



L1.1 Introduction to BIM-GIS Integration

Lecture Notes

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Summary

This lecture introduces the student into the topic of BIM-GIS integration by explaining why it is beneficial to combine these models and also what the difference between interoperability and full integration is. In its second part, the lecture takes up the main similarities and differences between the models and why the differences cause challenges to the integration.

Learning outcomes

At the end of this lecture, the learner is expected to be able to:

Explain why to integrate BIM and GIS based on their main concepts

Understand differences between interoperability and full integration

Know the differences between BIM and GIS that challenge the integration



Expected competences when entering the lecture

Knowledge of BIM and 3D GIS corresponding BIRGIT courses Introduction to BIM and 3D GIS, City Models and Digital Twins

Expected workload

12 slides with information and accompanying text, approximately 1.5 hours

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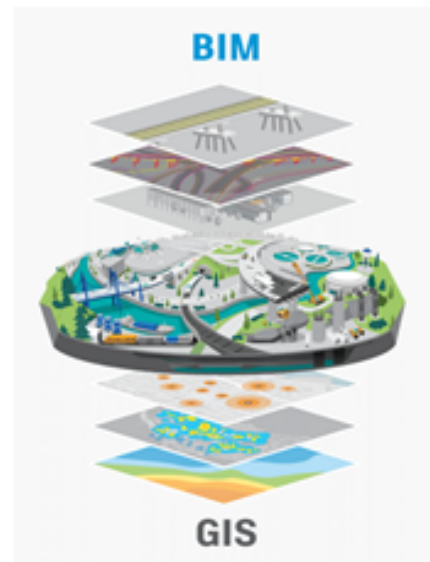
Introduction to BIM-GIS Integration

Course-block overview (L1.1 – L1.3)

Both BIM and GIS provide 3D data

- How easy or complicated is to use the data together?
- What are the benefits and the challenges?
- How does the process proceed?

[BIM-AND-GIS.png \(1233x919\) \(constructionplacements.com\)](#)



Course-block overview (Lecture 1.1 – 1.3)

Both BIM and GIS city models provide 3D data about buildings and other assets. Therefore, it should be possible to use them together, shouldn't it?



But is it so easy to do that? How does it proceed?

And what the gains and losses are if one does so? What is the best way to integrate these techniques?

These questions will we answer in the lectures of this course.




Introduction to BIM-GIS Integration



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Why to use BIM?


- Building Information Modelling
- Detailed digital 3D models of newly designed buildings, process for whole life-cycle



<https://bimcorner.com/augmented-reality-in-aec-industry/>

WHAT IS BIM?

BIMCORNER.COM



3D Model
Carrier of information and the dependencies of objects among each other

Technology
Used in Architecture Engineering & Construction

Information
Closely connected to the 3D model, allowing them to be easily found and accurate

Process
Starting from the investor's requirements, through design, construction stages, to the facility management during its lifetime

Documents
Appropriately named and placed in the CDE

Common Data Environment
As a disk space for information sharing available for all stakeholders

[Everything You Should Know About Basics of BIM Technology - Bim Corner](#)

Why to use BIM?

Architects and construction engineers nowadays create detailed digital models of every planned building, when they develop a project. The process of creation and usage of this digital model is called Building Information Modelling, shortened as BIM. To allow the construction, the model is highly detailed, showing and describing each building element.

Of course, the “building” is not necessarily a house, it can even be a facility, such as factory, sewage-station or power-plant, or an infrastructure.

To learn more about BIM, we recommend our lectures about the topics in Course package Introduction to BIM.

Great information can be also found on <https://bimcorner.com/>.



Introduction to BIM-GIS Integration



Why to use GIS?

- Semantic 3D city models in our context
- Each building is an individual object
- Can include attributes, interactions, environmental data etc.
- Can be completed by many other GIS data



Semantic 3D model of Zagreb, Croatia. Screenshot from ArcGIS Pro.

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Why to use GIS?

In context of this course, we will speak about 3D GIS, namely semantic city models.

The 3D city models show large urban areas with buildings, roads, vegetation and terrain, in order to provide realistic view of the city.

In the semantic models, each building is represented as own independent 3D object with (optimally) defined attributes and interactions. Of course, the models can be enriched by whatever GIS data available.

Similarly to BIM, we provide a course about 3D City Models, which contain all information needed to continue with this course: 3D GIS, City Models and Digital Twins.



Introduction to BIM-GIS Integration



Why to Integrate BIM and GIS?

- GIS informs BIM i.e. GIS provides the context to the detailed BIM models, such as surroundings, environment, population
- Environment influences the buildings and vice-versa
- New insights which would remain hidden without the integration



<https://bimicome.com/smartar-lector-better-7-a-tools-that-impact-the-arc/>

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Why to integrate BIM-GIS

So why should we put these two types of 3D models together?

As we have just heard, 3D GIS typically show whole built-up areas while BIM provides detailed information about the planned development. GIS represents the spatial relationships between buildings and their environment, but lacks the thorough semantic information, compared to BIM.

In this way, larger-scale GIS provides spatial context to the detailed BIM model; it is often said that “GIS informs BIM”. It is just logical to integrate them, since the environment influences the buildings and inversely, the new buildings will affect their environment.

Simply putting a BIM model to a city model, stakeholders can see how the building project fits into its surroundings or visually compare different designs. But that is not all. GIS is designed for diverse spatial analyses, which is of course possible even with an added BIM model. Such analyses are usually not possible in BIM softwares. Suddenly, one can ask questions like: Will the new building cast a shadow over a nearby schoolyard? How much solar energy can be produced on that new building? Will the underground parking be flooded after a heavy rain?

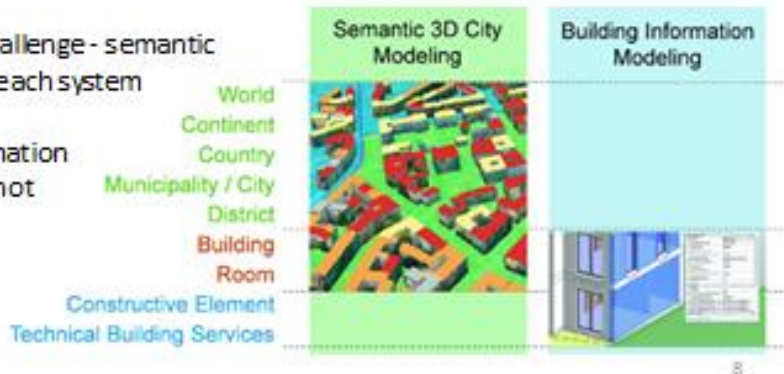
To summarize it, BIM is mainly a tool for creating information, and GIS is mainly a tool for analysing and managing information, in the BIM-GIS context. We will look at different applications more deeply later in the course.

Introduction to BIM-GIS Integration

BIM-GIS Interoperability

- Interoperability is ability to exchange and use information between different software tools
- BIM and GIS data are not completely compatible
- Semantics is the main challenge - semantic information is unique in each system
- Some parts of this information can be translated, some not

Relation of semantic 3D city modelling and BIM modelling with respect to scope and scale. From Kolbe and Dornau (2021) [Semantic 3D City Modelling and BIM | SpringerLink](#)



BIM-GIS interoperability

Why has the integration of BIM and GIS not been implemented sooner?

The main answer is that BIM and GIS data are not completely compatible. Besides that, there is the need for greater awareness of the potential benefits of integrating these two systems, in order to cross organizational barriers.

Both data models are highly complex. Although there are many similarities between them, their complexity is expressed in different ways. That is why there still are major issues challenging their interoperability and then, the full integration.

We can define the interoperability as ability to exchange and use information between different software tools. It is possible to distinguish three layers of interoperability, connected and built on each other.

The basic layer deals with technical matter such as software and hardware, and is no more an issue in case of BIM and GIS integration. Similarly, data syntax, i.e. different encodings, is solved.

The third layer – semantics – is the main challenge of the interoperability. The semantics indicates what the objects are and where they are, that is to say meaning of the messages to be exchanged. This semantic information is unique in each system, i.e. in BIM compared to GIS. Some parts of this information can be translated, some not.



Introduction to BIM-GIS Integration



BIM-GIS Integration

- Integration is the next level above interoperability
- Defined as “Progressive combining of system components into an overall system” = not only the ability to use information in different software
- Aggregating BIM and GIS data into a single unified database, sharing of information in it



BIM model used in a city model. Eni's training data, screenshot from ArcGIS Pro.

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BIM-GIS Integration

What is the difference between interoperability and integration, then?

We can see the integration as the next level above the interoperability. Integration is defined as “Progressive assembling/combining of system/software components into an overall system”. (Thus not only the ability to use information in different software, as interoperability is about, as we discussed above).

In our case, it means to aggregate both BIM and GIS data into a single unified model or database. This would allow BIM and GIS tools to share information by sending and retrieving data to and from that unified database.

We are now going to look at the causes challenging direct translation between BIM and GIS.

Introduction to BIM-GIS Integration

Different Scope and Scale of BIM and GIS

BIM

- Typically new buildings
- AEC industry
- Specific individual buildings
- Thousands of properties

GIS

- Large built areas
- Often public sector
- Many buildings with less properties
- Surrounding of buildings as well



<https://bimbus.ucc.ie/wordpress/wp-content/uploads/sites/2/2022/10/ux8-BIM-GIS.jpg>

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Different scope and scale of BIM and GIS

BIM model is typically for newly planned or recently build objects. It is in contrast with city models, which model is large, for already built areas, often whole cities.

That is also reason why BIM model producer and owner come from AEC (Architecture, Engineering and Construction) industry, while city model providers are usually municipalities or other stakeholders from public sector.

As BIM focuses on individual objects / specific buildings, the model is highly detailed. Sites are constructed from components like walls, slabs, stairs, pipes, cables or even power plugs, and so on. These components further include descriptive information e.g. about materials, dimensions, manufactures or costs.

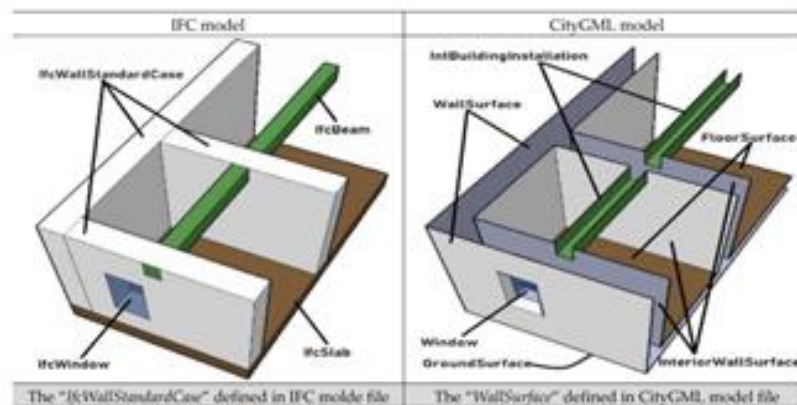
City models cannot be as detailed as the BIM ones for two reasons. First, their scope is high number of objects / buildings and to provide huge amount of detail would be too overwhelming, and even unnecessary. Second, the detailed information is simply not available, as a consequence of different process when creating the city models.

But on the other side, city models provide further thematic areas like transportation, vegetation, and water bodies, besides the built environment only.

Introduction to BIM-GIS Integration

Different Formats - IFC and CityGML

- Both semantic modelling
- IFC more semantically rich (=more info)
- It challenges conversion
- Limit IFC complexity prior the conversion



Example of differences between IFC and CityGML model. From: Ding et al (2017)

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Different formats – IFC and CityGML

Both BIM and 3D GIS deal with semantic modelling of the built environment. Both methods also have their open international standard format, i.e. IFC and CityGML (encoded as CityJSON, but we used the standard name CityGML in the text), respectively. (These formats were closely described in the BIM Introduction and the 3D GIS courses).

CityGML defines 13 themes that can represent the geometry, topology, semantic information, appearance, and other attributes of all relevant entities in the 3D city model. CityGML is widely used in Europe; the majority of capital cities in Europe provide CityGML models.

As BIM models have to provide much more detailed information about objects to be build, IFC is more semantically rich when compared to CityGML. This high semantic complexity of IFC is due to a bigger number of attributes as well as to high number of relationships associated to the objects and attributes.

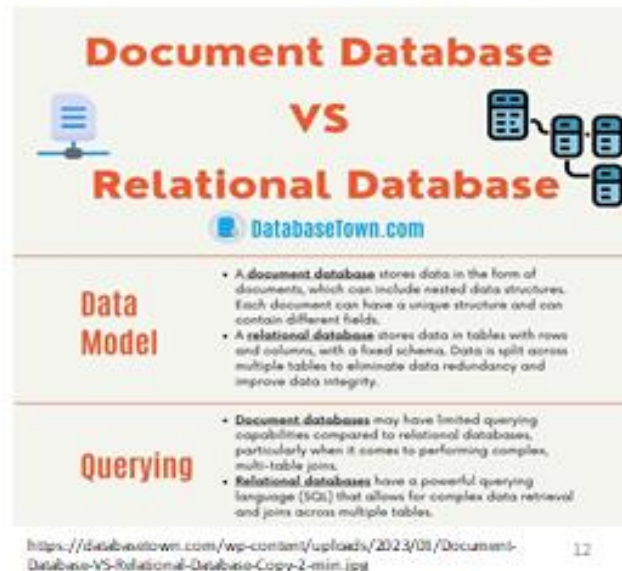
The high detail level of IFC provides the most faithful representation of the build asset, but can hinder BIM-GIS interoperability, as it challenges consistency in conversion. It can therefore be beneficial to limit IFC complexity by selecting only the data that are needed in the integrated model.

IFC and CityGML differ widely in the way they encode model components. Hence, the first step of the conversion is to define these components: semantics, geometry, topology and georeferencing. We will speak more about it later in the lecture.

Introduction to BIM-GIS Integration

Data Storage – File System and Database

- BIM and GIS use different systems of data storage
- BIM uses a file system, organised and accessible in Common Data Environment
- GIS data are stored in relational databases
- Can be accessed and queried by SQL



Data storage – File system vs Database

BIM and GIS use different systems of data storage.

BIM uses a file system, where the entire project data are stored as individual files. These files are organised and accessible in BIM Common Data Environment, CDE.

In contrast, GIS data are stored in relational databases. They can be accessed and queried by SQL in a database management system.

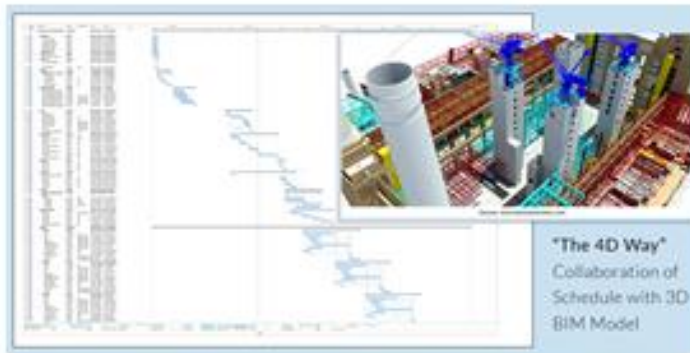
It is possible to create a relational database structure corresponding to the IFC model, but the procedure is not optimal and is quite complex.



Introduction to BIM-GIS Integration



Frequency of Updates



The-4D-Way-Collaboration-of-Schedule-with-3D-BIM-Model-8log-by-United-8BIM_.jpg

- BIM – frequent updates, especially during construction
- 3D City models– no need of frequent changes
- BIM-GIS integrated models need to be updated as often as the BIM itself
- Seamless compatibility crucial

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Frequency of updates

As BIM focuses on design and construction, IFC files are typically updated on short-term basis so that all stakeholders get up-to date information. Here we speak about weeks, at the maximum, in the most intensive phases of the building life cycle.

With the “as-built” IFC model for facility management, the frequency of updates will go down, as we will discuss later in the course.

City models can cover entire cities without constant changes and there is usually no need of continual updates. Plus, such frequent updates are not realistic.

This is one of the issues for the full BIM-GIS integration. If the integrated models should be updated and synchronized very often, it would have to proceed automatically. Seamless compatibility between the systems would be essential for that, which is not the case yet.

Introduction to BIM-GIS Integration

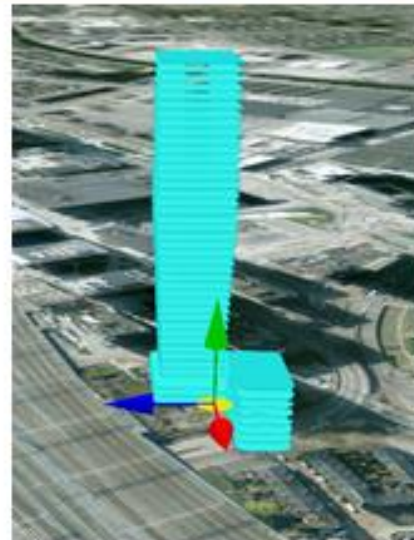
Georeferencing – total and local

BIM

- own local referencing system as default
- connected to the construction site

GIS

- always absolutely georeferenced = real-world coordinate system
- necessary to control if IFC is georeferenced otherwise georeference it or include georeferencing in the integration



Adding BIM model into GIS, Eni's training data, screenshot

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Georeferencing in BIM and GIS

BIM models have their own local referencing system, connected to the construction site and reflecting position to other objects there. However, this custom system is not always connected to any real-world coordinate system.

This becomes problem if we want to place the BIM model into GIS representing the real-world. In order to do that, the BIM model must be correctly positioned, with each 3D point absolutely georeferenced in a coordinate system. As the city models already are, in fact.

IFC supports georeferencing methods, but not all projects use them. It is necessary to control it prior the integration. If the BIM model is defined in the own system only, it is possible to georeference it directly in the BIM software, or during the integration itself. It is also crucial to control that the georeferencing is done correctly.

IFC has classes that can describe the information required for georeferencing. IFCSite can have the information of a geographic reference point for the project site in WGS84 with Longitude, Latitude and Elevation. If these values are given, it provides the absolute placement in relation to the real world.

The geographic reference point would be the location of the point 0.,0.,0. of the local referencing system of the IFCSite.

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LoD, Level of Detail

BIM

- also called “level of development”
- Information levels at various phases of the life-cycle

GIS

- Generalisation of the model
- Diverse LoD in the same model

LOD0

LOD1

LOD2

LOD3

Up: LoD in BIM. From: <https://www.3dparty.com/wp-content/uploads/2021/11/level-of-Development-LOD-3dparty-inc-3-1024x627.jpg>

Left: LoD in GIS. From: <https://www.gim-international.com/content/news/citygml-3-0-conceptual-model-approved-as-official-cgk-standard>

Level of Detail in BIM and in GIS

The concept of “LOD, Level of Detail” is used both in BIM and in GIS. However, their meaning differs between them.

In the context of BIM, LOD is nowadays referred rather as Level of Development, though both names are still used. In any case, it focuses on information levels at various phases of the design and handover. LOD includes not only geometry, but also how detailed is description of properties for each of the construction elements. LOD levels usually increase during the BIM process (see also BIM Introduction course):

- LOD 100 - Concept Design
- LOD 200 - Schematic Design
- LOD 300 - Detailed Design
- LOD 400 – Construction, Fabrication & Assembly
- LOD 500 - As-Built

Similarly, LOD in CityGML defines both geometry and semantics. In contrast to BIM, each object can have different spatial representations at the same time and one can switch between them. There are four predefined Levels of Detail (LOD 0-3). These LODs are:

- LOD0 – Highly generalized model
- LOD1 – Block model / extrusion objects
- LOD2 – Realistic, but still generalized model
- LOD3 – Highly detailed model

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For instance, a building can also be abstracted by a footprint or roof print (LOD0), by a 3D solid with flat roof (LOD1) up to detailed visualisation in LOD3.

Of course, higher LOD level represent objects with greater accuracy, but it also requires more data and computational resources. That means that the more detailed the model is, the longer time is needed to visualise it. In other words, too detailed model is not always an advantage, depending on the application.

References

Kolbe and Donaubauer (2021) Semantic 3D City Modelling and BIM, book chapter in Shi et al (eds.) Urban Informatics

[Semantic 3D City Modeling and BIM | SpringerLink](#)

Ding et al (2017) Integrating IFC and CityGML Model at Schema Level by Using Linguistic and Text Mining Techniques, IEEE Access

[Integrating IFC and CityGML Model at Schema Level by Using Linguistic and Text Mining Techniques | IEEE Journals & Magazine | IEEE Xplore](#)