FUTURE INSIGHT

Geonovum Testbed 2
7.1 Research sub-topic: BIM (Design information) for Digital Twins

1. Executive summary

The Testbed 2 Subtopic 7.1 workflow demonstrates a practical, standards-based approach for integrating IFC-based BIM models into geospatial Digital Twin environments. BIM data, typically created in local project coordinates, is filtered using BIM Query Language (BQL), accurately georeferenced through IFC metadata (IfcMapConversion, IfcProjectedCRS, IfcSite), and transformed into efficient 3D Tiles for web-based visualization. The resulting datasets are registered and composed within clearly.Hub, enabling combination with basemaps, CityGML/CityJSON models, OGC APIs, and in alignment with NLDT architectural principles. This pipeline enables scalable visualization, interoperability, and multi-stakeholder collaboration while preserving BIM semantics. Looking ahead, the work paves the way for regulatory and code-checking workflows that align Geo and BIM data without format conversion, supported by automated georeferencing diagnostics, semantic enrichment, and real-time update mechanisms for future Digital Twin scenarios.

2. Introduction

The integration of Building Information Modeling (BIM) with geospatial technologies has become a foundational requirement for modern digital workflows, particularly in domains such as digital twins, urban planning, asset management, and infrastructure lifecycle analysis. BIM models,especially those encoded in the Industry Foundation Classes (IFC) standard,offer rich geometric and semantic descriptions of the built environment. However, these models are typically authored in isolated project coordinate systems, optimized for design rather than large-scale spatial interoperability. At the same time, geospatial ecosystems rely on globally consistent coordinate reference systems (CRS), tiling schemes, and open web standards to support scalable visualization, analysis, and data exchange across cities, regions, or entire countries. Bridging these two worlds requires a robust methodology grounded in open standards, consistent georeferencing, efficient data transformation workflows, and interoperable web-based publication mechanisms.

To enable seamless GeoBIM integration, several international standards and widely adopted technologies play essential roles. IFC 4.x (ISO 16739) provides the foundational data structures for representing building geometry, semantics, and spatial hierarchies, along with key entities for expressing coordinate systems and transformation metadata. Complementary standards from the Open Geospatial Consortium (OGC), such as OGC API – Features, Tiles, and 3D GeoVolumes, offer scalable service interfaces for distributing geospatial datasets, while formats like CityGML and CityJSON provide high-level semantic urban context in which BIM data can be embedded. On the visualization side, modern web-based 3D platforms increasingly rely on 3D Tiles and glTF 2.0, formats built for efficient streaming of massive, heterogeneous 3D datasets. Metadata standards such as DCAT further ensure that datasets can be catalogued, discovered, and integrated within platforms like clearly.Hub in a consistent and machine-readable manner.

Achieving high-quality BIM–GIS integration also requires a well-structured methodological approach. This includes extracting model subsets using query languages, resolving and applying georeferencing transformations, converting BIM geometry into hierarchical 3D Tiles structures, and registering the resulting datasets within a digital twin platform where they can be composed with basemaps, contextual city models, and live sensor feeds. Query languages, such as BQL (BIM Query Language) or other IFC-centric querying mechanisms, enable filtering and selection of only the relevant building components, improving performance and supporting targeted use cases. Georeferencing workflows ensure that BIM models align accurately with national or global coordinate systems, preventing the common problems of misaligned datasets, floating geometries, or precision degradation. Finally, exporting to 3D Tiles and registering these models in platforms like clearly.Hub supports scalable visualization and analysis, enabling organizations to move from isolated BIM files toward integrated digital twin ecosystems.

The following sections provide a detailed overview of the standards, technologies, and methodological steps required for this workflow. Section 3 describes the relevant interoperability standards that form the foundation for GeoBIM integration. Section 4 outlines the methodology, spanning model filtering, georeferencing, data conversion, and dataset registration within clearly.Hub, ensuring that IFC-based BIM data can be effectively transformed into high-performance geospatial web content.

3. Related Standards and Technologies

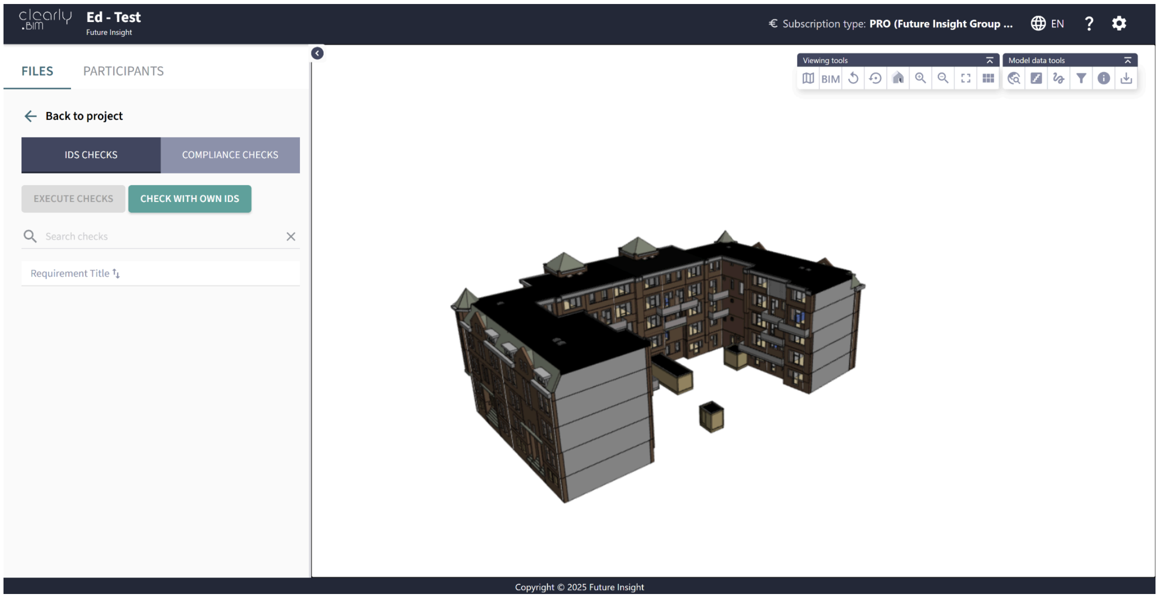
- IFC 4.x (ISO 16739): IfcGeometricRepresentationContext, IfcProjectedCRS, IfcMapConversion, IfcSite.
- 3D Tiles and glTF 2.0: streamable hierarchical 3D and payload format.
- CityGML 2.0 or 3.0: semantic city context; optionally CityJSON for lightweight exchange.
- OGC APIs (Features, Tiles) and 3D GeoVolumes; WMS or WMTS for rasters.
- DCAT for dataset metadata; catalog integration in clearly.Hub.

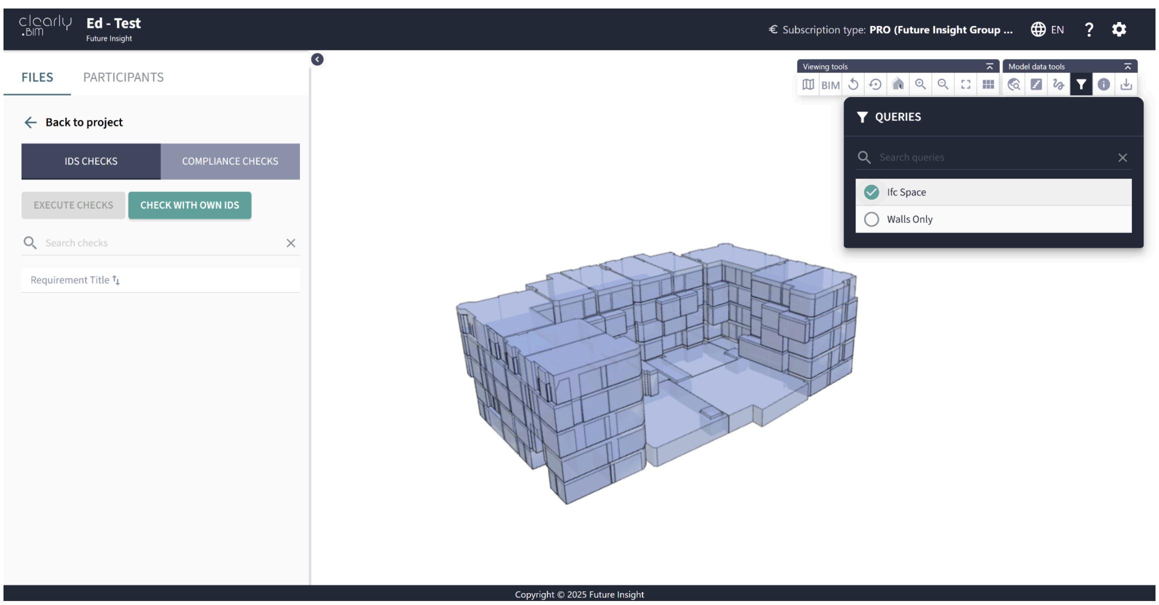
4. Methodology

4.1 Filtering with BIM Query Language (BQL)

Query languages provide an effective means to extract, filter, and analyze specific information from BIM. Since BIM models contain extensive geometric and semantic data, using a structured query mechanism allows users to retrieve targeted information efficiently. Query languages enable users to define conditions and parameters for selecting particular elements, such as walls, doors, materials, or spatial zones, based on their properties, relationships, or classification. This capability is essential for data-driven workflows, as it allows engineers, architects, and facility managers to focus on relevant subsets of information without manually navigating through complex model hierarchies.

In recent years, several approaches have been proposed for querying BIM data, including the use of traditional query languages such as SQL or SPARQL when BIM data is represented in relational or RDF-based formats. Additionally, domain-specific query languages, such as BIMQL or ifcJSON query expressions, have been developed to provide more intuitive ways of filtering IFC data according to industry standards. These query methods facilitate automated data validation, model checking, and integration with external systems such as GIS or facility management platforms. As a result, query languages not only improve data accessibility but also enhance interoperability, enabling efficient filtering and exchange of BIM information across diverse digital construction workflows.





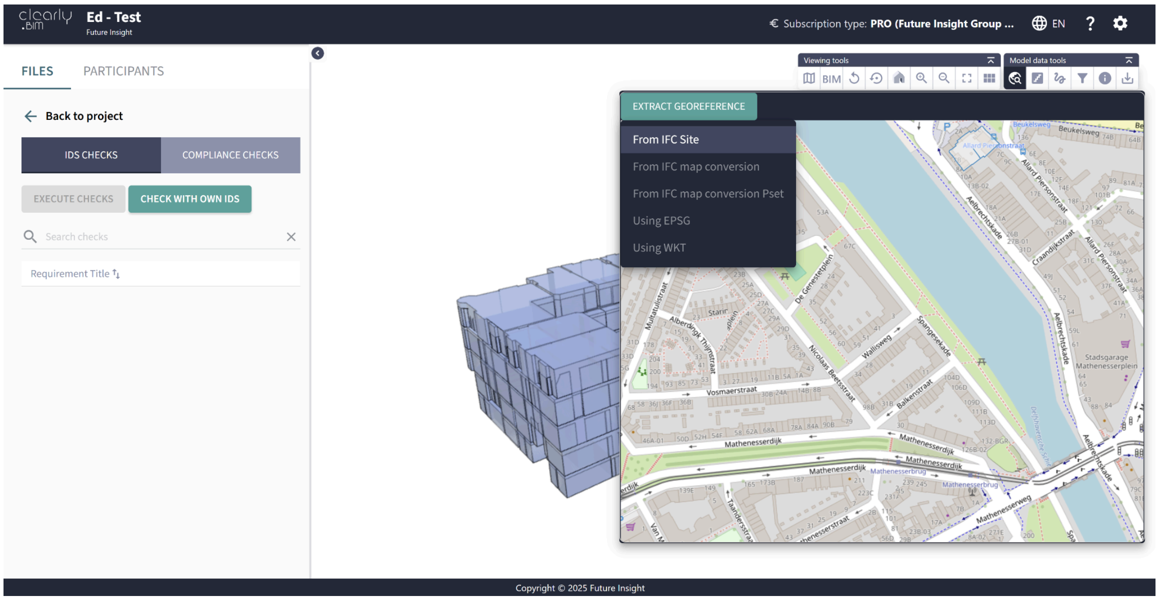
Above is the example of querying an IFC file for visualization of only spaces. Using BIM Query Language (BQL).

4.2 Georeferencing

The integration of geoinformation with Building Information Models (BIM), known as GeoBIM, has attracted considerable interest in professional domains. Nonetheless, achieving effective integration between 3D city models and BIM requires maintaining consistency and alignment between their respective elements and specifications. A key aspect of this process is georeferencing, which establishes a spatial link between digital models and the Earth's surface through coordinate transformations. Despite its crucial role, precise georeferencing of BIM models is frequently neglected, leading to difficulties in combining BIM data with geographical information.

In general terms, georeferencing an object involves transforming its geometric coordinates to ensure accurate positioning within its correct geographic location on a map, while maintaining consistency with other spatial features in the map's framework. This process is carried out through coordinate operations (ISO19111, 2019) that convert data from one coordinate system to another. A building model can be georeferenced when sufficient metadata (ISO19115-1, 2014) is available to enable a coordinate transformation from the reference system of the building or construction site to a target coordinate reference system, such as a map projection or national grid.

Furthermore, IFC files may include various geoinformation attributes, which can differ significantly depending on the version of the schema and the authoring tool used. These attributes, such as IfcMapConversion, IfcProjectedCRS, IfcSite placement data, or custom property sets, define how spatial reference information is stored and interpreted within the model. Because not all IFC schemas or software implementations represent georeferencing data in the same way, a GeoBIM platform must be capable of recognizing and supporting multiple forms of geoinformation representation. This adaptability ensures that the platform can correctly interpret spatial metadata regardless of how or where it is encoded, maintaining interoperability across diverse BIM sources and geospatial datasets.

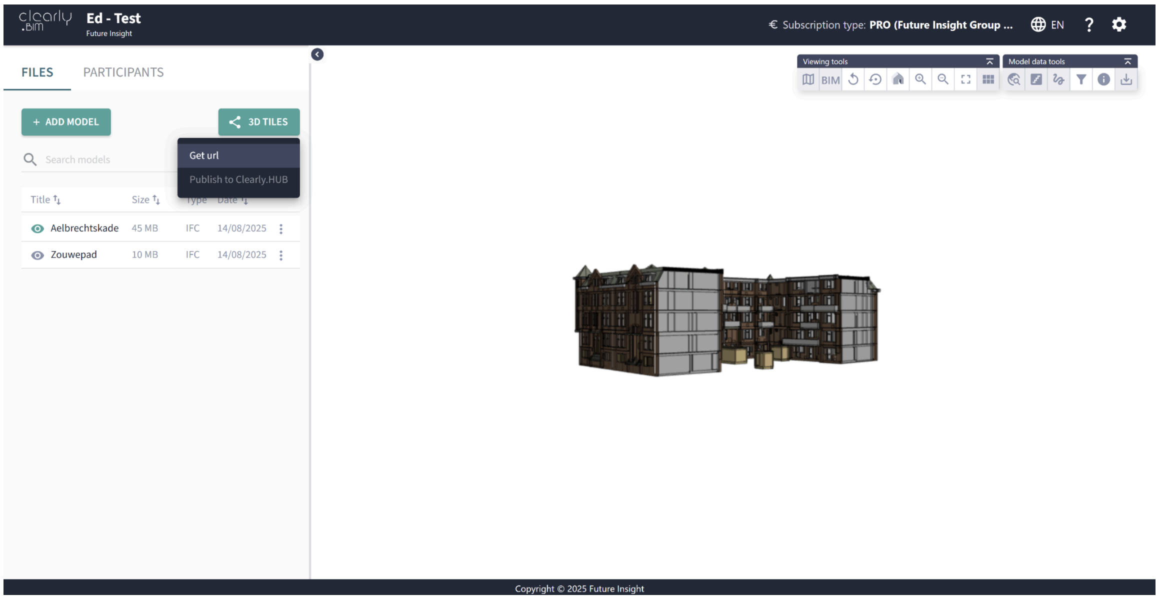


Priority of sources: IfcMapConversion with IfcProjectedCRS (preferred); otherwise IfcSite latitude, longitude, and elevation with WGS84 assumption and reprojection. Construct a scale from IFC units to meters, a rotation from XAxisAbscissa and XAxisOrdinate or TrueNorth, and a translation from Eastings, Northings, and OrthogonalHeight. Encode the result as the root transform in tileset.json to avoid large vertex coordinates and precision loss.

4.3 Export to 3D Tiles

3D Tiles is an open specification developed by Cesium for streaming and rendering large-scale 3D geospatial datasets. It is designed to efficiently deliver massive 3D models, such as buildings, terrains, point clouds, and vector data, over the web. The format organizes spatial data into a hierarchical structure of tiles, allowing for level-of-detail (LOD) management, where only the necessary tiles are loaded based on the viewer's position and zoom level. This approach enables smooth visualization and interaction with complex 3D environments in real time, even when dealing with city-scale or country-scale datasets.
Generating 3D Tiles from BIM models involves converting the detailed geometric and semantic information contained within IFC into a tile-based structure compatible

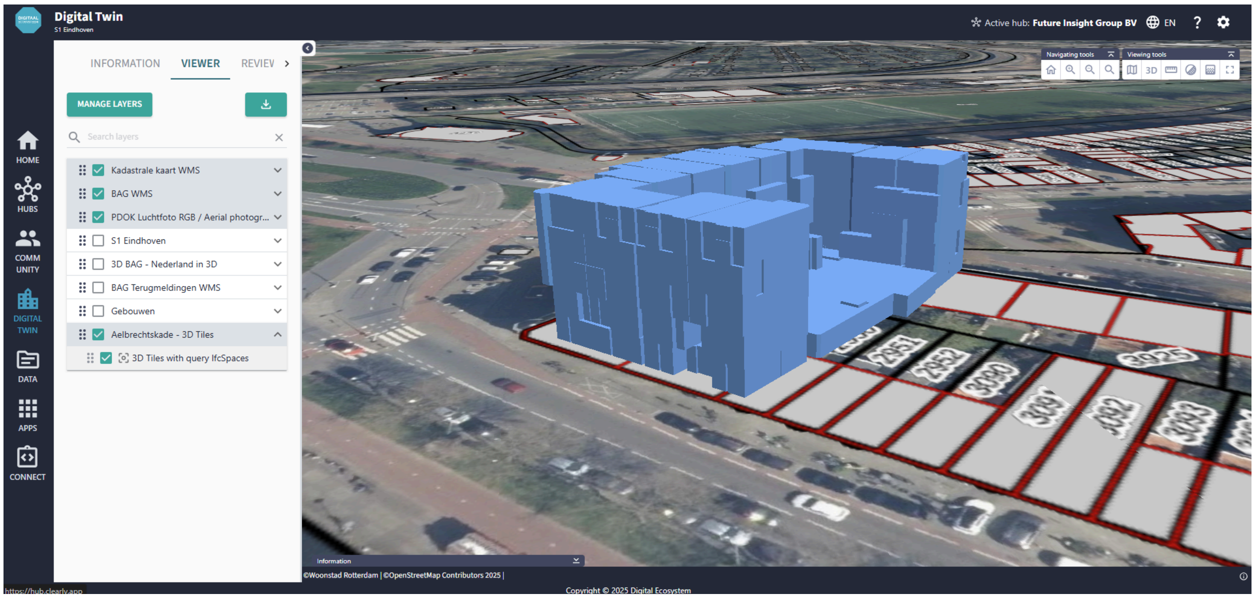
with the 3D Tiles specification. This process typically includes simplifying geometry, optimizing textures, and embedding relevant metadata to maintain essential building information while ensuring performance for web visualization. The resulting 3D Tiles dataset enables BIM models to be integrated into 3D geospatial platforms, supporting applications such as urban planning, digital twins, and infrastructure management where both geospatial context and building-level detail are required.



4.4 Registration and Composition in clearly.Hub

clearly.Hub is a cloud-based cataloging and visualization platform for managing, publishing, and composing geospatial and BIM datasets within Digital Twin environments. It supports dataset registration, metadata management, access control, and high-performance 3D visualization aligned with NLDT architectural principles. In the context of Testbed 2, clearly.Hub serves as the platform where IFC-derived 3D Tiles are published, enriched with metadata, and combined with additional spatial layers to form coherent, configurable Digital Twins.

Within this workflow, IFC-derived data is first registered as a 3D Tiles dataset and then promoted to a Digital Twin for composition. Registration involves creating a 3D Tiles dataset that references the tileset.json endpoint and adding metadata required for traceability, interoperability, and reuse. After registration, the dataset can be composed with basemaps, contextual 3D models, administrative vectors, and thematic geospatial layers, enabling a multi-layered environment suitable for visualization, analysis, planning, and collaboration.



5. Fit with NLDT Architecture and Capabilities

The service aligns closely with the NLDT architectural principles, supporting a federated, standards-driven digital twin ecosystem. It integrates seamlessly with core NLDT data structures,such as 3D GeoVolumes, 3D Tiles, and CityJSON,and can operate as a modular component within national and regional digital-twin platforms. Its design enables interoperability, composability, and the reuse of spatial and non-spatial datasets across domains. Within this ecosystem, Clearly.Hub functions as both a catalog and a visualization hub, providing a unified environment where datasets, models, and digital twins can be discovered, accessed, and viewed. This makes it a natural fit for scalable deployments, multi-stakeholder collaboration, and the broader NLDT vision of connected, interoperable digital-twin services.

6. Conclusion and Future Work

This workflow establishes a robust and practical bridge between BIM and geospatial datasets, enabling their combined use within Digital Twin environments. By integrating selective model extraction, standards-based georeferencing, and efficient 3D Tiles delivery with cataloging, discovery, and composition through Clearly.Hub, the approach supports high-performance, interoperable digital-twin applications across domains. The demonstrated pipeline shows how complex BIM data can be transformed into lightweight, georeferenced assets suitable for scalable visualization, analysis, and integration within national or regional ecosystems.

Another important future direction is the integration of GeoBIM data for regulatory and code-checking workflows without requiring format conversion, specifically avoiding the need to transform BIM data into CityGML or to force geospatial datasets into IFC. The goal is to demonstrate how heterogeneous datasets can be aligned, referenced, and evaluated together through interoperable services, shared semantics, and lightweight linking strategies rather than heavyweight model transformations. This approach preserves data fidelity, reduces processing overhead, and enables flexible validation pipelines that draw directly from authoritative geospatial sources and BIM models.

This research direction includes exploring reference-alignment techniques, spatial indexing methods, common georeferencing anchors, and schema-mapping overlays that allow code-checking engines to operate on both data domains in situ. By focusing on integration rather than conversion, the work supports more scalable, future-proof code-checking workflows while maintaining the integrity of both Geo and BIM information.

Going forward, additional work will focus on automating and strengthening the wider pipeline. Priority areas include automated georeferencing diagnostics, enhanced semantic alignment between BIM models, city models, and emerging NLDT profiles, metadata enrichment for better dataset discoverability, and stress-testing the workflow across diverse projects, conditions, and 3D viewers. Further exploration of real-time update mechanisms will also be essential for supporting dynamic and operational digital-twin scenarios.

References (indicative)

- ISO 16739-1: Industry Foundation Classes (IFC).
- OGC CityGML 2.0 or 3.0.
- OGC 3D Tiles and 3D GeoVolumes (draft) specifications; glTF 2.0.
- OGC API Features and Tiles; WMS and WMTS.

Appendix: Implementation Checklist

- IFC validates (schema and units)
- BQL scripts saved and versioned
- CRS extracted and verified; azimuth validated
- 3D Tiles export parameters documented
- Dataset created in clearly.Hub with metadata
- Digital Twin configured with layers and styles