

BIM Legal: Implementation of a standard for Cadastral Registration of Apartment Complexes in 3D

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Keywords: BIM Legal, 3D Cadastre, IFC, Apartment registration in 3D

Abstract

The potential of Building Information Models (BIM) to establish rights and responsibilities for multi-level building complexes in cadastral registrations has been explored in many previous researches. However, the implementation of BIM-based cadastral registrations in practice remains limited due to the complex interplay between technical potentials and legal implications as well as uncertainty about the additional complexity of a BIM model and the extra work that will be required to generate the BIM Legal model. In collaboration with Netherlands Kadaster, we have investigated the data requirements for a BIM Legal model that will support the 3D cadastral registration of apartment complexes and that aligns with BIM creation processes in practice. The BIM Legal model aims to visualise the spatial aspects of apartment complexes and to align the cadastral registration to the 3D data that is generated in the design and construction phase of new buildings. The BIM Legal file will be submitted when an apartment complex is being registered and is based on IFC, the open standard established by BuildingSMART International and used in the BIM domain. To make the implementation of BIM Legal feasible legally, technically, and economically, we apply a 3-phase approach. This paper presents the BIM Legal model as defined in Phase 1, which enables to generate a BIM Legal model compliant with current legislation frameworks with no/minimal manual interaction from BIM models as commonly generated in design processes. The paper describes the 3-phase approach, the context of Phase 1, the data requirement analyses, the defined BIM Legal data model, as well the questions that emerged during the specification process that need to be answered to further improve the implementation of Phase 1 and to further develop BIM Legal for Phases 2 and 3.

1. Introduction

The registration of multi-level property in cadastral registrations is an extensively studied topic. Although ownership has always been linked to space, the implementation of 3D cadastral registration in practice has become more prominent recently. This has several reasons. Firstly, 3D developments have made the maintenance, querying, and visualisation of 3D geometries possible. Second, the scarcity of space has made it more important than ever to accurately register the (3D) boundaries of ownership as well as the rights and responsibilities of the related installations. Finally, 3D information incorporated in Building Information Models (BIM) is getting mainstream in the design and construction domain, which is potentially a relevant data source to register 3D ownership information of buildings.

Numerous research initiatives have focused on BIM-based 3D cadastral registration. However, real-world implementations that define ownership information from BIM models for use in a BIM 'from-design-to-legal' workflow are still rare. A bottleneck is the required alignment between different domains to develop a solution that is feasible in practice from different perspectives i.e. technically, legally, and economically. Apart from technical solutions (i.e. modelling and validation), the BIM Legal

solution should meet legal conditions and regulations (including responsibility, reliability, and accountability of the digitally derived data). In addition, it should be economically feasible for all stakeholders in the BIM Legal workflow who must produce, submit, or register/maintain the BIM-based cadastral registration. Therefore, translating current workflows into 3D requires further exploration, not so much to develop a technical solution but rather to establish a framework of agreements between all stakeholders (designers, real estate developers, architects, builders, notaries, cadastre) that make the whole BIM Legal workflow, from design to registration, feasible.

This paper presents our solution to define BIM-based specifications for 3D registration of apartment complexes within the Dutch cadastral registration (maintained by the Netherlands Kadaster). It builds on previous 3D cadastral registration in the Netherlands (Stoter et al., 2017). However, the previous cases focused on a BIM-based 3D registration of building complexes, where the multi-level property rights were established via the right of superficies (not via apartment rights). In addition, at that time, only the 3D PDF could be registered, which had significant limitations for interactive querying and maintenance (e.g. using the underlying data in case of future changes). There was also no standard, agreed workflow, which limited the registration of new cases. This

paper, therefore, focuses on BIM legal specifications that enable the registration of the BIM Legal data itself and the definition of a design-to-registration workflow agreed upon with, and supported by, all stakeholders. The focus is on the registration of apartment complexes, as there are already regulations in place for the registration of (multi-level) apartment complexes, including regulations for the mandatory 2D drawings showing the division of private and common areas per floor. In addition, these areas can be easily derived from BIM models and can therefore benefit from recent technical developments in BIM modelling.

1.1 3-phase approach

We have opted for a 3-phase, step-by-step approach by starting 'simple' to ensure a feasible implementation. In doing so, experience can be gained at each phase which provides input for the next phase, and further alignment can be achieved throughout the whole chain based on lessons learned in each phase.

Phase 1 focuses on deriving the division drawing showing shared and private spaces from the BIM model complying with current legislation before submission. In this phase, the current 2D division drawing is still (only) registered, but this drawing is derived from a BIM Legal model that will be prepared for this derivation. This phase aims to gain experience in a multi-stakeholder approach in order to refine the BIM Legal specifications and prepare for the next developments. Phase 1 will trigger questions that need to be answered for the next phases. In Phase 2, both the BIM Legal model - which contains all information from the division drawing and could, therefore, in principle, replace the division drawing - is registered, as well as the division drawing itself. This allows the development of a solution for the actual registration process of the BIM Legal data. In Phase 3, a more comprehensive BIM Legal model will be developed in which the legal agreements on other than private and shared spaces can also be spatially represented. These agreements are established in the division *regulations* and may concern the use, management, and maintenance of specific building elements, installations, and areas that do not necessarily coincide with apartment units. Registering information on building elements and areas/spaces in general also aligns with the requirements and needs for other applications such as building log books and material passports required for energy transition and circularity.

1.2 Overview of this paper

This paper presents the BIM Legal data model that we defined for Phase 1. It first provides a further explanation and motivation of the scope of BIM Legal Phase 1 (Section 2). Section 3 describes the data requirement analysis that we carried out for BIM Legal Phase 1. Section 4 presents the data model for BIM Legal Phase 1, including the modelling choices that were made to implement BIM Legal in the open standard IFC, the open standard established and maintained by buildingSMART. Section 5 lists the questions that have emerged during the development of the BIM Legal model Phase 1. These questions will be addressed in a multi-stakeholder approach to refine BIM Legal model Phase 1, and to further develop the model for Phases 2 and 3. The paper ends with conclusions and further research.

2. Scope of BIM-Legal Phase 1

Phase 1 focuses on deriving the ownership spaces as depicted on a (currently required) 2D division drawing from the 3D BIM model (see Figure 1). This derivation process replaces the manually generated division drawing. The derivation takes place before the drawing is submitted to the Kadaster. The source BIM model is not included in the registration. Since Phase 1 focuses on the division drawing within current regulations, we first explain the role of this drawing in the current registration process.

2.1 Division drawing in the current registration

The (legal) purpose of a division drawing is to show how a building is divided into separate apartment units. A 2D drawing is required when a new apartment complex is registered. It details the spatial layout of the building and the dimensions of, and boundaries between, the different units. It contains a 2D overview per floor, indicating both private and shared ownership spaces (including parking places). There are formal guidelines for these drawings (Kadaster, 1994b) as well as best practices recommendations (Kadaster, 1994a).

2.2 Apartment complex regulations

Apart from this drawing, a document containing the regulations for the apartment complex is required to determine responsibilities for maintenance and restoration and to regulate other aspects of shared building management. An example can be found at (Verenigingen, 2017). These regulations, often referring to specific building elements, are outside the scope of Phase 1 and will be translated into BIM-based specifications in Phase 3.

2.3 Scoping BIM Legal Phase 1

BIM Legal Phase 1 will need only that information to clearly indicate the areas for private and shared use, to be depicted on the 2D division drawing and will therefore only contain the (empty) 3D spaces that are intended for private and shared use.

Figure 2 shows the change in the BIM Legal workflow compared to the current situation: the visualisation of shared and private spaces is derived from a BIM Legal model in one continuous workflow. In the current situation, these spaces are separately drawn on a 2D map causing an interruption in the workflow. This is inefficient and a potential source of inconsistency.

The aim of BIM Legal is not to copy the current drawing 1-to-1 but to see how the process can be improved and accelerated by deriving the 2D drawing from BIM Legal under current regulations. In Phase 1, experience will be gained to better understand and further elaborate the consequences.

The scope and aim of Phase 1 can therefore be refined by the following aspects:

By deriving the division drawing from the BIM model, the process of generating and registering the division drawing becomes more efficient and part of the entire

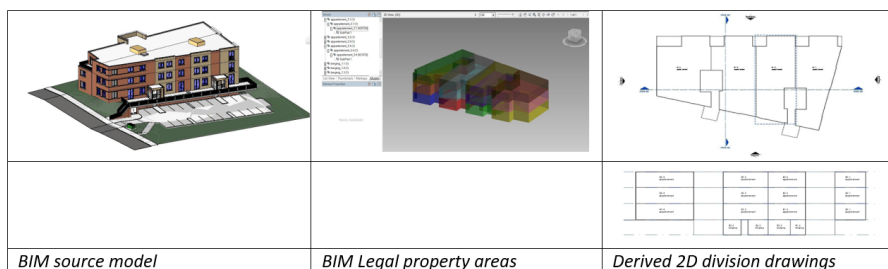


Figure 1. Private and shared areas (right) derived from BIM source model (left) and the spaces visualized in 3D (middle), Source: VDNDP Construction Engineers (from (Stoter et al., 2012))

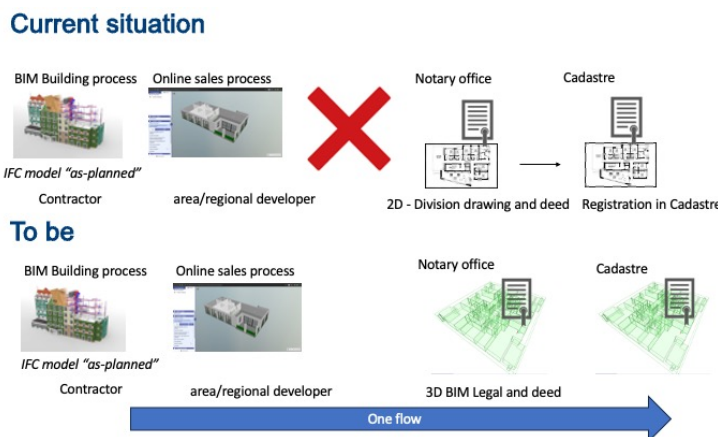


Figure 2. Changes in the BIM Legal workflow compared to the current situation.

chain (from design, permitting, and registration to realisation).

Through collaboration in the construction chain among real estate developers, architects, builders, notaries, and buyers, many errors in the division deed and 3D model are preemptively corrected, improving the quality of the whole process.

Deriving the 2D division drawing from the 3D model further ensures consistency between the division drawing and the 3D model. This consistency is expected to lead to significantly fewer errors in the division drawings that are provided to the Kadaster.

Phase 1 does not require any changes to the current working process of the Kadaster nor to the notary-Kadaster interaction, making it relatively simple and clear to implement.

Notaries who want to do so can gradually (and supported by Kadaster) gain experience with 3D, without the submission requirements changing.

The focused (and 'simple') scope allows joint experience to be gained and coordination to take place throughout the chain, in preparation for registering the BIM Legal model (Phase 2) and including rights other than apartment-related usage rights on both spaces and building elements (Phase 3) in the future.

3. Data requirements BIM Legal Phase 1

For the data requirements analysis, we have first determined the principles for BIM Legal that follow from the scope and purpose of BIM Legal Phase 1 as formulated

in the previous section (Section 3.1). Driven by these principles we studied the current requirements for the division drawing as defined in legislation, regulations, and guidelines and transferred these to data requirements (Section 3.2).

3.1 Principles BIM Legal Phase 1

The principles were defined in an iterative evaluation process with the involvement of both legal and technical experts. The following principles have been formulated, which will be tested in Phase 1 and expanded or adjusted accordingly.

Principle 1 The division drawing based on BIM Legal Phase 1 must provide spatial insight into which spaces are intended for private use linked to specific apartment units and which spaces are intended for shared use.

Principle 2 The BIM Legal model should reuse the BIM model as generated in the chain as much as possible with no or minimal additional edits. Other elements than private/shared space boundaries that must be included on the drawing (such as a north arrow, scale ruler, etc.) and that are commonly not part of a BIM model are initially manually added in Phase 1 by the person preparing the division drawing.

Principle 3 Desired and possible additions for the fully automatic generation of the complete division drawing with elements that are not a standard part of a BIM model are explored with the stakeholders during Phase 1 and the BIM Legal model is adjusted accordingly if desired. Adding these elements creates extra complexity

and challenges for feasibility, making it better to first test this in practice. It must also be taken into account that BIM Legal will ultimately replace the division drawing. Therefore, the generation of a 2D drawing from a BIM model will be temporary and it will be more interesting to explore how the 2D map-related requirements can be translated into a digital 3D model (see also Section 5.2).

Principle 4 From the principle that a BIM model is used as much as possible as it is developed in the chain with no or minimal geometric operations, follows that private and shared areas are constructed from the spaces that are present in the BIM model (usually to represent rooms). If these room-based spaces are not present as entities, they can easily be generated by BIM software. The outer boundaries of a specific apartment unit can be recognised from the BIM Legal model but this geometry is not per se available as a separate entity. The outer boundary can be made visible via the subspaces of an apartment unit, see Figure 3. Adding the outer boundary as a specific element is not trivial. Therefore, the outer boundary as an entity of the BIM Legal model falls outside the scope of Phase 1 and can be included later once this has been further explored with the stakeholders, i.e. whether the addition of the outer boundary geometry is necessary and how this boundary can be added (semi-automatically) based on the information in the BIM Legal model, see Section 5.

Principle 5 A division drawing does not show whether building elements (wall, floor, window) are shared since they are represented by a thick line. Such legal information is included in the division deed (the division regulations) but cannot be derived from the current division drawing and, therefore, falls outside the scope of Phase 1. This also applies to shared building elements that are located in private areas (e.g. load-bearing wall, balcony construction, construction floor).

Principle 6 The following elements that are part of a 2D division drawing, but that are not a standard part of a BIM as generated in the chain are initially not part of Phase 1 (in addition to the map-related elements mentioned above). It will be studied later how they can be added in an automated or otherwise efficient manner:

1. Georeference information, including north direction
2. Situation sketch
3. Building outline
4. Land plots
5. Land objects other than the land that is part of an apartment unit or shared areas

Principle 7 The BIM Legal model itself is not submitted in Phase 1. However, in order to prepare for Phases 2 and 3, BIM Legal model Phase 1 should only contain the elements of BIM Legal and no other information generated in the chain.

Principle 8 BIM Legal will be defined in IFC, the open BIM standard developed and managed by buildingSMART. The IFC format is supported as an open standard in the

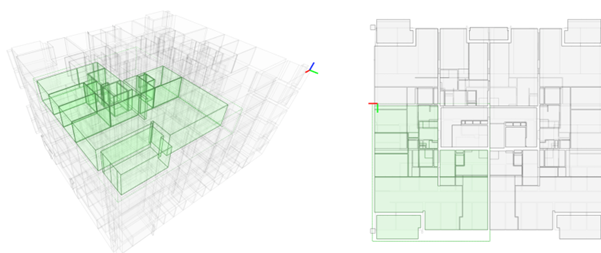


Figure 3. Representation of a specific apartment in 3D (left) and 2D (right) based on the information assigned to the rooms. Through this way of visualisation boundaries become visible; but they are not present in the BIM Legal model as a separate entity.

design and construction community and therefore, by adopting IFC, BIM Legal can be implemented as a specific view on already available BIM data. IFC is also on the Dutch “comply or explain” list of the standardisation forum (Forum Standaardisatie, 2024).

3.2 Data requirements for BIM Legal compliant with current legislation and regulations

The data requirements for BIM Legal were defined from the principles defined above and extended with a detailed study of the current legislation and regulations. The legislation, regulations, and guidelines that were studied are:

1. Regulations on apartment rights under Civil Code 5, Title 9 (Dutch Government, 2015)
2. Implementation Regulations of the Land Registry Act 1994, which contain further conditions for the division drawing (Articles 5 and 6) (Kadaster, 1994b)
3. Checklist division drawing of apartments, drawn up by the Kadaster (Kadaster, 1994a)

In the process of data requirements analysis, also other sources were taken into account, i.e. Land Administration Domain Model (LADM) (van Oosterom and Lemmen, 2015); BIM IFC specification - Central government real estate (Rijksvastgoed, 2019); and, previous studies in this area: (van Oosterom et al., 2021, Guler et al., 2022) (Atazadeh et al., 2016, Meulmeester, 2019, Oldfield et al., 2017, Alattas et al., 2021).

The data requirements (**R**) that were defined for BIM Legal model Phase 1 are as follows:

BIM Legal model (BLM) as a whole

R1 An apartment complex is defined by one BLM.

R2 A BLM contains the 3D model of one apartment complex delineating the private (i.e. the individual apartment units) and shared spaces, including the land belonging to the complex, so that floor plans, views of the building, as well as land belonging to the complex can be visualised.

R3 The entire complex (and thus the BLM) contains

two or more apartment units (and/or land) intended for separate (private) use and optionally one unit for shared use.

R4 There should be no overlap in spaces (topological requirement).

Apartment units

R5 The spaces enclosing the exclusive rights of use of apartment units should be identifiable as such.

R6 An apartment unit consisting of multiple parts (spaces) should be modeled as one (grouped) object, even if the parts are not adjacent or are on different floors.

R7 All parts of the same apartment unit should contain the apartment index number so that it can be displayed/retrieved as one unit.

R8 The apartment units must be able to be related to the deed via their index number.

Shared spaces

R9 If a space is not designated as private, the space is designated as shared space.

Boundaries between units

R10 Separations (boundaries) between individual apartment units should be clear from the BIM Legal model, but these do not fall within the private or shared spaces and are not themselves objects. Therefore, there can be ‘gaps’ at the location of these boundaries. NB: How the rights to the building elements at these locations (which can be various in a BIM Model e.g. doors, walls, windows) can be captured and made clear requires further exploration and is not part of Phase 1.

R11 Holes should coincide with boundaries. If not, there is either a private or shared space that is not indicated as such (and thus an error).

Rooms

R12 Rooms belonging to an apartment unit may be included but are not mandatory. The rooms have no legal significance and therefore do not need to be present in the model as separate entities.

R13 An apartment unit can optionally consist of the collection of separate, possibly adjacent rooms.

4. BIM Legal – Phase 1 data model

To define the BIM Legal Phase 1 data model, the data requirements are translated into classes, attributes and constraints, which are then transferred to an implementation in IFC through a class mapping (following the principle of minimal addition to the IFC as it is generated in the design process). In this section, we introduce the UML class diagram of the BIM Legal data model (Section 4.1 and discuss its IFC class mapping (Section 4.2). Section 4.3 presents an example file of the BIM Legal data model (which was generated from a BIM model produced in practice) and describes how the specifications are expressed in Information Delivery Specifications (IDS), which is currently developed by buildingSMART.

4.1 UML model of the BIM Legal data model

Figure 4 shows the UML class diagram of BIM Legal Phase 1. The classes of this BIM Legal data model are further detailed (relationships, constraints) in the Appendix (Section 7).

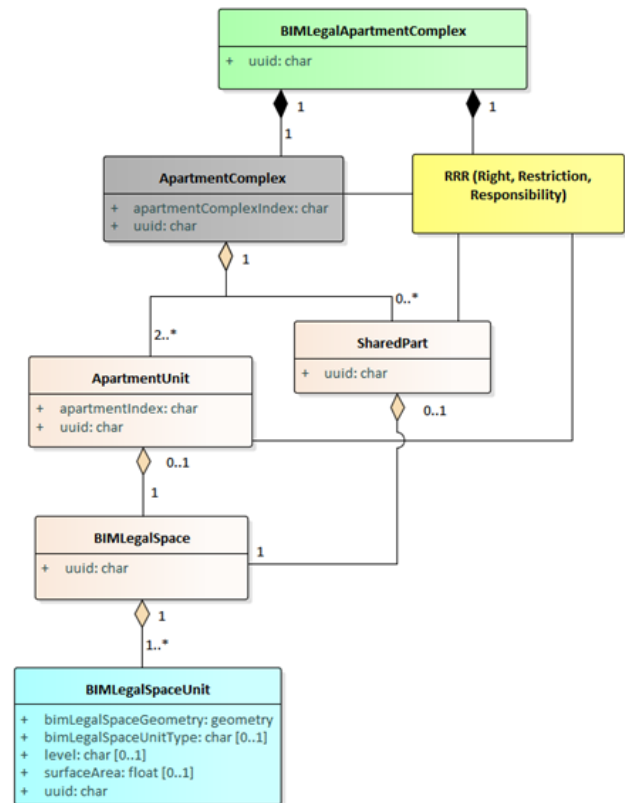


Figure 4. UML diagram of BIM Legal model Phase 1

Although the LADM principles are followed, the RRR class (right, restriction, responsibility) is not explicitly mentioned in the BIM Legal model Phase 1. Whether a space is legally part of either a specific apartment unit or of the shared space follows from either the ApartmentUnit or the SharedPart to which the space belongs. Other rights than these exclusive and shared use rights are described in the deed in Phases 1 and 2 and these are not part of BIM Legal. How different types of rights can be incorporated in BLM, such as maintenance rights for shared building elements is a topic of further investigation and will be added in Phase 3 (see Section 5.2)

4.2 Mapping between BIM Legal and IFC classes

Each class of the BLM is associated with an IFC class to ensure a one-to-one mapping while allowing a valid IFC output. This leads to the following IFC modelling approach:

The **BIMLegalModelApartmentComplex** class is the root class of a BLM and, as such, is mapped to the *IfcProject* class. It models the private and shared ownership spaces of one *ApartmentComplex* and in the future it may contain elements to which other rights and responsibilities are assigned than exclusive use rights.

The **ApartmentComplex** class is mapped to the *IfcBuilding* class, as it corresponds to a single building. It consists of two or more *ApartmentUnits* and zero or more *SharedParts*. This class does not contain geometry, as *IfcBuilding* in this phase is formed by the elements (i.e. private and shared spaces) that jointly define the geometry of the whole complex. However, a geometry at-

tribute will be needed if a building outline is to be added in a later phase.

An **ApartmentUnit** is modelled by *IfcGroup*. The motivation for this is that there is no direct correspondence for "Apartment" or "Unit" in IFC. We use *IfcGroup* as a container to represent a unit, in the sense of the group and not the geometry. An alternative could have been *IfcZone*. However, with *IfcZone* it is only possible to group spaces (*IfcSpace*) and not building elements, which will be required in Phase 3. Therefore, *IfcGroup* and not *IfcZone* is used for this intended grouping of both spaces and building elements. A BIM Legal IFC viewer will be required to support visualisation based on grouping (*IfcGroup* entities) together with the overall hierarchy structure of an *IfcProject*. This is not the case for all the available IFC viewers, as tested in our study.

A **BIMLegalSpace** corresponds to the spatial entity of an apartment unit (also for **SharedParts**). This class is modelled as an *IfcZone* class (with no geometry). All spaces belonging to one apartment unit (which can be separated, disconnected, and located on different floors) are represented by one **BIMLegalSpace**. *IfcZone* can group *IfcSpaces*, also if they are not on the same floor. *IfcSpace* can also group several *IfcSpaces*, but only if they are on the same floor; therefore *IfcZone* is used. One **BIMLegalSpace** can consist of one or more *BIMLegalSpaceUnits*.

The **BIMLegalSpaceUnit** class is the smallest entity in a BLM. It is mapped to the *IfcSpace* class and is the only entity with geometry, i.e. space or surface (in case of a parking). It could be used to model the space of a complete **ApartmentUnit** or to model the spaces and areas that make up the **ApartmentUnit**. Because **BIMLegalSpaceUnits** inherit the attributes of **ApartmentUnit**, they automatically get the same **ApartmentIndexNumber**. This makes it possible to represent them as one apartment unit.

Attributes and other IFC related choices

The naming convention for the IFC property sets used to generate BIM Legal specific attributes is as follows: PSet_BIMLegal_BIM-Legal-class-name, for example PSet_BIMLegal_ApartmentUnit. For all classes, the attribute UUID corresponds to the default GUID associated with each class instance in an IFC model.

More details about the attributes of each class of the BIM Legal model Phase 1 can be found in the Appendix (Section 7).

4.3 Implementation: Example files and IDS

Example IFC files have been generated compliant with the BIM Legal specifications Phase 1. One of the example files is shown in Figure 5 and also Figure 3. The source BIM-IFC file for this example was generated by BPD Gebiedsontwikkeling.

The specifications have been expressed in the Information Delivery Specifications (IDS), also a standard currently developed by buildingSMART. IDS offers machine-readable specifications that can be ingested by BIM tools and enables the possibility of validating a BIM model

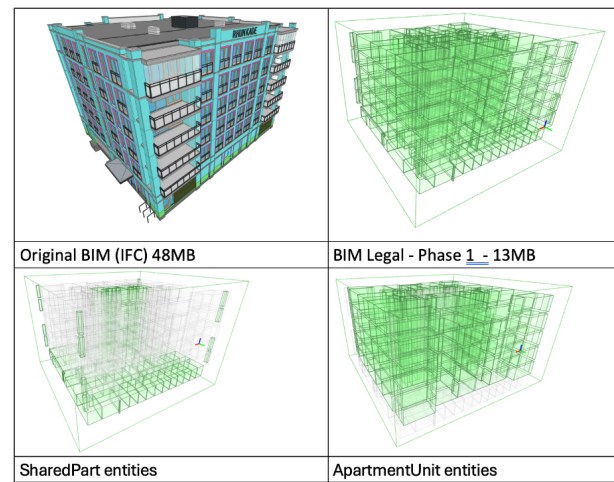


Figure 5. Example of a BIM Legal IFC file.

against it. The validation mechanism of BIM Legal models through IDS is a topic of further research.

As previously mentioned, only a subset of IFC classes are mapped to the BIM Legal data model. However, the current way in which the IDS standard is designed requires an explicit listing of the classes to be excluded in the specification file. That would translate to listing all IFC classes (over a thousand) except those used in the BLM IFC mapping and the necessary ones to ensure a valid IFC file. This issue is also a topic of further investigation. Meanwhile, a way to mitigate it is to focus on listing a subset of IFC classes only, such as the *IfcElement* family, and ignore others (e.g. *IfcRelationships* family). Scripts can also be used to automate such listing.

5. Questions from BIM Legal Phase 1 experiences

A step-by-step, iterative approach is employed in the implementation of BIM Legal in order to refine the specifications based on experiences and reflection by, and interaction between, the stakeholders. Questions and issues that arise during (initial) implementation are addressed through a multi-stakeholder approach. This section lists the questions that have arisen during the development of BIM Legal Phase 1 that are addressed to accomplish the optimal implementation of Phase 1 (Section 5.1) as well as to prepare for an optimal implementation of Phases 2 and 3 (Section 5.2). The answers to these questions will be determined through a process of prototyping and evaluating possible alternatives, leading to the establishment of agreements between the stakeholders on subsequent implementation steps.

5.1 Questions for Phase 1

5.1.1 Outer boundaries of private and shared spaces Boundaries of spaces are not included in the BIM Legal model Phase 1 as separate elements. By the index number associated with each individual unit and the grouping mechanism of *IfcGroup*, individual units can be visualised, as prescribed by the current guidelines. Is this sufficient or do the outer boundaries of apartment units also need to be defined (and thus generated) as

separate entities? If so, how can these outer boundaries of apartment units be derived from IFC elements in the BIM source data file?

5.1.2 Exclusive use of land like parking places

How to model exclusive use of land belonging to the building (e.g. for parking)? Should these be represented as 2D surfaces or as 3D space? IfcSpace supports both options. Related to this question is how parking places inside buildings should be modelled.

5.1.3 Use of colours to distinguish apartment units from each other

Article 5.2 of the Land Registry Act states that colours may be used: *If colours have been used in the drawing in addition to black and white, this shall be indicated on the copy of the drawing in a prominent place* Could this guideline be used to (better) distinguish apartment units from each other through colours in the drawing, in addition to visualising their boundaries? This would make the distinction between different units in a 3D viewer even clearer.

5.1.4 Rooms

Under current regulations, it is allowed to ‘indicate the mutual location of all rooms and other spaces belonging to that unit.’ Is this rule for BIM Legal limited to merely being able to visualise these rooms, or should these rooms be modelled as separate entities so that specific attributes can be assigned to them? In the current data model, rooms are not separate entities.

5.1.5 Volumes and areas of apartment units

Is there a need to include parameters like volumes and (floor) areas as attributes? Those values can be calculated from digital models. However, the calculation of these values, specifically of complex shapes, is not always straightforward and results can differ between software tools. Therefore it might be better to include such (confirmed) parameters as attributes in the model.

5.2 Questions for Phases 2 and 3

5.2.1 Legal meaning of 2D surfaces versus 3D spaces

The boundaries of each unit are shown in 3D in BIM Legal, whereas current legislation is based on 2D overviews per floor. The question arises as to whether the 3D spaces in BIM Legal have the same legal significance as the 2D units in the subdivision plan. After all, the two representations are different spatial views of the property situation (i.e. rooms or area), i.e. in a 3D representation more details can be represented.

5.2.2 Meaning and designation of partition walls and other separation elements

BIM Legal should visualise the private and shared areas, just as is done in the division drawing. In the 2D drawing, the boundary is shown by such a thick line that its exact location cannot be deduced nor how this legal boundary spatially relates to a dividing wall. In the 3D model of Phase 1, the exact location of the legal boundary of a private unit can also not be deduced, because there are no building elements included to provide a basis for dimensions or orientation. For Phase 1, the question was already raised if an outer boundary of an apartment unit should be modelled as a separate entity (Section 5.1.1). The question for Phases 2 and 3 is whether/how partition elements should be added to BIM Legal as objects and how do these physical

elements relate to legal boundaries. There is also the question of whether the legal boundaries of units should be indicated more precisely, now that BIM Legal allows this (in contrast to a line that is drawn). Is it the middle or right/left surface of a wall element, represented in IFC by a geometry with a thickness? How rights, restrictions, and responsibilities can be assigned to physical elements (and hence the issues raised by this question) needs also to be addressed for Phase 3.

5.2.3 Accuracy

Articles 6-1- i and j of the drawing regulations require a certain scale for the maps and drawings to be submitted. Can these be translated into accuracy requirements for a digital model, and if so, what accuracy requirements should be imposed on BIM Legal?

5.2.4 Mandatory inclusion of building-ID

Should the inclusion of the IDs that are registered in the Building And Address Register (BAG) be made mandatory so that the BIM Legal model can be integrated with other data sets? This applies both to the whole apartment complex (BAG-building) and to individual apartment units (that have a specific address). Related to this is whether the BAG ID for the building should be modelled at the highest level, i.e. assigned to the super class BIMLegalApartmentComplex or the ApartmentComplex.

5.2.5 Link between objects in BIM Legal/IFC and the notarial deed

In experiments, we have shown that a link between objects in the IFC model and objects as described in the deed can be established using the UID of the IFC and text sections in the PDF. For each legal rule, all objects to which this rule applies (e.g. the exclusive right of use related to a specific apartment unit) should be grouped so that the group gets one ID which can refer to one legal rule/text paragraph in the PDF. The BIM Legal model and the corresponding deed in PDF can be combined in a ZIP file which can be signed by the notary. By not including the legal information in BIM Legal itself, the BIM Legal model (including generation and maintenance) can be kept relatively simple. This way of working should be further tested with the stakeholders.

5.2.6 Map-related requirements

Several current regulations are intended to make the information on 2D division drawings readable. It is needed to translate these 2D map requirements into requirements that can clarify the information captured in BIM Legal in an interactive 3D model. The question is how this can be done. Examples of such map-related requirements are:
R boundaries should be indicated by an indelible line of eye-catching thickness
R the north direction should be indicated on each sheet of the drawing by an arrow.
R the apartment index is placed in the centre of each part of an apartment unit and should be readable
R the scale of the drawing is not larger than 1:100 and not smaller than 1:200 and should be stated on each sheet

5.2.7 Site plan

Several options are given in the current guidelines for adding a situation sketch for orientation, such as the cadastral land plots, house numbers, and a geographical map. Can this be further specified for BIM Legal?

5.2.8 Georeferencing information How can geospatial referencing information be included to process the submitted BIM Legal files and integrate them in a 3D cadastral map and potentially with other 3D geographical information? True North and georeferencing information is generally linked to the IfcSite class. In a future version of BIM Legal, it can be considered to include this class, e.g. between BIMLegalApartmentComplex and ApartmentComplex.

5.2.9 SpaceGroup This class is needed when two components of different apartment units need to be grouped because the same right of use/obligation is attached to them (not being a right of exclusive use as assigned to an individual apartment unit). Do these situations occur?

5.2.10 Additional properties from IFC models When a BIM Legal model is created from an existing BIM model, it could have properties associated with the BIM Legal classes that are not part of the BIM Legal specification. These can be properties of general interest, such as detailed dimensions of rooms, but also specialised properties such as energy analysis and lighting. How should such additional, optional information be handled (Phase 3) which can be relevant for other applications?

5.2.11 Specialisation of RRR How to specialise the RRR class if other than exclusive use rights for apartment units need to be incorporated?

6. Conclusions and further research

This paper presents the definition process of the BIM Legal Phase 1 data model, which enables the generation of an IFC-based BIM Legal model that complies with current regulatory frameworks to be generated with no/minimal manual interaction from BIM models as commonly generated in design practices. Phase 1 focuses on the derivation of the currently mandatory 2D subdivision drawing from a BIM Legal model prepared for this purpose. The presented BIM Legal data model is the first step towards a BIM Legal implementation meeting legal, technical, and economic requirements. This implementation starts with the technical solution of modelling legal information in a BIM model. However, the main challenge for implementation is establishing agreement frameworks and standards that make the creation, registration, and visualisation of BIM Legal information feasible and affordable. To achieve this, the BIM Legal Phase 1 data model will continue to be tested and improved, from generation and (IDS) validation to deriving the division drawing from it. This improvement process applies a multi-stakeholder approach to address the issues that have arisen during the initial definition of BIM Legal (as listed in this paper) by prototyping alternatives and building consensus among all stakeholders. After the completion of BIM Legal Phase 1, BIM Legal will be further developed to enable the registration of the BIM Legal model itself (Phase 2) and the inclusion of rights to building elements (Phase 3). Issues that arose during the definition of the BIM Legal Phase 1 model that need to be answered for these more advanced and extensive BIM Legal implementations have also been listed in this paper. With this approach, BIM Legal will pave the way for establishing mainstream 3D cadastral registration in

practice and for the broad digital acceleration of the entire chain, from design to permitting and registration, to realisation and redevelopment.

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7. Appendix: BIM Legal Model Phase 1 - class definitions

This appendix contains the class definitions of BIM Legal Data model phase 1, with their definitions, attributes, explanation, rules and the implementation in IFC.

7.1 BIMLegalApartmentComplex

Definition The whole of the land and areas situated on it, which are either legally involved in the division into apartment rights (=ApartmentComplex) or are not involved in the division into apartment rights but on which another (usage) right is established relating to the complex. The focus of Phase 1 is on private and shared areas. Therefore, the definition for phase 1 is limited as follows: A BIM Legal model phase 1 contains all information regarding the different parts of the buildings and land, which are either intended for shared use or to be used as a separate, private entity and whose exclusive use will be included in a specific apartment right.

Explanation The purpose of BIM Legal Phase 1 is to contain such information as is necessary to derive the private and shared areas as visible on a division drawing. The division drawing is registered; the BIM Legal model is not.

Rules An apartment complex is modelled using a single BLM. BIMLegalApartmentComplex contains the 3D model of the apartment complex consisting of the private and shared spaces, including the land belonging to the complex, so that floor plans of the floors, views of the building, as well as land belonging to the building can be visualised. BIMLegalApartmentComplex contains the information needed to indicate the boundaries of both private and shared areas on a division drawing. A division drawing does not show whether building elements (wall, floor, window) are shared. This information is therefore not present in BLM phase 1.

Attribute: UUID [1]

Relationships A BIMLegalApartmentComplex records the exclusive use rights (RRR) on ApartmentUnits and further includes the shared space(s) (SharedPart)

IFC constraints The class BIMLegalApartmentComplex corresponds directly to the class IfcProject.

7.2 ApartmentComplex

Definition This class refers to the entirety of space and land divided into apartment rights. They contain spaces and land either for shared use or for private use

Rules The apartment complex contains two or more apartment units with exclusive rights of use, intended for separate (private) use. The apartment complex may contain shared areas in addition to private spaces. Holes in the model should coincide with boundaries. Boundaries of (and between) individual units should be clear; but are not themselves objects.

Attributes

UUID [1]

apartmentComplexIndex[1], composed as follows: 'Cadastral Municipality' 'Complex designation'.

Relationships An ApartmentComplex consists of ApartmentUnits on which exclusive rights of use are established (RRR) and (optionally) of SharedParts

IFC constraint The ApartmentComplex class corresponds directly to the IfcBuilding class (no geometry in phase 1). The apartmentComplexIndex attribute is defined via a custom property set 'PSet_BIMLegal_ApartmentComplex' that contains a property named apartmentComplexIndex and the value type IfcText.

7.3 ApartmentUnit

Definition An apartment right means a share in the property involved in the division, which includes the right to the exclusive use of certain parts of the building which, according to their arrangement, are or will be intended to be used as a separate (private) entity. The share may also include the authority to exclusively use certain parts of the land belonging to the building.

Rules One A-unit may consist of several non-adjacent rooms, also on different floors. One A-unit can optionally consist of the collection of separate, possibly adjacent rooms. All empty space not assigned to an A-unit is by default SharedPart. There should be no overlap between apartment units or between apartment units and shared spaces.

Attributes

apartmentIndex[1] An apartment index consists of numbers. The quantity depends on the number of apartments in the complex. In practice, the letter A is put in front of the index, for example A1 or A-1. UUID [1]

Relationships Is spatially represented by one BIMLegalSpace object, which can consist of several parts (both rooms and spaces that are not per se connected). These parts automatically take on the attributes of A-unit.

IFC constraint ApartmentUnit corresponds directly to IfcGroup which enables grouping with building elements in the future. In phase 1, IfcGroup consists of exactly one entity built from the related spaces, that is BIMLegalSpace. The apartmentIndex attribute of IfcGroup is defined via a custom property set. This attribute called 'PSet_BIMLegal_ApartmentUnit' contains a property called apartmentIndex and the value type IfcText.

7.4 SharedPart

Definition Shared areas are those areas in an apartment complex that are not designated for separate (private) use.

Rules The shared areas of an apartment complex may consist of one or more rooms or ground parts belonging to the complex that do not need to be adjacent. SharedPart need not be present. All 'empty' space not allocated to an apartment unit is by default SharedPart. SharedPart space is spatially represented via BIMLegalSpace

Attributes UUID [1]

Relationships Consists of BIMLegalSpace

IFC constraint The class IfcGroup is used for this class, in the same way as for an ApartmentUnit. No custom attributes are needed at this stage.

7.5 BIMLegalSpace

Definition Space and/or land delineating a specific apartment unit or shared area/space. This is the spatial representation of either a specific apartment unit or shared space

Rules BIMLegalSpace can include both space and land. BIMLegalSpace can consist of:

- exactly one space
- a collection of unconnected rooms and ground
- the aggregation of spaces

Spaces should be aggregated to the legal entity to which they belong, i.e. either to an specific apartment unit or to all shared space together.

Attributes UUID [1]

Relationships BIMLegalSpace may consist of one or more BIMLegalSpaceUnits (which may also be land).

IFC-constraint A BIMLegalSpace corresponds to an IfcZone in that it groups one or more space units that together form the legal space of a specific apartment unit or of all shared spaces together.

7.6 BIMLegalSpaceUnit

Definition BIMLegalSpaceUnit describes the individual spaces that BIMLegalSpace can consist of

Explanation Separate spaces (and surfaces, e.g. for parkings) of BIMLegalSpace can be either separate rooms; or spaces that are not connected and/or are located on different floors.

Attributes

UUID [1]

bimLegalSpaceGeometry [1]

bimLegalSpaceUnitType [0..1] level [0..1]

surfaceArea [0..1]

IFC constraint The class BIMLegalSpaceUnit corresponds directly to the class IfcSpace.

The geometric representation of IfcSpace entities must be of type Brep (IfcShapeRepresentation.RepresentationIdentifier = 'Body' and IfcShapeRepresentation.RepresentationType = 'Brep'). The objectType attribute of IfcSpace can be used directly for the bimLegalSpaceUnitType.

The level attribute corresponds to floor (IfcBuildingStorey) or location (IfcSite, for example for spaces such as car

park) to which the space/surface is associated. That relationship is expressed in the IFC via the IfcRelAggregates relationship between the IfcBuildingStorey/IfcSite (RelatingObject) and the IfcSpace (RelatedObject). The surfaceArea attribute is defined via a custom property set named PSet_BIMLegal_BIMLegalSpaceUnit, which contains one property named surfaceArea with the value type IfcAreaMeasure.