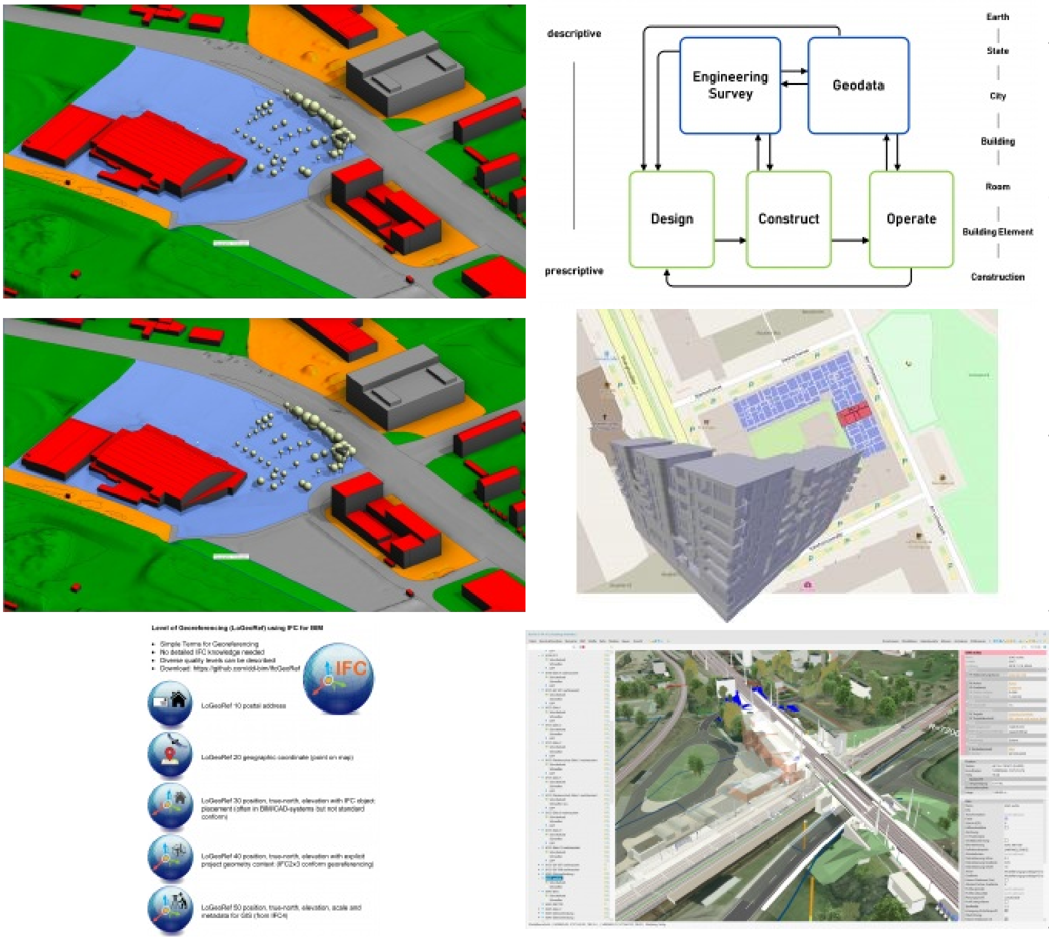
Bridging the gap between geospatial and construction



Although it is difficult to entirely close the gap between geospatial and construction data, building information modelling (BIM) could help to narrow it. This article explains how.

There is a gap in information exchange between the geospatial and construction domains. This is a serious issue, mainly because geospatial systems and engineering surveys are not yet aligned and integrated with building information modelling (BIM). The BIM method is expected to move construction activities from plan-based individual work to model-based collaboration. Such a paradigm shift will bring huge opportunities regarding planning, building and management of the built environment in a more productive, open and sustainable way. Although it is still difficult to entirely close the gap between these two fields, this article shows how that gap can at least be narrowed.

Building information modelling (BIM) is defined as a method using “a shared digital representation of a built object (including buildings, bridges, roads, process plants, etc.) to facilitate design, construction and operation processes to form a reliable basis for decisions” (ISO 29481). Despite its underlying diverse and complex structure, BIM is digital, model-based information exchange. Many regional, national and international business and academic networks are currently investigating the gap between the geospatial and construction domains. Two examples are the international working groups from ISO/TC 59/SC 13 – ISO/TC 211 JWG 14 ‘GIS/BIM interoperability’ and from OGC/buildingSMART working group ‘Integrated Digital Built Environment’ (IDBE). Both compare general modelling concepts as applied for building and geographic information, identify concrete obstacles in the data exchange processes between BIM and GIS and develop proposals for new standards.

Still, the implementation, usage and understanding of BIM varies according to the specific expectations of its users, e.g. public and private builders, project developers, general planning companies, construction companies, facility managers, etc. Each actor involved in a construction project brings along their own objectives, expertise and problem understanding. Thus, each stakeholder in an architecture, engineering and construction (AEC) project has specific information requirements.

The challenges of integrating BIM and GIS

When geospatial data enters the BIM world (Figure 1), it offers even higher potential. However, such potential also brings unrealistic expectations from stakeholders – expectations that cannot be met by current software implementations, system architectures and related domain cultures. Such technological and administrative hurdles can only be overcome with open standards for data, services and processes. OpenBIM prevents vendor locks and enables market access for small, agile and innovative software companies. The vendor-neutral data model for BIM is defined by the Industry Foundation Classes standard (IFC, ISO 16739). The equivalent for the geospatial world is the Geography Markup Language (GML, ISO 19136).

Figure 1: Information flow between the geospatial and construction domains along the life cycle of a built asset.

Even though there are many differences between the methods and processes underlying both approaches, there is a general tendency of combining them in order to benefit from their cumulated advantages. Reaching such a common vision would bring highly productive outcomes in the field of digital AEC. Indeed, integrating BIM and GIS offers benefits in terms of management of planning processes, notably during the design and construction phases. However, this is not trivial and comes with several challenges: a) an open common data environment for stakeholder collaboration, b) life cycle information, and c) component orientation.

a) Open common data environment for collaboration

BIM is not a monolithic database that contains all information in a uniformly structured data model with proper semantics. The term ‘common data environment’ (CDE) is deliberately kept generic and can mean either a simple file storage system or a service-oriented, federated infrastructure. Critical functionalities of such a CDE would allow information to be made accessible, assigned to a process, versionable and archivable, filterable and queryable, etc.

CEN/TC 442 has initiated a European standardization proposal: ‘OpenCDE’. Its aim is to establish a uniform application programming interface (API) for CDE system architectures, which until now have been exclusively proprietary. The geospatial community can make a major contribution due to its many years of experience with distributed information infrastructures (web map services, web feature services, etc.) and associated metadata services.

b) Life cycle information

It is difficult to achieve consistent and seamless use of the building information along a building’s life cycle. Companies bill their services in the grid of service phases and often have no economic interest in passing on information. However, the owner can benefit greatly from correct, available and well-structured information during the operating phase of the building. It will therefore be important that owners – and especially public owners – design specifications for the continuous transfer of information across all service phases.

buildingSMART developed the Information Delivery Manuals (IDM) methodology (ISO 29481) to capture and specify processes and information flow during the lifecycle of a facility. IDM comprises several use cases, being defined as an ensemble of exchange requirements (ER) that detail the geometric and semantic information requirements of the data delivery. For addressing this technically, ERs are developed as ‘model view definitions’ (MVD) to describe only the needed subset of the full IFC Schema. Various aspects of geographic information and engineering surveying must be considered in these documents. For this reason, it is very important for the geospatial community to participate when new BIM regulations are set up.

c) Component orientation

The shift from construction drawings to 3D models can be compared to the shift from maps to GIS. The geo-feature concept corresponds (in principle) to the component object. Building objects belong to an IFC class (e.g. IfcWall, IfcWindow, IfcColumn), are identifiable by means of globally unique identifiers (GUIDs), may have no or several geometrical representations, can belong to specific zones, can have topological relations to other objects and may ‘carry’ additional specific properties, defined through IFC property sets. In BIM applications, a building object is characterized by its geometrical representations (one per point of view) and its non-geometrical properties. For example, a wall can be represented either as a segment between two points or as a 3D geometry. Also, a wall’s representation will evolve during the considered building lifecycle phase following the addition of new construction details along with data regarding its engineering, schedule or even cost.

The IFC Schema has intentionally been created with a high expressivity. This means – in brief – that the standard contains a huge amount of types for geometry and semantics. On the one hand, such expressiveness is good because it reduces the potential issues related to software implementation. On the other hand, it gives too much ‘freedom’ and too many choices for software editors, resulting in numerous different implementations – not all of which are interoperable. The MVD standard is aimed at reducing this complexity by specifying a subset of the IFC Schema that must be checked against specific requirements as related to data delivery scenarios.

Figure 2: Geospatial datasets in BIM software (city, parcels, terrain and measured survey).

Benefits of linking geospatial and construction domains

Adding information management to model-based geospatial and building data opens up new opportunities for business process optimization. The list of use cases below provides some examples of the benefits of information integration in the various building life cycle phases.

Design and planning phase:

- Visualization of planning variants (Figure 2)
- BIM to geospatial: Use of building models for geospatial analysis, e.g. property and governmental approval, traffic simulation, environmental impact
- Geospatial to BIM: Nearby geographic context of the planned building, e.g. alignment to parcel lines, terrain and soil, location of building connection lines (Figure 3)

Construction work phase:

- Setting out and machine guidance
- Monitoring of work progress
- Area management of construction site (e.g. storage space, traceability)

Operation and maintenance phase:

- Ubiquitous and unified information on indoor assets (architectural model in conjunction with technical equipment in buildings) and

outdoor assets (utilities, parcels, trees, paths)
- Reliable and coordinated portfolio management and predictive maintenance
- Combined indoor and outdoor navigation (Figure 4)

Modes of information integration

In practical applications, the gap between the geospatial and the construction domains has many facets. These all need to be checked when designing migration processes between geospatial data and construction data, and vice versa. The interoperability of heterogeneous BIM and GIS data sources means it must be possible to analyse (derive) information which could otherwise not be deducted from separated data sources. For ensuring such reasoning over heterogeneous data, the key issue is semantic interoperability. Interoperability can be integrated, unified or federated (ISO 11354). *Integrated* approaches rely on the definition of a common form, with high expressiveness. All elements from the systems to be integrated must be described according to the common form. *Unified* approaches rely on a common meta model for the transformation. The meta model itself is not intended for execution and can range from a vocabulary to a complete ontology (knowledge representation with formal semantics). The most interesting, but also challenging, approach is *federation*. This is to be applied in contexts where the systems are too different to interoperate. The information is kept in the original domain model and can be queried via services by anybody, anywhere and anytime. For example, the Federated Architecture for OWL Ontologies (FOWLA) is an approach for federating independent ontologies and allowing them to be queried all together while keeping query answering time at its lowest (see 'Further Reading' for details of this and the GIS/BIM interoperability problem).

Figure 3: Automatically generated and georeferenced floor plans from open-source BIMserver on Open Street Map (OSM).

Georeferencing

With the right transformation parameters, a building model can be properly placed in a geodetic coordinate system. The topic of georeferencing plays a decisive role but is nevertheless poorly implemented in practice, i.e. in a manner that does not conform to standards and is technically insufficient, even though IFC (starting version 4) supports good georeferencing capabilities of IFC models. In this matter, software manufacturers must still significantly improve their products. Furthermore, the IFC standards currently lack a clear description of the geodetic scale, a conceptual data model for survey points and the inclusion of GIS-compliant attributes for geodetic datum transformation, e.g. as WKT/proj4 string.

In addition to the technical implementation, a detailed specification of the type and implementation of georeferencing in BIM exchange requirements needs to be established, at management level. For this purpose, LoGeoRef could be used to communicate (see Figure 5) and check the required level of georeferencing of an IFC model between information providers and information customers using a simple metric.

Spatial representation

A particular challenge in exchanging data among digital building models is the large number of geometric and topological representation types existing in BIM, e.g. boundary representation (B-Rep), constructive solid geometry (CSG), parametric models or hybrid model types. The complexity of adopting the correct geometric representation type is often underestimated. The transformation is not a simple 1:1 schema mapping. Geospatial features are mostly represented as points, lines or surfaces, and these are typically poorly supported (identifiable, visualized, selectable, analysed) by BIM authoring or collaboration tools, mainly because BIM focuses more on parametric solid representation.

Figure 4: Motivation and metrics for level of georefencing.

Data templates for aligned naming and atttribution of single components

IFC (ISO 16739) provides a semantic model, expressed with a huge range of entity types, type enumerations and predefined property sets. The semantic model can be extended with generic property sets and by using the so-called 'building element proxies'. However, the semantics of this user-defined extension are not standardized. In addition, the IFC is designed for model transfer rather than for expressing information needs.

In order to achieve aligned semantics between domains and projects without inflating the IFC and while remaining independent from IFC, several standards for product data templates are currently being developed by ISO working groups. The evolving standards cover a general taxonomy (ISO 12006-3, buildingSMART data dictionary), the general structure of data templates (ISO 23387), the expert process to describe, author and maintain data templates (ISO 23386), specific data templates and an IFC exchange structure for product data templates (ISO WI442018).

Level of information need

In practice, communicating the requirements for the level of detail of the building model regularly leads to misunderstandings because engineers use different terms or because it is not clear what the term 'detailing' actually means. For this reason, a European concept for describing the level of information need (LoIN) is standardized in CEN/TC 442.

In the past, the level of geometric detail (LoG) was indirectly 'implied' using the drawing scale. When working with models based on the BIM method, the 'detailing' must be defined in a more complex way: the LoG covers the detailing, dimensionality, spatial reference, graphic representation (appearance) and parametric behavior of the geometric information. In addition, the type of object identification (name, ID) as well as the type and structure of the object classification and attribution must be defined by the level of information (LoI). The level of documentation (DoC) regulates the amount and the scope of the documents that are supplied in addition to the virtual building model.

Figure 5: Integration of geospatial and construction models in a common data environment (CDE). (Courtesy: Korfin)

Examples of how to narrow the gaps

GIS to BIM
City models are uploaded to BIM in order to visualize the geographic context and use it for BIM/geospatial analysis, such as visibility analysis or calculations for building permits. Besides not supporting the semantics of city models, the spatial representation is very different between the two data models. Most solids in city models, representing a building, are collections of polygons. Currently, there are no quality standards that ensure the generation of watertight solids. However, this is extremely essential for BIM since high numerical precision is required.

BIM to GIS
When uploading simplified building models into GIS in order to check environmental or social impacts on diverse variants in construction and placement, the high diversity of possible BIM geometric representations makes it difficult to transform all objects completely from BIM to GIS. Even deriving a footprint from BIM for GIS is not easy, because the algorithm needs to select and intersect many component elements, e.g. outer walls. Ontologies and semantic web technologies also come in handy for tackling this issue, as they allow the definition of user-specific concepts based on existing ones. The ‘building envelope’ or the ‘highest storey’ are examples of concepts that can be defined using semantic rules. Once defined, such concepts can be queried directly.

BIM and engineering surveying
The shape of building elements, given as parametric model or CSG, needs to be recalculated for construction works, because total station surveys, machine guidance and progress monitoring are mostly related to points, not component objects represented as solids. The rules to export points/faces from parametric solids are not uniquely defined, which might lead to inconsistencies. The serialization of derived points in BIM (e.g. for surveying) along with their relation to the components/objects is not part of any standard. However, the major vendors of geodetic instruments provide good support for model-based surveying within their software, also supporting IFC import.

BIM and GIS for operation and maintenance of the built environment
Seamless 3D-Plan/3D-Map for facility management using indoor/outdoor data with the same interface is an important business model. The gap between geospatial and construction appears when the same real-world objects might be stored redundantly in BIM and GIS, e.g. IfcSpace for a room in BIM and a polygon in a geospatial database. There are no standards for expressing that the two geometric representations represent the same real-world object.

Conclusion

Many of the gaps that occur in practice can be solved with existing technologies but require an awareness of both the possibilities and the systemic difficulties. Open standards developed by OGC, buildingSMART International, ISO and CEN, along with national standardization organizations, will help to bridge the gaps between the construction and the geospatial domains. Last but not least, better training and tutoring has to be provided to professionals, while pushing forward the need for new processes and business models that tackle the issues discussed in this article.

Further reading

Tarcisio Mendes de Farias, Ana Roxin, Christophe Nicolle. FOWLA, A Federated Architecture for Ontologies. International Web Rule Symposium (RuleML 2015), Aug. 2015, Berlin, Germany. pp.97-111.

Ana Roxin, Elio Hbeich. Semantic Interoperability between BIM and GIS – review of existing standards and depiction of a novel approach. 36th CIB W78 – Information Technology for Construction, Sep. 2019, Newcastle, United Kingdom.

Christian Clemen, Hendrik Görne: Level of Georeferencing (LoGeoRef) using IFC for BIM, *Journal of Geodesy, Cartography and Cadastre*, 2019, pp.15-20

https://github.com/DD-bim/