatial digital twin provides the analytical and transformation capabilities required to convert raw geospatial observations into decision-relevant information and model-ready inputs. While simulation focuses on exploring alternative system states, geoprocessing primarily supports the operational analytics processes by enabling the implementation of workflows for spatial data analyses. This includes classical GIS operations such as overlay, buffering, spatial joins, and network analysis, as well as more advanced analytical modules such as terrain and hydrological modelling, viewshed and line-of-sight analysis, solar irradiation and photovoltaic potential assessment, wind exposure estimation, and multi-criteria analyses. In a digital twin environment, the geoprocessing component functions as a direct enabler of the simulation component. Simulations typically require structured boundary conditions, calibrated parameters, and derived spatial layers such as land-cover classifications, roughness coefficients, exposure indicators, or vulnerability indices, which are not available as raw. Geoprocessing, therefore, acts as the bridge between the data backbone and simulation, producing standardised inputs, updating scenario parameters, and ensuring spatial consistency across models. Consequently, geoprocessing is not only an analytical module but also a key component that enables simulations within the digital twin, enabling rapid generation of scenario-ready datasets for visualisation and decision support.

5 CONCLUSIONS

This paper presents the key outcomes of a research project aimed at developing the concept of a national geospatial digital twin of Slovenia. Our primary objective was to articulate how such a digital twin could be conceived and operationalised within the national geospatial ecosystem. Building on Slovenia's cyclic LiDAR and photogrammetric acquisition programs, together with complementary data sources, we demonstrate how an automated, standards-aligned 3D topographic production pipeline can serve as a robust basis for a future national digital twin environment. We outline how core digital twin functions, such as spatial analysis, simulation, visualisation, and data distribution, can be integrated into a scalable digital twin environment that supports continuous updating and interoperability across institutions. Overall, the presented concept provides a structured, feasible pathway toward a sustained national digital twin capability and a stronger spatial data infrastructure for Slovenia.

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