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BIM STANDARDS AND DIGITAL TRANSFORMATION OF AEC SECTOR

Abstract: The building information modeling (BIM) has evolved from the field in which the enthusiasts were engaged to a regulated professional activity. This advancement is reflected in the development of BIM standards that increasingly regulate this topic. Some standards are the basis for modern work in the field of BIM, while others are more technically oriented. Yet understanding of all standards by all participants in the AEC process is essential for the successful digital transformation of the entire sector and successful application of BIM technology.

Key words: BIM, standards, AEC practice, digital transformation

BIM STANDARDI I DIGITALNA TRANSFORMACIJA GRAĐEVINSKOG SEKTORA

Rezime: Informaciono modeliranje zgrada (BIM) evoluiralo je od oblasti u kojoj su entuzijasti bili angažovani do regulisane profesionalne aktivnosti. Ovaj napredak se ogleda u razvoju BIM standarda koji sve više regulišu ovu temu. Neki standardi su osnova za savremeni rad u oblasti BIM-a, dok su drugi više tehnički orijentisani. Ipak, razumevanje svih standarda od strane svih učesnika u AEC procesu je od suštinskog značaja za uspešnu digitalnu transformaciju celog sektora i uspešnu primenu BIM tehnologije.

Ključne reči: BIM, standardi, građevinska praksa, digitalna transformacija

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1. INTRODUCTION

The building information modeling (BIM) has evolved from the field in which the enthusiasts were engaged to a regulated professional activity. The main drive behind this was the decision of many governments around the world to require the mandatory application of BIM mostly in public or large projects. Today, it compromises of technologies, processes and regulations that enable collaborative model based design, construction and operation of facility. The model on which BIM relies is the shared digital representation of built asset that is a reliable source of all the information required to make decisions throughout the life cycle of the asset.

The simplistic view that still lingers among the AEC practitioners is that the BIM is 3D model plus information, but there is still no clear understanding on the nature of the BIM information. The most widely accepted view is that BIM implies the use of digital documents and that the basis for the transition to BIM is the process of digitization of the AEC sector, i.e. transformation of traditional documents to digital form.

Unlike traditional information, for the representation of which documents in analog (mostly paper) format are used and which require human interpretation, digital information can be represented both in the form of digital documents that require human interpretation and in the form of computer interpretable information [1]. The experience from other areas that have entered the digitization process shows that IT technologies enable the creation of huge amounts of information that exceeds the possibility of only human interpretation. Considering that the AEC sector is already characterized by a large amount of information, it is clear that a radical digital transformation of the entire sector is necessary.

The paper presents the basic steps that are being taken in this direction through the development of new IT technologies, processes based on them and through the development of standards that regulate these improvements. An understanding of these principles by all participants in the AEC process is essential for the successful digital transformation of the entire sector and successful application of BIM technology.

2. BIM STANDARDS

The process of digitization implies simple transformation of analog information to digital format i.e., rendering of traditional documents into strings of ones and zeros. The digitalization implies modification of certain processes under the influence of the use of digital information, like the use of CAD or BIM applications to create drawings. Digital transformation, on the other hand, implies a complete change of the whole process and the way of thinking about the process under the influence of digital information.

Under the influence of the development of BIM technologies, the AEC field is currently at the beginning of the digital transformation. An important aspect of this process is the development of BIM standards. The process of rigorous control and reaching a consensus of all participants in the adoption of standards guarantee their acceptance and applicability at the widest possible level.

2.1. ISO Standards

The International Organization for Standardization is an independent standardization organization that includes national standardization bodies from 165 countries as members. Obtaining the status of an ISO standard implies the broadest consensus and acceptance of a process or technology.

2.1.1. ISO 16739 - IFC

The Industry Foundation Classes (IFC) [2] was among first BIM standards to achieve level of ISO standard in 2005 year. It was first published as PAS and in 2013 it attained status of full ISO standard. The IFC is both a conceptual data schema and an exchange file format. As the conceptual data schema it defines classes necessary to represent all concepts related to the built assets during their lifecycle. Since it is not possible to predict all the parameters that comprise certain classes, only the common ones are part of the core IFC data model, and a mechanism has been introduced to add new parameters using the IfcPropertySet class. As the exchange file format the IFC uses plain text file format based on STEP standard [3] and Extensible Markup Language (XML) file format.

Although from the very beginning IFC was developed to enable the highest level of interoperability among applications, at the beginning there was a lot of misunderstanding about its use. Various applications had different approaches how buildings should be modeled, what information is required in exchange, and how different objects and parameters should be mapped to the IFC schema [4]. This showed that in order to achieve streamlined collaboration in the AEC sector, it is not enough just to define data structures and that it is necessary to regulate the processes and ways of using developed technologies. As for the use of the IFC format itself, the Model View Definition (MVD) was developed as a subset of the full data schema which includes only those data that supports one particular workflow in AEC sector. This approach has also enabled much more efficient certification of software for importing and exporting IFC files.

2.1.2. ISO 19650

The ISO 19650 is a series of standards that regulates the process of information management during all phases of build asset lifetime. This standard contains 6 parts that deal with specific aspects of the process: part 1 [5] defines the basic concepts and principles used in all other parts, part 2 [6] deals with information management during delivery phase of the assets that includes both design and construction processes, part 3 [7] deals with information management during operational phase of the assets, and part 5 [8] takes into account security of information. Parts 4 [9] and 6 [10] are in the development and covers detailed description of the process of information exchange and health and safety requirements.

The standards are based on best practices to achieve efficient BIM workflow. Much of the content is dedicated to information planning because experience has shown that only technology and standard information exchange formats are not sufficient for effective cooperation. The content of the standard can be viewed as a list of activities that should be carried out during the planning, contracting and implementation of BIM information management to achieve efficient workflow. The standards also specify the types of documents that should summarize the results of planning and negotiation and that are part of the contractual documentation.

The information planning starts from the party that initiates the project. They need to prepare documents that clearly states information requirements on organizational (OIR) and asset (AIR) levels that reflect on general information management policy of the company and their attitude towards information management of the assets. For each particular project a Project information requirement (PIR) document is prepared. The role of these documents is to determine in advance precisely what information and in what extent, at what defined moment, in which format, and for whom, is required during an asset life cycle. These documents form the basis for the contracting process of each phase of either the project [6] or the building operation event [7]. For each such event in the life of the building, a cycle of information management activities is implemented, which includes tendering, information planning and information production. The tendering process

includes creation of Exchange information requirement (EIR) document by the party that initiates the project. This document serves as the basis for the development of the BIM execution plan (BEP) by the team that delivers the information and later during the process of information production, it is a document based on which the fulfillment of the requirements is checked. The BIM execution plan is a document that states how delivery team is going to take into account information management and information production tasks and also gives clear account of their BIM capacity and capability.

Important aspect of the BIM process according to the ISO 19650 standard is requirement that all documents, which must be in the digital format, are managed through a Common data environment (CDE). The CDE operates on information containers, named and persistent collections of information. The name of the container should follow established naming convention that gives information about the role of the information container and provides the container with a unique ID. In addition containers should have assigned attributes that determine their suitability (status), revision and version, and classification. The CDE should be defined and set up by the party that initiates the project before the tendering process so that all tendering documents can be managed in CDE.

The CDE must allow information containers to transition between states, to enable secure access to containers, to guarantee ownership of the container even in the event that the author of the container leaves the project, and to provide an opportunity to record the name of the user and the date on which the transition took place. The information containers can have four states: 1) work in progress – containing unapproved information containers that are visible only to actors who are working on it, 2) shared – information containers that are checked, reviewed and approved for sharing with other actors in the project, 3) published - information containers that are accepted and authorized by the client, and 4) archive - information containers that are kept after the project.

The information planning from the side that delivers the information requires them to define how they will meet the requirements from AIR or EIR, to provide precise timing of information delivery, to define the federation strategy and breakdown structure for information containers and to describe how information will be coordinated with other teams, and to establish precise responsibility matrix.

2.1.3. ISO 29481- IDM

As a way to structure BIM process and determine what information is needed and at what times the buildingSMART developed Information delivery manual (IDM) framework. The ISO 29481 series of standards describe processes that occur during asset's lifetime and that require exchange of information. The part 1 [11] defines methodology for creation of documents that describe processes and required data and defines IDM format that consist of interaction map, process map and one or more exchange requirements. The part 2 [12] gives detailed account of interaction map. The interaction map gives enumeration of all the roles and transaction between them that make up a specific process in the AEC area. Each transaction has only one role that initiates request and one role that gives effect to request. The interaction map uses specific notation that is described in part 2. The process map is represented using a Business Process Modeling Notation (BPMN) and is used to set the boundaries of information contained in processes, and to establish activities and their sequence. Exchange requirement is a document written in understandable language that describes particular information exchange and that later serves to develop technical requirements for implementation in MVD. Due to the growing demands for support of specific BIM use cases, part 3 [13] of the standard is being developed, which enables the representation of IDM in a computer interpretable way.

2.1.4. ISO 12006

The ISO 12006 series of standards consider organization of information about construction works. The part 2 [14] gives general framework for classification. It was the first of the standards that achieved ISO status, but in the 2001 when first edition was published IFC efforts did not took into account classification systems [15] and this standard remained out of BIM standardization focus. When the question of core ontologies for the AEC field arose [15], the ISO 12006-2 took BIM in consideration. Since at the time of first edition there was not a single classification system that would comply with the standard, the second edition included experiences gained during the creation of the classification system in accordance with the standard. Modern construction classification systems like OmniClass and Uniclass are aligned to ISO 12006 - 2.

The IFC data format is structured, and elements are classified to represent one particular built asset. If we need to represent different project phases we need to make separate IFC model for each phase. But, if wee want to represent relations between project phases, or to represent relations between parameters of elements and building product catalogs we can not use IFC model. To that goal a data model that can be used to create dictionaries is devised and defined in the part 3 [16] of the ISO 12006 standard. This data model enables creation of concepts that are defined by means of properties, grouping of concepts, and definition of relationships between concepts. The core data model is often referred as International Framework for Dictionaries (IFD). Each concept is identified by a Globally Unique Identifier (GUID) and multilingual labels and descriptions can be attached to them. That way each concept is uniquely identified, and automatic translation between different languages is enabled.

The buildingSMART Data Dictionary (bSDD) [17] is a service provided by buildingSMART. The ISO 12006-2 is a conceptual basis of the bSDD, and bSDD is implementation of ISO 12006-3 data model (IFD). It is still under development, and currently includes new approaches based on interconnected data dictionaries. It combines concepts from many classification systems like CCI Construction, ETIM, NL-SfB, Uniclass 2015, etc. It also serves as a central repository of all IFC properties.

2.1.5. ISO 23386

The first idea behind bSDD was to create one overarching dictionary to include all concepts in AEC field. But, since this idea would require all existing standards to harmonize, and lot of construction organizations developed their own data dictionaries, a new approach is taken, where multiple interconnected dictionaries exist. Since the process of data dictionary creation requires approved domain experts to enter and maintain content, the non centralized approach requires standardized way to do that. To that goal the ISO 23386 standard [18] defines methodology to describe, author and maintain properties in interconnected data dictionaries and serves as the quality assurance procedure for the management of data dictionaries. It also gives extensive list of attributes that have to be used to describe properties in data dictionaries.

2.1.6. ISO 23387

This standard arose from the practical need to define a standard way of structuring information about construction objects [19]. It defines data structure that groups property definitions from data dictionaries created according to ISO 12006-3 and managed according to ISO 23386 to address specific information needs like a demand to give a common way to provide information about

products, or to structure information about product in accordance with specific market standards, or to create information requirements like AIR.

2.1.7. ISO 21597

According to ISO 19650-2 [6], the information delivery that contains multiple heterogeneous documents is the final phase of each appointment. The ISO 21597 series of standards tackle the problem of how to specify relationships between documents by providing links among them. The part 1 [20] defines the container format which consists of a header file and optional link files that define relationships among the documents, or to elements within them. The information in header and link files is defined using the RDF, RDFS and OWL semantic web standards. The part 2 [21] defines further specialization of the generic types of links specified in ISO 21597-1 by adding common link types that enable addition of information about the contents of a container and enable links to be human interpretable.

2.2. European Standards

In the first half of the 2010s many European countries started initiatives for implementing BIM in the public construction sector. To enable national BIM initiatives to be in line with EU legislation European Committee for Standardization (CEN) has established CEN/TC 442 - Building Information Modeling (BIM) technical committee. Important aspect is that all CEN standards must be implemented by the EU member states as national standards thus ensuring wide acceptance of CEN standards. The committee adopted the above mentioned ISO standards as European standards and has developed additional BIM standards.

2.2.1. EN 17412

Traditionally, the level of information in the AEC sector has been determined by the scale of the drawings. With the beginning of the application of the BIM models, the question arose how to determine the level of information needed in a particular data exchange. One solution was Level of Development (LOD) [22], a concept describing the degree of elaboration of BIM information by predefined levels (100, 200, 300, 350 and 400). The document gives detailed description of levels for each building element and is regularly updated. The ISO 19650 standards don't use the concept of LOD, but instead states that all information exchange should conform to appropriate Level of information need to prevent delivery of too much information. The EN 17412 standard establishes the Level of information need framework on EU level [23]. It does not give any predefined levels, but establishes general principles for specifying Level of information need. The main idea is to give more flexible framework that can establish precise granularity of information for specific information exchange, instead of using predefined levels. Each Level of information need should state prerequisites (purpose, delivery milestone, actor and object), geometrical information, alphanumerical information and documents.

2.2.2. EN 17632

The data dictionaries based on ISO 12006-3 and ISO 23386 standards enable information linking that is restricted to AEC domain. The Semantic Web and Linked Data technologies, on the other side, enable linking of data on the scale of the whole Web. That way, the concepts from the AEC domain can be linked to other disciplines, which is of particular importance now that the impact of

the AEC sector on the overall environment is increasingly being taken into account. The EN 17632 standard [24] defines the way Semantic Web and Linked Data technologies should be applied for modeling built environment information. The intention is not to replace existing data structures, but to supplement them with the structure that will make them more accessible, searchable, reusable and to increase the scope of linking. Linked Data technologies rely on the RDF, a data model data that links concepts in the form of subject - object - predicate triples, where each item is distinctively identifiable on the web using a Uniform Resource Identifier (URI). The concepts in the standard promise great advances in the interoperability of AEC data, but Linked Data technologies have a steep learning curve and it takes a lot of time while developers are able to make valid contribution to a network of data [25].

2.3. buildingSMART Standards

The buildingSMART organization first started to develop BIM standards. The ISO 16739 – IFC and ISO 29481- IDM standards were first developed by buildingSMART and later achieved ISO status. Today the buildingSMART still develops few standards.

2.3.1. Model View Definitions (MVD)

The Model View Definitions (MVD) [26] was developed as the technical implementation of IDM framework. Essentially, it is a technique to define subset of IFC schema that is suitable for particular use case and define ways in which software should deal with the data. It consists of the mapping of process maps and exchange requirements from IDM onto a data model like the IFC. The MVD serves as the basis for software certification of the IFC import and export functionality. The IFC 2x3 has only one certification MVD, the Coordination View 2.0, while IFC4 has two: 1) the Reference View that is similar as Coordination View 2.0, but simpler covering only coordination aspects, and 2) the Design Transfer View which covers aspects of exchanging models, so that they can be used by other applications.

2.3.2. BIM Collaboration Format [BCF]

The BIM Collaboration Format (BCF) [27] was developed as the standard for the BIM model related issue management. It has two implementations: 1) as the open XML-based data format that supports file based collaboration, and 2) as the bcfAPI that enables development of server based services. Using BCF the project participant create topic that has title, description, milestone, deadline and other information and these topic details are connected to a particular view position and unique identifiers (GUID) of affected building elements. That way it is not necessary to exchange any elements of the model but each participant in the project thanks to the reference to the elements in the model can create, sort out, explore and solve issues directly in their BIM model. Most today BIM applications support BCF based collaboration.

3. IMPACT ON AEC PRACTICE

At this moment the greatest attention is paid to organization and digitization of AEC information. The whole series of ISO 19650 standards treat information as reinterpretable representation of data in digital format regardless of whether it is intended for human interpretation only or computer interpretation is possible. Digitization of AEC sector is not an easy mission, especially since the whole sector is fragmented and mutually separated. In order to achieve results, it is necessary to

change this situation and achieve much greater cooperation of all participants in the process. The development of BIM standards is precisely aimed at that goal.

The series of ISO 19650 standards set the foundations that allow all participants to better understand their position and responsibilities throughout the BIM process. Insisting on a clear definition of information requirements through the development of OIR, AIR and PIR documents by the party that initiates the project provides assurance to organizations that deliver BIM models that what they are doing is exactly what is expected. On the other hand, the development of a BIM execution plan by the organization that delivers the information guarantees the project initiator that he will get what he expects. Although the whole process introduces additional documents that regulate the exchange of information and introduces new levels of information management through the role of lead appointed party it nevertheless provides all participants with a clear insight into their role in the process and guarantees that the information for which they are responsible will be fit for purpose. In that way, the trust of all participants in the BIM process is strengthened and the basis for greater cooperation between the participants is created.

Although at first glance it seems that only the series of ISO 19650 standards is important for everyday work, in order to use the potentials of digital technology, it is necessary to know other standards, regardless of the fact that at first glance they seem too technically oriented.

Understanding MVD prevents erroneous expectations from the exchange of information based on the IFC format. Likewise, the knowledge of IMD enables understanding of the process that was the basis for MVD modeling and to enable customization if a predefined solution does not fit a specific project.

Data dictionary, data templates and semantic modeling and linking are technologies which will only be useful in the future, but understanding the principles is already important today. Understanding the ability of computers to connect and process information and automatically provide reliable information about construction elements represent the first steps towards the digital transformation of the AEC sector. It took time for participants in the AEC sector to overcome mutual mistrust and this process is still ongoing and their cooperation and trust are based on new documents based on the ISO 19650 standard. But for true digital transformation, it is necessary to overcome the traditional affinity toward documents and gain trust in the direct manipulation of information. And these technologies and the standards that define them pave the way for this because they allow digitization in the AEC sector to spread down the supply chain to manufacturers of building elements. They also allow for the creation of a more distributed BIM environment in which smaller software companies will be able to provide customized solutions.

4. CONCLUSION

BIM technologies and standards have introduced the AEC sector into digital reality. But the most difficult step towards the digital transformation of the entire sector is yet to come. Architects, engineers and all other participants in the AEC sector must understand that the time of making and interpreting documents have passed forever and that the time of direct creation and use of information is coming.

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