GENERALIZATION OF BIM MODEL FOR PURPOSES OF FACILITY MANAGEMENT

A. Dlesk [1]*, K. Vach [2], R. Shults [3], P. Doubrava [3]

[1] Department of Geomatics, Faculty of Civil Engineering, CTU in Prague, Czech Republic – adam.dlesk@fsv.cvut.cz
[2] EuroGV, spol. s r. o., Rudná, Czech Republic – vach@eurogv.cz
[3] Research Institute of Geodesy, Topography, and Cartography, Zdiby, Czech Republic
– (shultsrv, petr.doubrava.33)@gmail.com

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ABSTRACT:

In some of the applications such as facility management, it is not always convenient to work with the full detail of the BIM model of the building. To fulfil the demands for the generalization of the model, generalization techniques were suggested. The aim of the contribution is to presents the suggested techniques of geometry and descriptive information generalization. The generalization is developed also in the relation to the Level of Development definition. The generalization methods were implemented to the software for facility management which is developed by EuroGV company in recent years. The impact of the generalization on work with the BIM model (loading and browsing) was tested in the developed software on two different computers.

1. INTRODUCTION

Any BIM is a bunch of different kinds of data. Those data are necessary to support the whole life cycle of a building. However, different building life cycle stages need various data sets, complexity, and grade of detail. At the design stage, the BIM is as highly detailed as possible to account for any further requirements concerning fabrication, construction, management, or exploitation. The BIM model contains detailed, precise geometric data and descriptive information at this stage. As a BIM model, the information presented in IFC format has become standard for years. The detailed BIM model in IFC format is suitable for exchange between the project as structural analysis, design, creating the assemblage process, collision check, quality check, etc. But for some applications such as facility management, smart house/building application, safety control, etc., the simplified BIM model with reduced geometrical information load is required and enough. Yet, it raises the question, how to reduce the data volume without a significant loss of information? The answer is a generalization procedure that has to be applied for the BIM throughout IFC model modification. The generalization originally came from cartography, where it is understood as the selection and generalization of objects and phenomena depicted on the map following the purpose, scale, content of the map, and features of the mapped territory. The sense of generalization is the handover of the principal, typical features of objects, their characteristics features, and relationship on the map. So the generalization boils down, to generalizing the qualitative and quantitative characteristics of objects to show their main features. Moving from maps to BIM, one may notice the common background. The only difference is that unlike rivers, buildings, fences, borders, etc. one has to deal with windows, doors, materials, various facilities, and so on.
The main goal of this contribution is to present a suggested method of generalization of BIM model data for facility management purposes. For purposes of facility management, the highest descriptive and geometrical data is not always necessary. The key features of the suggested methods are the simplicity of implementation, rapidity of the generalization, and convenience for the user. Together with the generalization processes, a discussion about levels of detail and levels of development has been carried out. Which detail of the model is the most convenient for selected purposes of facility management? How to get the demanded detail fast and efficiently? Those are the important questions.

1.1 Software for facility management

The BIM is a working process that deals with the building through its all life cycle from the design, construction, facility management until the building demolition. In the Czech Republic, BIM is already well implemented in the processes of design and construction. When the building is constructed, the created BIM model is handed over to the investor and consequently to the department of the facility management. From our praxis, the department of facility management does not have many experiences with dealing with BIM data. There could be many reasons. One of the reasons is that the legislation and standardization of BIM in facility management are still under development and under discussion. The other reason could be that the facility managers need specialized software tools where would be possible to work with rich BIM data and subsequently integrate their usual procedures into the BIM processes.
To fulfil mentioned demands, since 2020, EuroGV company, in cooperation with the Research Institute of Geodesy, Topography and Cartography in the Czech Republic, develops a system for facility management. The main features of the system are functions for common facility management tasks. On top of that, the system is able to fully integrate the data of the BIM model, enables to work with the BIM model, browse the geometry and descriptive information, and gives the possibility

* Corresponding author

to update it and then subsequently the user (facility manager) is becoming the member of the BIM processes.

2. BIM MODEL

The BIM model is possible to understand as a kind of database of a different kinds of information. The information is possible to divide into two groups. The geometric information defines the shape, dimension, and position of the object in the reference system and the descriptive information describes the character and properties of the object. Both groups together are essential for the BIM processes. The BIM models are usually handed over in IFC format. IFC format is a common standardized form how to transfer the data between the different kinds of applications that are included in BIM processes. In IFC format, the geometry and descriptive information can be stored. The format is hierarchical and very well documented. The extensive documentation helps to implement the import and export of the data to the specialized software of BIM processes. The IFC file can have different forms. Common is an IFC STEP file (IFC-SPF) form, XML form, or a compressed format IFC zip. When the BIM model is exchanged between the systems, it is also possible to choose which definition of the model should be used. For many applications, it is not necessary to work with the whole IFC model, but sometimes just a subset of the model is sufficient. The subset definitions are called Model View Definition (MVD). There are many MVDs, lot of them are still under development. Among all, it is possible to mention Coordination View for architectural disciplines. Basic FM Handover View is used mainly for facility management purposes. There are also specific definitions, like a definition for environment and energy performance assessment (Pinheiro, 2015).

2.1 Geometric representation

Nowadays, it is expected that the geometric representation of the BIM model is in 3D model form. For the modelling of the geometric representation of the elements of the BIM model, it is necessary to determine, which level of detail should the model have. The modelling is carried out in specialized CAD software. Most of the software has support for the classification schemes and the model is possible to export to the IFC format in different MVDs. The process of 3D model creation can differ. When it is a new building, the 3D model is an outcome of the architectural design enriched by the information which was obtained during the construction itself. The model could have been created from the library of the elements, where the elements with their properties were predefined. On the other hand, modelling of already built constructions requires, at first, some reverse engineering techniques such as laser scanning, photogrammetry, or common geodesy. Then the model is created from the measured data.

2.2 Classification and standardization of properties

Apart from the graphic 3D model, in the field of facility management, it is very important to have descriptive data about the structural elements of the model. For example, the data about the size, fire safety, guarantee, insurance, cost, etc. are needed for facility management purposes. When the BIM model is created during the design, the structural elements can also be gathered from the predefined libraries. The library elements usually have very rich descriptive information. In the case of reverse engineering, it is very complicated to gather descriptive information. In this case, the department of the facility management must play a major role in the information gathering. Then the information can be implemented in the BIM model. In this case, software for facility management which can work with the BIM model is necessary.

Overall, for the development of the software for facility management that works with BIM, it is necessary to have the elements of the BIM model classified and their descriptive data should be standardized. The classification and standardization help to understand the data. It also gives guidance on how to work with the data in the software, how to import them, update them and export them. Through past years, several classification systems have been developed. Among others, it is possible to mention OmniClass used mainly by the community in North America, British UniClass, Swedish CoClass, or Danish CCS. In the Czech Republic, there is developed SNIM and CCI. Due to the classification systems, it is possible to exactly determine, what the element in the BIM model represents. For example, the classification of the element can show whether the element represents a concrete wall or brick wall.

Descriptive data standardization defines which non-graphic data and in which form should they be added to a single element. It is also essential for software development. For example, when an unstandardized numerical value is added to the element, during the import, it is not clear what exactly the value means, what are the units, etc. But when there is clear information about the standardization system, the software has the information, what the value exactly means, and can store the value to the right place in the data structure. In the Czech Republic, so far, the most comprehensive standardization system is SNIM developed by the czBIM group. SNIM deals with more-less every possible structural element including building construction, road construction, or railroad construction. The suggested descriptive data are divided into groups according to their characteristics – basic information, dimensions, technical information, fire safety, and also information for facility management. Due to this fact, it is possible to state that this standardization system is useful and sufficient for different kinds of purposes of the BIM process.

3. LEVEL OF DEVELOPMENT

In the past, the detail and the accuracy of the geometric documentation were usually given by the scale of the drawing. Nowadays, in the era of digital modelling, the modelling is carried out on the scale 1:1. It means that the detail of the resulting model must be given differently. To provide some guidance in the modelling, several methods were suggested. In the literature, it is possible to encounter several terms regarding the model detailing such as level of detail, level of development, level of information, level of geometry, or level of definition. The guidance in the descriptive and geometric detailing is very important to praxis. It helps investors and contractors to agree on certain detail which should be delivered in the final model. Without the guidance, every project would have its specific description of demanded details and there would be possibly many misunderstandings.

3.1 Level of development

In 2004, Vico Software Inc. company came up with the term level of detail (LOD) in relation to the BIM and consequently with the guidance Model Progression Specification (MPS) (Trimble Buildings, 2013). In 2008, the American Institute of Architects (AIA) took the idea and further developed it, and changed the term to the Level of Development. The Level of Development describes both geometrical and descriptive detail of the BIM result and it is possible to say that the level of development is a summation of the Level of Information and Level of Geometry (Marveli, 2018). From the basics developed by the AIA, the working group of BIM forum (BIM Forum, 2019) created the Level of Development specifications. The specifications were being updated through the years and are available online on the BIM forum websites. According to the specifications, the Level of Development has 6 degrees – LOD 100, LOD 200, LOD 300, LOD 350, and LOD 400, LOD 500. The degrees are well described in the published specifications.

Level of Detail	Description
LOD100	The element is represented by a symbol or by other generic information. Any information is considered approximate.
LOD200	The element is graphically represented as a generic system with approximate quantities, size, shape, location, and orientation. Non-graphic information can also be presented.
LOD300	The element is graphically represented in terms of quantity, size, shape, location, and orientation. Non-graphic information can be also added. From this representation, the values can be measured directly from the model.
LOD350	The definition is the same as it is in the case of LOD300, but to this degree, the connection and links between the elements are added, and then it helps to the coordination overall.
LOD400	The element is fully graphically represented. The outcome can resemble the technical documentation of the object manufacturer. Non-graphic information can also be presented.
LOD500	The graphical representation of the element also reflects the actual state of the element – actual and accurate size, location, quantity, and orientation.

Table 1. Description of the Level of Development.

In the table (Tab. 1), there are presented only general descriptions of the levels. In the specification by the BIM forum, it is possible to find a detailed description for each structural element and also for subtypes of each element, e.g. interior swinging door, sliding door, and folding door. The specification has also an important link to the Omniclass. It is important to note that the Level of Development is not assigned to the whole model, but to each element. Then, each group of elements can have a totally different level. For example, main structural elements can have the highest Level of Development and interior objects such as furniture can be represented only by a generic symbol – a cuboid.

3.2 Level of detail – 3DGIS approach

In the literature, there is another definition of Level of Detail but refers more to the 3DGIS or Smartcity applications. This Level of Detail is given by the definition of the CityGML 2.0 Standard from the Open Geospatial Consortium. In this case, the Level of Detail deals only with the geometric detail and has 5 degrees starting with LOD0 to LOD4. The description of the degrees is stated in Tab. 2. and was created by the information read in (Biljecki, 2016).

Level of Detail	Description
LOD0	Only a 2D ground footprint is represented
LOD1	The building is defined also by the third dimension, usually represented by the height of the building. The outcome can resemble a simple box.
LOD2	The exact shape of the building envelope is given.
LOD3	The model of the building is a complex model with all the construction objects such as windows and doors.
LOD4	This degree has the same characteristic as LOD3 and the model is completed by indoor objects, such as furniture.

Table 2. Description of the Level of Detail.

4. BIM MODEL AND FACILITY MANAGEMENT

For facility management purposes, a method of the generalization of the BIM model has been suggested and implemented in the mentioned software developed by EuroGV. For some applications of facility management, the precise and detailed geometry of the BIM model is not needed. Also, in praxis, facility managers are not always equipped by computer with the highest graphic performance, and working with the detailed 3D geometry may be detrimental.

The facility managers can encounter different Levels of Development of the BIM model from LOD100 to LOD500. There are two approaches how to achieving the BIM model. The first approach is that the BIM model is generated already during the construction and design stage of the building life cycle. In this case, according to the praxis, the LOD400 may be expected. The LOD as well as the classification and standardization of descriptive data should be defined by the investor in the contract. The BIM model is usually created from the library elements. Library elements usually have very detailed descriptive information which is an advantage for consequent facility management purposes. To achieve LOD500 it would be necessary to geodetically document the actual state of the building and create a new BIM model or correct the original one. The definition of the Level of Development does not exactly say what accuracy should be expected. For the accuracy, according to the older guidance, it is possible to set the imaginary scale, e.g. 1:50 (even though the actual scale of the modelling is 1:1), and derived the accuracy from the set scale. LOD 500 can be also achieved when the building was built before the era of BIM and then the investor asks to create a new BIM model. Then, by the investor, it is necessary to declare the required LOD and accuracy of the model. The building is then measured using a different kinds of techniques chosen with respect to the requirements given by the investor. Among the techniques nowadays, it is possible to mention laser scanning and scan-to-BIM processes, or photogrammetry. In some cases, the classic tape measuring is also useful. In this approach, it is kind of time-consuming to gather all the needed geometrical and especially descriptive information about the elements. Sometimes, only very competent facility managers are able to gather all the descriptive data. This can be a continuous process during the life of the building. That is also why the facility managers need to have software that is suited especially for them and where they can continuously update the BIM model.

5. GENERALIZATION OF THE BIM MODEL

For the facility management software developed by the EuroGV company were implemented functions for generalization of descriptive and geometrical data. The methods of generalization are presented in the following paragraphs.

5.1 Generalization of the descriptive information

The rich descriptive data attached to each element of the BIM model can be generalized as well. Under concrete standardization, the data are usually divided into different topic groups. For example, the SNIM standardization divides the properties of the element into groups such as basic information, dimension, fire safety, etc. If all the data are presented, the work with the descriptive information of the BIM model can be confusing and more time-consuming. The specific data, especially data regarding safety, should not be presented to every user of the system. For the generalization of the descriptive data, different rules for different users are set. The administrator can see all the topic groups of the BIM model. On the other side, the technician can see only generalized data, and only selected topic groups are available for him (e.g. basic information and maintenance). The security can only see the topic groups which are related to the security, etc. Due to this generalization, the system is possible to use more efficiently and it increases the simplicity of the comprehensive system for facility management.

5.2 Generalization of the geometry

For many applications of facility management, the detailed geometric representation of every element is not always necessary and it can delay other important activities. In the facility management field, the performance of the computers is not always the highest, and working with the detailed 3D model does not have to be always fast, especially loading and also browsing the model. To ease the work with the 3D model, geometry generalization techniques of the BIM model in the IFC-SPF form were suggested. Every construction element has a different generalization technique. So far, there were suggested methods for major construction elements, such as windows, doors, walls, columns, etc., and for interior objects such as furniture, sensors, sanitary objects, etc. The generalization is designed to correspond to the definition of LOD for every element. The method of generalization is shown on the window example.

5.2.1 Generalization method (example on a window)

In the case of windows, the generalization method which is suitable to generalize the geometry of the window from LOD400/LOD500 to LOD350 and LOD300 was implemented. The LOD requirements were taken from the LOD specification by the BIM forum (BIM Forum, 2019).

The model in the IFC-SPF form is taken and every window element is found based on the correct assignment (in this case the assignment is IfcWindow). In the IFC-SPF, the geometry of the window is described by the links to the geometrical elements. Then the orthogonal view of the window is taken. Every geometrical element which does not interfere with the window surrounding (e.g. wall) are expelled by canceling the link between the window element and the geometry element. The expelled elements are not removed and stay in the file. This generalization can be considered as the step between LOD400/LOD500 and LOD350. In the next generalization, only the external frame which shares geometry with the surrounding object (wall) is left. Other geometrical elements are expelled but stay in the IFC-SPF. By this, the LOD300 may be achieved because it does not contain attachment details. The fact that the expelled elements are still included in the project enables to implementation of a switch between LODs to the 3D viewer of the software for facility management. The user can choose which LOD would like to work at any time. The same technique work with other elements. For other objects, like interior elements was also implemented a generalization to LOD100, where the element was substituted by the simple generic symbol, e.g. cuboid.

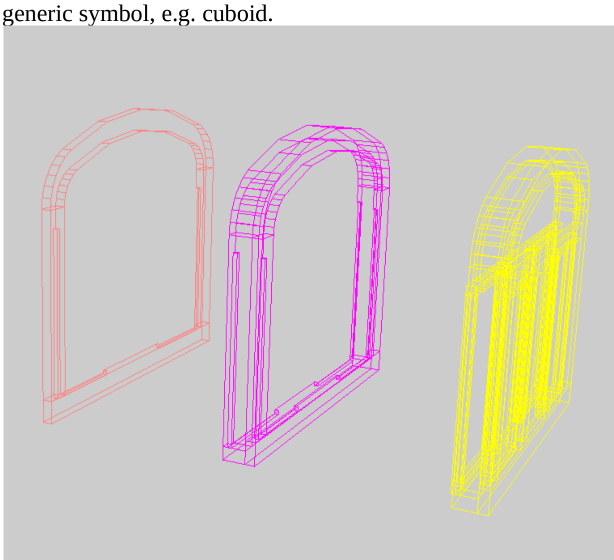

Figure 1. Window in three different LODs.

5.2.2 Testing of the generalization method

For the test of the geometry generalization method, the rich BIM model of a building was created and the windows were modeled in an actual state in LOD500 (Gen0). The building has more than 800 windows and there was a presumption that the generalization of the windows can affect the speed of browsing and working with the 3D model. To test the effect, the generalization method was applied on the model with windows in LOD500, and the model with widows LOD350 (Gen1) and LOD300 (Gen2) were generated. The test of the effect was carried out on two different computers. One of the computers (PC1) was from the higher price range with graphic adapter Intel® UHD Graphics and processor Intel® Core™ i7 – 10750H @ 2.60GHz. The other computer was from the middle or lower price range (PC2) and had a graphic adapter AMD Radeon™ Vega 8 Graphics and processor AMD Ryzen 5 3500U 2.1 Ghz. In our opinion, the PC2 belongs to the category of computers which are usually used by an average employee of the facility management department and where the developed software shall be used.

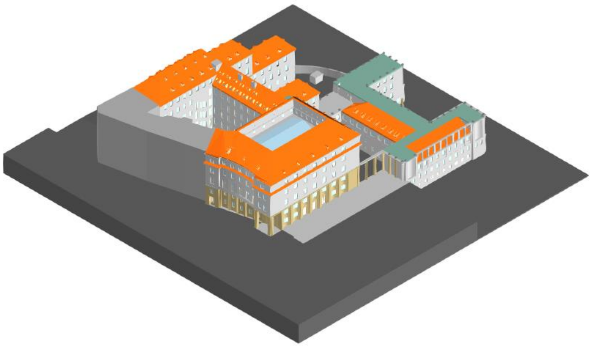

Figure 2. Model used for testing.

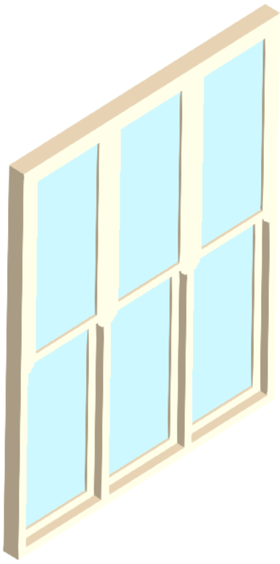

Figure 3. Example of a window in full detail - Gen0 or LOD500.

		Gen0	Gen1	Gen2
PC1	Loading	18.9 s	19.7 s	18.2
	Browsing	23 FPS	35 FPS	41 FPS
PC2	Loading	43.8 s	38.7 s	32.5 s
	Browsing	7 FPS	13 FPS	18 FPS

Table 3. Time of the loading and browsing.

In the case of PC1, the loading time was lower compared to the PC2, see Tab. 3. The testing showed that the loading time is not dependent on the generalization level. The reason is that even though the geometry elements of the windows were expelled they stay in the file. When the model is loaded, the software import all the elements to its database but then do not show the expelled ones. Then, the browsing of the model was tested. For every test, the model was browsed by the same trajectory and average frames per second (FPS) were measured. Turned out that the generalization helps to increase the number of FPS. In the case of PC1, even the most detailed version of the model was possible to browse very smoothly. By eye, it was possible to feel a difference between Gen0 and Gen1. The difference between Gen1 and Gen2 was not detectable by eye. On the other hand, the browsing of the model in version Gen0 on PC2 was not smooth at first sight (average FPS = 7). The generalization model increased the number of FPS and significantly helped the browsing of the model. For an eye, it is an important difference between 7 FPS and 13 FPS.

6. CONCLUSION

The degree of detail of the BIM model is one of the important topics in BIM processes. The detail of the BIM model should be agreed upon between the investor and the contractor. To offer some guidance for both sides, a few working groups presented definitions of the detailing. From our point of view, the most important and comprehensive definition was the definition of Level of Development (LOD) created by the BIM forum. In the definition, the geometric detail is described very well, but the definition is not focused on the accuracy of the model which is related to the LOD500. In facility management, the topic of the detail of the BIM model is also very important. The employees of the facility management department are not usually equipped with the computers with the highest performance and working with the BIM model can be delaying and unpleasant for them. In the developed software by the EuroGV company, functions for the generalization of the BIM model were implemented. The generalization of the descriptive standardized information is carried out by the set of rules which are assigned to the user of the system. The generalization of the geometry is carried out by the suggested method which is described in this contribution. The method enables to generalization of the different elements of the model from LOD400/LOD500 to LOD350 and LOD300. For some elements, the generalization is done also until LOD100. The technique of generalization enables the user to switch between different detail during working with the model. The method of the generalization was also tested on two different computers to check if the generalization has an effect on the user. The test showed, that the result of the generalization does not affect the loading time, because the expelled geometry elements are still included in the file. On the other hand, the generalization affects the browsing of the model. With the generalization of the model, the average of frames per second is increased. It is a very important fact because on computers from the lower price range the browsing of detailed 3D models is not always smooth. The implementation of the generalization to the developed software has a positive effect on the users of the system. So far, the generalization is implemented for the main construction elements which are the most common and also have an extensive geometrical structure with potential for generalization. In the next development, the generalization of more unusual geometrical elements will be included.

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