

## **BIM maturity levels in teaching the design process**

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**ABSTRACT:** The first step is presented in this article of academic education related to implementing building information modeling (BIM) technology and using the data contained in the models of buildings. When designing a course syllabus, given time constraints for a university course and students' initial knowledge and experience, the lecturer should specify the range and desired level of the 3D BIM model. For this reason, it is advisable to define the maturity level of BIM virtual models to be prepared by students. The authors believe that it is a good idea to introduce a transition maturity level of 1/2, which comprises full level 1 and some elements from level 2. By doing so, students will be prepared for the current requirements of the construction and design market, and become aware of benefits of using 3D virtual objects in simplifying the next stages of the design process.

### **INTRODUCTION**

In this article, the authors discuss the first stage of academic education related to the implementation of building information modeling (BIM) technology and using the data present in the models of buildings. Numerous limitations resulting from students' initial knowledge and experience, as well as limited duration of the university courses make it impossible to use the full BIM models. These limitations suggest one should introduce students to only the most important elements of BIM technology, making sure that enough emphasis is given to the benefits of its use and showing examples of its practical application throughout the course.

When preparing such introductory BIM courses, the lecturer should specify the range and advancement level of the 3D model and the amount of data fed into the model. For this purpose, it is advisable to define the BIM maturity level of the virtual objects on which the students are working. The authors' own experience seems to suggest that it is possible to introduce the transition maturity level of 1/2, so as to fulfil the basic requirements of teaching BIM and to show students the tools applied to design in the construction business. Elements of level 2, depending on needs, may be further completed with data in selected fragments or in strategic places of the building in the case of other-discipline projects. This allows students to get first design data and greatly facilitates co-ordination between the parties involved in the design process.

### **DEVELOPMENT LEVEL OF BIM MODELS FOR DESIGN PROJECTS**

When deciding on the contents of a course aimed at teaching techniques supporting the design process, it is necessary to take into consideration the circumstances in which future graduates of the Faculty of Architecture will be working. Building information modeling (BIM) technology offers a great number of benefits, but in real life, designers often will be unable to take advantage of the wide spectrum of possibilities offered by it [1][2].

Many investors, because of time and economic reasons, prefer not to resort to all-discipline BIM models that include structural elements, installations, and so on. Public tender commissions are a good example of such a situation. In such cases, while complying with the public tender conditions or following the investor's request, the designer must decide the level of maturity the BIM model will have. Price and time for preparing documentation are often highly important factors.

Other factors which influence the choice of development level of a BIM model are: the size of an architectural design office [3]; adequate software; economic aspects; and availability of other-discipline documentation. Quite often the level of advancement of the virtual 3D model has to be scaled down with the simultaneous optimisation of the work done by the design office. In the case of public tenders, the budget very often does not allow for incurring any additional costs,

which results in resigning from other-discipline BIM models and makes it necessary to feed the data into the model during the design stage or the construction stage. Similarly, numerous private investors choose not to incur any additional costs, often being unaware of the potential benefits during the construction stage, as well as during the management of the building in the future. Optimising the BIM model depends to a large extent on the designer, work organisation, particular logistical solutions and the detail quality of prepared documentation. Therefore, specifying the maturity level or development level of the virtual object becomes most useful. These considerations coupled with years of design experience allowed the authors to design a model one-semester university course for students of architecture.

## BIM MATURITY LEVELS IN UNIVERSITY EDUCATION

Maturity stages of BIM models are defined by four major levels [4], which reflect the extent to which the model is saturated with information (Figure 1). Taking into consideration the time constraints of university courses and the initial stage of the students' education, not all BIM levels will be available to students at first. They should be introduced gradually, with adequate emphasis given to the transition level 1/2 which, to a large extent, reflects the present reality in the market. The four levels could be described in the following way regarding their university application:

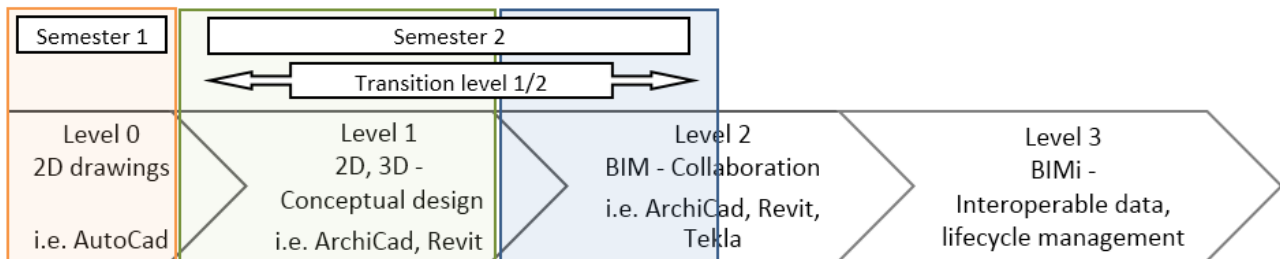


Figure 1: BIM maturity levels with the indicated transition 1/2 level (green and blue) - the student incorporates into their model the elements from level 2 (blue) (Authors' diagram, 2019).

### Level 0

This level is based on CAD programs and is easy to introduce to first-year students. It is mainly based on 2D drawings. By introducing a user co-ordinate system (UCS) cross-sections and façades of buildings can be generated. Thus, basic documentation can be produced based on 2D drawings. This level does not use 3D modelling.

### Level 1

This is most appropriate for introducing students to BIM technology. It is primarily used at the stage of conceptual design, which gradually develops as the course progresses. At this level, students may produce initial conceptual projects with general information on construction solutions and materials used. This assumes correlation of the BIM course with other courses offered to students at university, especially the ones connected to construction and design. Level 1 makes it possible to generate 2D documentation without detailed solutions of the 3D model, as well as potential other-discipline 2D documentation. However, due to insufficient detailing of the object, students cannot rely on the partial cross-section displays of the model. A simple object at this level of maturity constitutes excellent material to be developed further in some parts to level 2, and thus showing students the benefits offered by higher BIM levels.

### Level 2

Projects at level 2 are very difficult during an introductory BIM course. The main problem is that it should be complemented with construction, installation and interior data, which allow for more comprehensive 3D co-ordination. In this case, student co-operation on the level of particular faculties would be necessary (collaboration between faculties of architecture, construction and civil engineering). However, it is possible to introduce some elements that show how much this level may realistically speed up the analysis of partial cross-sections in overall co-ordination. Level 2 allows also for material specifications, and in particular information regarding quantity of materials, which may be useful for preparing cost evaluations and bill of quantities. It is important that some of these possibilities are shown to students during the introductory BIM course. An entirely separate part of the course should be devoted to initial management of the building based on a project in BIM and generating industry foundation classes (IFC) files.

### Level 3

This level can generate a well-developed BIM model, which allows for highly accurate management of the building. In the design practice it is rarely used because of time and financial considerations. Level 3 would be ideal for a more advanced BIM course. During such a course students could get acquainted with *smart building* systems and they could be shown how BIM technology may be used for the management of the building throughout its whole life cycle. Moreover, an accurately executed model could, for example, serve for the simulation of the construction process, safety, building maintenance and environment protection.

## INTRODUCTORY COURSES OF BIM TECHNOLOGY IN UNIVERSITY CONDITIONS

The syllabus of an introductory BIM course for students of architecture should reflect the constraints resulting from applying appropriate maturity levels. Based on the authors' own experience in design and observations made, while conducting BIM technology classes in the Faculty of Architecture at Cracow University of Technology, the following factors must be considered when deciding on the syllabus contents:

- students' knowledge of design and construction at the beginning of the course;
- students' preparation for working at a maturity level;
- number of course hours available;
- details regarding the project, i.e. size, function and functionality of the building being designed;
- present situation in the market; students should be aware of investors' requirements regarding the range of the project, availability of other-discipline 3D documentation, as well as current tendencies in public tenders;
- software available in the market and to what extent it is used in architectural design offices [5].

From the list of issues mentioned above, prior preparation of 2D drawings and conceptual drawings on the maturity level 0 are highly important. The BIM Technology course described here was preceded by one semester of classes during which students learnt, among other things, designing with AutoCad (2D). Laboratory class participants were able to get acquainted with the base software before reaching the next maturity level. This makes the transition into BIM technology a smooth process and gives students greater confidence when working in the new environment.

The BIM laboratory classes are scheduled as a 30-hour course in the second semester, during which students are acquainted with ArchiCad. The following semester teaches them alternative BIM software (Revit). Throughout the second semester students work on a small two- or three-storey building (300 m<sup>2</sup>) and go through subsequent stages of model maturity. Time constraints of the course necessitate optimisation of the course and its character, so that it reflects the situation in the market. For many private and public investors the most important consideration is time and economics, which results in the fact that potential benefits of using BIM level 2 are neglected, let alone level 3.

Bearing all this in mind, the student, and that is to say the future architect, should be trained to use the main elements from BIM model maturity level 2. In this way the design process can be greatly enhanced, potential collisions can be eliminated and the cost of generating project documentation can be reduced. Depending on the situation, further data can be selectively fed into the 3D model, e.g. data concerning only selected architectural or other-discipline details, i.e. the model is at transition 1/2 maturity level.

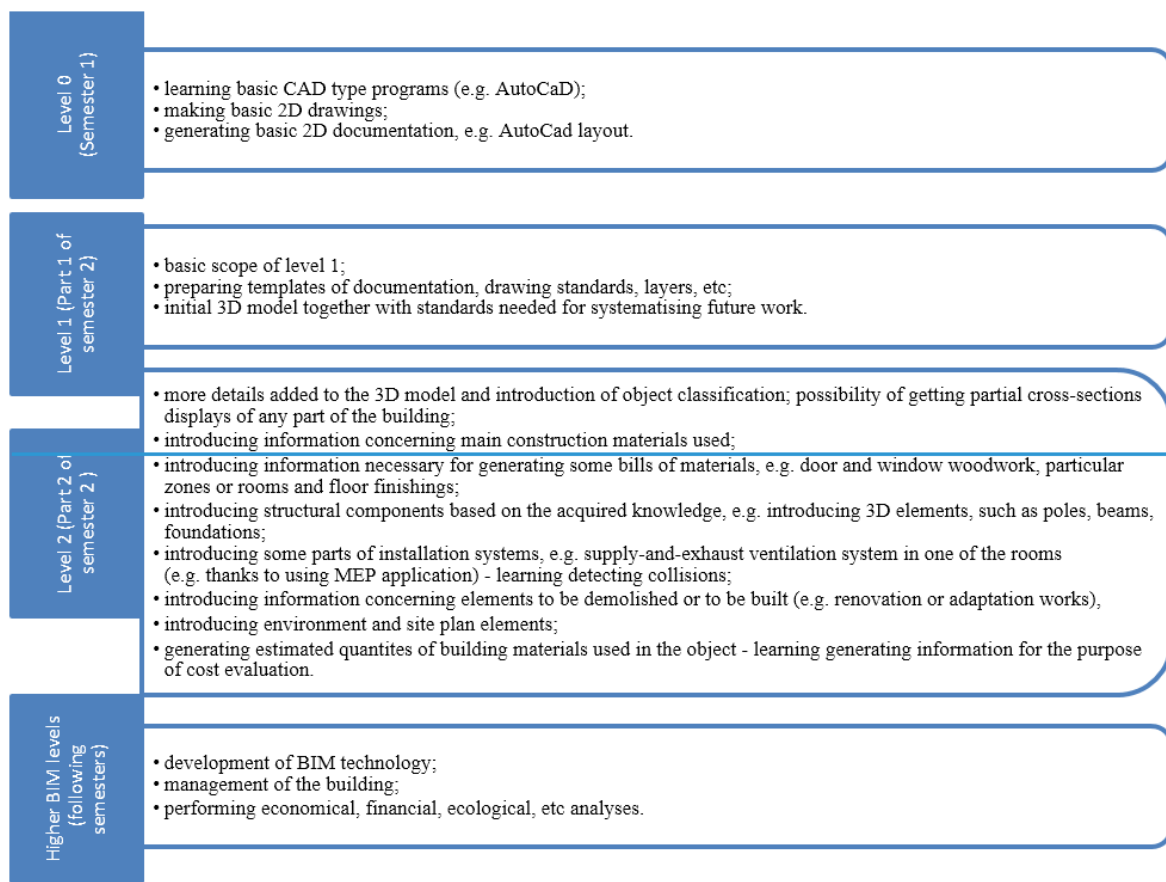


Table 1: Optimising the design process based on BIM maturity models to define the minimum level 1/2 (comprising level 1 and elements of level 2) for education (Authors' own material, 2019).

Relying on knowledge acquired during level 1, students must be reminded from the start of the design process about keeping maximum accuracy and adhering to the initial construction concept. First corrections with the course tutor involve refining the 3D object and particular layers of partitions, so that partial cross-sections are generated correctly. Students must maintain high work standards relating to preparing templates, layers, line thickness and general drawing precision, which can have serious consequences during the further stages of model development and the development of the next elements from the BIM maturity level. Without this assumption, it would be impossible to achieve final effects, such as components schedules or project documentation.

When designing the course, it is necessary to know the level of maturity to achieve. The authors of this article believe that during the second semester it is possible to achieve level 1 with some elements from level 2. Therefore, it seems only justified to introduce the term transition level 1/2. The minimum requirements for BIM level 1/2 for a one-semester university course have been presented above.

## ADVANTAGES IN UNIVERSITY EDUCATION OF USING ELEMENTS FROM LEVEL 2 OF BIM MATURITY

### Developing an Architect's Work Model

The second level of the BIM maturity model is characterised by accuracy and greater precision. The conceptual assumptions from the first level are not enough. In this case, it is necessary to establish the requirements for the detail of the 3D model, on the basis of which it will be possible to perform partial cross-sections throughout the building. As shown below, based on BIM software, for example Revit or ArchiCAD, the most important required elements are specified, which need to be included in the transition level 1/2:

- Course participants create a simple building focusing on the quality of work and subsequent documentation. Through BIM software, such as Revit or ArchiCAD, the most important required elements can be specified which need to be included in the transition level 1/2.
- Creation of a uniform system of generating documentation. In this case, determined first are the scale, units and accuracy of the final documentation. In the next steps, the colour scheme is prepared and the pen thickness to be used when creating the drawings. It is also important to adopt a clear list of layers used.
- Drawing accuracy. This is the basis for working at higher levels. For beginners, inaccuracies appearing after the decimal point often do not have any importance. However, it should be made clear that other architects and collaborators, other-discipline designers and ultimately engineers working on the construction site will be using the model and templates in the future [6].
- Creating a library and systematics for types of partitions, materials, and so on. Even if the BIM programs offer rich libraries, it is worth enhancing the work, e.g. by making several of the most commonly used walls in the project and assigning materials to them. On the basis of the template made in this way, creating further partitions is much easier. By assigning the appropriate nomenclature to the elements, the project and the 3D model are organised, and it will be easier to extract quotations and needed information in the future.
- Creating the necessary details and profile walls - by performing details of e.g. attic walls, curtain walls or stairs, the BIM software user saturates the model with further information. This is necessary to generate more advanced cross-sections, material calculations or system solutions.
- Introducing markings and relevant nomenclature: when describing the project itself, specific requirements should be adopted. This applies not only to dimensioning but also to markings of zones, windows, doors, glass sections, and so on. Ultimately, this information will be used to generate basic information in the form of a list of surfaces, materials and elements of the building. Acquiring information from a 3D model is one of the main features of BIM technology.
- Adapting to the project guidelines and requirements of applicable law: students should be taught how to introduce particular determinants resulting from current regulations to the 3D model. Much of the information can be applied to the virtual object automatically. A good example would be the required amount of daylight in a room intended for people's stay. By creating an appropriate rule in a surface combination, program default information can be obtained on the degree of insolation in the part of the object of interest.



Figure 2: Student's work - exhibition pavilion with reading room. Example of creating the details and profile walls, which is necessary to generate advanced cross-sections and system solutions (Author: Julia Sierpień, 2018).

## Structural and Material Awareness

Using elements of level 2 requires some basic construction knowledge. When introducing construction information into a one-semester course, account must be taken of certain limitations which result from the lack of an other-discipline model and students' limited knowledge regarding engineering. However, it is possible to use some solutions to help students understand the benefits of the next level of maturity or develop the idea of transition level 1/2:

- Applying the basics of construction knowledge: the most likely solutions for the load bearing system must be considered. The introduction of poles, beams and foundations demonstrates their importance in collision detection in the BIM model and potential co-ordination with other disciplines. Very often, in the design work, only 2D templates are used, so consideration should be given to introducing the construction items to the 3D model, regardless of the dimensions of the building. In this way, more accurate templates are generated which facilitates later co-ordination on the construction site.
- Introduction of a construction scheme: by assigning the load bearing function to elements, the structural framework can be generated. Although it is impossible to verify the statics without structural calculations, it can be used to show students whether or not they have made mistakes in the basic scoping.
- Use of appropriate building materials: by assigning load-bearing functions to the partitions, the appropriate building materials are assigned. Being consistent in this area is important so as to teach students that the future BIM model will be helpful in using this information to generate a bill of quantities.



Figure 3: Student's work - exhibition pavilion with reading room. Load-bearing functions were assigned to elements to generate the structural framework (Author: Yaroslav Matvieiev, 2018).

## Interdisciplinary Co-operation

Level 2 of BIM maturity should also include virtual models for other disciplines. As far as handing over project documentation is concerned, present regulations in Poland require 2D documentation, which can be attached in a BIM project, e.g. in the form of Xref drawings (eXternal reference). This is an acceptable form for less complex objects. The problem increases as the complexity of the object increases. The situation can be partially solved by the designer introducing 3D installation elements in the most critical places in the object. Special attention should be paid to this issue when teaching students further levels of maturity. In the absence of the BIM model of installations, using elements from the second level of maturity should be considered, especially in the area of:

- Application of several installation elements: for example, with the help of the mechanical/electrical/plumbing (MEP) modeller software, elements can be inserted - of a plumbing system for one room or to locate a rooftop unit and provide a simplified supply-and-exhaust ventilation system - in the designated places [7].
- Adjusting the height of the building levels: allowing space for installations and suspended ceilings.
- Introducing the installation shaft on all floors: course participants have to provide space for installation models they would potentially get from other-discipline designers.

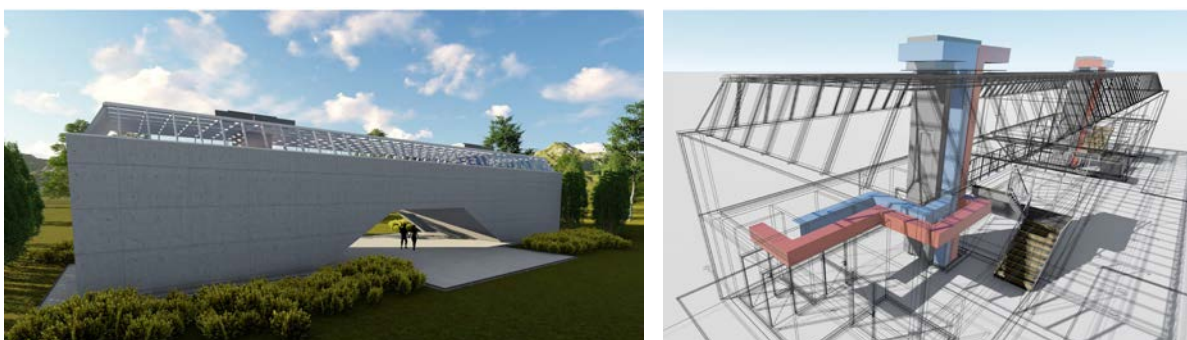


Figure 4: Student's work - exhibition pavilion with reading room. Example of introducing some parts of installation systems (thanks to using MEP application) - learning detecting collisions (Author: Kristian Machlarz, 2018).

## CONCLUSIONS

When designing a syllabus for an introductory course of BIM technology and bearing in mind a limited number of hours the course can have, consideration must be given to the present design reality in a given country. It often happens that when working on public tender commissions or private investors' projects, there is limited time and strictly defined budgets. Given such circumstances, it seems the best reasonable solution is to go for the most optimal maturity level of 3D model.

Using the transitional 1/2 level allows optimisation of the design process, even for a small design office. It also corresponds to the reality of a BIM course offered to university students where, apart from a limited number of hours available, there is no access to other-discipline design projects, and there is the limited design and construction awareness of inexperienced students. In this situation, students have to get as many benefits as possible from the maturity level 2, while learning at the same time the technique of work, design consistency and awareness of possibilities offered by BIM models.

The components' schedules and information regarding construction obviously is bound to be inaccurate because of insufficient data and students' lack of experience. Yet they still allow future graduates to become aware of how much the more developed 3D virtual object can simplify the next stages of design, construction, and finally, the management of buildings in the future.

## REFERENCES

1. EUBIM Taskgroup, Handbook for the Introduction of Building Information Modelling by the European Public Sector (2016).
2. Building and Construction Authority. Singapore BIM Guide. Version 2 (2013).
3. Calderisi, S., Building Information Modeling (BIM), Maturity in the UK Power Transmission Industry: Current Level and Comon Factors, Northumbria University (2013).
4. Succar, B., *Building Information Modelling Maturity Matrix*. In: Handbook of Research on Building Information Modelling and Construction Informatics: Concepts and Technologies. Information Science Reference, IGI Publishing, **4**, 65 (2010).
5. Logothetis, S. and Stylianidis, E., BIM Open Source Software (OSS) for the documentation of cultural heritage. *Virtual Archaeology Review*, **7**, 28-35 (2016).
6. Building and Construction Authority. BIM Essential Guide for BIM Execution Plan. Singapore (2013).
7. Bratton, J., Making the transition from CAD to BIM. The benefits of switching from CAD to Building Information Modeling (BIM) for electrical engineers and designers designing in today's virtual construction world. *Electrical Construction and Maintenance* (2009).