



## L1.3 BIM-GIS Data Conversion

### Lecture Notes

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#### **Summary**

The last lecture of this block goes more deeply into the data conversion. First, it provides information which data can be obtained from which model, before continuing with the description of the conversion in both directions. First, BIM-to-GIS path is described, including the challenging parts. It is followed by similar explanation of GIS-to-BIM procedure. In the end, the lecture provides a short overview of the software dealing with the conversion.

#### **Learning outcomes**

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

Summarize what information can be provided from BIM and GIS model

Describe the main steps and challenges of conversion BIM-to-GIS

Describe the main steps and challenges of conversion GIS-to-BIM



***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, completed L1.1 and L1.2

***Expected workload***

13 slides with information and accompanying text, approximately 1.5 hours

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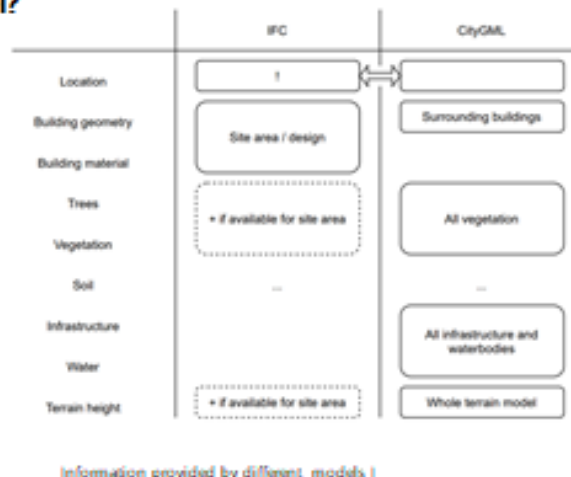
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## Data Conversion

### What information from which model?

- Conversion direction depends on application
- GIS provide spatial context, surroundings, environment
- BIM usually design of new facilities, restricted to project site
- Well defined integration goals needed



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### What Information from which model?

Whether to convert from BIM to GIS or vice-versa, it depends on the final application and on the user. If you are e.g. an architect, you probably need to import GIS data to a BIM model. If you are a city-planner, you more probably need to bring newly-planned building to the existing city model, i.e. BIM-to-GIS.

In general, GIS provide additional spatial context to BIM models, which are primarily aimed for design of new buildings or facilities and restricted to the project site. Some information about terrain and vegetation can be found even in the BIM model, if it is provided in the IFC file. In any case, the building and its materials will be usually extracted from IFC file.

However, GIS can add many additional data and for larger area. It can be data about terrain, land use or infrastructure networks, and surrounding buildings. This can enhance analyses on larger spatial scale, related e.g. to logistics or to environmental impact. Further, CityGML allows for modelling generic objects, which is not so easy in IFC (i.e. features that are not explicitly represented in the CityGML conceptual model and that can be defined by the user).

We should note that BIM-to-GIS means conversion from more-detailed model to less-detailed one, which necessarily brings certain simplification. GIS-to-BIM, i.e. less to more detailed model, is constrained by the unavailability of the information demanded in IFC.

In this lecture, we will look more deeply on how the translation between IFC and CityGML works.

## Data Conversion

### The newest versions of standards

#### CityGML 3.0 version

- better integration with BIM
- indoor spaces in different Levels of Detail support for dynamic sensor data
- time modelling
- Application Domain Extensions (ADEs)

#### IFC 4.3 version

- improved interoperability with CityGML
- 4D and 5D modelling
- energy and environmental entities
- Infrastructure BIM



Information provided by different models II from Bachert  
(2023) Mapping the Energy ADE to CityGML 3.0

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### The newest versions of CityGML and IFC standards

CityGML 3.0 version provides much better integration with BIM, compared to the older versions. It includes e.g. the ability to represent indoor spaces in different Levels of Detail (LOD), support for dynamic sensor data and for time modelling, and the capability to extend the information model into Application Domain Extensions (ADEs).

Similarly, IFC4 as the newest version of IFC and it has several improvements when it comes to interoperability with CityGML, to options for 4D and 5D modelling and to energy and environmental entities, compared to IFC2x3.

However, many data can still be in the older versions of the standards. In such case, it is recommended to consider their conversion to the newest versions.



## Data Conversion



### Conversion BIM to GIS I

- Visualizing and analyzing newly planned development together with existing objects
- CityGML model consists of a geometric and a semantic layer
- Geometric– semantic consistency needed for object existing in both layers
- Semantic and geometric conversion



New development visualised in existing city environment.  
Screenshot of EuR's training data.

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## Conversion IFC to CityGML I

Conversion from BIM to GIS allows visualizing and analysing the newly planned development together with existing objects located in its surroundings.

The CityGML model consists of a geometric layer and a semantic layer. If a specific object exists in both hierarchies, it is connected through relationships to form geometric– semantic consistency. For example, if a wall of a building has two windows and a door at the semantic level, the geometric representation of the wall must also contain the geometry of the windows and the door.

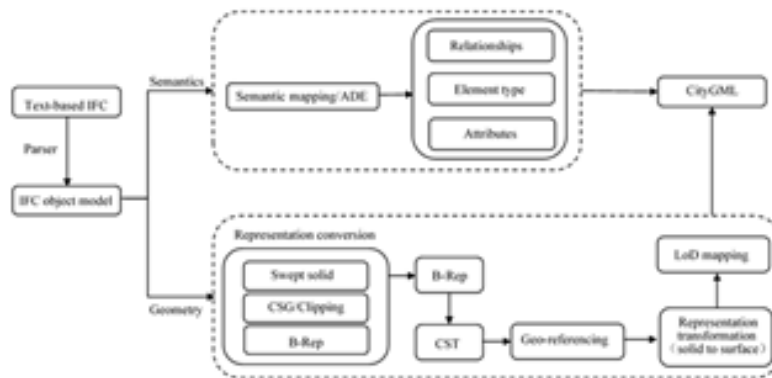
This approach allows independent navigation in both hierarchies as well as between them. It supports data integration as well as spatial semantic query and analysis. Thus, the main task of BIM-to-GIS is geometric conversion and semantic mapping (see later in more detailed description).

## Data Conversion

### Conversion BIM to GIS II

- 1) Parsing objects from IFC text-file
- 2) Conversion itself, semantic and geometry separately
- 3) Visualisation and validation

**Any conversion from IFC to CityGML entails loss of information.**



The IFC to CityGML Conversion. From: Tan, Liang, Zhu (2023) CityGML in the Integration of BIM and the GIS: Challenges and Opportunities. Buildings 13, <https://doi.org/10.3390/buildings13071758>

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### Conversion IFC to CityGML II

As the first step of the conversion, the text-based IFC file is parsed into an object model.

Then, the semantic and geometric information in the IFC object model is processed separately and converted to the CityGML model.

Finally, last step includes refinements and visualisation of the processed information to ensure that the output is valid.

As we already know, there are differences in the scope and intent of BIM and GIS, resulting in the contrasting IFC and CityGML data formats. As BIM is used for detailed modelling on a small scale, IFC uses classes to manage all thinkable elements of a building. There are over 800 classes in IFC4. However, only 60–70 of these 800 classes are related to geospatial information. And from these, only 17 classes can be mapped to CityGML.

In reality, the most relevant object classes for CityGML are only a subset of IfcSpace and all the subtypes/subentities of IfcBuildingElement. All other classes either represent movable objects or are abstract classes without geometry.

It is thus important to realize that **any conversion from IFC to CityGML entails loss of information.**

However, it is beneficial to preserve a certain subset of information from IFC, even if that information is not native to CityGML. What part of IFC information it is, it depends on use-case. Practically, it is possible by using the Generic module or CityGML Application Domain Extension (ADE).

## Data Conversion

### Semantic mapping

Mapping of element types, relationships and attributes from IFC to CityGML

Several situations:

- Some objects map directly one-to-one
- Other map into several CityGML classes
- Many IFC objects map into one CityGML class
- Indirect mapping

Semantics is usually the main limitation of the conversion

IFC-CityGML mapping. From: Sahleb et al (2020) Automatic conversion from CityGML to IFC, <https://doi.org/10.5194/isprs-archives-XLIV-4-W1-2020-127-2020>

CityGML	IFC
AbstractBuilding	IfcBuilding
-GroundSurface -FloorSurface -CeilingSurface	IfcSlab -GroundSlab -FloorSlab -CeilingSlab
RoofSurface	IfcRoof
-WallSurface -InteriorWallSurface	IfcWall -Interior Wall -Exterior Wall
WallSurface	IfcCurtainWall
GenericCityObject	IfcBuildingElementProxy
SolitaryVegetationObject	IfcBuildingElementProxy
Opening Door Window	IfcOpeningElement IfcDoor IfcWindow
BuildingInstallation	IfcBeam, IfcColumn, IfcCovering, IfcStair, IfcRailing, IfcRamp

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### Semantic mapping

Semantic mapping is the mapping of element types, relationships, and attributes from the IFC object model to the CityGML model.

The semantic mapping consists of identifying the semantics of the parsed IFC dataset and its subsequent conversion to a CityGML semantics model. Practically, series of conversion-relevant .obj files are exported from IFC and then the individual .obj files are transformed into CityGML.

Certain objects can be mapped one-to-one. For example, IfcDoor can be directly mapped to Door in CityGML, and IfcWindow can be directly mapped to Window in CityGML.

In contrast, one-to-many mapping means that an IFC class can be mapped to multiple CityGML classes. For example, IfcSlab can be mapped to OuterFloorSurface when the surface is up, to WallSurface when the surface is horizontal, and to OuterCeilingSurface when the surface is down.

Alternatively, multiple IFC classes can be mapped to a single CityGML class by many-to-one mapping. Here, we can name IfcColumn, IfcBeam, and IfcStair, which are all mapped to BuildingInstallation or IntBuildingInstallation in CityGML.

Indirect mapping refers to situations where the IFC class cannot be directly mapped to CityGML and that require further geometric operations based on the results of one-to-one and one-to-many mappings.



Then, it is necessary not only to map IFC classes to CityGML entities, but also to map the properties and relationships of the classes.

For instance, the properties of `IfcWindow` (such as thickness, material, etc.) need to be mapped to the corresponding properties of the `Window` entity in CityGML. This ensures that the converted CityGML model can retain and represent the relevant attributes of `Window`.

Additionally, it is important to map the relationships between `IfcWindow` and other classes, such as `IfcWalls` and `IfcOpeningElement`. This ensures that the converted CityGML model accurately represents the associations between `Window`, `Walls`, and `Opening`.

Altogether, all the named buildings part will belong to feature class `AbstractConstructiveElement`, subclass `BuildingConstructiveElement`, module `Building`, in CityGML3.

If the corresponding semantic information for the IFC model is not available in CityGML, the `Generics` module and the ADE extension mechanism can be applied (see also above). It happens also that some semantic information is missing in the IFC file but expected or required in CityJSON. In any case, semantics is usually the main limitation of the conversion.

## Data Conversion

### Geometry transformation



FZK Haus (known from IFC lecture) converted into CityGML by FME; building elements are visualised. Source: [GitHub - tum-gis/ifc-to-citygml3: An FME workspace for converting IFC data sets to CityGML 3.0 data sets](https://github.com/tum-gis/ifc-to-citygml3)

Each IfcObject in IFC file is checked if:

- it has a geometry
- it is outside or inside a building

It is then stored as a gml:Solid or a gml:MultiSurface.

Challenges arise from different geometric representation and different level of detail

Georeferencing and coordinate system transformation can be performed in this step

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## Geometry transformation

In the geometric transformations, each filtered IfcObject in the IFC file is checked whether it has a geometry and whether it is contained outside or inside a building. It is then stored as a gml:Solid or a gml:MultiSurface.

Similarly to the semantic mapping, some objects can be transformed directly, such as IfcRoof. In other cases, more decomposition is needed. This decomposition is done until a final mapping is found. For example, an IfcPlate on its own could have many meanings, so it needs to be decomposed further until e.g. IfcWindow, which is then mapped to Window in CityGML.

The challenges in geometric conversion arise from different geometric representation and different level of detail between IFC and CityGML.

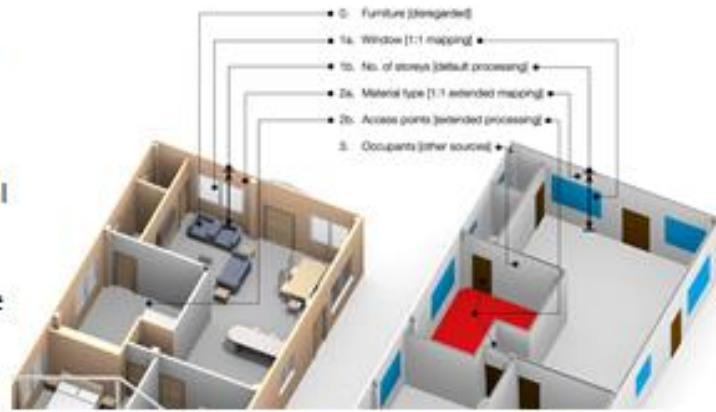
As we have already discussed, IFC defines five levels of development (LODs), but they do not match with the four levels of detail (LODs) defined in CityGML. Therefore, LOD mapping is necessary to convert IFC models to different CityGML LODs.

Georeferencing and coordinate system transformation can be performed in geometry transformation, if these were not done previously on the input data.

## Data Conversion

### Simplification

- Conversion BIM-to-GIS leads to simplification and removing details
- Choosing optimal level is crucial
- Best to customize IFC model already on BIM-level, not in the conversion
- Use of Model View Definitions (MVD) recommended



[Illustration of the relation between IFC and CityGML showing examples of categories in ppm \(850x478\) \(researchgate.net\)](https://www.researchgate.net/publication/325047811)

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## Simplification

To remind us, the conversion of IFC to CityGML implies simplifying and removing details and unnecessary information in the data. From those over 800 classes defined in the IFC schema is the majority not relevant in GIS.

Choosing an optimal level of details to be converted from a BIM-model is very important. Objects need to be modelled with enough details, according to the scope of work. At the same time, too many details will make the integrated model very large, multiply errors and cause software lagging.

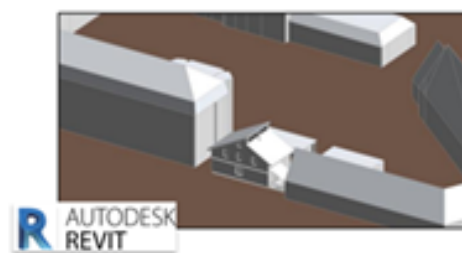
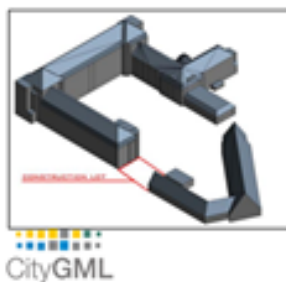
The IFC model can be customized already on BIM-level, not necessarily as late as in the IFC-CityJSON conversion. Model view definitions (MVD, see also BIM Introduction course) can be used to restrict the data model to a specific purpose, such as design or energy analyses. A range of predefined MVD can be found in the MVD database of buildingSMART International.

In any case, validating the output CityGML file against a schema should be a standard procedure because of all the introduced errors in different steps.

## Data Conversion

### Conversion GIS to BIM I

- GIS data used in BIM – usually conversion CityGML to IFC
- Improves information about surroundings



- 1) Defining surroundings in city model /CityGLM datafile
- 2) Export from CityGLM to IFC
- 3) Import to BIM software to join in with a planned building

Visualisation of CityGLM to IFC conversion steps. From: Salhab (2019) Automatic Conversion of CityGML to IFC, MSc thesis, TU Delft

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## Conversion GIS to BIM I

GIS-to-BIM means that the geospatial data created by GIS are used in BIM, which usually means CityGML to IFC conversion. This type of conversion used to be less common, as the simpler model is converted to the more detailed one.

However, bringing semantic 3D city models and terrain model into BIM highly improves the information about the surrounding environment, both for planned projects or for renovations. GIS data are stored according to the IFC model and managed from the BIM software in this case.

An application is thus to create a simplified BIM model of the surrounding buildings from CityGML and combine it with the full project-models using BIM software, as documented by the figures.

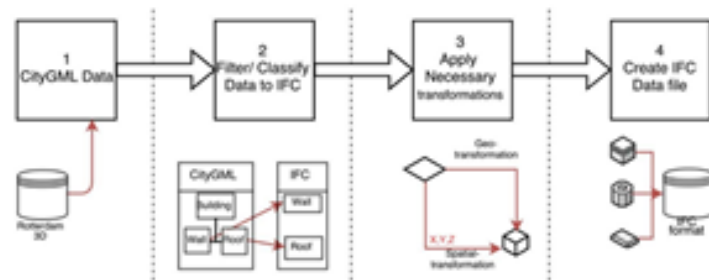
## Data Conversion

### Conversion GIS to BIM II

- Simpler model is converted to the more detailed one

Usage:

- Analyses for design and construction
- Digital twin, facility management
- Both IFC and CityGML are semantic models with strict separation between geometry and semantics



Schema of conversion workflow from CityGML to IFC. From: Selheh (2019) Automatic Conversion of CityGML to IFC, MSc thesis, TU Delft

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### Conversion GIS to BIM II

There is no doubt about advantages of visualisation and analysing of any new development within its surroundings. There are numerous applications in all phases of the life-cycle.

In the design phase, one can test different locations, building exposure or even the architectural-design itself. During the construction, it is possible e.g. to optimize logistics on the site. Later on, the detailed BIM model within its environment can optimally become a digital twin with all its benefits. There are lectures specialised to the applications later in this course (Block 2 and 3).

Similarly to CityGML, even IFC is semantic model with strict separation between geometry and semantics. As such, there are semantic mapping and geometry transformation as two different steps even in GIS-to-BIM direction.

## Data Conversion

### Semantic mapping I

- IFC has more classes than CityGML
- Only minority of classes relevant for conversion
- Common with different semantic meaning of objects

Challenge - how to best map semantics from CityGML to their equivalents in IFC?



Semantic mapping from CityGML to IFC. From Sahlab et al (2020) Automatic conversion from CityGML to IFC, <https://doi.org/10.5194/isprs-archives-XLIV-4-W1-2020-127-2020>

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## Data Conversion

### Semantic mapping II

Steps:

- Matching IFC and CityGML schemas
- Investigation which objects and attributes correspond to each other
- Relevant data filtered and classified into IFC

Certain loss of semantic information is inevitable because many parts are not applicable for the conversion

IFC objects	CityGML 3.0 objects
IfcProject	CityModel
IfcSite	LandUse
IfcBuilding	Building
IfcBuildingStorey	Storey
IfcSpace	BuildingRoom
IfcWallStandardCase	BuildingConstructiveElement
IfcBeam	BuildingConstructiveElement
IfcSlab	BuildingConstructiveElement
IfcMember	BuildingConstructiveElement
IfcDoor	Door
IfcWindow	Window
IfcRailing	BuildingInstallation
IfcStair	BuildingInstallation

Mapping between IFC and CityGML objects.

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## Semantic mapping I and II

IFC has a high number of classes, compared to CityGML. As we already know, only a minority of the classes are relevant in the conversion and it is common with different semantic meaning of objects. The question is then how to best map semantics from CityGML to their equivalents in IFC.

First step of the conversion is thus Matching IFC and CityGML schemas, which means investigating which attributes and entities correspond to each other. The relevant data are then filtered and classified into IFC.

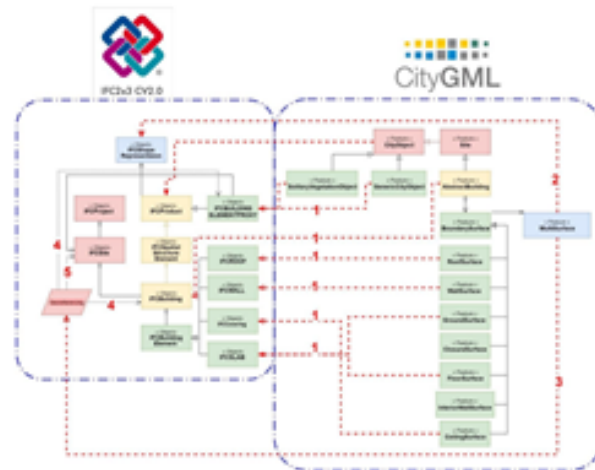
However, certain loss of semantic information is inevitable because of this fact that a lot of the entities are not applicable for the conversion.

## Data Conversion

### Geometry transformation

#### Steps:

- Creating Geometry resources for IFC objects based on source CityGML geometry (red line 2 in the figure)
- Creating georeferencing point from CityGML (line 3)
- Georeferencing IFC objects (4)
- Storing georeferencing information in the IFCSite (5)



Complete methodology of GIS-to-BIM conversion. Red lines marked 1 stay for the semantic mapping. From Salhab et al (2020) AUTOMATIC CONVERSION OF CITYGML TO IFC. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLIV-4/W1-2020

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### Geometry transformation

There are several steps in the geometry translation, as described on the slide and in the figure. These include creation of Geometry resources for the relevant objects and georeferencing.

IFC has several distinctive geometrical models, like Constructive Solid Geometry (CSG), Boundary representation or Sweeping. These do often not have a counterpart in CityGML, which complicates the direct translation.

IFC has also options to deal with topological models. Though, it is necessary to consider what part of topology information is needed and should be retained in the resulting IFC model.

Some BIM software (including Autodesk Revit) has a methodology to georeference models and provides ways to feed georeferencing data to BIM models. It is always necessary to check for the proper georeferencing, as the original BIM models usually have only local reference system, as we already know.



**Data Conversion**

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**Integration software**

- Free software  
    KIT Model Viewer
- Commercial software  
    FME  
    Esri-Autodesk apps
- Own algorithms

All convert in different ways,  
which results in varied outputs



Esri-Autodesk cooperation apps: Adding City Furniture from ArcGIS to InfraWorks. (up), BIM model added to a city model in ArcGIS GeoBIM (screenshots)

## Integration software

There is both free and commercial software for the BIM-GIS conversion. The third way is to develop tailored algorithms.

As different BIM software deals with IFC data in different ways, so does even the conversion one. As a result, the converted GIS or BIM models will differ from each other, depending on the software used.

Existing software packages offer high efficiency and robustness and provide nicely-looking models. On the other hand, they are expensive, may lack the ability to be adjusted according to specific requirements and they behave like a black box. The data processing steps are hidden from users and it is complicated to identify the cause if there are any errors.

The most advanced integration is provided by Esri's ArcGIS and Autodesk's software, which are compatible to each other. They can be used for data conversion, management, and visualisation in both directions, and of course deal both with semantics transfer and geometry conversion. With the Autodesk's software, the most relevant for BIM-GIS integration are Revit, dealing with detailed design, and InfraWorks, dealing with conceptual design and infrastructure.

Another commercial option is FME, Feature Manipulation Engine. FME also supports both geometric conversion and semantic mapping. However, it converts the file, but does not achieve complete conversion and visualisation in practical applications. It is ArcGIS that can be used as a platform for the integrated data management and visualisation.





Commercial software (such as Revit) often expects only completely accurate IFC models to be imported into it. If the IFC model is not complete, it might still work in free software such as KIT Model Viewer (follower of FZK Viewer). Though, the free software is usually less user-friendly, compared to the commercial one.

The custom scripting offers flexibility and can bridge the gaps in the source data, but is hardly to be widely used in practice.

## References

Bachert (2024) Mapping the Energy ADE to CityGML 3.0 Using a Model-Driven Approach, [ISPRS International Journal of Geo-Information](#) 13(4):121, DOI: [10.3390/ijgi13040121](#)

Salheb (2019) Automatic Conversion of CityGML to IFC, MSc thesis, TU Delft

Salheb et al (2020) AUTOMATIC CONVERSION OF CITYGML TO IFC. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLIV-4/W1-2020

Tan, Liang, Zhu (2023) CityGML in the Integration of BIM and the GIS: Challenges and Opportunities. Buildings 13, <https://doi.org/10.3390/buildings13071758>