Change toolkit for digital building permit

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V1.0	Final version	22/09/2025	Mayte Toscano

Contents

1 Executive Summary

This document, Deliverable D3.4 of the CHEK project, presents the final set of specifications and guidelines developed to enhance interoperability between geospatial (GIS) and Building Information Modelling (BIM) systems, with a specific focus on their application to Digital Building Permits (DBP). The objective is to provide a solid framework that enables the integration of GIS and BIM data, supporting standard-based workflows for permit automation, urban planning compliance, and data exchange in the built environment.

To address this challenge, CHEK developed a series of tools and methodologies organised in three main components:

- **GIS to BIM conversion**: The converter translates CityGML and related formats into IFC4, using a semantic mapping strategy that preserves geometry and attributes (Deliverable D3.1).
- **IFC georeferencing**: A structured procedure to detect or assign geospatial references in IFC files using IfcMapConversion and CRS metadata (Deliverable D3.2).
- **BIM to GIS conversion**: Using the IfcEnvelopeExtractor, IFC models are simplified and exported to CityGML/CityJSON with appropriate Levels of Detail (Deliverable D3.3).

Based on these tools, a set of standardisation guidelines has been proposed, covering:

- Semantic and geometric mappings between GIS and BIM.
- Best practices for georeferencing and LoD consistency.
- Attribute handling using Property Sets and Application Domain Extensions (ADEs).
- Validation procedures and recommendations for software implementation.

The deliverable also includes a rich compilation of recommendations and good practices identified through two workshops with stakeholders. These have been transformed into actionable user stories, aligned with real-world needs in DBP processes.

Finally, the results of this work have been disseminated and validated through their integration into the **Strategic Roadmap for GeoBIM** developed by the **OGC GEOBIM Working Group**, in collaboration with **buildingSMART** International (bSI). CHEK's user stories and recommendations serve as key inputs to this roadmap, guiding future adoption of open standards in urban regulatory workflows.

2 Introduction

The integration of geospatial information (GIS) and BIM models has not only transformed urban planning and infrastructure project management but also opens up new possibilities in the digitalisation of building permits and in innovative projects such as CHEK.

Digitising building permits involves transforming traditionally paper-based processes into integrated digital systems, where the convergence of GIS and BIM becomes an essential element to guarantee validation and regulatory compliance, optimisation of administrative processes and the promotion of transparency and collaboration. The integration of BIM models with geospatial data makes it possible to verify, for example, the exact location of a construction site, its relationship with existing built environment, infrastructures and city behaviour and its compliance with current urban planning and environmental regulations. In addition, the digitisation of permits facilitates the review and approval of projects by reducing time and resources, allowing authorities to quickly analyse critical aspects such as the impact on the urban services network and alignment with territorial development plans. Finally, a digital system that combines GIS and BIM improves data flows for the advantage of communication between municipalities, developers, architects and engineers, offering a collaborative platform in which each actor has access to timely updated and relevant information for decision-making.

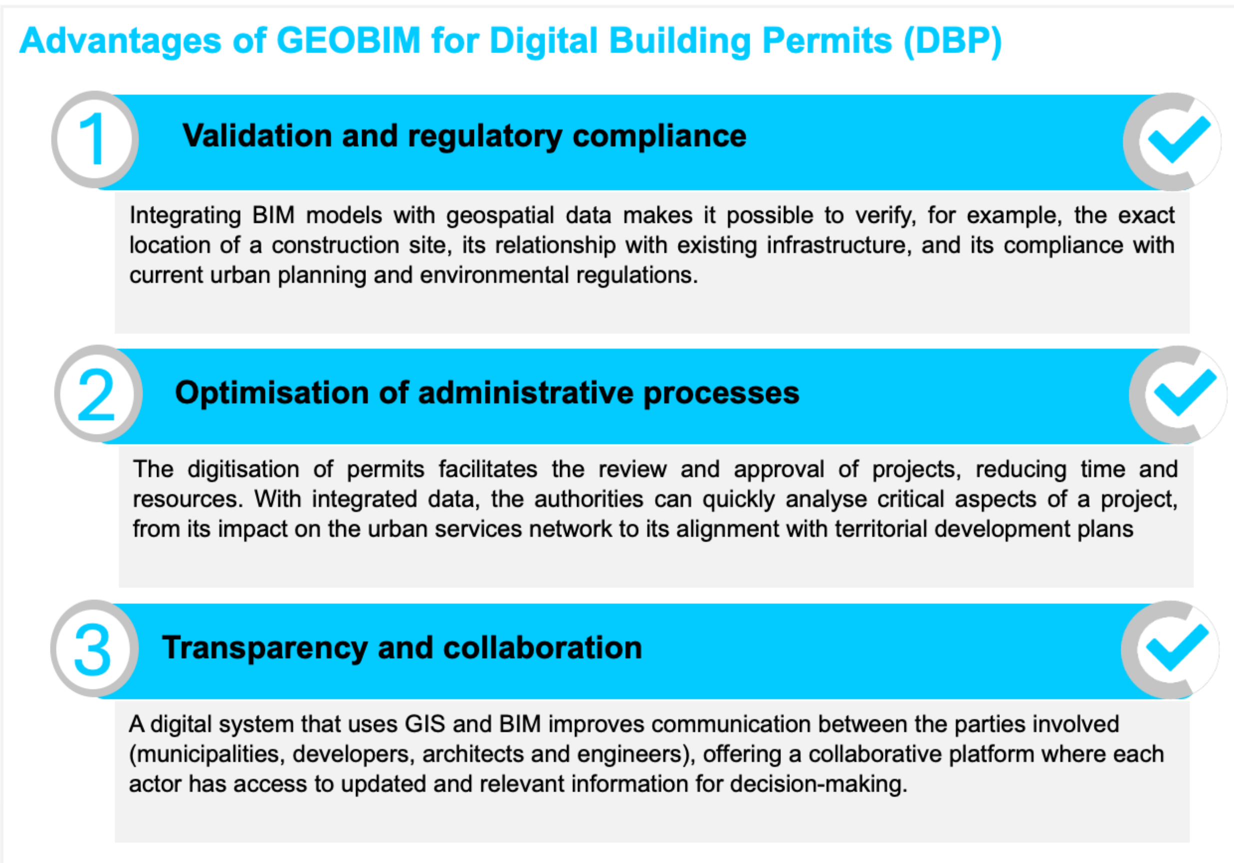


Figure 1. Advantages GEOBIM

2.1 Addressed challenges

As a motivation for the GeoBIM work planned and carried out in CHEK, several challenges were identified that limited the mass adoption of BIM-GIS flows:

1. **Lack of a unified approach to georeferencing in IFC**

   BIM data often lacks accurate information about its geographical location, making it difficult to integrate with GIS models. With the introduction of IfcMapConversion (in IFC4) and the use of property sets (in IFC2x3), there is a need for a standard process to guarantee the consistency of coordinates and the clear definition of reference systems (CRS).

2. **Non-standardised conversion methodologies**

   - **GIS → BIM:** Despite the existence of experimental converters that transform CityGML/CityJSON data into IFC, there is a lack of formal guidelines that define which entities and properties should be transferred and how to map them unequivocally.
   - **BIM → GIS:** Similarly, the extraction of the envelope of an IFC model (walls, roofs, floor slabs, interior spaces, etc.) and its subsequent representation in CityGML/CityJSON (or in other GIS formats) lacks standardised criteria that reflect the different levels of detail (LoD).

3. **Need to harmonise OGC and buildingSMART standards**

   Both the OGC and buildingSMART International (bSI) have developed specifications for geospatial and BIM environments, respectively. However, the convergence and compatibility of these standards requires the joint collaboration of both organisations, as well as the definition of clear interoperability flows and rules.

4. **Support for borderline cases and related standards**

   - More complex Application Domain Extensions (ADEs) would need to be considered in CityGML, as some urban environments include very specific attributes (e.g., heritage, underground facilities or transport infrastructure).
   - For georeferencing in IFC, compatibility with more recent versions (e.g., IFC4.3) that include linear infrastructure and road objects would be desirable.

5. **Better management of incomplete or inconsistent data**

   - In the Geo → BIM conversion, certain CityGML models lacked mandatory metadata or had geometries that did not conform to the standard. A 'self-correcting' module or more detailed error reporting would be needed to guide the user.
   - In IFC georeferencing, when RefLatitude or RefLongitude are missing, more automated data insertion mechanisms are required (for example, from a shapefile or a WFS service).

- For BIM → Geo, it was observed that the quality of the conversion depends to a large extent on the correct definition of the IFC objects and their topology. Pre-processing that detects 'gaps in' geometry, duplicates or inappropriate overlaps is recommended.

6. Expanded documentation and training

- End users and municipal authorities may require more specific guides that explain step-by-step how to integrate these tools into their workflows (e.g., pre-validation, EPSG configuration, interpretation of results).
- It would be useful to incorporate tutorials on customising mappings (for example, how to extend the mapping between CityGML and IFC to include special objects).
- Lack of transversal skills and culture allowing the experts in the two domains to communicate effectively and develop joint solutions and proper transitions.

7. Integration with third-party tools

- It is suggested that interoperability be reinforced with plugins or APIs for commercial or open source BIM and GIS modelling software (e.g., Revit, QGIS, BlenderBIM), facilitating adoption without leaving the usual working environment.
- For georeferencing, the possibility of integrating cloud services and automating mass validation processes (several IFC models at the same time) is another potential requirement in large project environments.

2.2 Background and standardisation efforts towards GeoBIM

Standardisation and compliance, as driven by the Open Geospatial Consortium (OGC), which defines standards for the management and interoperability of geospatial data, and by buildingSMART International (bSI), which promotes standards for BIM (such as the IFC format), are a first step towards allowing for the coherent integration of data sets from different fields.

Both the Open Geospatial Consortium (OGC) and buildingSMART International (bSI) have developed standards that, separately, cover geographical and construction domains. The most relevant background information is summarised in the Sections 2.2.1 and 2.2.2 below.

2.2.1 OGC standards oriented towards cities, buildings and infrastructures

- **CityGML[1] and its encoding CityJSON**[2]: It is a standard conceptual model, that models cities and infrastructures information defining different levels of detail (LoD). It was originally based on GML (Geography Markup Language), while other encodings exist, such as the SQL encoding, or CityJSON, offering serialisation in JSON format.

[1] https://www.ogc.org/standards/citygml/ Accessed 18/04/2025
[2] https://www.ogc.org/standards/cityjson/ Accessed 18/04/2025

- **InfraGML and LandXML**: Aimed at civil engineering and transport projects, to describe roads, bridges and other infrastructure elements.
- **IndoorGML**: Data model for indoor spatial information (especially intended for navigation purposes)[3]
- **Indoor Mapping Data Format (IMDF)**: generalized, yet comprehensive model for any indoor location, providing a basis for orientation, navigation and discovery[4]
- **Model for Underground Data Definition and Integration (MUDDI)**[5]: It supports the integration of diverse datasets about the underground space, using different information models, including, e.g., utility infrastructure, transport infrastructure, soils, ground water, or environmental parameters.

2.2.2 buildingSMART IFC standard and the move towards geospatial

IFC (Industry Foundation Classes): ISO standard (ISO 16739) that describes an open data model for the management of information on buildings and construction projects. Growing needs from construction and asset management use cases has generated the need to anchor these models in a geospatial context (coordinates, reference systems). From the version 4 of IFC, a set of classes, among which, primarily, **IfcMapConversion** (IFC4) offer a formal framework for specifying the geographical location of an IFC model. However, in practice there was a lack of clear guidelines for their systematic use, especially due to how BIM authoring software uses such classes in the IFC exporting phase.

The integration of GIS and BIM data offers multiple benefits: on the one hand, by combining spatial data with detailed construction information, greater precision and efficiency in decision-making is obtained; on the other hand, redundancies and errors are reduced by avoiding duplication of information thanks to the interoperability between GIS and BIM. However, it is important to point out that GIS and BIM use different formats, so transformations are required to ensure correct data integration. Furthermore, the ability to superimpose layers of information, such as existing infrastructure, urban regulations and construction details, optimises project management and analysis, providing advantages for both public administrations and developers.

Despite the fact that various initiatives have been carried out to unite GIS and BIM, for example, through scripts or specific converters that transform CityGML to IFC and vice versa, they still tend to lack a standardised framework that defines how to map entities, properties and coordinate systems. The lack of a precisely documented pipeline has led to heterogeneous results, with loss of semantics or incomplete geometry.

The purpose of this D3.4 is to present best practices and lessons learnt from the CHEK project investigations and tests as guidelines to work towards GIS and BIM connection and integration, from users, modeller, software developers and standards development points of view.

Primary activities of the CHEK project on which this document's contents are based are the adoption of formal georeferencing processes in IFC (described in deliverable D3.2), as well as bidirectional conversion between GIS and BIM (according to D3.1 and D3.3).

[3] https://www.ogc.org/standards/indoorgml/ Accessed 18/04/2025
[4] https://www.ogc.org/standards/indoor-mapping-data-format/ Accessed 18/04/2025
[5] https://www.ogc.org/standards/ Accessed 18/04/2025

3 Methodology

The GeoBIM topic was permeating the entire CHEK developments and investigations. Therefore, the contents of this deliverable come from the results of WP3, expressly on GeoBIM, but also to the wider picture of the project, starting with the involvement of different datasets in the process (WP1), and following with the information requirements definition, considering to the two different paradigms (WP2), up to the development of checking tools (WP4) and the systematisation of all the knowledge into WP5 (Upskill/reskill) and WP6 (Demonstrations). The developments were continuously iterating throughout the project, reporting the feedback of the following phases to the initial steps on data requirements and related guidelines and profiles, as defined in WP2 (CHEK IFC and CHEK CityGML). Such experiences were documented and came to be part of the final results as well as of the recommendations in this deliverable. Figure 4 depicts the central methodology part of CHEK related to GeoBIM, from the Data requirements definition in WP2 to the developments of checking software, with the steps across GeoBIM converters and data exchange and integration. In dark blue, the steps related to this deliverable elaboration, explained below.

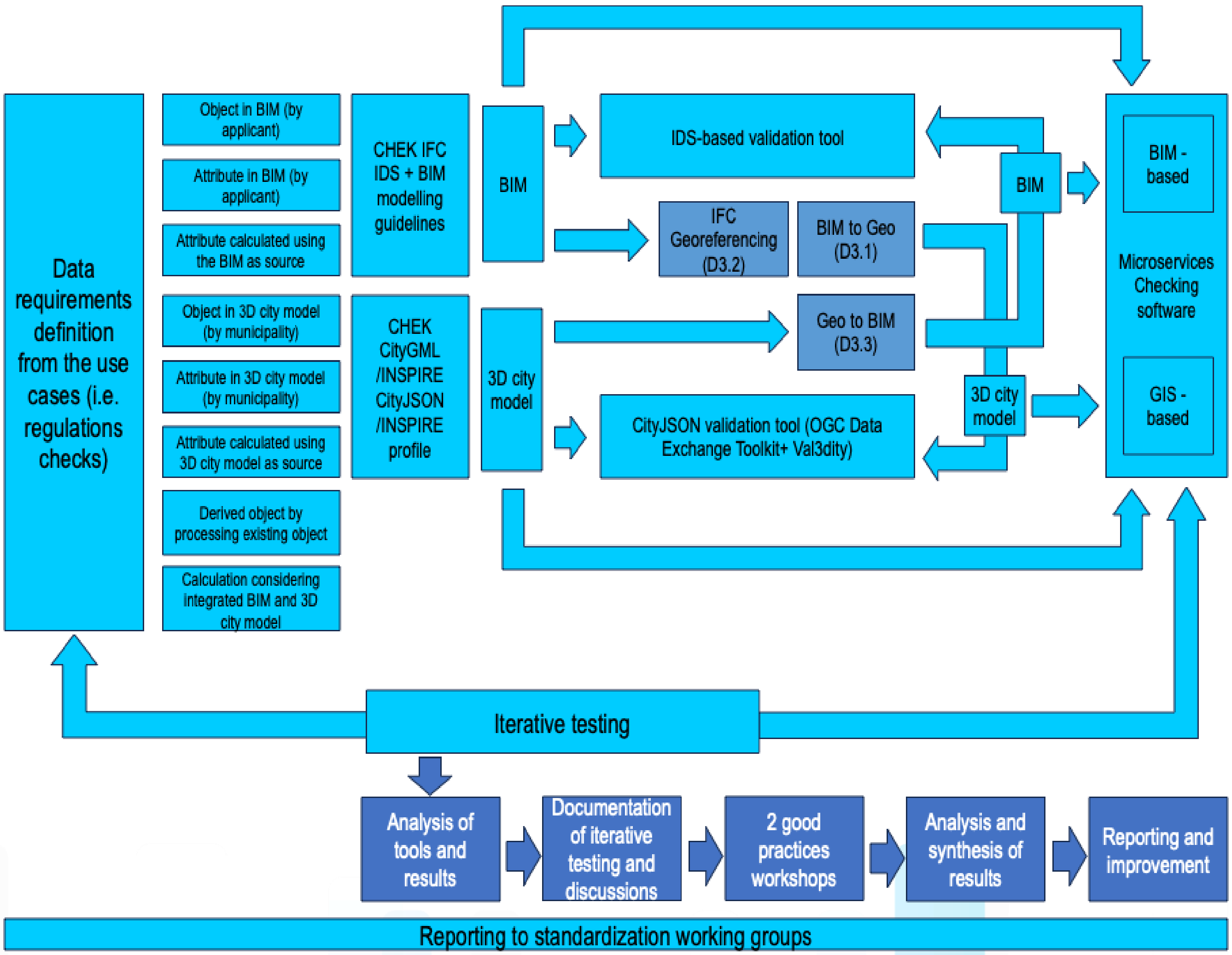


Figure 2 CHEK GeoBIM methodology (in dark blue, the steps leading to the formulation of this deliverable).

Analysis of tools and results

- In the first instance, the tools described in deliverables D3.1 (GIS to BIM conversion), D3.2 (georeferencing in IFC) and D3.3 (BIM to GIS conversion) were designed and refined.
- These solutions served as a basis for testing different scenarios and validating the technical feasibility of GIS-BIM integration.
- Once the tools had been developed, a detailed analysis of their functionality and the results obtained was carried out. This analysis made it possible to identify additional requirements, as well as areas for improvement to ensure the effective adoption of georeferencing and bidirectional conversion processes.

1. Documentation of iterative testing and discussion

- Each issue encountered during development and testing, as well as the identified solution, was documented and generalised as much as possible to represent a scalable indication for similar cases and support interoperability effectively.
- Extensive discussions within the multidisciplinary CHEK consortium about the arisen issues allowed examining the problem and alternative solutions to reach consensus on possible recommendations.

2. Organisation of two workshops to compile good practices

- **Online workshop:** A virtual session was held with GIS and BIM experts, OGC members and industry representatives. The aim was to present the tools, share initial user experiences and gather feedback on possible adjustments or improvements.
- **Face-to-face workshop at the CHEK General Assembly (Vila Nova de Gaia**): A second face-to-face workshop was organised as part of the assembly to deepen the technical discussions and validate the preliminary results. During this meeting, good practices were exchanged and the applicability of the proposed guidelines in different contexts was discussed.

3. Analysis and synthesis of results

- After the workshops, the participants' contributions were consolidated and compared with the project objectives.
- The coherence and consistency of the proposals were evaluated, identifying the key elements for the adoption of the georeferencing and bidirectional conversion mechanisms.

4. Drafting of the CHEK GeoBIM specs

- With the information gathered, the CHEK GeoBIM specs (this deliverable) was drawn up, presenting the proposed guidelines and technical justifications based on the use cases and tests carried out.
- The document aims to support GeoBIM efforts in practice and within the standardisation communities (OGC Standard Working Groups and Domain Working Groups, buildingSMART Working Groups, GeoBIM joint bSI-OGC Working Group; CEN, national standardisation bodies, etc.), offering concrete recommendations for the possible integration or extension of these mechanisms to future standards or technical guides.

In addition, the results and lessons learnt were reported and discussed within relevant standardisation bodies events and dissemination venues throughout the whole project: bSI-OGC joint GEOBIM working group; OGC member meetings (CityGML, 3DIM working group, GeoBIM workshop in Delft Member Meeting in March 2024); bSI; UNE; UNI;

BDTA working group; CEN TC442/WG9 and other relevant conferences in the field (see WP7 reports). These sessions promoted the exchange of opinions and debate on possible improvements to the proposal, encouraging collaboration between the different standardisation bodies.

Thanks to this methodological approach, the proposed guidelines are based both on practical experimentation with specific tools and on subsequent needs analysis and the exchange of experiences with the community of experts in GIS and BIM, thus laying the foundations for a solid and scalable adoption of interoperability processes in building information modelling environments and data exchanges between the GIS and BIM domains and working environments.

4 CHEK GEOBIM supporting tools

CHEK project has developed a set of innovative tools that enable data conversion and **exchange between GIS and BIM systems**, thus supporting interoperability between geospatial models and Building Information Models. These tools are structured around three main components, as detailed in Deliverables D3.1, D3.2, and D3.3:

1. **Geo → BIM Conversion (Deliverable D3.1)**
   A specialized GIS library has been developed by extending a Geometry Modelling Kernel to interpret and visualize geospatial data formats such as CityGML, CityJSON, LandXML, InfraGML, and generic GML. This library enables a semantic mapping between GIS model classes (e.g., Building, RoofSurface, WallSurface) and equivalent IFC entities (e.g., IfcBuilding, IfcRoof, IfcWall). The resulting process generates an IFC4 ADD2 TC1 file that:
   - Preserves the original GIS geometry by converting it into appropriate IFC geometric representations.
   - Inserts attributes and properties into dedicated IFC Property Sets when no direct mapping is available.
   - Maintains semantic integrity to the greatest extent possible, ensuring compatibility with standard BIM tools.
2. **IFC Georeferencing (Deliverable D3.2)**:
   A formalized workflow has been established to verify or assign geographic reference data within IFC models, supporting both IFC4 (using IfcMapConversion) and IFC2x3 (using dedicated property sets). The process involves:
   - Detection and validation of existing georeferencing metadata within the IFC file.
   - Selection of a coordinate reference system (CRS) using EPSG codes or topographic control points.
   - Computation of spatial transformations (translation, rotation, scale, and orthogonal height) optionally refined using least squares adjustment algorithms.
   - Insertion of the computed georeferencing parameters into the appropriate fields of the IFC model.
   - Final validation by visualizing the model in its georeferenced position using maps or specialized viewers.
3. **BIM → Geo Conversion (Deliverable D3.3)**
   To support the use of BIM models within GIS environments, the IfcEnvelopeExtractor tool has been developed. It allows the extraction of the geometric envelope of a building represented in IFC.
   This tool:
   - Filters structural external elements (walls, roofs, floor slabs).
   - Applies pre-filtering, generalisation, voxelisation, and ray casting techniques to reduce model complexity, remove non-structural elements (windows, doors), and identify visible surfaces.
   - Generates CityGML or CityJSON outputs with appropriate Levels of Detail (LoDs), tailored to specific geospatial use cases.
   - Where IfcSpace elements exist, it also supports the export of interior spaces (e.g., rooms, functional areas) into the GIS model, preserving the original IFC semantics.

5 CHEK GeoBIM workflows using the developed tools

The proposed methodology for interoperability between GIS and BIM systems is based on three main components, as described in deliverables D3.1, D3.2 and D3.3:

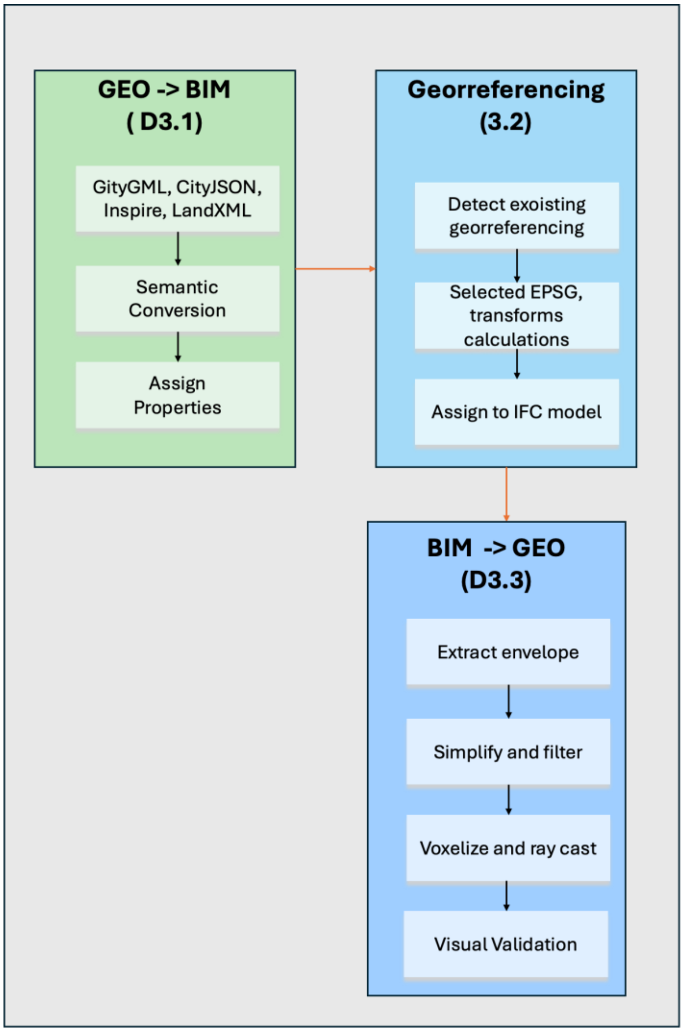


Figure 3. Chek workflow

5.1 Conversion Geo → BIM (D3.1)

- **GIS library:** A Geometry Modelling Kernel is extended to be able to interpret and visualise GML, CityGML, CityJSON, LandXML and InfraGML data, converting them internally to an RDF/OWL model (Section 3 of D3.1). This allows GIS entities (e.g., Building,WallSurface, RoofSurface) to be mapped to equivalent IFC classes (e.g., IfcBuilding, IfcWall, IfcRoof).
- **Geo to BIM Converter**: With the support of the previous library and an IFC engine, an IFC4 ADD2 TC1 file is generated. The procedure includes:

  - **Semantic analysis**: The GIS class is identified (for example, WallSurface) and associated with the corresponding IFC entity (IfcWall or IfcBuildingElementProxy if it lacks a more precise definition).
  - **Geometric conversion**: CityGML/CityJSON geometries (MultiSurface, CompositeSurface, Solid, etc.) are transformed into IFC representations (IfcClosedShell, IfcProductDefinitionShape, etc.).
  - **Properties and attributes**: These are inserted into dedicated Property Sets if there is no direct correspondence in the IFC schema (Sections 4.2.2 and 4.2.3 of D3.1).
- In this way, the converter produces an IFC model that can be read by BIM software, maintaining most of the semantics and geometry.

5.2 IFC georeferencing procedure (D3.2)

- **Detection of metadata:** It is verified if the IFC file already contains IfcMapConversion (IFC4) or the georeferencing property sets in the case of IFC2x3.
- **Selection of EPSG and calculation of transformations**: If location data is not available, the user (or the application) chooses a CRS (EPSG). From there, offsets (Easting, Northing), height and possible rotation are calculated, according to the methodology described in Section 3.3 of D3.2. Survey points and least squares algorithms can be used to refine the accuracy.
- **Injection in IFC**: The resulting values are assigned to IfcMapConversion, including attributes such as SourceCRS, TargetCRS, OrthogonalHeight, Scale and rotation vector. In IFC2x3, specific property sets are used (Section 3.1 and 3.2 of D3.2).
- **Visualisation and validation**: The option of visualising the real position of the model on a map is offered (Section 3.3.3 of D3.2), confirming the coherence of the georeferencing.

5.3 BIM → Geo conversion (D3.3)

- **Extraction of envelope**: Using IfcEnvelopeExtractor, the IFC objects that make up the ‘skin’ of the building (walls, roofs, floor slabs) are filtered. Depending on the level of detail (LoD) required, different steps are applied (Section 3.2 of D3.3):
  - **Pre-filtering and simplification (3.2.1):** To reduce complexity, highly detailed elements (windows, doors) are replaced by bounding boxes.
  - **Voxelisation and ray casting (3.2.3, 3.2.4):** Roof surfaces and wall surfaces are identified and isolated by combining voxel columns and ray shots to distinguish visible elements.
  - **Generation of LoD (3.2.2, 3.2.3 and 3.2.4):** Depending on the detail, models of type LoD0.0, 1.0, 1.2, 2.2, 3.2, etc. are obtained (Section 3.1 of D3.3).
- **Creation of CityGML/CityJSON**: Once the surfaces have been defined, a CityGML/CityJSON file is generated with the appropriate semantics and hierarchy (e.g., a Building Block that encompasses RoofSurface, WallSurface, etc.). IFC attributes without direct mapping can be converted to ADE or generic attributes (Section 3.2.6 of D3.3).
- **Interior spaces: If** the IFC contains IfcSpace, it is possible to export Rooms or interior spaces in CityGML, depending on the selected LoD (Section 3.2.5 of D3.3).

The general methodology, therefore, covers **three flows** that can be combined:

1. **From a (georeferenced) GIS model to a (georeferenced) IFC:**
   - (D3.1) Convert the GIS to IFC.
2. **From an IFC model to a CityGML/CityJSON in an appropriate LoD**:
   - (D3.2) Verify or assign georeferencing to the IFC.
   - (D3.3) Extract the envelope and generate the final GIS model.
3. **Verification and validation:**
   - The tests in D3.1, D3.2 and D3.3 have included the comparison of the result in different viewers (3DEditor, Revit, CityGML viewers, etc.) and the geometric and semantic validation through the tools developed within T2.5[6].

[6] https://chekdbp.eu/wp-content/uploads/2025/06/D2.4_CHEK-data-validity-supporting-tools_v1.0_Final.pdf

6 GeoBIM recommendations and good practices

Based on deliverables D3.1, D3.2 and D3.3 of the CHEK project, a series of good practices, recommendations and relevant standards have been identified. These focus on the work carried out on GIS-BIM conversion, georeferencing in IFC and levels of detail (LoD) in the representation of urban models.

Recommendations, standards and good practices are defined as follows[7]:

- **Good Practice**: A set of actions, methods or procedures that have been proven to be effective and efficient in specific situations, based on experience and empirical evidence.
- **Recommendation**: A suggestion or piece of advice issued by experts, aimed at improving processes or decisions, and based on analysis, good practices and specialised knowledge.
- **Standard**: A set of mandatory rules, standards or criteria that must be met. It is generally backed by regulations, certifications or official institutions.

Comparative Table of Characteristics

Characteristic	Good Practice	Recommendation
Based on empirical evidence	Yes	No
Validated in practice	Yes	No
Expert advice	No	Yes
Theoretical orientation	No	Yes

[7] ISO. (2004). *ISO/IEC Guide 2: Standardization and related activities – General vocabulary*. International Organization for Standardization.

6.1 GIS → BIM

6.1.1 CityGML/ CityJSON to IFC mapping

<table>
<tr><th>Title</th><th>CityGML to IFC mapping</th><th>Types</th><th>Recommendation</th></tr>
<tr><td>Description</td><td colspan="3">In document D3.1 (Section 4.2.2 ‘CityGML-RDF / RDFS to IFC non-geometrical semantics mapping’) the mapping between CityGML/CityJSON classes and IFC4 entities are established. The objective is that the GIS model (with its urban environment-related semantics) is correctly represented in a BIM environment. Several cases are included:

GIS to BIM Mapping Table

<table>
<tr><th>CityGML / GIS Class</th><th>Mapped IFC Entity</th><th>Notes</th></tr>
<tr><td>Building</td><td>→ IfcBuilding</td><td>Root entity for built structures</td></tr>
<tr><td>WallSurface</td><td>→ IfcWall / IfcBuildingElementProxy</td><td>Use proxy if type is undefined</td></tr>
<tr><td>RoofSurface</td><td>→ IfcRoof</td><td></td></tr>
<tr><td>Door</td><td>→ IfcDoor</td><td></td></tr>
<tr><td>Window</td><td>→ IfcWindow</td><td></td></tr>
<tr><td>VegetationObject, WaterObject</td><td>→ IfcGeographicElement</td><td>Trees, water bodies</td></tr>
<tr><td>AbstractBridge, Tunnel, TransportObject</td><td>→ IfcTransportElement</td><td>Generic mapping for infrastructures</td></tr>
<tr><td>CityFurniture</td><td>→ IfcFurnishingElement</td><td>Benches, lights, etc.</td></tr>
<tr><td>ReliefComponent</td><td>→ IfcGeographicElement</td><td>Terrain and landscape features</td></tr>
<tr><td>ImplicitGeometry</td><td>→ IfcMappedItem</td><td>Repeated geometries like cloned trees</td></tr>
<tr><td>(Unmapped classes)</td><td>→ IfcBuildingElementProxy</td><td>Fallback for undefined CityGML classes</td></tr>
</table>
</td></tr>
<tr><td>Benefit/Impact</td><td colspan="3">

Enables consistent and traceable translation between GIS and BIM models while preserving urban semantics.
Facilitates automation of GIS-to-BIM conversion processes by avoiding ambiguities.
Supports interoperability between public administrations, developers, and technical stakeholders through explicit mappings between geospatial classes and IFC entities.
Enhances reuse of existing GIS data in digital permitting, urban planning, and digital twin environments.
Reduces errors when interpreting GIS data in BIM contexts by providing a standardized mapping table.

</td></tr>
<tr><td>CHEK Example</td><td colspan="3">

. Buildings
Building → IfcBuilding
Corresponds to the root entity that groups all construction in IFC.
WallSurface → IfcWall
If the type of wall is not clear (or there is a lack of semantics in CityGML), IfcBuildingElementProxy can be used.

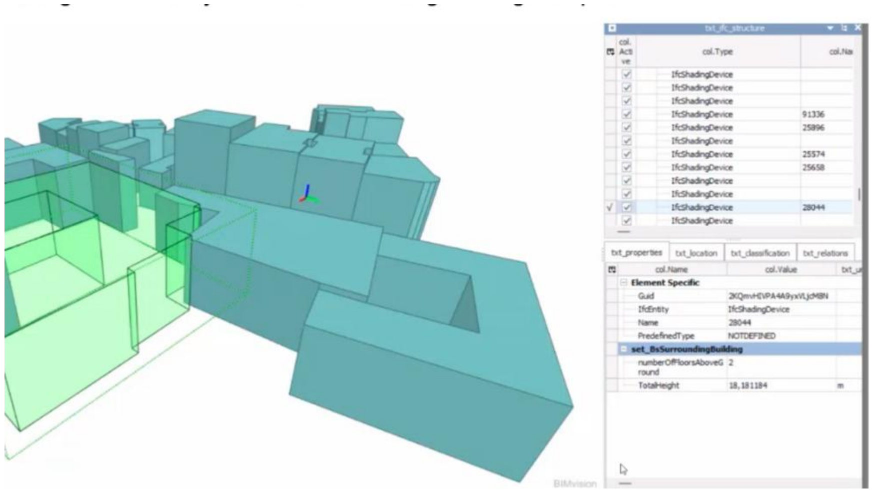
</td></tr>
</table>

	• RoofSurface ⟶ IfcRoof
	• Door ⟶ IfcDoor
	• Window ⟶ IfcWindow
	
	• **Urban / infrastructure elements**
	
	• VegetationObject / WaterObject ⟶ IfcGeographicElement
	  ○ It is assumed that these correspond to geographic objects without a more specific BIM classification (plants, lakes, etc.).
	• AbstractBridge, AbstractTunnel, TransportationObject, LandUse, etc. ⟶ IfcTransportElement
	  ○ As there are no detailed IFC entities for bridges or tunnels in IFC4 ADD2, they are mapped to IfcTransportElement.
	• CityFurniture ⟶ IfcFurnishingElement
	  ○ Street furniture (lampposts, benches, litter bins) are assimilated into furnishing objects.
	• ReliefComponent ⟶ IfcGeographicElement
	  ○ It highlights the terrain or features in the GIS.
	• ImplicitGeometry ⟶ IfcMappedItem
	
	When an object is repeated many times in CityGML (e.g. cloned trees), IFC uses IfcMappedItem to avoid duplicating geometry.

Comments	

6.1.2 Fallback (no specific correspondence)

Title	**Fallback (no specific correspondence)**	**Types**	**Good Practice**
Description	When there is no recognisable CityGML class, IfcBuildingElementProxy could be used as a generic category. However, this generates issues for leaving the semantics of the represented objects totally open and therefore not sufficiently defined for automatic processes. Therefore, this is avoided, and other classes are preferred, based on the intended use of each object.		
Benefit/Impact	• Encourages more meaningful and semantically rich mappings by avoiding the overuse of generic proxy entities. • Promotes better data quality and clarity in BIM environments, especially for automated processes. • Highlights the need for ongoing analysis and refinement of unmapped objects to ensure accurate representation. • Supports semantic interoperability by suggesting alternative IFC classes based on the intended role of objects. • Enhances analysis workflows by assigning appropriate roles to previously unmapped GIS elements.		
CHEK Example	For example, although this is not the optimal solution and futher investigations will need to be carried out, IFCShadingDevice is used in the cases context objects are considered for their shading effect (Figure 4). Even better solution would be to define classes able to represent the unmapped objects properly, based on the role they should assume for the analysis.		

	 Figure 4. Surrounding buildings encoded as ShadingDevices With regard to **geometry**, D3.1 (Section 4.2.3) explains that GIS entities such as MultiSurface, CompositeSurface, Solid, etc. are converted to IfcClosedShell, within an IfcProductDefinitionShape with IfcShapeRepresentation (type BREP) and IfcStyledItem (for styles or materials). **Attributes or properties** that do not correspond directly to a native IFC attribute are transferred to Property Sets. For example, if the Building class in CityGML has a numberOfFloorsAboveGround attribute, an IfcPropertySet is created in IFC with a 'NumberOfFloorsAboveGround' property of type IFCINTEGER (D3.1, Section 4.1 and 4.2.4).
Comments	

6.2 BIM → GIS

6.2.1 IFC to CityGML/ CityJSON mapping

Title	**IFC to CityGML/ CityJSON mapping**	**Types**	**Recommendation**
Description	In D3.3 there is no table as explicit as in D3.1, but the processes that lead from IFC to CityGML/CityJSON are described. Key sections: • **Section 3.2.1 (Prefiltering and simplification)**: Filters relevant IFC objects (IfcWall, IfcRoof, IfcSlab, etc.) to form the 'envelope'. • **Section 3.2.2, 3.2.3, 3.2.4**: Algorithms of extrusion, voxelisation and ray casting determine which surfaces are labelled as 'roof' or 'wall'.		

- **Section 3.2.5:** Explains how IfcSpace can be converted into interior spaces (LoD2.2, 3.2).

BIM to GIS Mapping Table

IFC Element / Method	Mapped CityGML Element	LoD
IfcBuilding	Building	LoD 0 – 3.2
IfcWall	WallSurface	From LoD 1.0
IfcRoof	RoofSurface	From LoD 2.0
IfcDoor	Door	From LoD 3.2
IfcWindow	Window	From LoD 3.2
IfcSpace	Interior spaces	LoD 2.2 and above
IfcCovering / IfcBuildingElementProxy	BuildingPart or generic	If no detailed subclass

Benefit/Impact

- Clarifies how IFC entities can be systematically translated into CityGML/CityJSON elements, even in the absence of direct equivalences.
- Supports automated extraction and transformation of BIM geometry and semantics into geospatial formats.
- Enables semantic alignment between BIM and GIS by establishing links between IFC classes and CityGML elements.
- Facilitates Level of Detail (LoD)-based generalization of BIM data for urban-scale modeling or visualization.
- Encourages use of open tools and methods (e.g. IfcEnvelopeExtractor) to improve data interoperability.

CHEK Example

Although there is no chapter with direct equivalences (‘IfcWall → bldg:WallSurface’), it can be deduced from the IfcEnvelopeExtractor tool (D3.3, 3.2) that:

1. **IfcBuilding** becomes Building in CityGML/CityJSON.
2. **IfcWall** translates to WallSurface,
3. **IfcRoof** to RoofSurface,
4. **IfcDoor** to Door and
5. **IfcWindow** to WindowSurface.

Likewise, if an object is not specifically defined in IFC (e.g. IfcBuildingElementProxy or IfcCovering without subclass), it is mapped to a BuildingPart or left as generic. With regard to properties, much IFC data is ‘collapsed’ into generic CityGML/CityJSON attributes or into an ADE (Application Domain Extension).

Comments

It should be noted that **the relationship with the Levels of Detail (LoD)** in CityGML/CityJSON is strongly geometric: LoD1.0 corresponds to a simple extruded volume, LoD2.2 includes roof subdivision, etc. D3.3 describes how IfcWall + IfcRoof are ‘simplified’ to the required topology. The key point is that, semantically, an IfcWall is a WallSurface and an IfcRoof is a RoofSurface, provided that the detection of the outline is fulfilled.

6.2.2 Unmapped properties

Title	Unmapped properties	Types	Recommendation
Description	In both GIS→BIM and BIM→GIS workflows, certain properties or attributes may not have a direct class or entity correspondence between CityGML/CityJSON and IFC. These "unmapped" properties can be preserved using Property Sets in IFC or as Application Domain Extensions (ADEs) or generic attributes in CityGML. This ensures that relevant domain semantics—such as wall types, roof types, or geographic classifications—are not lost during the conversion process, even if they fall outside the standard data models.		
Benefit/Impact	• Ensures that relevant semantic attributes are not lost during GIS ↔ BIM conversions by mapping them to property sets. • Enhances data richness and semantic completeness even when no direct class equivalence exists. • Promotes flexible use of IFC through mechanisms such as Property Sets and Application Domain Extensions (ADEs). • Supports the interoperability of non-standard or domain-specific attributes across different data models. • Encourages awareness of how elements like tunnels, vegetation, or roof types can be meaningfully preserved through custom mappings.		
CHEK Example	When an IfcWall has particular psets (e.g. 'Pset_WallCommon'), the BIM→GIS converter can create attributes in CityGML, either as 'ADE' or 'generic'. (D3.3, Section 3.2.6). In the opposite direction (GIS→BIM), CityGML defined, for example, roofType, which if it does not coincide with a native IFC attribute is set as a property set (D3.1, Section 4.2.4). IfcTransportElement has been proposed in D3.1 for bridges/tunnels (AbstractBridge, AbstractTunnel). But CityGML/CityJSON does not always model the interior of a tunnel as a 'Tunnel', sometimes it is catalogued as part of a building structure. IfcGeographicElement is frequently used for vegetation, water or terrain elements, as IFC does not have a standard subclass for each type of geographic object (D3.1, Section 4.2.2).		
Comments			

6.2.3 Use of classifications

Title	Use of classifications	Types	Recommendation
Description	Attribute standardisation ensures that key properties and domain-specific information are correctly preserved and translated between BIM (IFC) and GIS (CityGML/CityJSON) models. This includes defining appropriate mappings to IFC Property Sets, creating Application Domain Extensions (ADEs), and aligning the use of materials and textures. Standardising attributes is essential to avoid data loss, maintain semantic richness, and ensure visual consistency across different domains.		
Benefit/Impact	• Prevents the loss of essential domain-specific data during model transformation. • Enhances semantic clarity by aligning custom GIS/BIM attributes with standard IFC or CityGML/CityJSON structures. • Facilitates cross-domain interoperability by supporting attribute reuse and recognition. • Promotes consistency in material and texture representations across visual and analytical platforms. • Supports more accurate digital permitting, simulation, and analysis by preserving relevant metadata.		
CHEK Example	• For GIS→BIM, D3.1 recommends that the classification in CityGML be as precise as possible, so that WallSurface, RoofSurface, Door, Window, etc. are used and generic classes are not overused. • For BIM→GIS, D3.3 emphasises the importance of using specialised entities (IfcWall, IfcWindow, IfcDoor, etc.) in IFC to facilitate the automatic identification of surfaces in CityGML.		
Comments	These rules **ensure that** the two extremes are conceptually coherent and avoid the loss of semantics. In this way, the objective of sharing 'urban' and 'construction' models in the same data ecosystem, as proposed in the CHEK deliverables, is fulfilled.		

6.2.4 Insertion and use of georeferencing parameters

Title	Insertion and use of georeferencing parameters	Types	Recommendation
Description	Precise georeferencing is essential for ensuring that BIM models are correctly aligned with geospatial data in GIS environments. This recommendation focuses on the use of IFC structures and standard CRS identifiers to enable accurate and interoperable positioning of models in real-world coordinates.		
Benefit/Impact	• Ensures consistent spatial alignment between BIM and GIS data sources. • Facilitates integration into broader spatial data infrastructures and digital twins. • Supports spatial analysis, clash detection, and regulatory compliance at the territorial scale. • Promotes interoperability by using standard EPSG codes and IFC structures. • Increases positional accuracy through survey points and transformation parameters.		
CHEK Example	• Adopt the IfcMapConversion (IFC4) structure as the main method for positioning the model in geographical coordinates, describing how Eastings, Northings, Orthogonal Height, rotation, scale factor, etc. should be specified (D3.2, Section 3.2).		

	• For IFC2x3, promote a set of standardised property sets that allow the same information to be reflected (D3.2, Section 3.2.1). • Recommend the use of CRS identifiers (EPSG codes) and, where possible, survey points with adjustment algorithms (Section 3.3 of D3.2) to ensure high accuracy.
Comments	

6.2.5 Consistent definitions of levels of detail (LoD)

Title	**Consistent definitions of levels of detail (LoD)**	**Types**	**Recommendation**
Description	The concept of Level of Detail (LoD) is critical to ensure consistent interpretation of geometric and semantic information when converting between BIM (IFC) and geospatial (CityGML/CityJSON) models. This recommendation aims to harmonize LoD definitions and their practical implementation in both domains, particularly when using simplification, voxelisation, and ray casting techniques. A consistent approach to LoD enables accurate model generalization, comparison, and integration.		
Benefit/Impact	• Ensures consistent and predictable model transformations between BIM and GIS domains. • Avoids misinterpretation of geometry or semantics due to ambiguous LoD classifications. • Supports the specification of validation criteria and quality control for LoD levels. • Facilitates automated processes for simplification and conversion based on LoD thresholds. • Enhances data interoperability by aligning LoD concepts between standards like IFC and CityGML/CityJSON.		
CHEK Example	• Base the description of LoD on the ones contained in CityGML or CityJSON standards (OGC, 2021; Biljecki et al., 2016), matching it with the levels of simplification and extraction described in D3.3 (for example, 'LoD0.0, 1.0, 2.2, 3.2, etc.'). • Standardise how the LoDs are reflected in IFC (e.g. whether LoD1.0 corresponds to a bounding box in IfcWall/IfcSlab or whether LoD2.2 includes a certain subdivision of the roof), in accordance with the voxelisation and ray casting algorithms described in D3.3, Section 3.2.3 and 3.2.4. • Specify quality criteria: minimum requirements for each LoD (enclosure of solids, level of detail in openings, etc.), avoiding ambiguity when converting IFC models to CityGML and vice versa.		
Comments			

6.2.6 Attribute standardisation

En ingles	Attribute standardisation	Types	Recommendation
Description	Attribute standardisation refers to the consistent and reusable definition of properties across BIM and GIS domains, particularly focusing on attributes without direct correspondences between models. This includes the use of IFC Property Sets (psets) when GIS data provides specific properties (e.g., number of floors above ground or zoning attributes), as well as the use of CityGML ADEs (Application Domain Extensions) or CityJSON extensions to transfer BIM attributes that lack direct equivalents. The aim is to prevent the loss of critical domain-specific information. It also includes the standardisation of material and texture definitions using IFCMaterial and X3DMaterial to ensure semantic and visual consistency.		
Benefit/Impact	• Prevents the loss of critical information during domain transformations. • Ensures semantic and visual consistency across BIM-GIS data exchanges. • Enables structured interoperability through well-defined attribute correspondences. • Supports controlled data extension through reusable ADE templates.		
CHEK Example	• Property Sets IFC: when GIS data provides specific properties (for example, 'Number of floors above ground' or zoning attributes), define a clear set of psets or a mapping to the predefined IFC psets (D3.1, Section 4.2.4). • CityGML ADEs (Application Domain Extensions) or extensions in CityJSON: to transfer BIM attributes that have no direct equivalence in CityGML/CityJSON. The Discussion Document can propose examples of ADE templates, based on the experience in D3.3, Section 3.2.6. • Minimise loss of information: prevent critical attributes of a domain from being discarded because they do not have a one-to-one correspondence. • Control of materials and textures: as far as possible, standardise the use of IFCMaterial and X3DMaterial, as described in D3.1 (Section 3.2.7) and D3.3 (Section 3.2.1) to maintain visual and semantic consistency.		
Comments			

6.2.7 Validation and quality process

Title	Validation and quality process	Types	Recommendation
Description	The validation and quality process focuses on ensuring the correctness, consistency, and traceability of BIM-GIS data during integration and transformation. It includes the use of validation tools—such as the bSI Validation Service for IFC and CityGML/CityJSON validators—for checking geometry (e.g., closed solids, no overlapping surfaces), semantics (e.g., classification and completeness), and the structure and syntax of conversion results. This process also involves validating georeferencing implementations (e.g., via the IfcMapConversion class), defining geometric and semantic consistency checks, and requiring quality-related metadata and provenance information to ensure transparency and traceability in complex projects.		
Benefit/Impact	• Ensures accurate and reliable data transformation between BIM and GIS. • Reduces errors related to geometry, semantics, and conversions. • Improves consistency and interoperability across different tools and formats.		

	• Facilitates traceability and auditing through metadata and documented data provenance.
CHEK Example	• Use validation tools (IFC: bSI Validation Service, GIS: CityGML/CityJSON validators – D2.4) to validate geometry (e.g. no overlapping surfaces, closed solids in IFC and CityGML), semantics (consistent classification, complete properties), structure and syntax of the results of conversions. • Validate IFC georeferencing application and storage, using, as recommended, the IfcMapConversion class (D3.2, Section 3.3.3). • Define checks for consistency, both geometric and semantic, • Require metadata on the quality of the dataset (accuracy of georeferencing, resolution of voxelisation, version of IFC/CityGML), including provenance documentation (i.e., explicitly mentioning the conversion details and origin file features) facilitating traceability in complex projects.
Comments	

6.2.8 Compatibility with versions of the standards

Title	**Compatibility with versions of the standards**	**Types**	**Standard**
Description	Ensuring compatibility with current and future versions of IFC, CityGML, and CityJSON is essential to maintain long-term interoperability and adaptability of GIS–BIM workflows. This recommendation encourages forward-looking mappings that accommodate ongoing standard evolution and can be extended to other relevant formats such as LandXML or InfraGML.		
Benefit/Impact	• Future-proofs data models and conversion workflows against evolving standards. • Facilitates integration with multiple tools, platforms, and domains. • Reduces maintenance costs and the need for rework when adopting newer standard versions. • Promotes broader interoperability with infrastructure-focused and domain-specific schemas. • Enables consistent and scalable mappings across different generations of geospatial and BIM standards.		
CHEK Example	• Favour compatibility with IFC4 ADD2/ADD2 TC1, the future • e IFC4x3, and future ones, as well as with CityGML v2 and v3 and CityJSON 2.0, and future ones, according to the versions contemplated in D3.1 (Section 3.1) and D3.3 (Section 3.1). • Design the mappings in such a way that they can be extended to LandXML, InfraGML or other GML schemas (D3.1, Section 3.1 and 3.3).		
Comments			

6.3 Georeferencing

6.3.1 Georeferencing

Title	Georeferencing	Types	Recommendation
Description	Georeferencing is essential for placing BIM and GIS models in a common spatial context. While semantic mappings define the meaning of features, their actual position in space requires the use of georeferencing structures like IfcMapConversion (in IFC4) or equivalent property sets (in IFC2x3). In CityGML/CityJSON, the CRS is defined at the CityModel level and provides global positioning via X, Y, Z coordinates.		
Benefit/Impact	• Enables accurate spatial integration of BIM models with geospatial data. • Supports location-aware applications, such as permitting, urban planning, and infrastructure analysis. • Clarifies the relationship between semantics and spatial reference systems. • Facilitates alignment between IFC and CityGML/CityJSON models by clearly defining positioning methods. • Enhances the ability to reuse, compare, and overlay models in a georeferenced environment.		
CHEK Example	• Semantic mapping does not in itself resolve the location in space but is complemented by the use of IfcMapConversion (in IFC4) or property sets (in IFC2x3) (D3.2). • In CityGML/CityJSON the CRS is defined in the CityModel, and the global position of the Building is derived from the final X, Y, Z axes.		
Comments			

Thanks to these guidelines, progress is being made towards a standardised framework that will enable the unification of georeferencing processes and interoperability flows between GIS and BIM systems. This approach helps to reduce duplication of effort in the various phases of the development and management of built assets, facilitating the reuse of data and avoiding inconsistencies between systems. In addition, semantic and geometric consistency is ensured throughout the entire life cycle of buildings and infrastructure, from initial planning and design to construction, operation, maintenance and eventual demolition or transformation. This alignment between spatial and building information models not only improves technical efficiency but also promotes more informed and sustainable decision-making.

7 CHEK Recommendations and good practices

The recommendations presented in this section are the result of a collaborative process carried out through two dedicated workshops organised by the CHEK project **towards the end of the project**, **after the main investigation and testing activities had been completed**. These sessions brought together experts in GIS and BIM, members of OGC, and industry stakeholders to evaluate and refine the proposed tools and workflows developed in CHEK.

The first session was an online workshop, designed to present the initial set of tools and collect user feedback. Participants shared their early experiences, allowing the consortium to identify improvements and better align the outputs with real-world needs.

The second session was a face-to-face workshop held during the project's General Assembly in Vila Nova de Gaia. This event allowed for deeper technical discussions, peer exchange on best practices, and validation of the preliminary results in diverse use cases and deployment contexts.

Figure 5. Workshops

Together, these workshops provided essential input for formulating **practical recommendations, standards, and good practices**, which aim to support broader adoption and effective implementation of GIS-BIM interoperability solutions based on open standards.The list of these recommendations and good practices that are gathered in these workshops is as follows:

7.1 Define rules and minimum data for GEO→BIM conversion

Title	Define rules and minimum data for GEO→BIM conversion	Types	Recommendation
Description	Clarifies scope and content of GIS-to-BIM transformations. Establishing clear rules and a minimum set of data for the transformation of geospatial information (GIS) into BIM models is essential to guarantee the consistency, interoperability and usefulness of the models in contexts such as the processing of digital permits or infrastructure planning. **Key elements of this recommendation:** • Technical standards: define which geospatial data should be translated and how —for example, plot boundaries, service networks, environmental elements such as trees, pavements, accesses, detailed topography. • Shared responsibility: the process requires consensus between urban planners, infrastructure managers, BIM/GIS technicians and responsible authorities. • Scalability: the criteria should be applicable to both large projects (housing developments, stations, hospitals) and smaller projects (single-family homes, renovations). • Transparency and automation: if these rules are well defined, they can be used in automatic conversion processes based on standards (such as InfraGML, CityGML, or IFC Alignment). • Define data requirements according to standard methods (IDS, OGC Data Exchange Toolkit) and in machine-readable format, to support data validation as well. • Example of minimum level of data requirments needed in 4 rule implementations		

Check (DBP Use Case)	Required Entities & Properties	LOIN (what is needed & why)	Standards Reference	Validation / Tooling
Maximum building height	BIM (IFC): IfcBuilding , IfcRoof , IfcWall , Pset_WallCommon.IsExternal , CHEK_common.Height (if used). Geo (CityJSON): Building + attribute +legalHeight (CityJSON ext).	Geometry: Building outer shell, roof intersection line; LoD 2–3.2 (façade + roof edges). Alphanumeric: IsExternal on walls; legal height threshold. Docs: Legal article/reference.	LOIN: ISO 7817-1 (purpose, actors, milestone). Actors: ISO 19650-4. Properties: ISO 23386. Schemas: IFC 4.3, CityGML/CityJSON v3. Zoning: INSPIRE (Planned Land Use).	Pre-check: IDS pack (IFC). Geo check: CHEK City Validator (val3dity + SHACL). View/compare: VC Map / BIMserver.center.
Min. distance to parcel boundary	BIM (IFC): IfcWall (exterior), openings. Geo: CadastralZoning (INSPIRE), parcel boundary geometry.	Geometry: Building outer shell; parcel boundary; LoD 1–2 (BIM), LoD0 (parcel). Alphanumeric: distance threshold per zone/plot type. Docs: Parcel ID , zoning ref.	LOIN: ISO 7817-1. Actors: ISO 19650-4. Props: ISO 23386. Schemas: IFC 4.3, INSPIRE Cadastral/Planned Land Use.	Pre-check: IDS (IsExternal walls present). Measure: OGC API Processes workflow; Validator report (JSON).
Building–building distance (windows consideration)	BIM: IfcWall (external), IfcWindow . Geo: CityJSON Building , WallSurface with +hasWindows .	Geometry: Two façades with window surfaces; LoD 2–3 (façade planes). Alphanumeric: +hasWindows flag on façades; threshold values.	LOIN: ISO 7817-1. Props: ISO 23386. Schemas: IFC 4.3, CityJSON ext (façade/window flags).	Validation: SHACL profile for +hasWindows ; val3dity for geometry; report in JSON/PDF.
GFA / Buildability index	BIM: IfcBuildingStorey , IfcSpace (gross areas). Geo: Zoning element buildability/plot ratio.	Geometry: Storey boundaries; LoD 1–2. Alphanumeric: area by storey; codelist for use; zoning index. Docs: Method note (gross/net).	LOIN: ISO 7817-1. Props: ISO 23386. Schemas: IFC 4.3; INSPIRE Planned Land Use (specificLandUse , indices).	Pre-check: IDS (area props); Calc: DBP calculator service (OpenAPI); Audit: trace to legal article.
Georeferencing & CRS consistency	BIM: IfcSite / IfcMapConversion (IFC 4.3), survey points. Geo: City model CRS (EPSG), vertical datum.	Geometry: Model origin, rotation, scale. Alphanumeric: EPSG codes , vertical datum . Docs: Georeferencing report.	LOIN: ISO 7817-1. Schemas: IFC 4.3 georef, CityGML/CityJSON CRS.	Tooling: IfcGref (geo-reference checker); Gate: pre-submission pass/fail.

Figure 6. Minimun requierement

Benefit/Impact	**Impact:** • It facilitates the reuse of existing GIS data in BIM environments. • It reduces ambiguity about what information must be present in a BIM model in order for it to be validated. It improves communication between public administrations and private agents in processes such as the granting of licences or urban impact analysis.
Examples or Details	Agreement on what infrastructure or site elements must be translated
Comments	Involves urban planning and infrastructure stakeholders

7.2 Move towards GIS-IFC federation instead of conversions.

Title	**Move towards GIS-IFC federation instead of conversions.**	**Types**	**Good practice**
Description	Instead of converting data between GIS and BIM formats (such as from GML to IFC or vice versa), a federation of data allows both worlds to work together in a coordinated manner, without the need to transform or duplicate information. **What does a GIS-IFC federation involve?** • Geospatial layers (GIS) and BIM models (IFC) are viewed and used together, without loss of information. • Each domain maintains its semantics and precision, but they are interconnected by means of common identifiers and interoperability rules.		

	• Advanced viewers are used that allow work to be carried out on both environments in parallel (for example, those based on standards such as I3S, OGC API - Tiles, or integrations with BCF for communication). Key requirements: • Tools that support the simultaneous visualisation of IFC and GIS without the need for conversion (e.g. platforms such as BIMserver, FZKViewer, Cesium, ArcGIS GeoBIM). • Definition of rules of spatial and semantic alignment between the two domains. • Institutional acceptance of this approach, moving away from the traditional 'BIM to GIS' or 'GIS to BIM' paradigm.
Benefit/Impact	Reduces complexity and duplication in data workflows Advantages: • Less redundancy of data and errors in synchronisation. • Updates in real time from the original sources. • Greater traceability, as each piece of data retains its origin and technical context. Time savings in collaborative or administrative projects, such as digital building permits, where multiple agents are involved.
Examples or Details	Real-time interaction between IFC and GIS layers without needing format transformation
Comments	Requires platform interoperability and viewer support

7.3 Improve classification of IFC elements to handle curved geometries

Title	**Improve classification of IFC elements to handle curved geometries**	**Types**	**Good practice**
Description	One of the main bottlenecks in the automatic processing of BIM models for digital permits or for integration into environments is the incorrect or overly generic classification of elements within the IFC file. Because when elements are not properly classified — for example, when a sloped roof is labeled simply as an IfcBuildingElementProxy — it becomes nearly impossible for downstream systems to interpret their function, geometry, or regulatory implications. This issue is especially critical for complex or non-standard geometries, such as curved walls, sloped roofs, or non-orthogonal elements, where precise classification is essential for spatial reasoning, compliance checking, and semantic integration into geospatial datasets. **What does this recommendation consist of?** • Avoid using IfcBuildingElementProxy, which acts as a generic category for unclassified elements. • Classify elements explicitly using specific classes such as: ○ IfcWall, IfcWallStandardCase for walls.		

	○ IfcRoof for roofs. ○ IfcSlab, IfcWindow, IfcDoor, etc., as appropriate. • This allows for a more precise semantic interpretation and avoids errors in automated processes such as: ○ **Extraction of the building envelope.** ○ **Conversion to levels of detail (LoD) for CityGML or other GIS formats.** ○ Processes of voxelisation or spatial simulation, as has been detected in the Gaia and Prague test models.
Benefit/Impact	• More accurate envelope extraction and LoD generation. • Improves the geometric and semantic fidelity of the model when it is exported or interpreted by other systems. • Facilitates the development of automatic rules for normative validation. • Reduces the need for manual post-processing on platforms such as the Municipality GIS platform of Vila Nova de Gaia or tools that generate generalised models (such as the ones based on envelope extraction) for city models.
Examples or Details	Replace IfcBuildingElementProxy with specific classes like IfcWall, IfcRoof to avoid voxelisation errors (e.g., in Gaia and Praha test models)
Comments	Included in D3.3, Sections 4.1 and 4.4

7.4 Manage non-standard properties with appropriate mapping strategies

Title	**Manage non-standard properties with appropriate mapping strategies**	**Types**	**Good practice**
Description	One of the main challenges in interoperability between BIM models and geospatial information is the preservation of relevant attributes during conversions between formats such as IFC, CityGML or CityJSON. Many of these attributes are not part of the core of the model, but are found in extended properties or context-specific properties (e.g. number of floors, type of enclosure, materiality, etc.). What does this recommendation propose? • Implementing strategies for semantic mapping that preserve important properties, even when there are no direct equivalences between models. • Examples: ○ Properties from CityGML such as numberOfFloorsAboveGround → should be mapped to Property Sets in IFC, for example within Pset_BuildingUse or a custom PSet. ○ IFC properties such as Pset_WallCommon.IsExternal or FireRating → can be transferred to ADEs (Application Domain Extensions) in CityGML or to custom fields in CityJSON Extensions. Requires: • Clear definition of equivalence tables between properties of different models.		

	• Support in conversion tools (such as FME, Ifc2gml, BIM2CityGML) to manage these mappings. • Coordination between BIM and GIS experts and those responsible for the design of data models (especially if ADEs or custom extensions are used).
Benefit/Impact	Preserves relevant attributes during conversion. It avoids the loss of key information during conversions between formats or levels of abstraction. It ensures that BIM and GIS models maintain semantic coherence in processes such as regulatory validation, urban simulations or environmental analyses. It enables the development of automatic transformation pipelines without compromising data quality.
Examples or Details	CityGML attributes like numberOfFloorsAboveGround → IFC Property Sets; IFC psets like Pset_WallCommon → ADE or generic in CityJSON
Comments	Covered in D3.1 (4.2.4) and D3.3 (3.2.6)

7.5 Use specific object typologies in BIM and GIS models

Title	**Use specific object typologies in BIM and GIS models**	**Types**	**Recommendation**

Description	The semantic quality of a BIM or GIS model depends to a large extent on how its objects are classified. When generic classes are used —such as IfcBuildingElementProxy in BIM or GenericCityObject in CityGML— the capacity for automatic interpretation is lost, which negatively affects the validation, simulation or analysis processes.
	
	What is recommended?
	
	• Use specific and standardised classes in both domains:
	  ○ In BIM (IFC): use IfcWall, IfcWallStandardCase, IfcRoof, IfcSlab, IfcDoor, etc.
	  ○ In GIS (CityGML/CityJSON): use typologies such as BuildingWallSurface, RoofSurface, GroundSurface, Door, Window.
	• Avoid excessive use of 'proxy' or generic objects, which tend to act as wildcards when the object is not known or well defined.		

Benefit/Impact	• Improves semantic interoperability between formats and domains. • Facilitates automatic processes of conversion, normative validation and analysis.		
Examples or Details	Avoid generic classes like Proxy; use IfcWallStandardCase, WallSurface, etc.		
Comments	Recommended in D3.1 and D3.3		

7.6 Optimise voxel size for surface detection and processing efficiency

Title	Optimise voxel size for surface detection and processing efficiency	Types	Good practice

Description	When voxelisation techniques are used to simplify or analyse 3D models (for example, during BIM→LoD conversion or to validate envelopes), the voxel size has a direct impact on:
	• The accuracy of the geometric result.
	• The computational load (memory, calculation time).
	• The quality of the detection of surfaces such as walls, roofs, openings, etc.
	What does this recommendation propose?
	• Select an optimal voxel size based on the type of building and the purpose of the processing.
	• In the case of medium-sized buildings (residential, standard offices), a voxel of between 0.3 m and 0.5 m has been identified as providing:
	  ○ Good fidelity for detecting envelopes and surfaces.
	  Low computational cost, allowing execution in urban environments with many objects.		

Benefit/Impact	• Balances detail and computational load
	• It speeds up processes such as:
	  ○ Generation of LoD (Level of Detail).
	  ○ Comparison between proposed model and buildable volume.
	  ○ Extraction of key geometric features for regulatory validation.
	• It improves the scalability of digital permitting systems when large volumes of models need to be processed.		

Examples or Details	Voxel size between 0.3 m and 0.5 m works best for medium-sized buildings during conversion processes		
Comments	See D3.3 Section 3.5.2		

7.7 Use IfcMapConversion and EPSG codes to ensure accurate georeferencing

Title	Use IfcMapConversion and EPSG codes to ensure accurate georeferencing	Types	Good practice
Description	One of the basic conditions for BIM models to be integrated into GIS systems and used in digital permit flows is that they are georeferenced correctly. Without this, the models cannot be aligned with plots of land, infrastructures, urban regulations or base layers of the environment. What does this recommendation imply? • Use the IfcMapConversion entity in the IFC model to define:		

	◦ The spatial reference system (using EPSG codes). ◦ Reference or control points. ◦ Rotation and translation necessary to place the model on a precise geospatial basis. • In models that do not include this information or that are poorly referenced, it is recommended to use tools such as IfcGref, which allows: ◦ Correcting the georeferencing a posteriori. ◦ Assigning known EPSG. ◦ Export a corrected IFC compatible with GIS viewers and platforms.
Benefit/Impact	• Facilitates BIM-GIS federation without manual intervention. • Ensures that models are correctly integrated into platforms such as CityGML, GeoBIM viewers, or digital permit viewers. • Avoids errors in regulatory validations that depend on location (alignments, distances to boundaries, setbacks, etc.).
Examples or Details	IfcGref tool assigns EPSG codes or control points to fix missing or incorrect geolocation in IFC files
Comments	Described in D3.2 Section 3.3

7.8 Implement urban 3D model viewers for visual and contextual inspections.

Title	**Implement urban 3D model viewers for visual and contextual inspections.**	**Types**	**Good practice**
Description	Urban 3D viewers allow geospatial data and BIM models to be integrated into an interactive visual environment, greatly facilitating visual inspection, contextual review and communication between agents in digital building permit processes. What does this recommendation propose? • Integrate a 3D viewer into the DBP system capable of: ◦ Loading the proposed model (IFC, glTF, CityJSON...). ◦ Display the existing urban environment accurately. ◦ Overlay normative layers (e.g. buildable volumes, environmental restrictions, setback lines). ◦ Allow interactions such as measurements, sections, visibility analysis, shadows, etc. • This functionality has already been validated in pilot cases such as Lisbon and Ascoli Piceno, demonstrating its technical feasibility and added value. Requires: • Support for open 3D visualisation standards (Cesium, 3DTiles, glTF, OGC API – 3D). • Ability to load local data and connect to normative and spatial databases. • Appropriate user experience for technicians, developers and the general public.		

Benefit/Impact	• It allows the visualisation of construction proposals in a real geospatial context. • Improves the understanding of projects by municipal technicians and citizens. • Facilitates the rapid validation of visual and spatial criteria, such as integration with the environment, distances, orientation. • Reinforces transparency and traceability in the authorisation process.
Examples or Details	3D viewers configured for local data in pilot cases such as Lisbon and Ascoli Piceno.
Comments	It should be a requirement for the DBP system.

7.9 Use IfcEnvelopeExtractor to convert IFC models to CityJSON with levels of detail (LoD).

Title	**Use IfcEnvelopeExtractor to convert IFC models to CityJSON with levels of detail (LoD).**	**Types**	**Good practice**
Description	One of the most frequent —and often most complex— tasks in the digital building permit process is the conversion of detailed BIM models into simplified and standardised GIS representations. Why? Because geospatial systems require lighter, abstracted geometry and semantics that differ from the full richness of BIM models. To support this transformation, tools such as IfcEnvelopeExtractor can be used to automate the process and produce outputs in CityJSON with varying levels of detail (LoD), as defined in CityGML/CityJSON standards. **What does IfcEnvelopeExtractor do?** • Automatically extracts the **outer and inner geometric envelope** of the IFC model. • Generates **simplified representations** with different levels of geometric abstraction — from **LoD0.0** (basic volume) to **LoD3.2** (including interior elements such as walls, floors, and ceilings). • Exports the result in **CityJSON format**, which is lightweight, easy to process, and compatible with most GIS and 3D web platforms.		
Benefit/Impact	Simplifies integration between BIM and GIS, reducing errors and conversion times. Advantages: • It saves time and reduces dependence on manual conversions or complex tools. • It improves semantic and geometric consistency between BIM and GIS domains. • It allows spatial validations or contextualised visualisations to be applied more easily. • Ideal for workflows on DBP platforms that require both environments.		
Examples or Details	Automatic conversion of exterior and interior geometry, with support for LoD0.0 to LoD3.2 and output in CityJSON format.		
Comments	See Annex 1 – for BIM2GEO practical guide on the data modelling requirements, and guidelines to use or implement the IfcEnvelopeExtractor.		

7.10 Use Geo to BIM conversion tools that respect open standards.

Title	Use Geo to BIM conversion tools that respect open standards.	Types	Good practice

Description	To achieve real, two-way integration between GIS and BIM environments in processes such as digital building permits, it is not enough to convert BIM to GIS; it is also necessary to generate BIM models from geospatial data, especially in planning phases or in environments where the BIM model does not yet exist.
	
	What does this g**ood practice** propose?
	
	• To use conversion tools that:
	  ○ Transform CityGML or CityJSON data into IFC4 ADD2 TC1 models.
	  ○ Be compatible with the open standards defined by buildingSMART and OGC.
	  ○ Generate models with structured and semantically valid information, not just geometry.
	
	Functional example:
	
	• The Geo to BIM converter allows you to create IFC files that represent plots, normative volumes or the built environment, directly from geospatial data.
	Important note: currently, the parcel boundary with dimensions (for example, minimum front or back restrictions) is not automatically included and must be incorporated manually or by means of additional rules.		

Benefit/Impact	• It facilitates the start-up of BIM models in contexts where only cartography or urban models exist. • It guarantees interoperability in both directions: from BIM to GIS and vice versa. • It reduces data duplication and improves the consistency of spatial information. Facilitates BIM-GIS integration and ensures compatibility with open standards.		
Examples or Details	Using the Geo to BIM converter to generate IFC4 ADD2 TC1 files from CityGML or CityJSON.		
Comments	Plot limit with dimension limit that can be not included. It is not included now.		

7.11 Define specific standard profiles for GIS and BIM data models.

Title	Define specific standard profiles for GIS and BIM data models.	Types	Good practice
Description	Interoperability does not only depend on compatible formats, but also on a common semantic understanding. By using RDF (Resource Description Framework) technologies and ontologies, it is possible to represent urban data in such a way that it can be interpreted, connected and validated automatically by machines and distributed systems. What does this recommendation propose?		

	• To develop RDF profiles that describe BIM and GIS urban models with standardised vocabularies, for example:
	  ○ IFC OWL ontologies (buildingSMART).
	  ○ GeoSPARQL, CityGML RDF, INSPIRE RDF ontologies.
	  ○ Other extended ones such as Smart City Ontology, SOSA/SSN, etc.
	• Use these profiles to:
	  ○ Validate models using SPARQL queries or SHACL rules.
	  ○ Facilitate semantic translation between platforms.
	  ○ Link normative, spatial and design data in an urban knowledge graph

Benefit/Impact	It facilitates interoperability and reduces data interpretation errors. Improving interoperability and understanding of urban data.
Examples or Details	Creation of RDF models for urban data following standard ontologies.
Comments	Interoperability agreement between shared concepts in GIS and BIM.

7.12 Develop tools with IFC specifications for georeferencing.

Title	**Develop tools with IFC specifications for georeferencing.**	**Types**	**Good practice**

Description	Although the IFC standard allows for the inclusion of precise georeferencing through entities such as IfcMapConversion, many BIM modelling tools (especially Revit) do not correctly implement this functionality or omit it in the export. This generates inconsistencies when trying to federate BIM models with GIS data.
	
	What does this recommendation propose?
	
	• To develop and promote tools (plugins, scripts, viewers) that:
	  ○ Read and validate the georeferencing of IFC models.
	  ○ Correctly correct or insert the IfcMapConversion entity with data such as EPSG, base point, rotation, etc.
	  ○ Allow the user to visually check if the model is correctly positioned in relation to the official coordinate system.
	• Practical example in Revit:
	  ○ A plugin that:
	    ▪ Reads coordinates from the model.
	    ▪ Automatically assigns the EPSG and the transformation.
	    ▪ Exports the IFC correctly georeferenced.
	    ▪ Facilitates positioning on orthophotos or 3D urban models.		

Benefit/Impact	• Facilitates the integration of BIM models with GIS systems.		

	• Increases the spatial accuracy of models from the outset. • Avoids errors and rework in subsequent integration or validation processes.
Examples or Details	Process IFC models to ensure accurate georeferencing and consistency with spatial data.
Comments	This is related to define specific standard profiles for GIS and BIM data models. Revit: A good practice will be to have a plugin to place in the correct site the IFC file. The plugin has to read the coordinates and locate correctly the building.

7.13 Design automated conversion flows between CityGML and IFC with data validation at each step.

Title	**Design automated conversion flows between CityGML and IFC with data validation at each step.**	**Types**	**Recommendation**

Description	Full interoperability between GIS and BIM systems cannot depend on manual processes or isolated tools. It is essential that the DBP platform implements automatic flows of bidirectional conversion —from CityGML to IFC and from IFC to CityGML— that integrate validations at each stage.
	What does this recommendation propose?
	• To configure a chain of tools that:
	  ○ Take a CityGML/CityJSON model and convert it to IFC (Geo → BIM), generating structured entities (IfcWall, IfcSite, etc.).
	  ○ Take an IFC model and convert it to CityGML/CityJSON (BIM → Geo), with levels of detail and conservation of key properties.
	  ○ Perform automatic validations after each conversion:
	    ▪ Check for valid geometry.
	    ▪ Semantic correspondence of classes.
	    ▪ Check for essential attributes.
	    ▪ Detection of losses or conflicts.
	• Include in the DBP platform an accessible function (button or API) that activates this conversion automatically, ideally with a graphical interface and configurable options.		

Benefit/Impact	Ensures consistency in the transition of data between GIS and BIM systems. Guarantees consistency of data throughout the entire GIS-BIM flow. Dramatically reduces the risk of human error or loss of information. Makes the work of technicians who are not conversion experts easier. Increases transparency in the traceability of urban planning and design models.		
Examples or Details	Set up conversion tools that preserve data semantics in both directions (Geo to BIM and BIM to Geo).		
Comments			

7.14 Promote the use of OGC API to directly integrate GIS data into BIM flows.

Title	Promote the use of OGC API to directly integrate GIS data into BIM flows.	Types	Recommendation

Description	The evolution of OGC standards towards RESTful APIs (such as OGC API - Features, - Tiles, - Processes, etc.) allows for a much more direct and dynamic integration of geospatial data in BIM platforms, without the need for intermediate conversions or manual uploads.
	
	What does this recommendation propose?
	
	• To use the new OGC APIs to:
	  ○ Directly connect spatial data (e.g. plots, zoning, networks, altimetry) from public sources (INSPIRE, municipal geoportals, etc.).
	  ○ Integrate this data into BIM environments to enrich the context of the model and facilitate regulatory checks, visualisation or simulations.
	• Implement or use specific plugins in BIM tools (such as Revit, Archicad, AIBIM) that:
	  ○ Consult OGC API – Features services to obtain vector data in real time.
	  ○ Consume OGC API – Tiles type layers for orthophotos or base maps.
	  ○ Enable this information to be superimposed in the BIM environment as a reference.		

Benefit/Impact	• Simplifies real-time integration between GIS and BIM for regulatory and planning flows. • It eliminates the need to manually export/import GIS data. • It guarantees that the spatial data used is up-to-date and official. • It facilitates the development of federated and validated flows between urban planning systems and design platforms. • It adapts to architectures based on microservices and interoperable platforms.		
Examples or Details	Implement RESTful APIs to consume INSPIRE data in BIM platforms for analysis and visualisation.		
Comments	plugin that connected OGC API.		

7.15 Use IFCCoupleSRS to associate accurate reference systems in IFC models.

Title	Use IFCCoupleSRS to associate accurate reference systems in IFC models.	Types	Recommendation
Description	One of the persistent challenges in the BIM-GIS federation is the correct interpretation of systems of coordinates and spatial references. Although IfcMapConversion allows for an approximation, the incorporation of the IFCCoupleSRS concept provides a formal and more robust structure for managing multiple reference systems simultaneously. What does this recommendation propose? • To use IFCCoupleSRS (concept extended in IFC 4.3) to:		

	○ Define explicitly the global coordinate system (e.g. EPSG). ○ Also associate a local coordinate system (internal model). ○ Establish the exact transformation between the two (translation, rotation, scale).
Benefit/Impact	• Improves interoperability between GIS and BIM systems by ensuring consistent georeferenced data. • Avoid common mistakes in the interpretation of the model's positioning. • Increase the precision and reliability of automated processes. • Facilitate spatial coherence between heterogeneous sources. • Improve the usability of IFC data in GIS environments without manual intervention.
Examples or Details	Incorporate IFCCoupleSRS to define global and local coordinates more accurately.
Comments	

7.16 Automate construction line adjustments using algorithmic solutions such as val3dity.

Title	**Automate construction line adjustments using algorithmic solutions such as val3dity.**	**Types**	**Good practice**
Description	Validate complex geometries in IFC and CityJSON using specific tools such as val3dity.		
Benefit/Impact	Reduces time and human error in the adjustment of normative and geometric data in BIM. Ensures that geometric entities comply with international standards.		
Examples or Details	Automate the verification of building lines and their distance to plot boundaries with tools such as val3dity.		
Comments			

7.17 Ensure the use of IFC4x3 files or compatible versions for accurate conversions.

Title	**Ensure the use of IFC4x3 files or compatible versions for accurate conversions.**	**Types**	**Standards**
Description	The version of the IFC schema used has a direct influence on the quality of the conversions to GIS formats, on the semantic interpretation of the elements, and on the capacity to represent relevant attributes such as georeferencing, open spaces or spatial relationships.		
Benefit/Impact	Ensures compatibility and accuracy in GIS export.		
Examples or Details	Support for IFC2x3 and IFC4 with specific adaptations such as Psets for georeferencing.		
Comments			

7.18 Representation of surrounding buildings in IFC

Title	Representation of surrounding buildings in IFC	Types	Good practice
Description	CHEK proposal: Export each of the surrounding buildings as a separate IFCBuilding. Use a PSET to identify that it is a surrounding building or look at the IFC file to see if it contains levels, walls, doors, windows.		
Benefit/Impact	• Promotes semantic clarity by distinguishing between project buildings and surrounding context in IFC exports. • Avoids confusion or misinterpretation in BIM tools caused by incorrect IFC hierarchy or georeferencing. • Enables modular design and review by keeping surrounding buildings in separate reference files. • Reduces risk of errors in regulatory checks or validation platforms like CHEK by using consistent PSETs or file structures. • Aligns with best practices in federated modeling and improves support for city-scale assessments.		
Examples or Details	**1. How will it affect Revit? We've done some testing in Revit and found two main issues:** 1. Any mass exported will become an IFCBuilding, even if not a surrounding building. 2. Surrounding buildings exported as IFCBuilding will appear as children of the main IFCBuilding and IFCSite, which is incorrect. **2. How will it affect CYPE?** 1. Older software versions may assign different local references to each surrounding building, requiring manual user intervention to select the correct one. 2. Newer versions could read the 'surrounding' PSET or look for specific elements to identify them properly. **Additional points from stakeholders:** - proposes creating one IFC file per building and a separate file for urbanization. Surrounding buildings not part of the project would be brought into the modeling program as reference geometry only. - BSI notes that Revit may soon improve support for multiple IFCBuilding exports and that exporting selected elements may lead to duplicate GUIDs. - The general consensus is that surrounding buildings should not be exported as part of the main project IFC, but handled separately by the CHEK platform.		
Comments			

7.19 Representation of the Plot in IFC

Title	Representation of the Plot in IFC	Types	Good practice
Description	Current practice and challenges in plot representation vary across tools: The representation of the plot or parcel in IFC is inconsistent across authoring tools. CYPE currently exports the plot as an IFCExternalSpatialElement defined by a 3D polygon. Revit lacks a direct way to export the plot, as its "Property Lines" are only 2D and not included in IFC exports. Workarounds like cutting terrain to match the plot are problematic, as plots are typically defined in GIS as volumetric entities. Stakeholders suggest that the correct representation should involve using IfcSite for the plot and IfcGeographicElement for the terrain. Export plugins could project property lines into 3D and convert them to proper IFC entities. Autodesk has acknowledged limitations and is expected to support IFC export of property lines in future updates.		
Benefit/Impact	• Ensures that the plot is represented in a geospatially correct and semantically appropriate way for GIS/BIM integration. • Avoids the misuse of workaround methods (e.g., cutting terrain) that distort the definition of the plot. • Supports downstream tasks like georeferencing, permit validation, and land-use analysis. • Facilitates interoperability between design tools and validation platforms by using consistent IFC entities (e.g., IfcSite). • Prepares for future compatibility with improvements in authoring tools like Revit, enhancing long-term sustainability.		
Examples or Details	• CYPE exports the plot as IFCExternalSpatialElement, representing it as a 3D polygon. • Revit does not have a dedicated IFC entity for the plot. Options include: 1. Using Property Lines (not exported to IFC; only shown in 2D floor plans). 2. Creating terrain surfaces clipped to match the plot, which contradicts the GIS definition of plots as 3D polygons. • CHEK proposal: To be defined. Potentially include cadastral reference as attribute. **Feedback from stakeholders:** • SIA suggests using Revit Property Lines within Revit but notes the lack of proper IFC export. Opposes terrain cutting as a workaround. • BSI confirms IfcSite is the appropriate entity for plot representation, while terrain should be represented using IfcGeographicElement. • CYPE agrees with using IfcSite for the plot and IfcGeographicElement for terrain. Revit's limitations remain an issue for this mapping. • A workaround proposed is for export plugins to project 2D property lines as 3D model lines and export them as IfcSite geometry.		

	• Autodesk has acknowledged this limitation and a fix is expected in an upcoming open source update. Exporting 2D plan view elements is currently possible but results in IfcAnnotation.
Comments	

8 CHEK GeoBIM impact

The developments and results achieved for the GeoBIM connection and integration domain in CHEK were reported to relevant standardisation venues, to ensure these are well connected to further initiatives and fruitfully feed future actions ensuring the CHEK impact.

8.1 GEOBIM working group

Within the GEOBIM working group, OGC has been coordinating with buildingSMART international to develop a roadmap for interoperability between geospatial data and building information modelling data.

The GEOBIM working group is structured as a joint initiative between communities of experts in open standards, with the aim of developing sustainable, user-oriented actions that promote BIM-GIS integration throughout the life cycle of built assets and infrastructure.

The primary objectives of the roadmap are:

- Solve impactful use cases that benefit from improved connection of BIM and GIS data.
- Provide standardized toolkits to advance use cases in real-world applications.
- Demonstrate the advantages of adopting open standards for data modeling and integration.
- Educate a new generation of data suppliers and users who are simultaneously adept at enterprise-scale BIM-GIS data and acutely aware of the use cases that demand continuity in information modeling.
- Engage the traditionally siloed BIM and GIS communities with a common purpose to foster a collaborative, harmonized, and consistent approach to information management across their ecosystems.

The development of the strategic roadmap was driven by a group of committed professionals with extensive experience in BIM-GIS integration. Between October 2022 and December 2023, several working sessions were held focused on taking advantage of existing knowledge, identifying challenges and opportunities, establishing priorities according to the most relevant use cases and designing a framework that would allow for sustained progress. This approach sought to ensure that the roadmap had a practical basis, responded to real challenges and, at the same time, paved the way for innovative solutions.

The work will be based on the roadmap developed by OGC and buildingSMART, which identifies common challenges, strategic priorities and best practices to facilitate effective interoperability between BIM and GIS models. Building on this shared foundation, the GEOBIM group will move forward with the following lines of action:

1. Shared governance

- A joint steering committee will be established between representatives of OGC and bSI.
- Experts from different domains will participate: building, infrastructure, rail, airport, maritime, electrical and regulatory.

2. Use case-driven development

- Real user stories have been collected and grouped, organised by themes such as construction control, environmental impact, infrastructure planning, life cycle management and digital twins.
- These stories will be used as a basis for the development of standardised use cases that will guide the adoption of technologies and standards.

3. Creation of common tools

- A toolkit for the deployment of standards will be developed, including reference workflows, transformation guides and implementation examples.
- This toolkit will be validated in pilots and adapted to different domains through agile cycles (development sprints and feedback).

4. Collaboration with the market

- The integration of standards into commercial software will be encouraged, aligning suppliers' development plans with priority use cases.
- The availability of APIs and practical interoperability between GIS and BIM tools will be promoted.

5. Training and institutional adoption

- Training resources (short courses, quick guides) and onboarding materials will be developed for public agencies and organisations.
- Data modelling and information exchange policies based on open standards will be defined.

6. Dissemination and community

- The GEOBIM group will pay special attention to the dissemination of tangible results, including success stories and lessons learned in pilots.
- Presentations will be organised at conferences, webinars and activities to attract new entities and form specific Geo+BIM working groups.

The roadmap recognises that the development of open data standards, their integration into software tools and their subsequent adoption by the various actors in the built asset sector (such as owners, consultants, researchers, policy makers, administrators, among others) varies according to the field of activity and depends on the urgency of the use cases. It also recognises that different standards are required for different domains, and that the adoption of these standards and their implementation in software may differ within the same sector depending on the type of use or application.

Therefore, in order for organisations to effectively connect data between BIM and GIS tools, it is essential to start by identifying specific use cases in each business area. In this sense, the roadmap emphasises that the first step should be to identify the highest priority and highest value use cases, in collaboration with communities such as buildingSMART, OGC and other related organisations.

Figure 7 present example use stories in the buildings and highway infrastructure domains where BIM and GIS data need to be connected. It is expected that such stories, when sourced from the wider community of practice and used as a foundational building block, will drive sustained engagement, awareness, and interest in the roadmap’s activities. They are the starting points for activities related to open data modeling standards, data exchange standards, data procurement standards, and software implementation pathways.

User Story	User Story Description	Epic
Develop Existing Conditions Model	As `architect`, **I want to** get existing site information on property line, surrounding streets, utility lines, zoning and other property related constraints, **so that** I can create ...	02-Design
Create Digital As-Built (Digital Twin) for Building	As `emergency responder`, **I want to** get information on Building Utility Connections, Building Inventory and Condition (including capabilities of damaged structures) and ...	08-Emergency ...
Create Maintenance Work Request	As `building occupant`, **I want to** find my building, room so that I can post a work request to facilities management...	06-Operations
Identify Critical Assets	As `facilities manager`, **I want to** know where my critical assets are located and review their information (e.g. room number/name etc.), **so that** I can take appropriate ...	06-Operations
Update Asset Inventory using Digital As-Built	As `facilities owner`, **I want to** get as-built data on new construction, **so that** I can update the asset inventory with information about the asset	05-Handover

Figure 7. GeoBIM roadmap

The GEOBIM Group will continue its development following a clear, results-oriented roadmap. First, it will work on refining the existing user stories and use cases, collaborating closely with OGC to refine and prioritise the most relevant ones. As a result, a final list will be published with the use cases that are best rated for their applicability, impact and feasibility.

At the same time, the steering committee will be expanded to include representatives from both buildingSMART and OGC, ensuring balanced representation of the various domains involved, such as infrastructure, building, transport and construction, among others.

- A priority line of action will be to improve awareness and dissemination.
- To this end, success stories and tangible results obtained in pilot projects will be shared. Industry participation will also be encouraged through presentations at sector conferences and the organisation of webinars.
- To address the specific challenges of each area, thematic working groups focused on Geo+BIM will be created, according to the priorities identified by domain or business area.

- A toolkit of standards and practical guidelines will also be developed, including example workflows and guidelines for data transformation in priority use cases. This toolkit will ensure that open models, such as IFC and CityGML, can effectively support the identified scenarios.
- Another key focus will be collaboration with software providers. Efforts will be made to align their roadmaps with open standards, offer APIs and encourage pilot integrations in widely used tools.
- In addition, training resources and onboarding materials will be created for agencies and user entities. This will include quick start guides, short courses and data modelling and exchange policies to facilitate practical adoption.
- Finally, the work will be organised into agile cycles or 'sprints', allowing standards and tools to be developed, tested and improved in short iterations. This approach will facilitate the continuous updating of the toolkit based on the progress made and the feedback received.

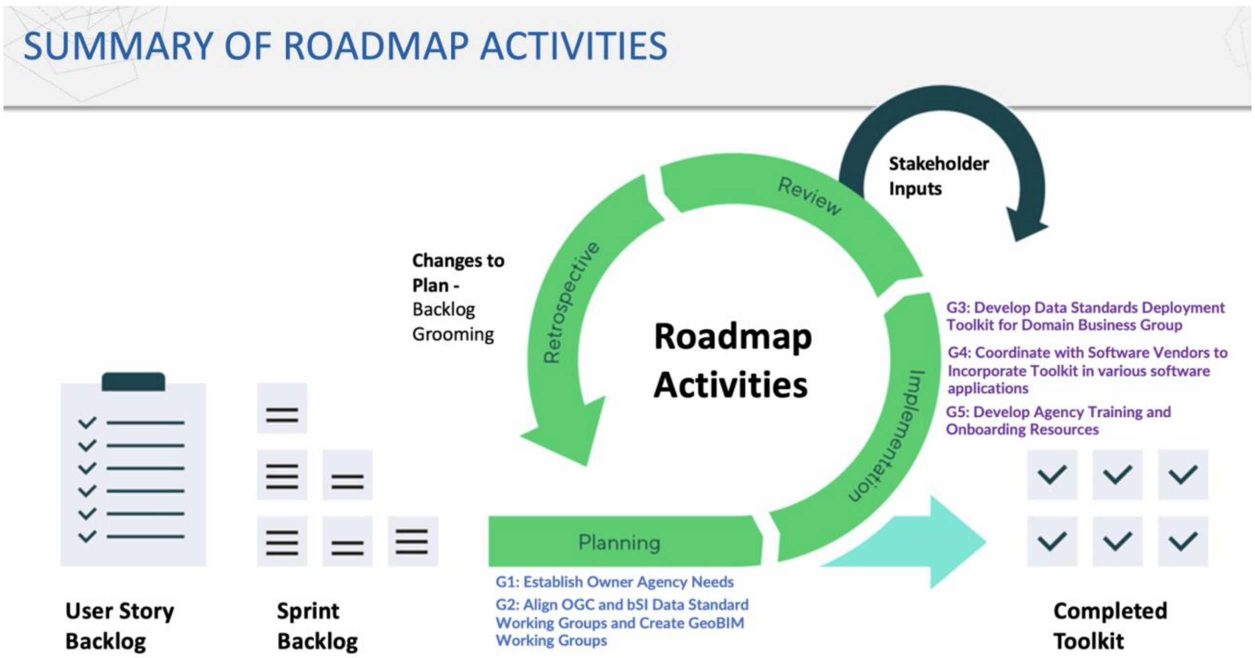


Figure 8. Summary of roadmap activities

The CHEK project contributes to this roadmap by providing a case of specific use, identified from the good practices and recommendations compiled throughout the project. These cases reflect real needs and lessons learned in the application of open standards for BIM-GIS interoperability and serve as a reference to guide future actions and facilitate their adoption in different contexts.

9 Reporting of results

Throughout the CHEK project, a set of good practices and technical recommendations in the field of BIM-GIS integration applied to Digital Building Permits (DBP) have been compiled, systematised and validated. These good practices have been derived both from the implementation of tools (such as BIM↔GIS conversion flows, IFC georeferencing or LoD generation in CityJSON), as well as from the experience shared in the project workshops and the analysis of real cases.

As part of the dissemination strategy, the results have been presented in different specialised forums:

GEOBIM working group

Throughout the duration of the project, **CHEK has been actively represented in the GEOBIM Working Group of the OGC,** directly contributing to the development of **the Strategic Roadmap for BIM-GIS Integration, j**ointly developed by the OGC and buildingSMART International (bSI). Within this framework, the user stories developed in the project (see section 6) have been incorporated as priority use cases in the roadmap catalogue, aligning the real needs of the sector with the future deployment of open standards.

The roadmap (document OGC/bSI 24-057) identifies five key lines of action:

- Collection of needs and priority use cases in each domain.
- Coordination between standardisation working groups (CityGML, IFC).
- Development of deployment kits for BIM-GIS integration.
- Collaboration with software developers to support standards.
- Training of agencies and regulatory bodies.

The CHEK team has actively contributed to groups G1, G2 and G3, especially with regard to semantic definitions, automated validation, and BIM-GIS federation for DBP

OGC Member Meeting (Rome, March 2025)

During the session entitled '**GeoBIM Integration for Digital Building Permits'**, the lessons learned from the CHEK project were presented, focusing on how CityGML and CityRDF can contribute to more robust and transparent regulatory automation. Key messages included:

- The role of **CityGML as a three-dimensional base model** of the built environment, acting as a digital skeleton on which to apply urban planning rules.
- The introduction of **CityRDF as a semantic layer**, which allows urban geometry to be linked to regulatory standards, facilitating the execution of SPARQL queries on enriched urban models.
- The possibility of connecting CityRDF with 3D visualisation technologies and web engines, so that the responses to queries are not only tabular, but also visual and interactive.

- The use of **GeoSPARQL extended to 3D** and RDF modelling for entire cities, as support for automated regulatory validations.
- The need to clarify the correspondence between CityGML and IFC, improve support for ADEs, and establish common strategies for LoD, interior and georeferencing representation.
- The promotion of tools that integrate CityGML with common BIM and GIS software (Revit, BlenderBIM, QGIS), through APIs and standardised connectors.
- The proposal for ongoing collaboration between OGC and buildingSMART to ensure future alignment between CityGML 3.x and IFC 4.x/5.

With this presentation, CHEK has placed semantic interoperability at the centre of the future of DBP, underlining how OGC standards can support automated, traceable and aligned regulatory flows with the creation of urban digital twins. The collection of user stories presented (see section 6) reflects these needs and priorities in a structured way, and has been integrated as part of the OGC GEOBIM WG roadmap.

UNE working group

The conference, organised by the UNE CTN 148 committee in collaboration with the Barcelona Metropolitan Area (AMB), served to disseminate the project's good practices in an environment more oriented towards local administrations, planning professionals and regulatory agents. The following topics were addressed:

- The current **difficulties in standardising BIM-GIS** flows in DBP due to differences in geometries, LoD, semantics and reference systems.
- The value of **OGC standards** for aligning the different data levels (raster, mesh, building models, regulations).
- The importance of **establishing a common semantic framework** that allows for the automation of regulatory validations and the reduction of ambiguities in the interpretation of urban planning regulations.
- The proposal to display **regulations as validatable 3D geometry**, integrable into design or electronic processing tools.

BDTA working group

The '*Enabling Digital Building Permits through OGC Standards and Best Practices for Geospatial Technologies'* paper will be presented as part of the **BDTA 2025 conferences**, in which the following were highlighted:

- The ability of OGC standards to connect cadastral, urban planning and architectural data.
- The use of CityGML as a structured 3D urban model, with levels of detail (LoD) adaptable to regulatory validation requirements.
- The role of CityRDF as a semantic layer that allows the linking of regulations and urban geometry, facilitating automatic verification using SPARQL.
- The importance of OGC APIs and the Data Exchange Toolkit for integrating regulatory validators into digital processing platforms.
- The advance towards an urban digital twin that represents not only the buildings, but also their regulatory conditions and their geospatial environment.

All these presentations allowed not only the **sharing of results**, but also the **dissemination of good practices collected in CHEK** and positioning them as a structural contribution to the strategic roadmap of the OGC's GEOBIM Working Group. The use cases generated (see section 6) have been proposed as priority entries for future implementation guides on DBP and interoperable urban models.

10 Conclusion

The experience accumulated in deliverables D3.1, D3.2 and D3.3 of the CHEK project highlights the potential for integrating GIS and BIM models whenever there is clear semantics in the source models (e.g., classes explicitly defined in CityGML and well-structured IFC entities). On the one hand, the transfer of objects and attributes between the two environments is effective in most cases when the source models comply with the standards and have a detailed classification. On the other hand, the combination of advanced techniques such as voxelisation and ray casting (in D3.3) with refined metadata assignment (in D3.1) and correct georeferencing (in D3.2) offers a solid framework to guarantee interoperability between GIS and BIM.

Although both geometric and semantic difficulties have been detected — for example, incomplete geometries or inconsistencies in the classification of elements — in practice most of these problems are resolved by adjustments in the assignment of categories, the simplification of the representation of components and the subsequent validation of the models. These adjustments include standardising nomenclature, cleaning up geometries and adapting semantics to the requirements of each domain (urban planning, infrastructure or building permits).

Taken together, these results demonstrate the viability of a unified standard promoted by OGC and buildingSMART (bSI) that adopts the guidelines proposed in CHEK. Such a standard would enable the seamless integration of geospatial data and BIM models in real-world applications of urban planning, infrastructure management and licensing, providing a common language and robust interoperability mechanisms for the exchange of information throughout the entire project life cycle.

11 References

11.1 List of figures

11.2 List abbreviations

ADE	**Application Domain Extension** An extension of the CityGML schema that introduces new classes and properties for specific domains (e.g., energy, infrastructure). It allows the standard semantics to be extended without modifying the CityGML base.
BIM	**Building Information Modelling** Methodology and digital representation of a construction project, covering geometry, semantics, properties and documentation. The open IFC standard is the basis for BIM interoperability.
BREP	**Boundary Representation** Geometric representation of a solid based on its surfaces and boundaries. IFC uses IfcFaceBasedSurfaceModel or IfcClosedShell to store BREP.
CRS	**Coordinate Reference System** Coordinate system that defines the geographical position of data (e.g., EPSG:4326). For IFC georeferencing, EPSG codes and attributes in IfcMapConversion are used.
GML	**Geography Markup Language** XML language for modelling geographic information. Based on CityGML and other OGC specifications.
IfcMapConversion	IFC4 entity that defines the transformation between the local coordinate system of a BIM model and a projected CRS. It includes attributes such as Eastings, Northings, OrthogonalHeight, Scale, XAxisAbscissa, etc.
LoD	**Level of Detail** Degree of abstraction of the geometry and semantics of a model, used mainly in CityGML/CityJSON. For example, LoD1 (simple volumes) to LoD4 (full architectural details, interiors).
Psets	**Property Sets**

	An extension mechanism in IFC that allows additional attributes not defined in the main schema to be stored (e.g., 'Pset_WallCommon' or custom sets).
Ray casting	A technique for detecting intersections of a ray with 3D objects. In D3.3 it is used to identify roof surfaces or walls in the extraction of the envelope.
Voxelisation	The process of discretising a 3D space into cubic cells (voxels). It allows geometries to be filtered and grouped, and is applied in D3.3 to determine the outer envelope of a building (walls, roofs).
WASM	**WebAssembly** Binary format executable in web browsers. Several tools (IfcGref, etc.) offer WASM versions for use without additional installations.

11.3 List OGC regulations and standards

OGC CityGML	OGC City Geography Markup Language (CityGML) Encoding Standard, versions 1.0, 2.0 and 3.0 (in development). https://www.ogc.org/standards/citygml
OGC CityJSON	JSON format for CityGML encoding, versions 1.0.x and 2.0. https://www.cityjson.org
OGC InfraGML	OGC specifications for infrastructures, based on GML. https://www.ogc.org/standards/infragml
GML (Geography Markup Language)	ISO 19136:2007 https://www.ogc.org/standards/gml

11.4 List BuildingSMART regulations and standards

IFC (Industry Foundation Classes)	ISO 16739:2013 and ISO 16739-1:2018 (IFC4). IFC4 ADD2 TC1 version (used in deliverables D3.1 and D3.3). https://technical.buildingsmart.org/standards/ifc

11.5 Other references of interest

LandXML	Open format for civil engineering and topography. http://www.landxml.org/
EPSG Registry	EPSG code database for reference systems. https://epsg.org
ISO 19111:2019	'Geographic information — Referencing by coordinates'.

Annex 1: BIM2GEO conversion best practice

Description:
CHEK created a robust **BIM-to-GEO interoperability workflow** based on the IfcEnvelopeExtractor and BIM2GEO converter, ensuring that IFC models can be automatically transformed into CityJSON and validated against zoning and cadastral requirements.

- **Core Best-Practice Elements:**
  - IFC-to-CityJSON conversion using IfcEnvelopeExtractor, supporting multiple LoDs (LoD0.0 to–LoD3.2).
  - Requirements per LoD structured into low, medium, and high complexity rules (see D3.4).
  - Federation of IFC and GIS constraints into a unified GeoBIM dataset, enabling DBP checks (height, GFA, distance).
  - Integration with OGC API – Features for model access and re-use in DBP platforms.

- **Workflow Steps:**
  - Export IFC model with IDS-based schema settings.
  - Run BIM2GEO conversion via IfcEnvelopeExtractor.
  - Validate geometry and semantics using val3dity and SHACL rules against CHEK CityGML.
  - Integrate zoning/cadastral data from CityJSON into the same dataset.
  - Use OGC API endpoints to serve federated data for DBP rule-checking engines.

- **Recommendation to SDOs:**
  - Submit as **OGC Best Practice** to GeoBIM DWG.
  - Recommend bSI to extend IFC5 with stronger georeferencing to simplify BIM↔Geo alignment.

- **Detailed description of the workflow BIM2GEO using the envelope extractor algorithm**

The algorithms used in the IFCEnvelopeExtractor tool have been developed to work with models created by people who may not be BIM experts. As a result, the tool can accept some input files that do not follow conventional IFC best practices. However, to increase the chances of a successful conversion, there are some requirements that should be followed whenever possible. The list of requirements for the exterior envelope extraction is divided over the three different complexity levels (see list below). The requirements per level build on top of the ones of lower levels. This means that for middle level shell extraction, the middle level detail requirements + the lower level requirements are generally required. The requirements within each level are listed in order of importance.

The requirements for the input IFC models to generate the exterior envelopes are:

- Lower level shells (LoD 0.0, 1.0 & voxel shells):
  - Valid IFC4.3, IFC4 or IFC2x3 file
  - Valid units
  - Correctly classified objects[11]
  - No IfcBuildingElementProxy objects

- Site modelled only with proper Ifc classes, or site and building separated in isolated files
- Middle level shells (Lod 0.2, 1.2, 1.3, 2.2):
  - Correctly modelled roofing structure
- High level envelopes (LoD 3.2):
  - Correctly modelled and watertight building exterior

The requirements for the envelopes with interior data are:

- Correctly geometrically shaped IfcSpace objects that comply with its surrounding/binding geometry, such as walls, floors and ceilings.
- Correct relationship between IfcSpace objects (Object CompositionType and relating classes) in cases where both spaces and zones are used in a single file12
- Correctly set up IfcRelContainedInSpatialStructure object for Storey relationships

Other recommendations:

The performance of the tool depends on the complexity of the input model. The tool has proven to function well on simple models in the current but can struggle with more complex shapes. Especially, computing an output of LoD3.2 is very resource intensive and prone to errors. It is recommended to not use this abstraction process unless other LoD abstractions cannot be used for the desired downstream processes.

If objects are used that have an extremely high polygon count that play a minor role in the modelling of the exterior or interior shell, it can be beneficial if these are manually removed from the file prior to processing. For example, certain gutter objects can be modelled with a very fine mesh shape, this will reduce the effectiveness of the software.

Partial support of IFC2x3 and 4.3 is primarily noticeable during the copying of attributes. Not all the relationships between classes that are supported by IFC2x3 and IFC4.3 are supported. This can possibly cause certain objects to be incorrectly typed as a wall while they should be windows as certain attributes are missing. IFC4 has almost complete support of all relationships.

```
CityJSON File
└── Building Object*
    ├── Outer Shell
    └── Inner Shell*
        └── Storey**
            └── Space/Room**
```

Figure 9. CityJson

The structure of the output JSON file can be seen in the image above (Figure 9):

* Object that does not directly store any geometry.

**Depending on the quality of the input, the nature of the input and the user settings, these objects can occur many times.