BIMy Project:
D2.1 BIM Model

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Version history

Version	Date	Author	Change
0.01	2019-04-09	SGO	Introduction and scope
0.02	2019-05-03	EPA	Overview of model data used
0.03	2019-05-14	SGO/SS	Stability of object identifiers through time and scale
0.04	2019-06-04	HWA	Modelling conventions to filter by time & IFC use
0.05	2019-06-05	SVT	Scope: Parameters within Revit, Methodology: fire parameters
0.06	2019-06-06	HWA	
0.07	2019-06-07	SGO	Modelling time and scale: notes from the workshop
0.08	2019-06-19	SVT, TGO	Modelling fire
0.09	2019-06-20	HWA	Modelling time and scale
0.10	2019-09-23	HWA,LBI	Document structure, modelling geometry, information, time & scale, export & filtering
0.11	2019-11-27	HWA,LBI	How to model Circular Economy data
1.01	2019-12-19	TGO	Reviewed – Submitted to ITEA

1.02	2020-09-21	JLA	Checking in native software, Path of travel functionality (Revit)
2.0	2021-03-22	All	Final review
2.01	2021-03-23	JLA	Reviewed – Submitted to ITEA

Table of Contents

1. Introduction

This document defines the required mapping rules to convert between the BIM and GIS data standards that are used in the BIMy platfom. This chapter introduces the context, objective, scope, and methodology applied to write this document.

1.1. Context: BIMy as a collaborative platform

The BIMy project, as stated in the Full Project Proposal (BIMy consortium, 2017), aims at providing an **open collaborative platform for sharing, storing and filtering BIMs among different BIM owners/users and integrating and visualizing them in their built and natural environment**. BIMy can be seen as an open and generic intermediary that enables interactions between existing and new applications through a unique standardized open API platform. Such a platform will provide a secure collaborative working environment where different stakeholders can benefit and/or utilize BIM models not only at single building level but also at larger levels that can be scaled up to wider-area smart city applications.

BIMy will overcome the limitations of current BIM exchange platforms, providing the following features: **BIM with scale and time** (supporting different levels of details and different stages of the building lifecycle), **BIM/GIS semantic and dynamic integration** and **cloud storage** (integrating BIM in their built and natural environment), BIM filtering (providing relevant information according to stakeholders and applications), cooperation (supporting stakeholder interactions), simulation and 3D visualisation (mixed and augmented reality through different devices).

BIMy is bringing into the consortium all the actors necessary to the successful completion of the platform. There are **large companies** that can provide a **Cloud infrastructure** for hosting the BIMy platform and contribute with bigger resources when needed. The **smaller companies** offer more focused know-how to specified tasks as collaboration or BIM sharing and visualisation. The **research partners** will support companies with more complicated problems such as creating simple API and modelling and integrating BIM and GIS at different scales and times. **BIM owners/users** have an important role in definition of the requirements, modelling, in offering their expertise for different applications and business models as well as the evaluation of demonstrators. The demonstrators in two different countries improve the chances to make BIMy more replicable to new countries and environments. This enhances remarkably the market potential of BIMy.

1.2. Objective

As stated in the Final Project Proposal (BIMy consortium, 2017), the goal of this deliverable is to formally model the semantics and geometric representation of time and scale for BIMs. This modelling will be based on the needs of the domain (stakeholders). T2.1 will then **extend the existing standard IFC with time and scale**. The goal is to **support querying/filtering BIMs in different levels of details** and/or at different stages of the life cycle of a building.

1.3. Scope

1.3.1. Overall description

The operation of the BIMy platform depends on data (BIM models) submitted by its users. It is therefore important that this data is formatted in a way that is (1) practical for the creators and users, (2) close to the current practices in BIM, and (3) can be interpreted by the platform.

This deliverable investigates:

- How geometry and information in BIM models is structured: current practices and optimal approach.
- How the concepts of time and scale are handled in BIM.
- How the BIMy platform can interpret BIM models through filtering and mapping.
- How specific geometry and information can be stored in BIM in order to support the selected use case scenarios:
    - Fire prevention
    - Circular economy
    - Digital building permit

1.3.2. Constraints

1.3.2.1. Geography

The research in this deliverable was predominantly executed by the Belgian partners of the consortium and is therefore based on the State-of-Practice in Belgium.

1.3.2.2. Design and construction

Since the consortium has no partners with experience in facility management or professional building ownership, the research has a strong focus on the design and construction phases of a building's lifecycle. The exploitation/maintenance phase is taken into account but not (yet) investigated in depth.

1.3.3. Assumptions and exclusions

Several assumptions are made in order to focus the scope of the initial research. Some of these assumptions could be addressed in further research. See chapter 9.

1.3.3.1. BIM protocol & BIM execution plan

It is assumed that all BIM models have a BIM protocol and/or BIM execution plan that is followed by all parties involved in its creation and use. The BIM protocol contains all relevant modelling conventions and ensures that all parties who create or edit the model do so in a consistent way. This makes the BIM model usable throughout all stages of the building's lifecycle.

Problems that arise due to the absence of a BIM protocol are not discussed. It is understood that these models will not be able to make full use of the BIMy platform (for now).

In Belgium, the first template for a BIM protocol was published in 2018 (C. Euben (CSTC) & S. Boeykens (D-studio et KU Leuven), 2018). It can therefore be assumed that the composition of BIM models has been increasingly harmonized since then.

1.3.3.2. Discrete BIM models

The BIMy platform will host discrete, published BIM models of buildings in different stages of their lifecycle. The models are snapshots of a building's lifecycle. The current version of a BIM model on the platform can be updated once a new complete version of the model is published.

The platform is therefore not a BIM modelling or editing tool, nor will it be used for construction planning. These tasks will be performed with existing, designated tools.

1.3.3.3. IFC format

It is currently assumed that all BIM models are first modeled and edited in a native software using a native file format such as *.RVT (Autodesk Revit) or *.PLA (ArchiCAD), then exported to the open standardized IFC format, before they are uploaded to the BIMy platform.

Therefore, this deliverable discusses the modelling conventions, as well as the export process from a native format to IFC.

A detailed discussion of native formats and IFC can be found in D1.1 State of the Art (BIMy consortium, 2019a).

1.3.3.4. Stable object identifiers

Each object in a BIM model has a globally unique identifier (GUID), that can be used to identify, address and track it. In the context of the BIMy platform, it is generally assumed that the object identifiers remain stable during their lifecycle.

An exception is made for some known cases in which GUIDs are known to change or disappear. These cases will be discussed in chapter 4.

1.4. Related requirements

The information needs to include structured information into BIM models can be derived from the requirements that are specified in deliverable 1.2 (BIMy consortium, 2019b). These include the following:

1. Req_Y1_1: associate additional information with BIM objects - LOI

2. Req_Y1_2: Raise design issues on the model or the actual building regarding a specific object of the model - LOI (BCF format)

3. Req_Y1_5: Querying and Filter of specific rooms in specific apartment/part of the building

4. Req_Y1_11: Query and filter the furniture's safety level and visualize it for AR/VR training

5. Req_Y1_14: Virtualize the evacuation route from any specific location of the building to the nearest gathering point

7. Req_Y1_19: Query and visualize the entire 3D model of the targeted building

10. Req_Y1_25: Time filtering according to building lifecycle

11. Req_Y1_27: Provide guidance on how to structure and classify BIM information

12. Req_Y1_29: Query available materials from buildings in demolition / transformation phases

13. Req_Y1_34: Filter BIM models from different disciplines or create an assembled BIM model

14. Req_Y1_36: Compatibility with IFC

20. Req_Y1_57: Visualisation of a simplified 3D IFC Model for the fire brigade

22. Req_Y1_66: Convert downloadable GIS data in a format compatible with BIM software (Revit)

2. Definitions

BIM	Building Information Modelling
BIMy	BIM in the City: this research project and/or the platform it intends to develop
GIS	Geographic Information System
GUID	Globally Unique Identifier
IFC	Industry Foundation Classes; a platform neutral open file format for BIM
LOD	Level of detail of a BIM model; umbrella term for LOG/LOI
LOG	Level of detail of the Geometry of a BIM model
LOI/LOIn	Level of detail for the Information included in a BIM model
PLA/PLN	BIM file format used by Graphisoft Archicad
RVT	BIM file format used by Autodesk Revit
UCS	Use Case Scenario

3. Test projects & datasets

Five BIM datasets were used for testing en development of the BIMy platform and its end us applications. Each dataset consists of multiple complimentary BIM models in various file formats. The first two datasets are ongoing or finished building projects by the consortium partners and give a realistic idea of how BIM is currently used by the AEC sector. The next two are limited size datasets created by one of the consortium partners specifically for testing and prototyping. The last one is a publicly available BIM dataset.

3.1. Project: Kortrijk Care Campus Sint-Jozef (Belgium)

Author / copyright: (ASSAR Architects, 2019)

Building description: Public care center that consists of a nursing home (135 beds), an after-school-care facility for 105 children, and a social services center.

Georeference information: No georeference, only project-based coordinates

Available versions for BIMy testing (shared in project OneDrive):

Folder name: OCMW Kortrijk

Model arborescence: Linked models per discipline

- Architecture & Structure: 015.10_CM_Architectuur_Stabiliteit.rvt (108 Mb)
- Surroundings: file name: 015.10_CM_Omgeving.rvt (10,5 Mb)
- Lay-out (Revit “sheets”): 015.10_CM_Plot.rvt (25,0 Mb)

Available formats: .RVT / .IFC

Native software / version: Autodesk Revit version 2019.2

Project phase: Construction tender (by e-tendering)

Classification system: Customized version of BB-Sfb: only the first 2 digits in the name of the object follow the standard classification.

3.2. Project: Willemen Office, Hasselt (Belgium)

Author / copyright: (Willemen, 2018)

Building description: New office of Willemen in Hasselt (Belgium)

Georeference information: According Lambert72 (in the Project Base Point)

Available versions for BIMy testing (shared in project OneDrive):

Folder name: Office Kumpen

Model arborescence: Linked models per discipline

- Architecture IFC: kantoor Kumpen_AR.IFC (88.3 Mb)
- Architecture RVT: kantoor Kumpen_AR.rvt (645 Mb)
- Structure IFC: kantoor Kumpen_IRS.IFC (2.2 MB)
- HVAC IFC: kantoor Kumpen_HVAC.IFC (111.1 MB)
- Plumbing IFC: kantoor Kumpen_SANI.IFC (84.7 Mb)
- Electricity IFC: kantoor Kumpen_ELEC.IFC (31.7 Mb)
- Surroundings IFC: kantoor Kumpen_AA_Infra (5.9 MB)

Available formats: .RVT, .IFC,

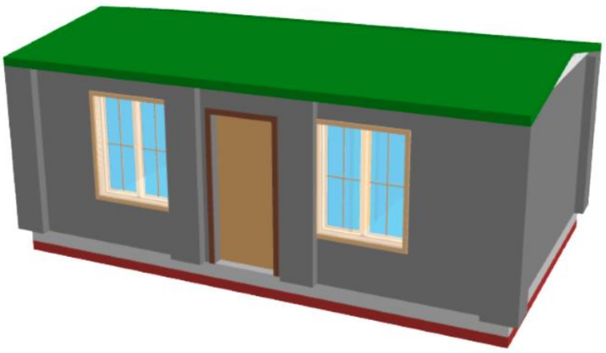
Native software / version: Autodesk Revit 2016

Project phase: As Built

Classification system: VMSW (Vlaamse Maatschappij voor Sociaal Wonen

3.3. Dataset: House A @ Skopje (North Macedonia)

House A @ Skopje is a BIM dataset designed within Erarge. It contains 197Kb of IFC2x3 data and 493Kb generated 3D model. The dataset is widely used for AR and VR development.



Author / copyright: (ERARGE, 2020)

Building description: Old and simple house located in Skopje, North Macedonia

Georeference information: No georeference, only project-based coordinates

Available versions for BIMy testing

Model arborescence: Linked models per discipline

- Architecture & Structure: BIMy_ERARGE_House_A.ifc (197kb)
- Generated 3D model: BIMy_Erarge_House_A_3D.dae (493kb)

Available formats: .IFC, .DAE

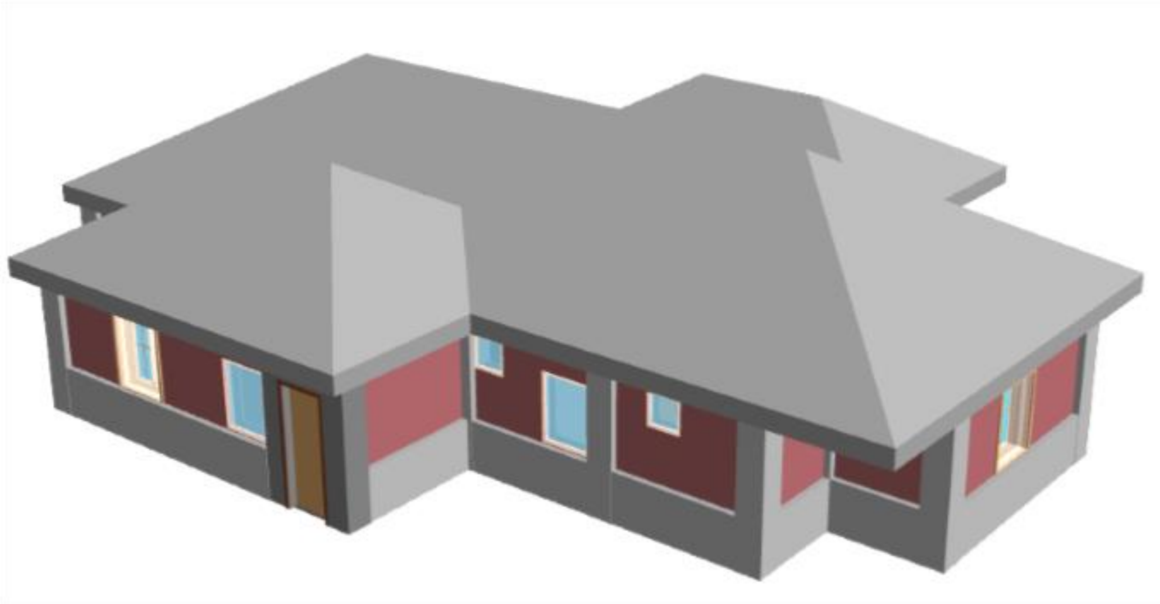
Native software / version: Autodesk Revit 2021

Project phase: As planned & As built

Classification system: /

3.4. Dataset: House B @ Skopje (North Macedonia)

House B @ Skopje is a BIM dataset designed within Erarge. It contains 451Kb of IFC2x3 data and 531Kb generated 3D model. The dataset is widely used for AR and VR development.



Author / copyright: (ERARGE, 2020)

Building description: Modern and complex house located in Skopje, North Macedonia

Georeference information: No georeference, only project-based coordinates

Available versions for BIMy testing

- **Model arborescence**: Linked models per discipline
  - Architecture & Structure: BIMy_ERARGE_House_A.ifc (451kb)
  - Generated 3D model: BIMy_Erarge_House_B_3D.dae (531kb)

Available formats: .IFC, .DAE

Native software / version: Autodesk Revit 2021

Project phase: As planned & As built

Classification system: /

3.5. Dataset: Schependomlaan, Nijmegen (Netherlands)

Schependomlaan is a BIM dataset published under Creative Commons License. It contains 3 Gb of data, including a native ArchiCAD model, IFC extract, IFC from suppliers, point clouds, schedules (in excel and in IFC with Synchro), construction log files, drone videos and BCF issues. The dataset is widely used as a benchmark and/or test case for research in BIM.

Author / copyright: (openBIMstandards, 2014) Creative Commons

Building description: Apartment building (10 units)

Georeference information:

Available versions for BIMy testing (shared in project One Drive):

Folder name: Schependomlaan

Model arborescence:

- Design model in .IFC en. PLA (Archicad)
- Issues (collision / clash detection) in BCF (.bzfzip) and in .TBP (Tekla BIMsight Package)
- Subcontractor models in .IFC and .DWG
- Coordination models in .TBP
- Schedule/Planning in .pdf and .xml
- As-planned models in .IFC and Synchro file format.
- As-built models in point cloud formats .ASCII and .PLY
- Results comparison as-planned and as-built models in .xls
- As-planned Event log in .xlsx and .csv
- As-built Event log in .xlsx and .csv
- Event log with actors in .xlsx and .csv

Available formats: .PLA, .IFC and other

Native software / version: Archicad

Project phase: As planned & As built

Classification system: /

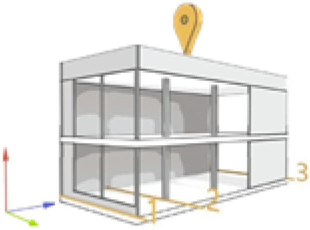
4. General modelling conventions

This chapter provides an overview of the most important modelling conventions that are currently considered best practice in BIM (WTCB & BIM Cluster, 2019). Using these conventions ensures that a model can be correctly exchanged and interpreted by different parties throughout its lifecycle. The BIMy platform will rely on these conventions to perform its main functions: filtering and querying BIM models.

Images in this chapter, unless mentioned otherwise: (WTCB & BIM Cluster, 2019)

4.1. Geometry

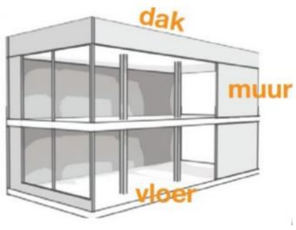
4.1.1. Georeferencing



The geolocation of the building and information about the coordinate system should be included in the model. Both a global origin and project origin should be defined, as some BIM tools have difficulty processing models at a large distance from the origin.

4.1.2. Structuring geometry

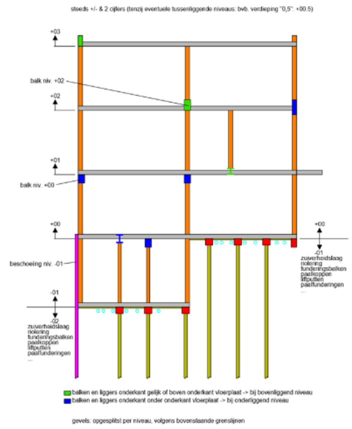
Consistent use of entities



It is considered good practice to use the correct entity to model elements. For example, floors should be modelled with the floor function in the design software. This is important to ensure that each element can be interpreted correctly when the project is transferred to a different file format. While this can be corrected manually using a mapping table, it is not recommended.

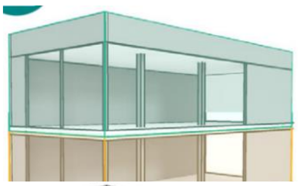
Levels

Building stories should be available in the model, and modelling of elements should be per floor as that is how it will be constructed. It is important to consider which elements are linked to which floor. The illustration below shows that this does affect the way of modeling. In general, architects and engineers look at building stories differently since one considers the floor underneath linked to the building story and the other considers the ceiling belonging to underlying building story.

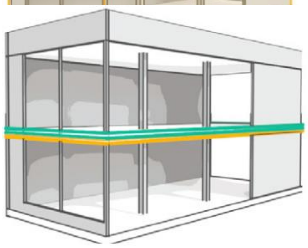


Example of linking elements to floors (WILLEMEN)

Division of elements

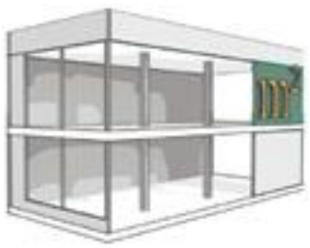


Divide elements according to homogeneous properties (function, execution sequence ...).
Non load bearing objects should be modelled separately from the load bearing structure.

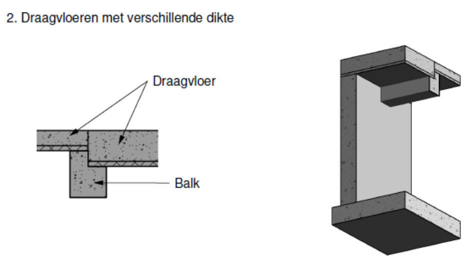


It is important to part all composed objects or to model each layer separately as all separate layers. For example, insulation and brick will not be constructed at the same time. The construction will happen in layers, first insulation and then the brick for an outer wall, therefore all elements should be parted or modelled separately. When a composed wall is not parted, this element will have just 1 GUID for the different layers of the composed wall (brick layer, insulation...) and the whole object will receive just 1 construction date parameter for all 3 the layers.

4.1.3. Interpretation of objects



The way objects are modeled also depends on how they are interpreted by different parties. An engineer looks at a beam as it is considered when calculating its strength. A contractor looks at a beam in terms of construction practice which means only a part of the 'calculated' beam is effectively a beam. The top layer is actually the floor above in some cases. This affects the quantities that are derived from the model. Many contractors have their own modelling guidelines available for this purpose.



Example of modeling guidelines for beams and floors (WILLEMEN)

4.2. Status of BBRI's BIM Cluster work on Modeling Guidelines

4.2.1. Context

There is not just one good method for building BIM models. How a BIM model should ideally be built depends on the objectives (what do we want to do with the BIM models? What do we want to use them for?) which in turn is linked to the parties involved and phases over time and is project-dependent. Therefore it is important to start with one particular phase, for one particular purpose. In the beginning, it is also very important to establish a good working method, which we are currently working on.

4.2.2. Current work

A number of nodes (see Fig. 1) have been developed for the transfer of the design team (architects, consultancy and engineering firms, etc.) to the main contractor in a traditional form of contract (contract in which the design and execution are put out to tender separately, each at a different time).

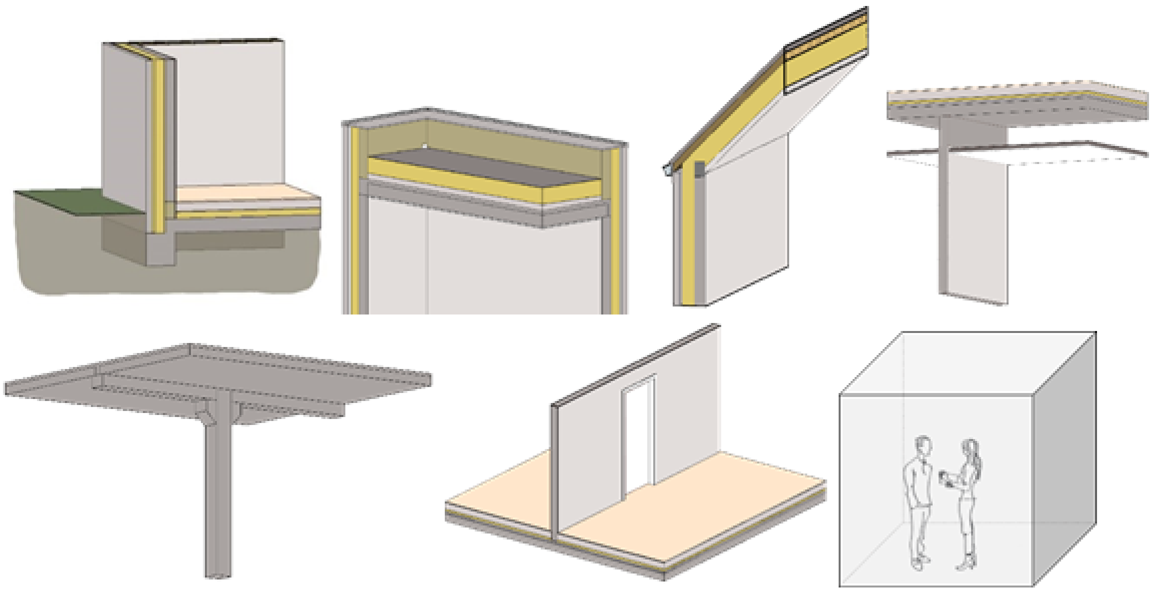


Fig. 1 - The treated nodes in our first step of research into BIM modelling guidelines: foundation attachment - roof edge flat roof - connection sloping roof and outer wall - connection false ceiling and inner wall - connection column/beam/floor - inner door - space

The choice of the phase (transfer of design team to contractor) was made on the basis of a survey of the working group (a working group with contractors, architects, engineering firms, software suppliers, clients... from practice) which showed that the need for BIM modelling guidelines is highest there. Today, there is still a lot of duplication of work; BIM models built by designers often do not meet the wishes of the contractors, so they are rebuilt.

The selected construction nodes are also the result of a survey of the working group. They are common nodes of which the principles can be extended to other nodes.

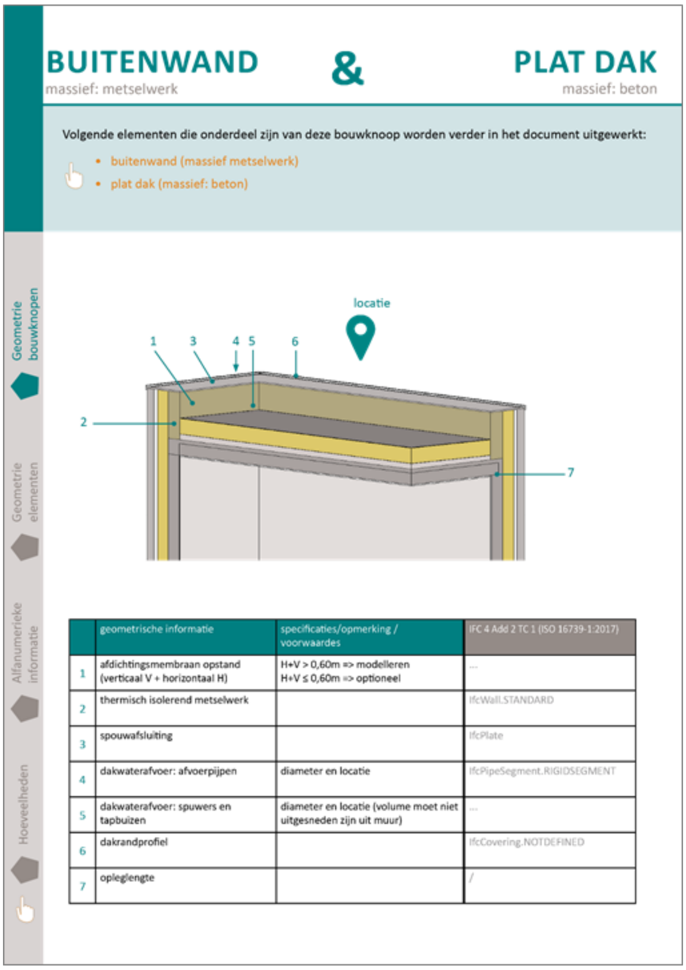
In a first sprint in May 2019, we worked out the above building nodes with 6 contractors (Willemen, Bam, CIT Blaton, Vanhout, Dethier and Democo). What are the wishes of the contractors with regard to these nodes? How should they be built geometrically and what alphanumeric information should be present?

In a second sprint in August 2019 we and designers (architects and engineering firms stability with Jaspers-Eyers, Bimplan, ARAS, Bureau Bouwtechniek, Archipelago, Macobo, Mouton, VK Architects & Engineers) offered an answer to the wishes of the contractors. To what extent are they prepared to meet the requirements of the contractors from sprint 1?

A third sprint, where we are trying to reach a consensus with both teams, has not yet been completed.

In the meantime, we have already sat down with the software suppliers (sprint 4, January 2020) to discuss how we can publish the software-neutral BIM modelling agreements and the software-specific agreements as one coherent whole. This also applies to the corresponding mock-ups that we will make per node.

In Q3 of 2020 we wish to achieve the first results (an example of the state of affairs can be found in Fig. 2, Fig. 3 and Fig. 4). But in addition to the results (as mentioned earlier), the methodology in this first step is also very important. If in this first exercise (a limited number of nodes to be transferred from design team to main contractor) we arrive at useful results (both in terms of content and form of publication), we have already carried out a very important task that will form the basis for further research into other nodes and other phase/objectives.



BUITENWAND & PLAT DAK

massief: metselwerk — massief: beton

Volgende elementen die onderdeel zijn van deze bouwknoop worden verder in het document uitgewerkt:

- buitenwand (massief metselwerk)
- plat dak (massief: beton)

Geometrie bouwknopen / Geometrie elementen / Alfanumerieke informatie / Hoeveelheden

	geometrische informatie	specificaties/opmerking / voorwaardes	IFC 4 Add 2 TC 1 (ISO 16739-1:2017)
1	afdichtingsmembraan opstand (verticaal V + horizontaal H)	H+V > 0,60m => modelleren H+V ≤ 0,60m => optioneel	...
2	thermisch isolerend metselwerk		IfcWall.STANDARD
3	spouwafsluiting		IfcPlate
4	dakwaterafvoer: afvoerpijpen	diameter en locatie	IfcPipeSegment.RIGIDSEGMENT
5	dakwaterafvoer: spuwers en tapbuizen	diameter en locatie (volume moet niet uitgesneden zijn uit muur)	...
6	dakrandprofiel		IfcCovering.NOTDEFINED
7	opleglengte		/

Fig. 2 - Example (screenshot) of interim results for the construction node 'flat roof edge'. This screenshot shows the requirements for the connection between the flat roof and the outer wall and refers to the specific elements that make up the node.

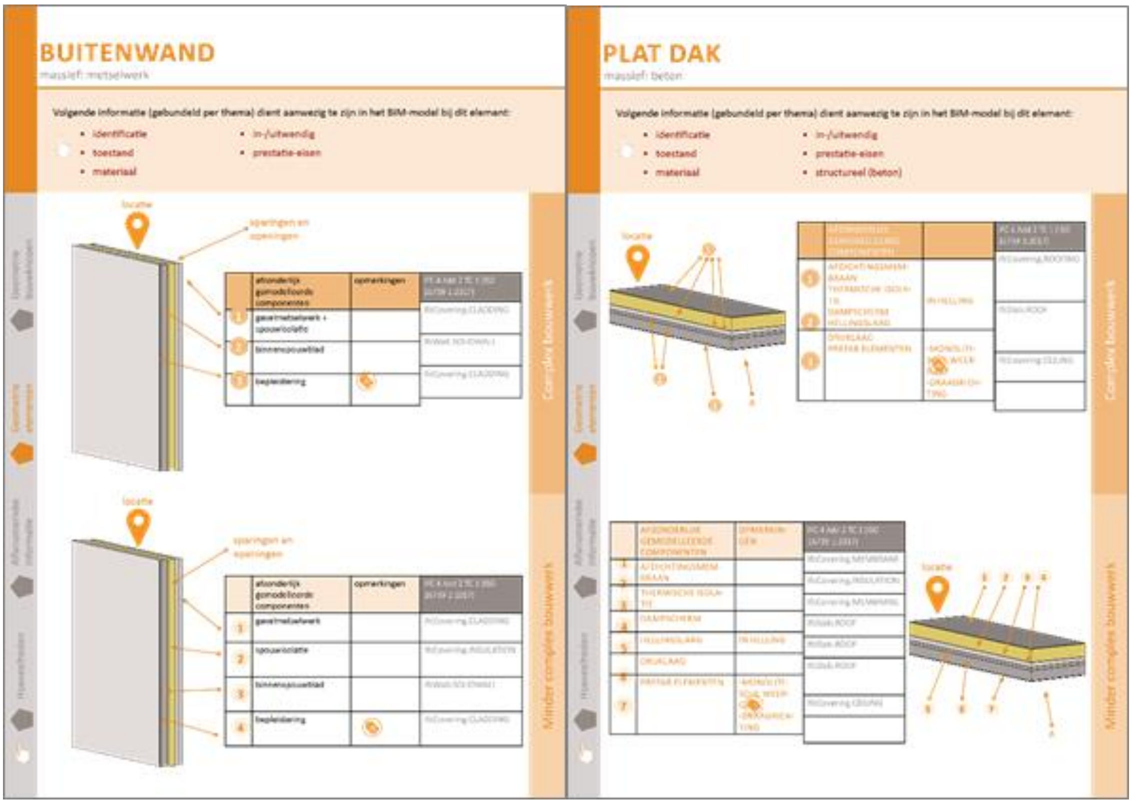


Fig. 3 - Example (screenshots) of interim results for the construction node 'flat roof edge'. These images show the requirements for the elements (outer wall and flat roof). What are the requirements in terms of geometry and alphanumeric information?

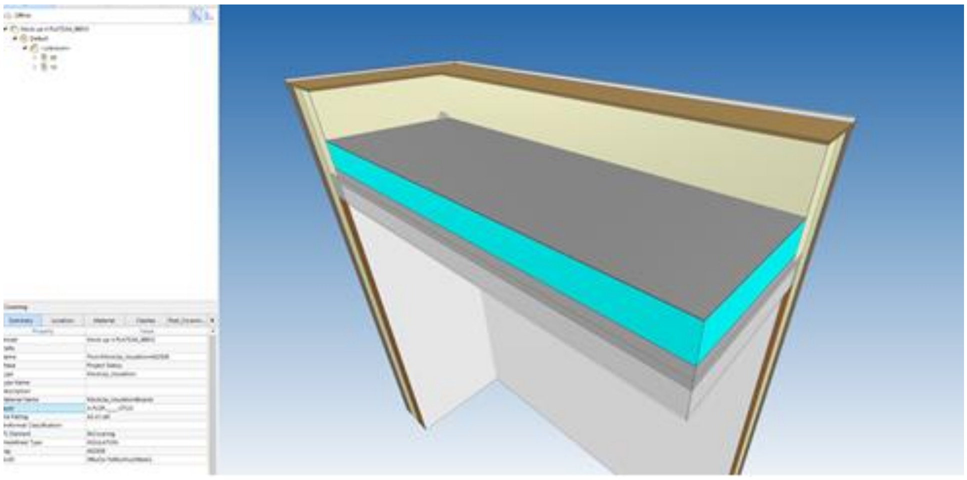


Fig. 4 - Example (screenshot) of the mock-up of the building node 'roof edge flat roof'.

4.3. Information

BIM models also include a lot of non-geometrical information. This section provides pointers on how to include structured information into BIM models, and which information that should be.

What kind of information is in the model is usually dependent on the type of project, the project partners and the purpose or goals that have been set to achieve by using the model.

There is a difference in:

- What is required from a legal perspective (could be modelled at the type-level)
- What is required by the customer (or platform in a broader sense)
- What an object is made of or capable of (could be modelled at the instance-level)

How this information is structured is also something that can differ greatly from one model to another. In Belgium, there is no standardized classification or set of properties (yet) that is required by the government.

Additionally, there are different levels on which information can be added inside a model:

- On the level of a site, building, building story or project information
- On the level of an entire object or assembly which can consist of several layers or other objects
- On the level of one layer of a composite object

Furthermore, names and values of attributes in a model can be in different languages, or just named in different variations or alterations which makes it hard to compare similar information from different models.

Therefore, it is very important to define all necessary information and a framework of structuring this information inside models intended to be used inside the BIMy platform.

4.3.1. Minimum required information

As a best practice, the following attributes/information should always be present in a BIM model:

For each MODEL

- Software application and version the model was made in
- For IFC: IFC File schema and view definition

For each SITE/BUILDING

- Name of the site and/or building
- Owner of the site and/or building
- Location of the site and/or building
    - Geographical
    - Post address

For each BUILDING STORY/LEVEL

- Name and height of building stories

For each BUILDING ELEMENT/MATERIAL

- Name of the material
- Building story, building and/or site to which the element belongs
- Globally Unique Identifier (GUID)
- Element classification

4.3.2. Classification

The construction industry currently uses various classification systems for building elements. Outside the standardized systems, numerous company-based or project-based custom classification systems are used. Most systems define objects, object types/classes as well as properties. However, property classification is often omitted in practice or strongly adapted to the needs of the project. Furthermore, most classification system in Belgium are from a pre-BIM era and don't comply with the needs of BIM designers.

In the absence of a universal (or at least national) classification system, it is difficult to define a general structure or naming convention for information in a BIM model. For now, it is strongly suggested to use one of the more common classification systems, as explained in 'De classificatiesystemen en BIM' (Huerdo Fernandez & Dewez, 2018).

4.3.2.1. Revit standards

In recent years, organizations like the Revit Standards Foundation have created standard guidelines for structuring data in BIM, such as the Dutch Revit standards (Revit Standards Foundation, 2019), Belgian Revit Standards (first version released in October 2020), and the International Revit Standards (under development). These standards are gaining interest and are implemented more and more. The Dutch Revit standard has been published a few years ago now and is quite widely used in the Netherlands. In Belgium, the AEC industry started to adopt the Dutch Revit standard in recent years since no Belgian initiatives where ready to be used. Since the Revit standards foundation did announce to be working on the Belgian Revit standard, and it would be similar to the Dutch Revit standard, a lot of professionals landed on using the Dutch Revit standards temporarily.

The release of the Belgian Revit standard will very likely kick start the use of a uniform classification system within Belgium. Allthough the Belgian Revit standard mainly focusses on naming conventions, and less on modeling guidelines, it definitely helps with optimizing the exploitability of the native models and exports to other file formats (e.g. IFC). The naming schema for the Belgian Revit standards uses nlSFB as a way of classification for the different types of elements.

An elaborate discussion of existing classification standards, their benefits and shortcomings can be found in the D1.1 State of the Art or D6.1 Standardization perspectives (BIMy consortium, 2019c).

4.3.3. Linked Data

For both construction site and facility management, it is relevant to have detailed product information, but this should not be stored inside the BIM model. This implies that there are three environments: GIS, BIM, and linked data. A systematic approach is needed for linking both current data (e.g. during construction process we want to link to technical data of products that are currently available) and archived data (e.g. for as-built-situation and use cases in later stages, we need archived product information, avoiding data loss in case the online data of producers changes or gets lost).

4.4. Industry Foundation Classes (IFC)

4.4.1. Definition

"The Industry Foundation Classes IFC specifications is a neutral data format to describe, exchange and share information typically used within the building and facility management industry sector. IFC is the international standard for openBIM and with IFC4 an ISO standard. (ISO 16739-1:2018)" (ISO, 2018)

4.4.2. Use of IFC in BIMy

BIM models are generally created using proprietary software that uses a closed data format. Examples are Autodesk Revit or Graphisoft ArchiCAD. In order to exchange or publish models, they can be exported to the open IFC format. For now, BIMy will only use models in the IFC format.

4.4.3. IFC 2x3 vs IFC 4

Different versions of the IFC specifications exist:
https://technical.buildingsmart.org/standards/ifc/ifc-schema-specifications/

IFC2x3 TC1 and IFC 4 / 4.1 are currently the official versions.

BIMy will make use of IFC2x3.

IFC2x3 is:

- currently the most supported and stable format
- certified in most software applications
- recommended for production;

IFC4 is:

- still in beta in a lot of software applications (certification process in progress)
- offers certain advanced possibilities but is not widely supported yet;

A list of certified IFC software vendors can be found here:
https://www.buildingsmart.org/compliance/software-certification/certified-software/

At the time of writing, 3 software venders are certified for IFC 4, while 66 are certified for IFC2x3.

4.4.4. General practices

When exporting a model from proprietary software to IFC, the following general guidelines should be followed to ensure the models integrity and readability:

Images in this chapter, unless mentioned otherwise: (WTCB & BIM Cluster, 2019)

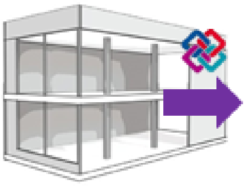
Composition of the model

If, for any reason, duplicates exist inside the model, these shouldn't be exported to avoid excess geometry and information.
If a model contains only a specific discipline and is to be seen in combination with other discipline-specific models, 'dummies' or indicative elements are to be excluded from the export.
With regards to the use case specific modeling conventions (chapter **Fout! Verwijzingsbron niet gevonden.**), it is important to consider composite elements and how their geometry and attributes are accessed.

Phases

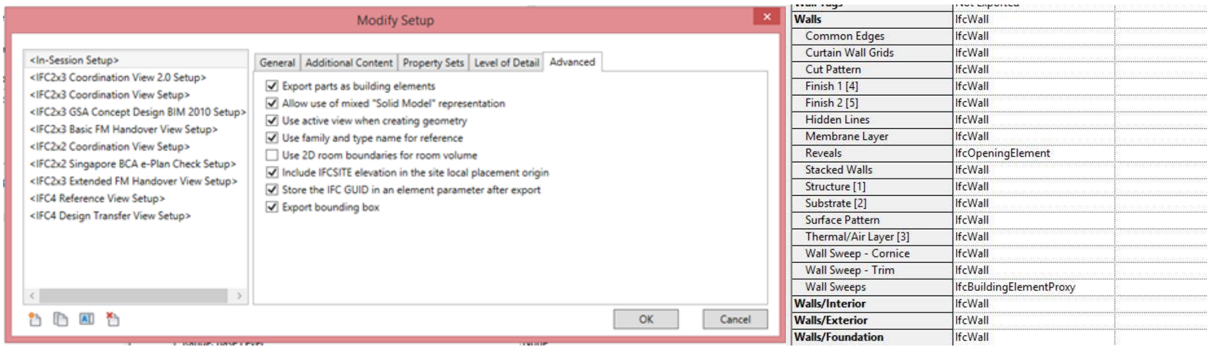
Regarding phasing and renovating, the entire model or parts of the model are to be consciously exported according to reliability, intended use and with regards to the existence of other relevant models.

Software specific and IFC-settings



Different software packages allow the model to be exported in different ways. Different IFC formats or Model View Definitions (MVD) can usually be selected. It is important to choose these settings considering the intended use of the model. Usually, it is advised to change individual settings. The geographical information available should in any case be exported. Special attention should be paid to the export of composite elements, and selection of elements and property sets to be exported.

Mapping of f.i. Revit Classes to IFC Classes should also be done, as BuildingSMART recommends. Further information on this subject can be found in chapter 6 of this document.



Screenshot: Mapping of parameters in Revit to IFC properties

4.4.5. Issues

4.4.5.1. Data loss during export

Since different software packages/modeling practices have different reputations of export integrity, the exported model should be checked for completeness and errors.

4.5. Globally Unique Identifiers (GUID)

4.5.1. GUIDs in BIM

A GUID is a unique identifier that is used in BIM to identify and track objects. GUIDs are usually formatted as 128-bit integer numbers.

For example:

123e4567-e89b-12d3-a456-426655440000

Since the probability that two randomly generated GUIDs are the same, is near-zero, there is no need for a central control mechanism.

4.5.2. Stability of GUIDs through time

Throughout the lifecycle of a building object, it is important that the BIM models representing this object use a stable object identifier. For example, a BCF topic can then safely relate to an existing object.

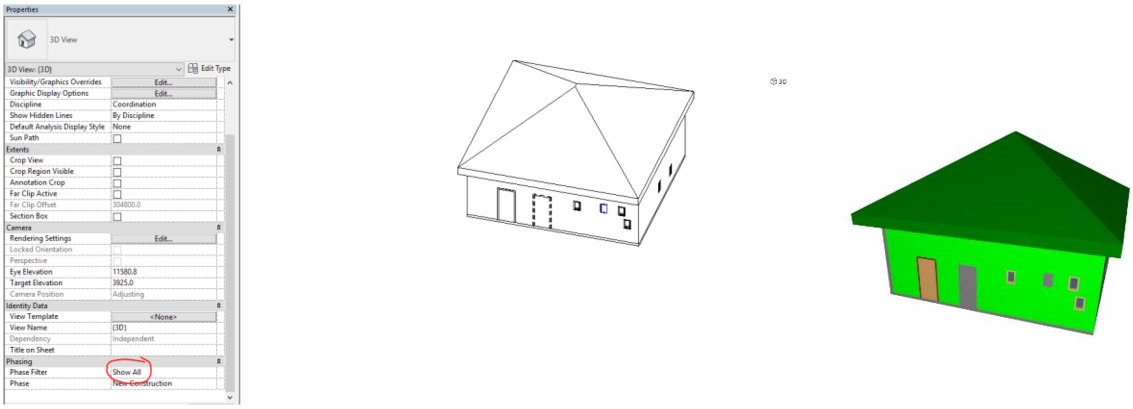
BIM tools handle the stability of identifiers in various ways.

4.5.2.1. Revit

Revit (AutoDesk, 2019) does not preserve object identifiers (GUID) when an object is split into parts and the model is afterwards exported to IFC. Revit does preserve the GUID of the original object, but the parted layers of this object will receive another GUID. Whenever an object e.g. a wall that consists of 3 layers is parted, this wall has a GUID on Object level and 3 additional GUIDs, 1 GUID for each of the parted layers. If the object is merged and then parted again, the GUID of the object remains the same, although the GUIDs of the parted layers will change. An object can therefore be parted just 1 time to preserve the original GUIDs.

This is a known problem with Revit which makes that contractors state in the BIM execution plan, how to use and part a Revit model. Some contractors rather model their BIMs themselves to have full control of the model use.

Demolishing a door (indicated in dashed line in the picture) creates a new wall as replacement for the demolished wall. This new piece of wall is not merged with the whole wall, but is a separate wall, giving it a new GUID.

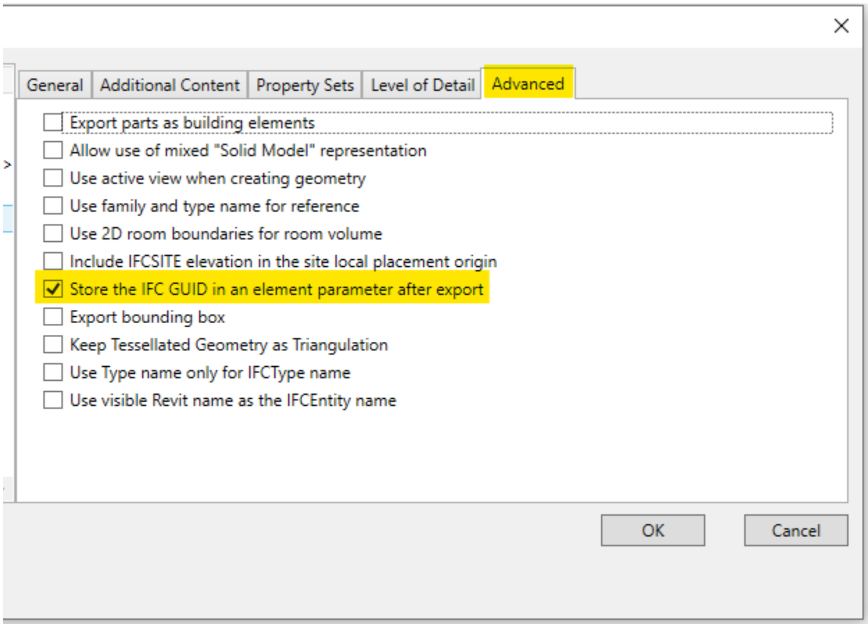


GUIDSs remain the same when objects are replaced with for example an object with higher LOD. When objects are deleted and a new object is added, obviously the new object gets a new GUID.

Deleting and adding a new object is often more time efficient for modelers. Also for designers usually it does not make any difference when a GUID or Revit identifier has changed as designers/modelers barely make use of object identifiers. For IFC based contractors this makes a huge difference in their methodology as object continuity is broken once an object's GUID changes.

Apart from physically deleting and adding a new object, the GUID of an element will also change when its phase is changed. Therefore, the correct phasing should be used when creating the elements. Changing the phasing of elements should always be avoided, as well as creating a new phase in the project from the moment the design is started to being shared with multiple people, and the GUIDs start being important for certain parties. Creating the needed phases at the start of a project is therefore an important responsibility from the partner who starts the model and does the setup. A workaround for this problem is using the option during export to write the IFCGUIDS to a

Revit parameter. This will ensure later exports will keep the same GUID although the phase would be changed.



4.5.2.2. Solibri

Contractors often classify information to extract quantity takeoffs or for other purposes. Classifying is usually automated with predefined rules on parameters present (asked by the contractor and defined in the BIM execution plan) in the IFC. Often it occurs that information is wrong or missing in the IFC. The contractor then classifies these objects manually. Manual classifying in Solibri relies on the objects' GUID. If the GUID has changed in a new IFC export, all manual classification in Solibri will disappear. (Nemetschek, n.d.)

During its construction and maintenance lifecycle, building objects can of course be demolished and (re)constructed. Also, a wall can be demolished in part.

4.5.2.3. SimpleBIM

SimpleBIM (Datacubist, 2019) does a good job at preserving stable object identifiers of IFC files.

There is also a function inside SimpleBIM to generate completely new GUID's for all objects inside a model.

4.5.2.4. ArchiCAD

ArchiCAD (Graphisoft, 2018) does a good job at preserving stable object identifiers of IFC files.

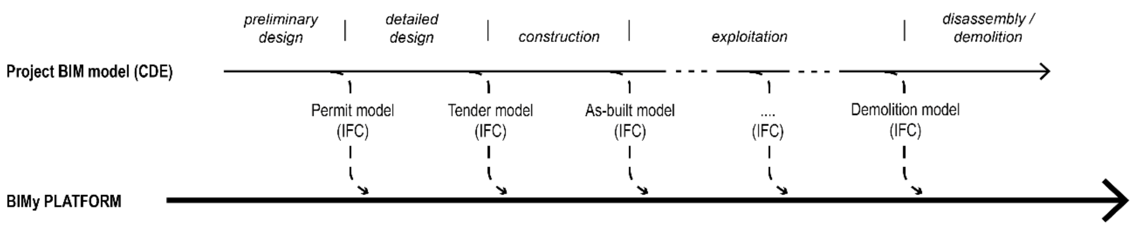
5. Modelling time and scale

5.1. Time

Several aspects of time can be distinguished that are important in the BIMy Context.

1) **Time in the lifecycle of a building or site (phasing and versioning)**
Each building project goes through several phases in its lifecycle: preliminary design, detailed design, construction, exploitation, (multiple) renovation(s), and disassembly or demolition. The corresponding BIM model will reflect these changes.

While the project BIM model - managed by its creators or users in a common data environment - is usually in constant evolution, the end of each phase is marked by a new finished version of the model: a permit model, tender model, as-built model, etc. Sometimes multiple finished versions are created, e.g. to compare different options in a preliminary design. These finished versions can be exported to IFC and uploaded to the BIMy platform.



2) **Time in the lifecycle of a building element (lifecycle management)**

Time can also be interpreted on a micro scale: to manage the lifecycle of building elements:

- Required maintenance interval
- Last maintenance date
- Production date
- Expected lifespan
- Replacement date (of f.e. a lightbulb)

Since this information is often most relevant during exploitation and disassembly/demolition, BIM design tools are usually not well-adapted to store or update these parameters.

5.1.1. Phasing and versioning in Revit

The Phase parameter in Revit can be used to show the evolution of a site or building throughout time: demolition projects, long term urban projects with different phases, etc. Each object has two parameters to indicate in which predefined phase it was created, and in which phase it was demolished. It is possible to also assign phasing to a parted object.

Phasing in Revit is only used for large changes, and not for construction planning or lifecycle planning of objects. This is due to the combinatorial explosion: every object must be modelled in every phase.

Revit's export-to-IFC functionalities only allow us to export 1 phase to IFC. It is possible through a workaround to visualize all phases of a project in 1 IFC export by showing all phases in the Revit 3d view. However, this is not practical. In general, each finished phase in in Revit will correspond to a new version of the exported IFC file.

5.1.2. Phasing and versioning in IFC (LOD/LOG/LOI)

5.1.2.1. Attributes to distinguish changes

Some relevant properties to distinguish changes between versions in IFC, are listed below:

IfcOwnerHistory

The IFC has parameters tracking the history of edits that happened in the design software whenever a new export is made from the design software.

```
ENTITY IfcOwnerHistory;
        OwningUser : IfcPersonAndOrganization;
        OwningApplication : IfcApplication;
        State : OPTIONAL IfcStateEnum;
        ChangeAction : OPTIONAL IfcChangeActionEnum;
        LastModifiedDate : OPTIONAL IfcTimeStamp;
        LastModifyingUser : OPTIONAL IfcPersonAndOrganization;
        LastModifyingApplication : OPTIONAL IfcApplication;
        CreationDate : IfcTimeStamp;
```

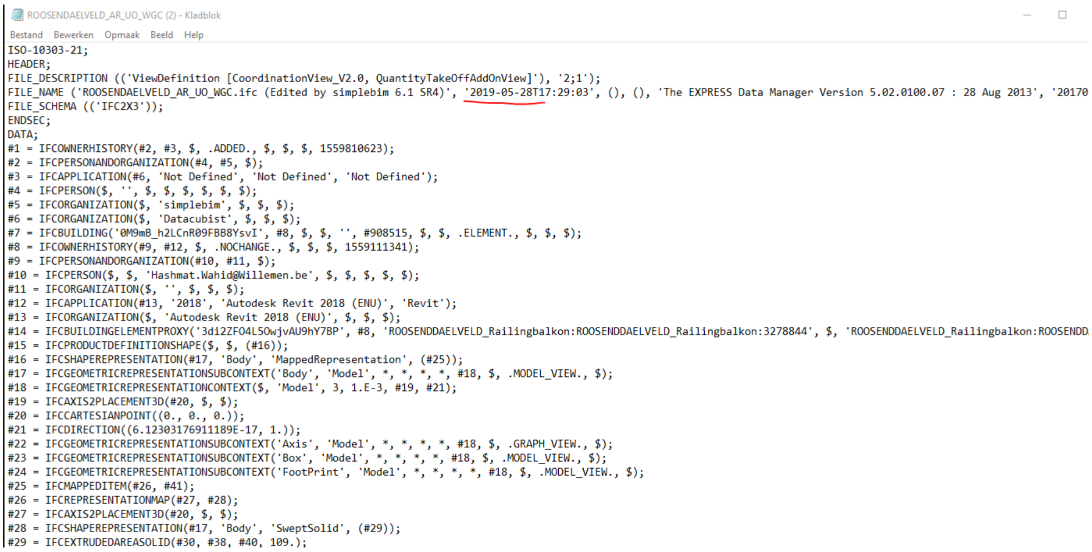
Changes to the IFC in editing software such as SimpleBIM will be visible in the IFC. Although the IfcOwnerHistory properties are not always clear on who or which company has edited the file.

```
#1 = IFCOWNERHISTORY(#2, #3, $, .ADDED., $, $, $, 1561538186);
#2 = IFCPERSONANDORGANIZATION(#4, #5, $);
#3 = IFCAPPLICATION(#6, 'Not Defined', 'Not Defined', 'Not Defined');
#4 = IFCPERSON($, '', $, $, $, $, $, $);
#5 = IFCORGANIZATION($, 'simplebim', $, $, $);
#6 = IFCORGANIZATION($, 'Datacubist', $, $, $);
#7 = IFCBUILDING('1W9Gr8ua5E0vZjuwUt9jiW', #8, 'aaa', $, '', #997633, $, 'aaa', .ELEMENT., $, $, #14);
#8 = IFCOWNERHISTORY(#9, #12, $, .NOCHANGE., $, $, $, 1561538119);
#9 = IFCPERSONANDORGANIZATION(#10, #11, $);
```

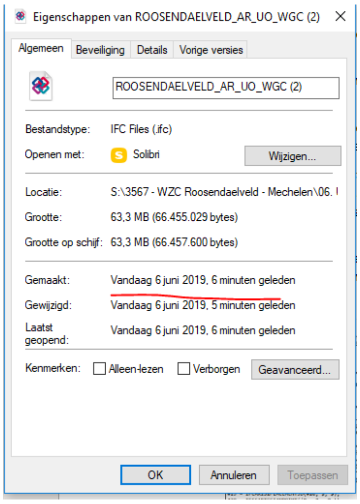
IfcTimeStamp

The IFC gets a timestamp when an export is made from the native design software. Later edits to the IFC will NOT change this date. In other words, the timestamp written in the IFC indicates when the export was originally made. All modifications to the IFC afterwards will not be written in the IfcTimeStamp. That information is only available in the file's metadata.

The picture below shows the source code of an IFC file that is exported on 29/05/19 and edited on 6/6/2019. Only the export date is stored in the IFC.



Information on the last edit date can only be found in the properties of the file:



IFCs that have been edited after the export are for this reason not suitable to be filtered on the IfcTimeStamp.

5.1.3. Life cycle management in Revit

In Revit, micro-timing can be stored in custom parameters, but not be visualized. When exported to NavisWorks (AutoDesk, 2016) the whole timing becomes available. Revit Dynamo can be used to programmatically set these timing parameters.

5.1.4. Life cycle management in IFC

IFC 2x3 is still inadequate for life cycle management during the maintenance phase or for the scenario of the circular buildings. Further development is still needed in this are for IFC 2x3. ISO proposed life planning information in the IFC4 standard including IFC property sets to support information on life service planning, service life, and environmental impacts. IFC4 is for this reason more interesting for the scenario of circular economy.

5.2. Scale

In BIM tools, it is possible to refine the scale of an object, both in geometry as information, but only one level of detail can be stored in the model at the same time (unlike CityGML). The levels of detail/geometry/information evolve during the development of a project and are defined in the BIM protocol. BIM models usually contain a lower level of geometry/information in design phases and higher level of geometry/information in the construction phase. In exploitation, the LOD/LOG/LOI is sometimes reduced again to reduce the file size (and increase the operability) of the model.

5.2.1. Scale and geometry (LOD/LOG)

5.2.1.1. Replacing Families/Family types

Revit has the possibility to change the family of an object (the same instance) into a family with a higher level of detail (preserving the previous parameter settings). The previous family disappears though. The object identifier is preserved during this change. However, at one time, one level of detail is possible. Another limitation is that currently almost no companies have Revit families with 5 LODs.

It is possible to replace the Revit Family/FamilyType of an object during the building lifecycle. The French company AREP is currently one of the only in the world that has 5 levels of detail for all its Revit Families, since it is very time and resource intensive. (*BIM Data Management for Operation and Maintenance*, 2018)

TechBIM is a provider of Revit and ArchiCAD families that has a similar generic-to-specific workflow that allow an object “HVAC unit” to be specialized into a specific one (e.g. a product BIM). At one time, one level of detail is possible. The identifier is preserved during the change.

In Revit, when a family is changed from a type to another, parameters existing in both types are copied. However, depending on how the family is built, built-in parameter like length or width cannot be adapted.

To overcome this issue, a simple POC Revit Plugin has been developed, to change all the instances of a element family, (here Windows) from the actual family and its LOD, to another family belonging to another LOD. It is possible to force parameters to be set to the new family. Unfortunately, all the information that is not present in both families or not forced to be copied, is lost. This method is therefore most suitable for LOD downgrade. It is possible to store the uncopied data in the extensible storage of Revit Elements in case we want to go back up in LOD, but development for this solution is way more time consuming.

This type of plugin can open different solutions or ideas for the BIMy platform:

- Making standard families available to users, for each main family and LOD, with parameters specific for the BIMy needs.
- Perform automatic changes, client side, or server side.

- Asking for the upload of IFC or RVT files created with families that are exported correctly in .ifc format, eventually one for each LOD.

For server side operations on a Revit Model, Autodesk Forge is the most obvious solution, but can quickly become expensive since operations are charged per unit. Desktop Revit does not allow headless programming. However, another POC has been successfully proceeded to change all windows families from a project, using only one bash command. Revit will effectively be opened on the computer, but all the operations can be programmed and executed without any human intervention. It is therefore possible to program server side asynchronous LOD downgrade, or even IFC export of a .rvt model, free of charge.

5.2.1.2. Detailing Families/Family types

In design software, the user has the possibility to model new families or to import existing ones. As described before, replacing families is not practical for most companies, since it is time consuming to have a set of families with different LOD. For this reason, most companies improve/raise the geometry of a family whenever it is needed.

Product BIM data is becoming increasingly available. For example, the French company bimobject.com manages a platform where product providers can maintain their product libraries. In practice more work is needed, because importing BIM Objects product BIMs into a Revit model has been known to negatively affect the model's integrity. For example, the language settings or the level of geometry, or the parametric settings can become corrupt.

Also, the connections between objects (e.g. an HVAC unit is connected to ducts) may need to be upgraded. This interdependency between objects can be difficult to update. The Building Topology Ontology (BOT) defines the notion of bot:Interface, as a connection point between two BIM objects.

Detailing self-made or imported families is most common in today’s practice (affecting LOI, see next section). Only for some families, the level of geometry will be raised, resulting in a BIM model consisting different LOG families.

5.2.2. Scale and information (LOI)

5.2.2.1. Adding or refining attributes

When families, types or individual instances of objects are detailed as described in the previous section, but this detailing consists of adding or refining attributes of the objects, this can be seen as adding or changing the scale of an object as an aspect in information, which affects LOI. The methodology is similar to the scale aspects in geometry, meaning this can be done both by replacing the family/type/instance, or detailing it.

6. Filtering & mapping BIM

Once a BIM model is created, exported and submitted, the BIMy platform will filter the available information in order to perform useful queries. This can be achieved through (a combination of) multiple methods.

6.1. Filtering by classification

While filtering through a standardized building classification system is possible in theory, there are significant practical barriers (see section 4.3.2). For this reason, filtering by classification is often done using workarounds.

Examples from case studies:

Issues:

- Designers, contractors, subcontractors use different names for the same parameter or have different input types for the parameter
- Even if they use the same naming convention, this convention should be readable by the BIMy platform.

Solutions:

- There should be a general text file containing all possible parameters which can be imported in the native software to make sure all partners use the same Parameters. Filtering can then happen on the same parameter.

Workaround used by Willemen:

- In Solibri, all parameters with the same information are merged under a new 'Willemen' parameter. This new parameter will then be added to the IFC using SimpleBIM.

6.2. Filtering by IFC classes and IFC properties

The IFC format has more than 900 definitions for recording data of a building. IFC aims to be a standardized universal format while at the same time being very flexible format to use.

6.2.1. IFC Class

Each modelling software has its own default way of mapping element categories and subcategories to IFC classes. At the same time the user has the freedom to adjust the mapping to IFC Class completely to their own wishes. BuildingSMART has defined on their website on how to map IFC Class correctly, but this is not implemented fully in the BIM software currently.

Example of wrong IFC Class use:

When we use IFC classes (Or something that is automatically an attribute of every object (f.ex: a wall, a floor, …), we should be aware of which objects are classified in the IFC class. The IFC class ifcWall contains all objects which are modelled as a wall, this also includes wall finishes. But do we want wall finishing when we query for walls? No, wall finishing should be classified in ifcCovering according Buildingsmart. IfcCovering contains all finishes such as wall finishes, floor finishes and ceiling finishes. This can be changed in the mapping options in Revit but is not standard.

Walls	IfcWall	
Common Edges	IfcWall	
Curtain Wall Grids	IfcWall	
Cut Pattern	IfcWall	
Finish 1 [4]	IfcWall	
Finish 2 [5]	IfcWall	
Hidden Lines	IfcWall	
Membrane Layer	IfcWall	
Reveals	IfcOpeningElement	
Stacked Walls	IfcWall	
Structure [1]	IfcWall	
Substrate [2]	IfcWall	
Surface Pattern	IfcWall	
Thermal/Air Layer [3]	IfcWall	
Wall Sweep - Cornice	IfcWall	
Wall Sweep - Trim	IfcWall	
Wall Sweeps	IfcBuildingElementProxy	
Walls/Interior	IfcWall	
Walls/Exterior	IfcWall	
Walls/Foundation	IfcWall	

Picture: Snapshot from Revit's IFC mapping table

In this case, the mapping table can be overwritten for the way this specific element is exported by defining shared parameters named IFCExportAs and IFCExportType (AutoDesk, 2017).

6.2.2. IFC properties

The IFC standard has a large and ever-growing amount of predefined property sets and properties that make it easy to use as a standard exchange format. Certain Revit parameters, such as dimensions, are automatically mapped to corresponding IFC properties. Many designers work with custom parameters and property sets. When exporting to IFC, these parameters are not mapped to the correct IFC properties and property sets automatically. However, in many software packages, such as Revit, it is possible to map Revit parameters to the corresponding IFC properties.

A mapping text file allows you to export Revit values to any IFC property. Each line in the text file links a Revit parameter to an IFC property, and the associated IFC property set. The data type of the Revit parameter should be the same as that of the IFC.

1 = IFC property set
2 = IFC property
3 = Revit parameter

```
      1                  2                         3
Pset_WallCommon ThermalTransmittance     U-Waarde
Pset_WallCommon Compartmentation         BIMY_Compartment
```

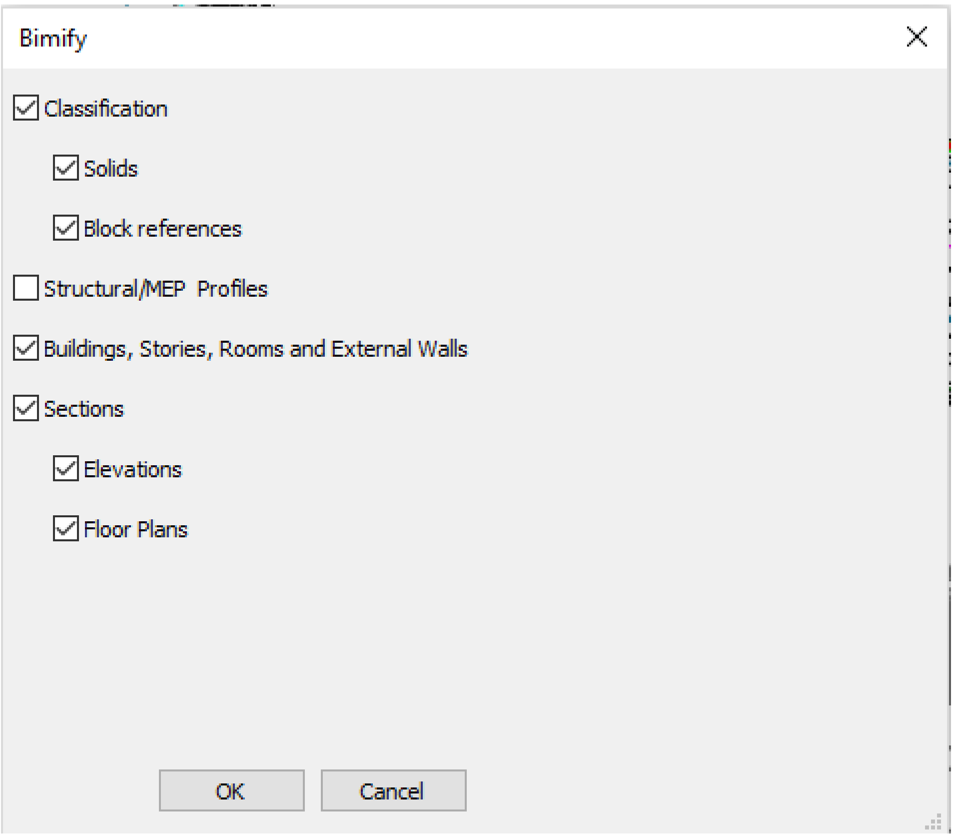
6.2.3. Combining IFC classes and IFC parameters

Since the IFC format is meant to be as universal as possible, standard IFC classes are often too general for specific queries. This can be solved by creating additional parameters in the original model.

For example, it is generally not possible to query 'only exterior walls' as ifcWall contains all walls, both interior as exterior. A possible solution for this might be the addition of an extra parameter 'building envelope'. Filtering should be then done on IFC class and the 'building envelope' parameter for this example.

By the same logic, general IFC attributes could be read by the BIMy platform.

Important to mention is the upcoming technology of artificial intelligence in this domain. BricsCAD BIM (Bricsys, 2018)for example uses AI to let the software itself determine if an object is an interior or external wall. BricsCAD can also automatically link objects to the correct level, add room information, add profile types, etc.



Picture: view of BricsCAD BIM AI-tool 'Bimify'.

6.3. Filter by documentation

In native design software and quality control software a url can be added to objects that refer to technical specifications. It is then possible to filter on whether an object has a url linked to it, but not to filter on the information in the documentation.

6.4. Filter by BIMy-defined information, mapped to the model

To solve several abovementioned problems, a standard set of BIMy classification can be defined, optionally variable for different LOD/LOG/LOIs. In this case, a mapping of these standard properties with the properties available in the model should be presented and filled in by the user that uploads (and has knowledge of) their model. Also, a similar mapping could be presented for the values of these properties to bypass language- and/or other definition differences.

7. Use case specific modelling conventions

In the following chapter, three potential applications for BIM models on the BIMy platform are discussed: fire safety, circular use of construction materials, and digital building permits. Each section addresses what specific information should be included and how it is best formatted using current standards and technology.

7.1. Fire safety (UCS 1 & 14)

7.1.1. Related use case scenario

1 BE: Fire intervention (Fire Brigade access information in case of intervention)

14 BE: Fire prevention

7.1.2. Information to include

In order to use a BIM model for fire prevention and intervention purposes, the following information should be included in addition to the general geometry and layout of the building:

- Passive fire protection measures:
  These are essential fire safety characteristics that ensure the robustness and safety of the building at all times. They do not require any action.
  - Fire resistance of building elements
    - R-value: Load bearing capacity of a structural element in case of fire
    - E-value: Integrity; resistance of a bounding element (wall, floor, etc) against the propagation of flames and hot gases from one side to the other.
    - I-value: Insulation; resistance of a bounding element against heat transfer from exposure to a fire on one side.
  - Fire compartments
  - Evacuation routes
    - The length of the evacuation routes to a staircase or open air determines if the route identifies as an evacuation route. In some modelling software f.i. Autodesk Revit (version 2020 and newer) there is the possibility to use 'path of travel' lines to symbolize the routes. This function will draw the route based on 2 points (a room and an exit) and factor in obstacles in the model. From these lines the lengths can be scheduled to find routes that don't comply.
  - Flammability of materials
- Active fire protection measures:
  Elements in the building that are manually or automatically activated in case of fire in order to stop the fire from spreading or to extinguish the fire.
  - Fire hydrants (indoor/outdoor)
  - Wet/dry risers
  - Extinguishers
  - Sprinkler systems
  - Door closing mechanisms

Other useful information that is often not displayed on 2D plans, but would be useful to include:

- Usage:
    - Occupancy of rooms and compartments
    - Profile of building users: sleeping or awake, mobile or not, familiar with the building or not, etc.
- General data:
    - Assumptions about the applicable legislation that can be used by public fire services to evaluate fire safety.

7.1.3. Property sets available in IFC

IFC already contains many relevant properties in different property sets

ifcZone

Pset_ZoneCommon

Pset_SpaceFireSafetyRequirements

Pset_SpaceOccupancyRequirements

Pset_SpaceThermalRequirements

7.1.4. How to include the information

Several challenges in current modelling practice have to be addressed in order to create BIM-models with useful, transferable fire safety data.

- Some data is commonly added as 2D-annotations (lines, shapes, text) on a specific view instead of modeled as a BIM-element. This data would be lost if the model was exported to a different format. This problem can be solved for some data types, but other data types require further research. E.g.: How to model evacuation routes in BIM.
- There is currently no consistent protocol for adding, storing and naming fire prevention information in BIM.

An overview of how some information can be included in Revit:

- **Fire resistance** of a wall in Revit is a type parameter. When a value is given to that type of wall, all other walls of that type receive the same values. This might be a problem when 2 walls of the same type have different fire resistant values and can be solved by creating another wall type.
- **Fire compartment parameters or zones**: A shared parameter should be included in the Revit file attached to the wall, floor and roof Revit-categories, which afterwards can be mapped to the corresponding IFC properties. The parameter contains information whether a building component encloses a fire compartment zone. Information on area and volume of the fire compartment zones can't be derived from this property.
  For this purpose, it is possible in Revit to group spaces and make zones. Zones will be exported to ifcZone and its associated property sets.
- **Active fire protection measures** should be mapped to the right class.
  IfcFireSuppressionTerminalType can be used for all types of sprinkler systems or any other form of terminal that is connected to a pipework system and used for suppressing a fire.

7.1.5. Legal Minimum vs Required vs Actual Value

For each fire safety parameter, multiple values could be included in the model.

- Legal Minimum Value: The minimum level of safety that is required by federal, regional and/or local legislation.
- Required Value: The level of safety that is determined by the project team during the design phase and that should ideally be met throughout its entire lifespan.
- Actual Value: Usually determined by characteristics of the used material. E.g.: a concrete wall often has a high fire resistance, independent of legal requirements or the goals set by the project team.

The three values are related as follows:

Legal Minimum Value ≤ Required Value ≤ Actual Value

In general, it is most useful to include the Required Value in the BIM model. It sets a clear reference for all parties throughout the lifespan of a building.

If only the Legal Minimum Value were included, additional fire safety measures might be accidently destroyed during construction or refurbishment, and the building would not be used to its full capacity.

On the other hand, if building elements have a higher safety level (Actual Value) than required, it is often not useful to include this in the model either. The higher safety level of a single building element is usually accidental and not sufficient to improve the fire safety of the building, unless it was considered in the overall building design. Adding this information would make the model or plans more difficult to interpret. It could also lead to unnecessary spending on useless fire prevention measures.

7.1.6. Fire information and building phases

Fire safety information is added to the BIM-model during different phases in the building's lifespan.

Design phase:

- General geometry of the building
- Required Values of building elements

Permit:

- Fire brigades performs checks to see if the proposed design (Required Values) meet the Legal Minimum Values. The BIMy platform could be used to share the model with the Fire Brigade.

Bidding:

- (Potential) contractors use the information in the model to calculate the building costs and make an offer.

Constructions phase:

- Building materials/products are selected. The project team verifies whether they meet the Required Values. BIMy could use external services to perform this check.

- Datasheets with the product information (Actual Values) are linked to the elements in the model using Linked Data.

Maintenance/Renovation phase:

- Maintenance staff can search the database of linked datasheets for information about maintenance and repair.
- The Required Values can be used as a reference in renovations.

Demolition phase:

- Building elements such as doors can be repurposed in other projects, if the fire information is compatible with the new context.

7.2. Circular Economy (UCS 2)

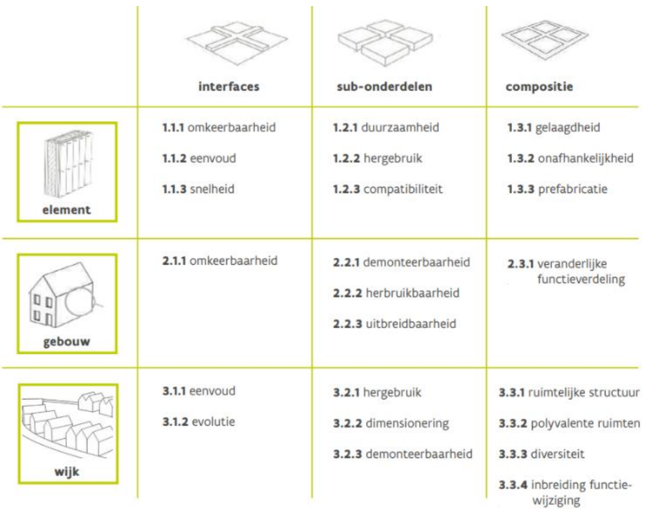
7.2.1. Related use case scenario

2 BE: long term vision – circular economy – urban mining

7.2.2. Information to include

A BIM model should contain information on whether a building element or material is designed for circularity. OVAM created 24 general design guidelines in collaboration with different research institutions VUB, VITO and KU Leuven) and architectural firms (OVAM, 2016).

The 24 guidelines define the importance of change-oriented buildings and how these guidelines can be integrated into the design phase. The 24 guidelines are subdivided on material level, building level and neighborhood level. Although there is no research conducted on how to implement circularity information in a BIM yet.



7.2.3. Property sets available in IFC

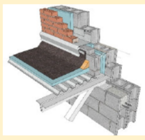
Other information such as the use of spaces, use of buildings, and service life parameters can also prove useful for this scenario.

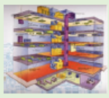
IFC4 already includes several 'Circularity' IFC Property sets, such as:

- *Pset_BuildingUse*
- *Pset_Condition*
- *Pset_ManufacturerTypeInformation*
- *Pset_ManufacturerOccurrence*
- *Pset_MaterialCommon*
- *Pset_MaterialCombustion*
- *Pset_ServiceLifeFactors*

In the table below: The useful and already available Properties and Quantities in IFC4 are listed next to the relevant change-oriented building guidelines.

	Guideline for change-oriented building at district level, for the time being outside the scope of the BIMy project
	Guideline for change oriented building applicable to 'urban mining' + reuse of buildings
	Guideline for change-oriented building applicable to the reuse of buildings

Level	Interfaces							
	Principle	Meaning	Possible visual representation on BIMy platform	Filtering on BIMy platform IFC4 Entity	IFC4 Pset / Qto	IFC4 Property / Qu	Available in model download	In which phase should information be included in BIM?
Element	reversibility	Have reversible connections been used?	Function 'connections' for elements -> standard view Opening link to website or technical documentation available in the model  	N/A	N/A	N/A	Yes, visually + possibly relevant properties + possibly technical documentation	Design(Designer) Execution(Contractor)
	simplicity	Are complex/standardized connections used?						
	speed	Is the number/accessibility of connections manageable?						
Building	reversibility	Do connections between elements (walls, floors, roofs...) allow for replacement?	See above	N/A	N/A	N/A	Yes, visually + possibly relevant properties + possibly technical documentation	Designer(Designphase) Execution(Contractor)
Neighborhood	simplicity	Are there simple connections between building and infrastructure?	See above	N/A	N/A	N/A	Yes, visually + possibly relevant properties + possibly technical documentation	Execution(Contractor)
	evolution	Is parcel separation adjustable?	Visualisation of filtered elements/properties -> Link to Government website?	IfcSite	Pset_LandRegistration Qto_SiteBaseQuantities	LandID IsPermanentID LandTitleID GrossPerimeter GrossArea	Yes, visually + possibly relevant properties + possibly technical documentation	Asbuilt?

Level	Sub-parts							
	Principle	Meaning	Possible visual representation on BIMy platform	Filtering IFC4 Entity	IFC4 Pset / Qto	IFC4 Property / Quantity	Available in model download	In which phase should information be included in BIM?
Element	durability	Is materialisation wear-resistant? What is the lifespan?	Visualisation of filtered elements/properties ->	Ifc*	Pset_*Common	DurabilityRating	Yes, visually + possibly relevant properties + possibly technical documentation	Execution(Contractor)
					Pset_EnvironmentalImpactIndicators	LifeCyclePhase		Asbuilt(contractor)
						ExpectedServiceLife		Execution(manufacturer)
					Pset_ServiceLife	ServiceLifeDuration MeanTimeBetweenFailure		
					Pset_ServiceLifeFactors	QualityOfComponents DesignLevel WorkExecutionLevel IndoorEnvironment OutdoorEnvironment InUseConditions MaintenanceLevel		
				IfcElement	Pset_Condition	AssessmentDate AssessmentCondition AssessmentDescription		
				IfcElement	Pset_ManufacturerTypeInformation	ProductionYear		
				IfcElement	Pset_Warranty	WarrantyStartDate WarrantyEndDate WarrantyContent		
	reusability	Are products reused?	Visualisation of filtered elements/properties ->	Ifc*	Pset_*Common	ElementStatus		Design(Designer) Execution(Contractor)
	Compatibility	Are components standardized? Brand?	Visualisation of filtered elements/properties ->	IfcElement	Pset_ManufacturerTypeInformation	Manufacturer ArticleNumber GlobalTradeItemNumber	Yes, visually + possibly relevant properties + possibly technical documentation	Design(Designer)
Building	demountability	Is it possible to selectively disassemble mount/carrier?	Visualisation of filtered elements/properties ->	Ifc*	Pset_*Common	ExtendToStructure	Yes, visually + possibly relevant properties + possibly technical documentation	Design(Designer) Execution(Contractor)
	reusability	Are elements usable in the same/other construction project?	Visualisation of filtered elements/properties ->	IfcElement	Pset_EnvironmentalImpactIndicators	LifeCyclePhase	Yes, visually + possibly relevant properties + possibly technical documentation	Execution(manufacturer)
				Ifc*	Pset_*Common	ExpectedServiceLife IsExternal LoadBearing		
	expandability	Are technical elements over-dimensioned? Are pipes strategically placed? Can insulation be added?	Functions for 'technical planning' -> standard view(s) 	IfcElement	Pset_ConcreteElementGeneral	StructuralClass StrengthClass ReinforcementStrengthClass	Yes, visually + possibly relevant properties + possibly technical documentation	Design(Designer)
				IfcBuilding	Qto_BuildingBaseQuantities	FootPrintArea		
				IfcBuildingStorey/IfcSpace	Qto_BuildingStoreyBaseQuantities / Qto_SpaceBaseQuantities	NetFloorArea NetVolume Height		
Neighborhood	reusability	Are existing buildings and infrastructure reused?	Visualisation of filtered elements/properties ->	IfcBuilding	Pset BuildingCommon	ConstructionMethod YearOfConstruction YearOfLastRefurbishment IsLandmarked	Yes, visually + possibly relevant properties + possibly technical documentation	
	dimensioning	Amount of static infrastructure limited?						
	demountability	Selective removal of infrastructure and building possible?						

Level	Composition							
	Principle	Meaning	Possible visual representation on BIMy platform	Filtering			Available in model download	In which phase should information be included in BIM?
				IFC4 Entity	IFC4 Pset / Qto	IFC4 Property / Quantity		
Element	stratification	Is there decoupling in functional and technical lifetime layers?	visual inspection of chosen elements Link to technical documentation	N/A	N/A	N/A	Yes, visually + possibly relevant properties + possibly technical documentation	Execution(manufacturer)
Element	independence	Are components assembled independently? (Shape)	visual inspection of chosen elements	N/A	N/A	N/A	Yes, visually + possibly relevant properties + possibly technical documentation	Execution(manufacturer)
Element	prefabrication	Pre-assembled in the factory?	Visualisation of filtered elements/properties ->	IfcElement	Pset_ManufacturerTypeInformati Pset_ConcreteElementGeneral	AssemblyPlace Constructionmethod ('insitu' of 'pr	Yes, visually + possibly relevant properties + possibly technical documentation	Execution(manufacturer)
Building	changing distribution of functions	Is the building layout polyvalent, movable parts of the building?	Visualisation of filtered elements/properties ->	IfcBuilding	Pset BuildingUse	MarketCategory	Yes, visually + possibly relevant properties + possibly technical documentation	Designer(Designphase)
				Ifc*	Pset_*Common	ExtendToStructure		
				Ifc*	Pset_*Common	Compartmentation		
				IfcSpace	Pset_SpaceCommon	GrossPlannedArea NetPlannedArea PubliclyAccessible HandicapAccessible		
				IfcSpace	Pset_SpaceLightingRequirements	Illuminance		
				IfcBuilding	Qset_BuildingBaseQuantities	FootPrintArea		
				IfcBuildingStorey/IfcSpace	Qto_BuildingStoreyBaseQuantities / Qto_SpaceBaseQuantities	NetFloorArea NetVolume Height		
Neighborhood	spatial structure							
Neighborhood	multipurpose rooms	Public facilities multi-purpose?						
Neighborhood	diversity	Diversity of functions, housing types?						
Neighborhood	extension of the function change	Possibility of compaction?						

7.2.4. How to include the information

7.2.4.1. IFC Class

In Revit it is possible to export a model using an IFC mapping file: for each category and subcategory the user can define to which IFC class it gets exported. This mapping should be standardized according to how BuildingSMART defined the mapping should be.

7.2.4.2. IFC Properties

IFC 2x3: Time properties in the IFC are linked to construction planning which might not be very useful for this project. Time parameters containing information about the lifecycle of materials of objects are is currently lacking in the IFC2x3.

IFC4: IFC4 is more suited for this scenario, because of its Life Service Property Sets. Native software though doesn’t have life service parameters included in the standard Property Sets of the software. For this reason, a set of project/shared parameters should be imported or created in the design software and afterwards mapped to the corresponding IFC property.

Not all relevant information for Circular Economy can be translated to available Property Sets in IFC4 yet, meaning the modelling of information for the circular economy is limited for now to the properties currently available in the IFC4 format. We also provide a suggestion to add new property sets regarding ‘Circularity’ to future IFC file format versions.

Some IFC data formats such as IfcDate and IfcDuration are currently not supported by any/most software. In Revit 2020 the datatype parameter ‘Time’ does exist, but it can’t be mapped to IFC time properties yet.

For this reason, the research focuses on Property sets that can be mapped to the IFC property sets.

7.3. Digital Building Permit (UCS 7)

7.3.1. Related use case scenario

7 BE: Digital building permit platform

7.3.2. Information to include

The following (graphical) data should be available in BIMy, in order to use it for a building permit application in Flanders (Belgium) in accordance to current legislation. (Vlaanderen Departement Omgeving, 2018).

Parallel versions of the models:

- Licensed (what is permitted under the last permit; only necessary if different from existing)
- Existing (Elements that will be demolished should be indicated as such)
- New (completed state after construction is finished)

Location of the building or construction

- It is required to indicate the location/footprint on the Flemish GRB reference map (Informatie Vlaanderen, 2019).
- This location links the building to one or multiple adjacent plots/parcels that each have a cadastral registration code and (usually) an address.
- Also: Surrounding parcels with main function, cadastral registration code and address.

Site and surroundings:

- Site design: paved areas/green areas/main underground infrastructures (sewers, rain water collection tank)
- Main features of the public domain surrounding the site: roads, pavement, planting, public infrastructure (benches, etc) , main underground infrastructure
- The terrain profile/elevation of the building site and its immediate surroundings. May need multiple versions if there are differences between existing, licensed and new.
- Pictures of the site (min 6) with indication of the camera view points (location, direction and ID)
- Existing easements (“erfdienstbaarheid”)
- Façades of adjacent buildings

The building

- General building elements: geometry, materials (incl colors for façade materials), fire resistance for walls/doors/windows/floors/roofs
- Levels, with one level (usually the ground level) being the reference level at 0.00m. The elevation of the reference level is tied to a general reference system (vb. TAW)
- Rooms with name and function

Fire safety

- Fire compartments with name, area and occupancy
- Evacuation routes
- Areas covered by sprinkler systems

- Several building elements that need to be displayed when queried (usually already included in model): extinguishers, central detection system, smoke ventilation system, evacuation doors (property of door element), etc.

7.3.3. Property sets available in IFC

There is a property set 'Pset_Permit' defined by BuildingSMART: property set for the properties of a permit to do work or carry out an action, if available. Other property sets that could be interesting:

Pset_BuildingCommon

ConstructionMethod
FireProtectionClass
SprinklerProtection
NetPlannedArea
GrossPlannedArea
NumberOfStoreys
YearOfConstruction
YearOfLastRefurbishment

Pset_BuildingUse

MarketCategory
MarketSubCategory
PlanningControlStatus
NarrativeText
VacancyRateInCategoryNow
TenureModesAvailableNow
MarketSubCategoriesAvailableNow
RentalRatesInCategoryNow
VacancyRateInCategoryFuture
TenureModesAvailableFuture
MarketSubCategoriesAvailableFuture
RentalRatesInCategoryFuture

Pset_BuildingUseAdjacent

MarketCategory
MarketSubCategory
PlanningControlStatus
NarrativeText

Pset_PropertyAgreement

None of these property sets are available in Revit and mapping is required.

8. Summary of BIMy Modeling Conventions

The table in this chapter translates the general modelling conventions in chapter 4 and the BIMy use case specific modelling conventions in chapter 8, into specific, technically elaborated arrangements, categorized under specific LOD/LOG/LOI's the model subsequently represents.

Topic						LOIN 200 (preliminary design)	LOIN 300 (definitive design)	LOIN 400 (work preparation)
responsibility						design team	design team	contractors
fase						until contest	until permit/end of design changes	for execution
Algemene toelichting						In general: Everything that doesn't satisfy LOIN 300	**Demand at virtual commissioning**	In general: Everything that has been enriched after virtual commissioning by the contractors
ALL DISCIPLINES								
Model								
Division						Per building, divided by floor	Per building, divided by floor	Per building, divided by floor
Spaces								
Geometry						Modelled	Modelled	Modelled
Elementen (LOG)								
Position						Unreliable	Definitive	Definitive
Geometry						Unreliable	Definitive	Definitive
							Modeled as described in the modeling conventions	Modeled even more detailed than described in the modeling conventions
Principles and documents								
Fire compartmentalisation						Preliminary	Developed and added to the model	Developed and added to the model
Details (building nodes, ...)						Preliminary	Developed and added to the model	Developed further
Element type	**Parameter**	**Value**	**Data type**	**Unit**	**Specific parameter mapping**	**LOIN 200**	**LOIN 300**	**LOIN 400**
ALL DISCIPLINES						(x = available and reliable)	(x = available and reliable)	(x = available and reliable)
Everything (except spaces/environmen	**Material**	*free**	Text	/	Material		X	X
	** depends on software*							
	Verdieping	-01/+00/+01/...	Text	/	Building Storey	X	X (or correctly linked to building storey)	X
	Dummy	Yes/No	Boolean	/	DUMMY_WIL	X	X	X
	Classification	*according to classification*	Text	/	Artikel_WIL		X	X
	Unique identifier (name)	*free*	Text	/	Mark		X	X
	FireRating	R120/E90/EI100/...	Text	/	FireRating	X	X	X
	LoadBearing	Yes/No	Boolean	/		X	X	X
	Reference of technical documentation	#	Text	/				X
	Technician	*free*	Text	/				X
If different from global LOIN of the model	**LOIN**	100/200/300/400	Integer	/			X	X
If existing	**Reference to building node detail**	#	Text	/			X	X
Concrete element	**Number of the reinforcement plan**	#	Text	/			X	X
	Environmental class	E0/EI/EE1/EA3/...	Text	/			X	X
	Strength class	C12/15 | C20/25 | C20/22 | ...	Text	/			X	X
	Esthetische eisen per zijde	*free*	Text	/			X	X
Stair	**Number of steps**	#	Integer	/			X	X
	Height of the riser	*free*	Decimal	mm			X	X
	Depth of the tread	*free*	Decimal	mm			X	X
Masonry wall	**Visible**	Yes/No	Boolean	/			X	X
	Reinforcement	Yes/No	Boolean	/			X	X
	compressive strength	*free*	Decimal	N/mm²			X	X
ARCHITECTURE + INTERIOR						(x = available and reliable)	(x = available and reliable)	(x = available and reliable)
Space	**Comfort temperature**	*vrij*	Decimal	°C		X	X	X
	Unique number	#	Decimal	/		X	X	X
	Function	*Office/living room/hallway....*	Text	/		X	X	X
	Maximum occupancy	#	Integer	personen		X	X	X
	Finishing of floors, walls, ceilings	*vrij*	Text	/		X		
Suspended ceiling	**Acoustical value**	*vrij*	Text	/			X	X
Door/Window	**Information from door/window list**	*vrij*	Text	/			X	X
Plaster	**To be painted**	Yes/No	Boolean	/			X	X
Finishing	**Type of finishing, color,...**	*vrij*	Text	/			X	X
STRUCTURE						(x = available and reliable)	(x = available and reliable)	(x = available and reliable)
Secan pole wall	**starting level**	*vrij*	Decimal	mm/cm/m/...			X	X
	cut-off level	*vrij*	Decimal	mm/cm/m/...			X	X
Pole foundation	**cut-off level**	*vrij*	Decimal	mm/cm/m/...			X	X
	Loadbearing capacity	*vrij*	Decimal	N/mm²			X	X
MEP						(x = available and reliable)	(x = available and reliable)	(x = available and reliable)
All devices	**Inventory number**	*volgens nummering onderhoudsinventaris*	Text	/			x	x
	Manufacturer	*Vaillant/Buderus/...*	Text	/			X	X
	Power	*Vrij*	Decimal	kW			X	X
Primary pipes and ducts	**Type**	*Aanvoer/Afvoer*	Text	/			X	X
	Medium	*Lucht/Water/...*	Text	/			X	X
	Flow rate	*Vrij*	Decimal				X	X
	Isolated	*Yes/No*	Boolean	/			X	X
Secondary pipes and ducts	**Type**	*Aanvoer/Afvoer*	Text	/				X
	Medium	*Lucht/Water/...*	Text	/				X
	Flow rate	*Vrij*	Decimal					X
	Isolated	*Yes/No*	Boolean	/				X
Environment						(x = available and reliable)	(x = available and reliable)	(x = available and reliable)
All	**Material**	*free**	Text	/			X	X
	** depends on software*							
	Classification	*according to classification*	Text	/			X	X
	Technician	*free*	Text	/				X
	Reference of technical documentation	#	Text	/				X
Ground	**Loadbearing capacity**	*vrij*	Decimal	N/mm²			X	X
If appliccable	**Inventory number**	*according to inventory*	Text	/			X	X

9. Conclusions and further research

The current best practice guidelines for modelling geometry and information in BIM, coincide largely with the prerequisites made by the BIMy platform.

Modelling time and scale in BIM is, however, still challenging. 'Time'-aspects such as phasing are often only implemented in proprietary software but are difficult to export to other formats. A solution would be to export every phase as separate versions of the BIM model that would be hosted in parallel by the platform. The concept of scale is currently not supported by BIM tools. Switching between scales without information loss is only possible through resource intensive workarounds. Applications can be developed to downgrade the scale (LOD/LOG/LOI) of a model or object, but information is lost in the process.

Various complementary methods can be used for filtering BIM data on the BIMy platform. However, the lack of a universal classification system for objects and properties is still a major drawback. For now, additional manual mapping is necessary to make a model completely readable for the platform. Machine learning could be used to automate this process. Using automated checks can help in verifying models on their level of compliance.

The selected use case scenarios provide useful insight into the barriers that are encountered when the BIMy platform is put to use in various practical applications.

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