BIM data management in AEC disciplines

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Abstract— **The importance of data sharing and management has been increasing in the past decades. The AEC industry has to be able to integrate and use various types of information from different sources to maintain and increase the efficiency. In this process, BIM and data management has become even more important. This paper presents a theoretical approach of BIM way of thinking in order to broaden the application of BIM method in different sectors in particular of higher education. It is also aimed at laying down the theoretical foundations for the Building Information Platform (BIP), which facilitates interdisciplinary collaboration by a cloud-based data sharing system and recommends a framework for the the expected minimum level of information of different purposes and work stages of a project.**

Keywords—AEC industry, BIM approach, Building Information Platform, data sharing

I. Introduction

In digital transformation the role of information and data transmission has become more important. The huge amount of data generated by business, research, educational or public activities represents a significant value, which can be used for decision making processes in several fields. However, the continuously widening data resource is still underutilized due to the lack of open data sources and appropriate management systems. Therefore, the digital transformation will require a change of the traditional mindset of data ownership towards to a data-sharing culture [1].

The architecture, engineering and construction (AEC) industry is substantially multidisciplinary, therefore developing an integrated environment and collaborative platform is essential. During a design and construction process a large amount of data is produced, which is often ill-structured and poorly coordinated. It is clear, that the AEC industry needs to address the storage, exchange, processing and visualization challenges of these information. The basis of data sharing between the disciplines is the Industry Foundation Classes (IFC), which is a standardized, object-oriented data model. This file format is a vendor-neutral, digital description of the built asset industry [2]. It provides the accuracy and unity of information by including not only the object geometry but also the metadata. Regarding the interdisciplinary communication it is also important to store and manage these files in order to increase efficiency. Here, the cloud computing technology enables on-demand access of computer system resources and data storage with minimal management effort of the user, therefore it is widely applied in different fields and has also appeared in Building Information Modeling (BIM) in recent years. An integrated cloud-based BIM model allows efficient collaboration and communication between the team members. However, its practical application is yet limited [3], because only a few cloud-based systems support the use of private clouds and less are compatible with IFC format [4]. Therefore, this is a relevant research area with several promising results. For instance, Jiao et al. [5], Ding and Xu [6] reports on a cloud-BIM system for lifecylce analysis and data management, Wu and Issa [7] recommended a cloud-based tool for the process of green building certification according to the Leadership in Energy and Environmental Design (LEED), and Fang [8] presents the possibilities and current trends of cloud-based construction cost management systems. In this perspective, the cloud-based BIM tool is already a new direction in BIM development to facilitate the collaboration between the team members. In this paper the importance of data sharing and the widening of BIM way of thinking is emphasized. Since the information content of the workflow is a key factor, the objective of this research is to investigate the definition of Level of Information (LOI) and to lay down the theoretical framework for interdisciplinary collaboration at BIM Level 3.

II. Need for data sharing

Data sharing is the practice of creating, collecting, storing and sharing information between different organizations, individuals and governments, which existed already before the digital technology. The performance and quality of services can be enhanced considerably by combining data from different resources and using them as decision-support tools. However, the process and scale of data sharing has changed significantly in recent decades. The volume, availability and quality of data have increased, while the storing, processing and transferring has become simple and affordable. The digital transformation has created the term big data, which refers to data that is too large, fast or complex to allow its procession by using traditional methods. The combination of big data and high-powered analytics can improve efficiency, quality and profit in any scientific or industrial sector. For instance, the use of big data has an important role in medical research and healthcare. Health services researchers can develop predictive models to improve health policy, pharmaceutical chemistry can use clinical and molecular data for drug design and clinical records can be used to help diagnose and prevent illnesses [9]. In energy sector several solutions were developed for smart

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energy management to support sustainability goals, such as clean power generation, efficient power transmission, dynamic power distribution and rational electricity consumption [10]. In financial industry the big data can be used for systemic risk modelling, which is an important area of risk management [11]. Consequently, data sharing, creating databases and developing a central system for the usage is an important factor in efficient application of these information. However, many organizations inhibit access to information and discourage data sharing, which undermine the effort to maximize efficiency by data analytics and often results in duplicated data at different levels.

The BIM methodology has become a key approach recently in AEC industry, which gives different options for collaboration between disciplines. Although the definition of BIM originated in the late XX. century [12], many different formulations can be found in literature [13,14,15]. However, it is also appropriate to clarify the meaning of BIM way of thinking, which goes beyond the application of a 3D model. As is widely known, the BIM model consists of geometrical and non-geometrical information, therefore the data sharing is centric to BIM. Furthermore, the different disciplines require different types and level of information, which also depends on the work stage and purposes of the project. For the geometrical information, the Level of Development (LOD) Specification [16] can be used as a reference for defining the content and characteristics of model elements. The LOD descriptions identify the specific minimum content requirements at five levels of completeness, which determines the usability and limitations of the model. The LOD levels can be vary depending on the disciplines and model usage, which is usually included in the contract as well. For specification of non-graphic information, the Level of Information (LOI) specification can be used, parallel with the EN 17549 [17] standard, which describes the information structure, the exchange data templates and data sheets for construction objects. However, the practice does not apply it yet, which leads to disagreement in the data schema for different objects or products. Introducing of LOI and separating it from LOD is important because the maturity degree of geometrical and non-geometrical information can vary for different objects even in case of the same purpose. For instance, the building services objects are often appearing with quite low LOD level but high LOI degree. For this reason, the National Building Information Model Standard (NBIMS) Development Team has worked out a standard called Construction Operations Building Information Exchange (COBIE) [18]. COBIE is a data schema for defining minimal dataset for the elements of operation, maintenance and asset management. The building services objects were grouped according to their function in order to simplify the data requirements. The application of this dataset is the most powerful when it is connected to a classification system, the proper IFC type, location data and geometrical information according to ISO 19650 [19]. Furthermore, the BS EN 17412 standard [20] introduced the term Level of Information Need (LOIN), which defines the quality and quantity of the geometrical and non-geometrical information in order to develop a consistent methodology of information exchange according to the requirements.

Based on the literature, the Common Data Environment (CDE) is the center of the BIM process, which provides a common platform for the team members by collecting all of the project information. In practice, there is still many uncoordinated data even in a BIM process, such as the order of layers or technical specifications, which are usually made as text documents. Therefore, CDE is usually working as a document management system with many different types of data and a lack of using open standards and real collaboration possibilities [21].

III. BIM APPROACH IN HIGHER EDUCATION

The education of BIM method is increasingly necessary with regard to the international trends in industry and standardization processes. Many educational institutions have already BIM-related programs [22, 23, 24], while in some universities the integration is under process. Usually, the teaching method mainly focuses on the BIM applications corresponding to the educated profession. However, not only the theoretical and technical training is important but also the implementation of the BIM way of thinking, which could be a powerful tool in facilitating the collaboration between disciplines. Furthermore, the BIM approach fits well into the Digital Education Strategy of the government, which indicates the information retrieval, processing and the use of collaborative ICT-supported solutions in the learning tasks [25]. The higher education sector is primarily organized by vertically oriented structures, therefore the different programs are focusing on their own internal goals and objectives than on interpreting the subject in broader environment or enhancing the connection between the courses [26]. According to the research of this area [26, 27, 28] the interdisciplinary connection should be strengthened between professors and students of different disciplines, which could support to accomplish institutional purposes as well. The Széchenyi István University (Győr, Hungary) has architectural and civil engineering programs belonging to the same faculty, which enables to seek common points in the curricula. The educational method is a coupling of horizontal and vertical activities in order to support student learning and understanding the connections between professional fields. Each semester consists of different courses related to the building materials, structural and architectural design methods, building construction design, CAD applications, infrastructural design methods, etc. Besides the teaching of theory and practical applications, the practice-oriented and problem-solving educational strategy is emphasized, which is evaluated

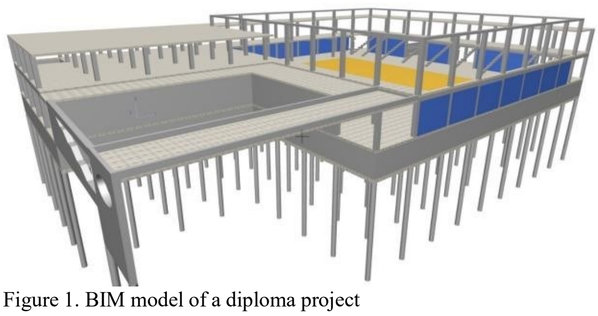

Figure 1. BIM model of a diploma project

as an effective learning method and also considered preferable by the students [29]. Therefore, the basis of these courses is mainly a design project, which can be examined and completed in parallel from different aspects.

From 2018 the structural engineering masterprogram was started in the university, where the whole curricula builds on the diploma project, which is generally the structural design and preparing the construction plans of a large-scale building (Fig. 1.).Students start with architectural design of the building according to the functional requirements and local building code in the first semester and prepare a preliminary plan of the structure, considering the mechanical engineering systems as well.

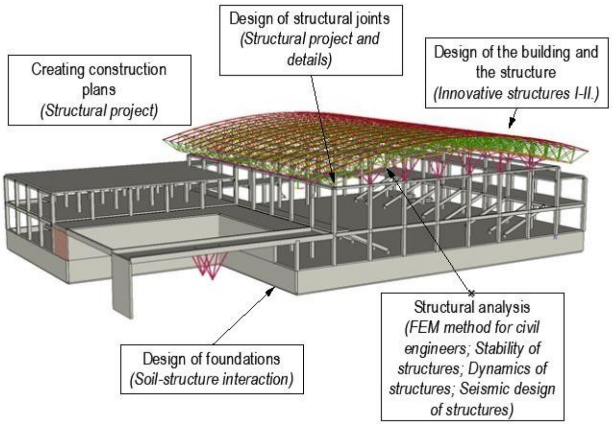

Figure 2. Structural model of a diploma project, the main tasks and the connecting courses

During the design task the BIM method appears as an integrated approach though the different courses (Fig 2.). Students are responsible for their own project, therefore they are architects, mechanical, geotechnical and structural engineers at the same time. From the second semester, students are focusing on the structure, they perform finite element analysis, design the structural elements and prepare the construction plans of the entire structure. The design task is fulfilled by preparing the construction project plan and scheduling.

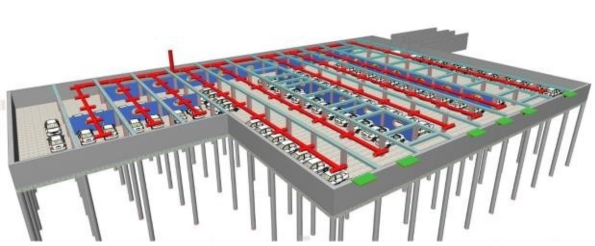

Figure 3. Mechanical engineering model of a diploma project

The projects are completed by using the BIM method; the architectural model includes the structural elements and also a simplified mechanical engineering model is created which enables to complete the collision detection (Fig. 3.). For the structural analysis the model was exchanged by using the IFC format. The BIM model provides input data for the quantity statements, the cost estimation and scheduling as well.

The structural engineering masterprogram is naturally focusing on the structural design and analysis. In regard to the diploma project, not only the course-integrated BIM approach is significant, but also the collaboration between the disciplines plays an important role, which is fundamental to BIM. As a result of applying BIM as a project-based solution, students get insights in the tasks and mindset of the connecting disciplines and multidisciplinary collaboration outside their professional field. It is true, that the different parts of the project cannot be worked out in the same depth, but the object of the program is to help develop a complex and up-to-date BIM-mindset besides the gaining knowledge in detailed structural design.

Furthermore, the new curricula introduced in 2017 has the definite aim of integration of BIM, therefore new BIM-related courses were incorporated into architectural and civil engineering programs. The Structural BIM and BIM Management courses belong to the 7th semester, which allowed merging these trainings to simulate collaboration between disciplines in educational environment. During the semester students get experiences in teamwork, sharing information, discussion of design aspects, exchanging models and use BIM data for different goals through designing real projects. However, there is still a need for escalate the connections between the courses, that requires stronger cooperation between educators and departments. In practice, the collaborative courses usually belong to the same department, the educators are in daily contact, therefore common tasks can be executed more easily. However, students' perspective could be especially widened by finding common points between courses of different departments or even faculties. Ideally each course has a precise timetable and definite tasks to be fulfilled, therefore the „input data" and the results can be determined precisely. This information could be collected and treated as a database, which makes it possible to find further opportunities for cooperation.

IV. BUILDING INFORMATION PLATFORM

Although the information technology has been developing significantly over the past decades, its potential has now started to fulfill in AEC industry, in which the BIM has an important role. If BIM is professionally integrated, it can decrease waste, cost and time from the processes during the whole life-cycle. However, the implementation of BIM method is a long-term process, in which four maturity levels were defined to characterize the stages of development: BIM level 0 means an unmanaged digital drawing process including only 2D drawings. Level 1 means a managed computer aided design process, which consists of 2D and 3D information, but lacks the collaboration between project team members. Level 2 is a 3D-based design process, where common standards enable the data and model exchange between the disciplines. Level 3 ensures a collaborative working environment by combining BIM with the internet of things, integrated big data analytics and the digital economy. It requires a synergic combination of different sciences and creating networks not only between project participants, but also between computers, users and computational capabilities, therefore this is an important research direction of cognitive infocommunications [30]. The current practice is at Level 2, which is the global basis for BIM according to ISO 19650 [19].

The whole data generated on a project requires thinking at platform level. Since the number of used software and databases are expanding, there is a need for an environment that is able to create, exchange, store and synchronize data between different platforms. Authors introduce the term Building Information Platform (BIP), which can help the interoperability between disciplines in AEC industry by ensuring the exchange, filter and use the available information. This platform could work as a single source of information, which is connected to databases and ensures the coherent and equivalent data flow at different levels. Although the information content of the model can be very large and many different disciplines are involved in the BIM workflow, the specialists only need a defined type and amount of data for their work. For instance, for energy analysis the key inputs are the location and orientation of the building, the geometry and dimensions, the construction solutions, the building type and the applied systems such as heating, ventilation, air conditioning and so on. It is also important to define the purpose of the energy analysis with regard to the building life cycle. In the conceptual design phase the energy analysis is mainly used to find options for reducing energy use by the building form or orientation, or to estimate the performance of the different building solutions. During the design development the energy analysis is already used for defining and evaluating the real performance of the used solutions or systems [31]. In the case of structural design, the input data is the building location, function, the materials, the dimensions and fire rating for the preliminary plan. In this phase, structural analysis is used for approximating the dimensions of the structural elements, which are designed in detail in the following phase. It is clear, that the results of the structural analysis have a significant effect on the architecture and vica versa, if the architectural model changed, the structural model has to be updated as well. The situation is the same in all cases: there is a continuous need for data exchange due to the effect of the results of one discipline's design process on the others.

Furthermore, in construction phase, the structural elements are completed at first, so here the structural design documentation is the basis of the quantity statements. After that, the quantities of the insulation work or the finishing come from the architectural model and so on. Therefore, the information has to be separated and managed according to the schedule. It also must be considered, that many different contractors and sub-contractors are working on the same project, or even on the same building structure, which requires to further distinguish this information. Consequently, different data is needed according to the purpose of the model, the exact task and the work stage, therefore the LOI specification could be expanded to these aspects.

BIP could be a framework for collecting and managing the information content of the BIM workflow. With the help of cloud-based systems the BIM models could have real-time connection with each other and also with different databases such as the construction materials, productivity rates, environmental profiles, etc. Therefore, it enables synchronizing and updating information according to the selected standard or dataset. Here the key factor is the equivalency between databases, which can be ensured by integrating the standardized IFC structure and classification systems into cloud computing technology. Once, there is a clear connection between the models and the databases and the LOI is defined for the work stages and the main purposes of the model, the information can be filtered and only the required data at a defined level could be exported for the disciplines' work. BIP could be work as a mixed cloud-based system, which is a hybrid of private and public cloud system [32]. The BIM model belongs to a limited access cloud in order to protect intellectual property, while the databases can be reached in a public cloud with different access rights according to the organizations' rules.

The implementation of this platform presents many challenges. First of all, a complex BIM model is needed including several disciplines, which requires more time and cost in the design process. This work has returns primarily in the construction phase due to the more precise quantity statements, the eliminated errors by the collision detection, the improved coordination possibilities among many other examples. However, owners have not yet seen the benefits of this method, so the higher price of the design work is not generally accepted. Furthermore, the roles and responsibilities in a BIM-based project are also questionable. In complex design offices usually there is a BIM team including modelers, coordinators and a BIM manager. In this case, the BIM modelers can be software experts with basic knowledge of the different disciplines. On the contrary, in case of specific design offices, the specialists have to create their own BIM model, therefore a fundamental BIM skill is required. In any event, the education of BIM method and collaborative approach is the key factor to achieve this goal.

V. Conclusions

As it is widely known, Building Information Modeling is more, than a 3D model; the difference is in the information content. Since the value of information is continuously increasing in these days, data sharing is becoming even more important, especially in case of AEC industry. In larger projects a significant amount of data is generated, which requires time and resources for managing, filtering and applying it for different purposes. For that purpose, authors introduced the term Building Information Platform, which could be the framework for collaboration between AEC disciplines through the lifecylce. Here, the different models and databases could be collected, shared and managed efficiently. The information could be organized according to the different disciplines and work stages, so only the required data could be exported for the further work. In order to make BIM method general it is also important to realize for owners, that the need for effort and cost appears already in the design phase, while the investment shows return primarily in construction and operation phase.

The BIM way of thinking is much more, than a method for increasing efficiency during construction projects. This is a complex approach including data sharing culture and collaborative environment, which enables better cooperation between different fields.

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