Toward the Utility of BIM Models

Igor Svetel
University of Belgrade, Innovation Center, Faculty of Mechanical Engineering, Serbia
isvetel@mas.bg.ac.rs ORCID: https://orcid.org/0000-0001-7821-1412

Abstract: Building Information Modeling (BIM) technologies have recently reached a high level of organization and are largely based on international standards that regulate both the structures of information models and the processes of their creation and management. Numerous data formats have been developed that enable automatic checking of model quality. However, the entire development so far treats information only as a highly structured collection of data.

If we take into account that information implies communication and that information does not exist without the receiving party, we will understand that all existing BIM models represent only a source of information, and that the information itself is created based on the needs of the recipient. The current solution for determining what information is needed by those using BIM models are information requirements. Up until now, they were realized as classic documents, now they get a formalized form that is computer interpretable in the form of the Information Delivery Specification standard. The format enables specification of four prerequisites (why, when, who and how) that are specified by Level of Information Need standard as the way to ensure relevance of BIM information.

The paper explores ways of providing greater support for the needs of information recipients, which would enable more successful use of complex BIM models and enable obtaining relevant information in the process of daily use of BIM models for real events in the building during its construction or use.

Keywords: BIM; information requirement; information delivery specification, common data environment

1 Introduction

Lately, BIM technologies are experiencing a great upswing and have reached a level of maturity where many guiding principles are defined in international standards. This situation enabled intensive development, and today extremely complex BIM models are developed every day. New technologies that automatically add the necessary parameters to the model and automatically control the quality of the models are developed contributing to the efficiency of the process. In the context of all this progress, it is interesting that the concept of information is not given enough attention (Svetel 2022).

The concept of information appeared in the 1920s with the development of communication technologies. In communication participants use symbols (patterns that based on previous agreement convey a meaning). By selecting one symbol and sending it over the communication channel the sending party excludes all other available symbols that can be chosen. As symbols are added, the number of possible symbol combinations decreases and the information becomes more precise. The final mathematical theory in which symbols are free from any psychological aspects and reduced to formal patterns was presented by Claude Shannon (1948). This theory enabled the subsequent intensive development of information technologies.

Most of today ICT systems base their organization on the concept of DIKW (data, information, knowledge, and wisdom) pyramid (Ackoff 1989). According to it, data consist of raw, unorganized symbols that denote items in the real world. Information presupposes the organization of data in a structure that provides additional meaning that goes beyond basic references to objects or concepts.

The mathematical model only quantifies information, and the DIKW concept provides notion that information should have some formal structure. Both do not answer how information is created or how it becomes useful. One of the solutions to that problem dates back to classical antiquity and originates from the works of Aristotle (Sloan 2010). The principle of “Seven Elements of Circumstance” asserts that to provide valuable argument it is necessary to answer to seven questions: Why, Where, When, What, With Whom, By Whom, and How. The same concept appears in journalism as the Five Ws principle which establishes questions who, what, when, where and why as essential in gathering information.

The connection between information and communication, which was postulated in the first works on the subject of information, is often overlooked in modern ICT systems. Long before today's ubiquity of information technology Peter F. Drucker (1970) pointed out that formal and impersonal information processes will separate people and will require efforts to restore the human relationship embodied in communication. He noted that the person who receives information is the one who communicates. Without the receiving party there is no communication, no information, but only the physical process of sending signals. The communication is on the side of receiving party. In order for the information to be understood, there must be some prior agreement

about the used symbols. Information should be relevant to the recipient and must take into account the motivation (values, beliefs, aspirations) of the recipient to be valuable, otherwise it is treated as noise.
Since the beginning of the development of BIM technologies, information has been treated in accordance with the mathematical theory and concept of the DIKW pyramid. Accordingly, various data structures were developed for the representation of construction objects, among which the IFC format stands out as the basis of the entire open BIM development. The principle of open BIM development is the creation of technologies that are vendor neutral and that enable the seamless connection of all BIM tools.
Currently, BIM technologies are mostly used to create classic documents such as 2D drawings and tables, primarily because clients and regulatory bodies prefer such a representation of construction objects. However, the model-based approach to managing all information in the AECO (architecture, engineering, construction and operation) sector is becoming more and more popular. In parallel with this development, the role of information is receiving increasing attention. The ISO 19650 series of standards lays the foundation for information management throughout the life cycle of the built asset. According to ISO 19650-1 standard information is defined as "reinterpretable representation of data in a formalized manner suitable for communication, interpretation or processing" (ISO 2018). This definition treats information according to the DIKW pyramid concept. And other concepts that determine information management in the BIM environment, such as information container (named persistent collection of information) and information model (collection of structured and unstructured information containers) support seeing information as a formal data structure. The only concept that considers the issue of information usage and reminds of "Seven Elements of Circumstance" is information requirement defined as "specification for what, when, how and for whom information is to be produced" (ISO 2018).
This paper is a continuation of research on the nature of information and its use in the BIM environment (Svetel 2022). Chapter 2 shows the techniques that are currently available to users of BIM technologies for expressing information requirements, while chapter 3 describes information technologies for displaying information that have been developed recently and are based on the principles of open BIM. Chapter 4 discusses how these technologies relate to the presentation of the information presented in this chapter.

2 Information requirements

Within the BIM processes defined by the ISO 19650 standards, information requirements occupy a central place around which information management takes place. The party initiating the project should clearly specify its information requirements at the very beginning of the process by specifying organizational, asset and project information requirements. During the process of design, construction or operation of the building, a separate document, the so-called exchange information requirements (EIR), is created for each phase (milestone), and defines the information needs and their granularity in detail for actual phase. Teams that deliver information can create their own information requirements for business coordination with other teams or to create requests for information about construction products from their manufacturers. Information requirements are most often created as traditional documents or spreadsheets using templates that allow a scope and content of BIM models to be defined in advance.
The Information Delivery Manual (IDM) is the oldest method, developed to define Model View Definition (MVD), a subset of full IFC specification that fits particular AECO process, and is specified as an ISO 29481 standard (ISO 2016). To describe particular AECO workflow the IDM uses a formally structured document that defines a process and the required data. The document contains an interaction map, a process map and one or more information exchange requirements. The process map defines information boundaries, activities and their order. The interaction map lists all roles and their transactions. Exchange requirement is a document that describes in natural language specific information exchange. Recently, a computer interpretable format (idmXML) was developed (ISO 2022b). The new IDM format consist of use case, business context map (process map, interaction map), and information requirements. The scheme gives an extensive description of information requirements, but it is directed toward implementation of software solutions that support particular MVD.
Data Dictionaries is a technology that has been in development for a long time and has only recently taken shape that is beginning to be practically applied (ISO 2022a). It was developed as a method for structuring general information in the AECO sector by defining relationships between concepts. Technology presupposes existence of multiple dictionaries, where the concept belongs to one dictionary and can be linked to concepts in other data dictionaries. Each concept is specified by their properties, allowed values, units and translations. The current implementation of this technology, buildingSMART Data Dictionary (bSDD), contains interrelated concepts from Industry Foundation Classes (IFC), classifications and standards.

Product Data Templates are attempt to specify an industry agreed data structure that describes construction objects. It is a structured set of property groups and properties which describe the function and construction of a group of similar products. Previously, it was accomplished through spreadsheets. According to the ISO 23387 standard, PDT should be implemented within the data dictionary (ISO 2020b). Since PDT represents an empty structure that is subsequently filled with values, it can be used to accurately describe the requirements for materials or products.

The Level of Information Need, under development as the ISO/DIS 7817 standard (ISO 2023), was developed with the aim of specifying the content of the exchange information requirements (EIR) more precisely. The standard identifies four prerequisites that shall be considered for each information exchange: purpose of information (why), milestones (when), actors (who), and objects (what). The standard only specifies the need to consider the four prerequisites, but does not specify them. The application is not limited to milestones, but can also be applied to stage, phase, or data drop. The Level of Information Need specifies extent and granularity of geometrical information, alphanumerical information and documentation. It also provides framework for verification and validation of information content. The verification process ensures the completeness of information, while validation ensures that the ways of using information are met. One of the reasons for defining the level of information needs is to prevent the delivery of too much information. However, one should not insist on the minimum amount of information because the amount of information delivered for a specific object may be greater than that determined because it is needed for some other purpose within the same information exchange.

The Information Delivery Specification (IDS) is a buildingSMART standard under development (buildingSMART 2023b). It is a computer interpretable format developed for the specification and verification of information requirements. The IDS is an XML file that contains metadata and list of specifications. The description, purpose, and milestone are a part of the metadata and plain text is used as a representation, without a predefined structure. The description part specifies who will use the IDS, why it is created, for what projects, etc. The purpose clarifies what the IDS will achieve and the milestone explains the phase of the project to which the IDS applies. Each specification describes one entity in the model (wall, window, etc.) and contains metadata, applicability, and requirements sections. Metadata can include a description field that explains why a particular element is important to the project and instructions that define who is responsible for providing the information and how. Applicability and requirements are structured sections formatted as facets. Each facet describes information that a single entity in the model can have, using fixed parameters. If used in an applicability section, the facet defines the information required for the specification to be applicable to the entity. If used in the requirements section, the facet defines information that an entity needs to have. The first version of IDS supports basic information and relationships in IFC common to all disciplines. More advanced information requirements will be considered in future versions.

IFC property templates are new concept introduced in IFC4 (buildingSMART 2020) that enables users to define custom properties and element quantities and link them to elements in IFC model. They can be used to specify how information should be delivered in an IFC model.

It is one thing to define the information requirements, another to get that information. The next chapter outlines some of the technologies that make this possible.

3 Information fulfillments

The IFC format is oldest among IT solutions to represent information about assets in AECO sector and represents the basis around which all open BIM technologies are developed. It is conceived as both a conceptual data schema and an exchange file format. As the conceptual data schema IFC defines classes that represent concepts related to the built assets during their lifecycle. Concepts include objects, processes, actors, and controls. The IFC data schema was developed to cover all possible cases that appear within the life cycle of AECO asset, but for practical use, predefined segments of the entire specification, so-called Model View Definition (MVD), corresponding to specific AECO processes are used. The IFC standard is in constant development in order to adapt to perceived shortcomings and expand to new areas of application. It represents the basis around which all other information technologies are developed. Latest official version is IFC4.3 (buildingSMART 2023a).

The IFC format is mainly used to display the model of the whole object and the structure of the data schema is thus defined. Technically, it is possible to create a file that describes only one element of the entire object, but the file structure must contain all the classes defined by the data schema as project, site, building, building storey, etc. At the same time, both due to the limitations of BIM modeling software and the need not to overload the model with unnecessary data, the models are divided into individual AECO disciplines such as

architecture, construction, MEP, energy efficiency, etc. For the purposes of mutual cooperation and conflict control, individual profession models are related in a so-called federated model.
In order to control access to the latest and relevant information by all stakeholders, the ISO 19650 standard recommends the use of common data environment (CDE) solution and workflow. CDE workflow presupposes that all information containers (named persistent set of information retrievable from some computer based source) should be in one of four states: work in progress, shared, published and archived. Containers should have unique identification (GUID), predefined codification of the container name (filename), assigned attributes that determine their suitability (status), revision and version, and classification. The CDE must allow information containers to transition between states, provide secure access to the containers, guarantee ownership of the container, and record the name of the user and the date when a particular state transition occurred.
Since ISO 19650 gives only general recommendations, an attempt to provide more specific recommendations was made by German DIN SPEC 91391 (DIN 2019). Subject of specification are CDEs which implement the information management according to BIM-Level 2 as defined in ISO 19650-1 standard (ISO 2018). This means that the smallest unit of information for data exchange is information container, and applications built on top of CDE, like Model viewers, enables access to lower levels of models like objects and properties. The content and structure of information containers should be defined in early stages by the party that initiates project using exchange information requirements (EIR) and verified by content creators in BIM execution plans (BEP). Access to CDE functions and information exchange takes place via the Internet. The access to information containers is achieved through metadata. Metadata can be encoded as a file name through predefined naming convention or associated with a container as additional information. The method of defining and checking the functionality of CDE should be based on creating CDE use cases, preferably using IDM. Open, software-independent formats should be supported, and support for native formats can be additionally provided.
Conceived as a central repository representing the "single source of information", CDE is progressively viewed as a distributed system of interconnected local CDE solutions (Werbrouck et al. 2023). To support seamless transition of data between different CDEs, building Smart is developing OpenCDE API standard (building Smart 2022). It is a collection of API (application programming interface) standards. At the bottom is Foundation API which ensures a unique way of user authorization and authentication across all CDEs. Documents API provide a unique way to manage documents such as uploading, downloading and searching documents. BCF (BIM collaboration format) API supports consistent issue management across different CDEs. Latest addition is the Dictionaries API that provides uniform access to the buildingSMART Data Dictionary.
The ISO 19650-1 standard (ISO 2018) specifies that at the end of the project information containers in the CDE should be reviewed, the information required for operation phase should be translated into the asset information model, and the rest should be archived. The ISO 21597-1 standard (ISO 2020a) defines structure of the Information Containers for Linked Document Delivery (ICDD) which was initially intended as a container format for archiving. The container format consists of three folders packed together in ZIP file. On top of the folders is a header serialized as RDF file that relates to the container ontology and the linkset ontology. The payload folder contains actual documents. The ontology folder contains two files serialized as RDF that define the concepts of container and links that are used in header file. The payload triples folder contains files serialized as RDF that define linkset ontology which specifies links between documents or elements within documents. The container enables the storage of included or remote documents and ontologies can be extended to meet any use case.

4 Toward model utility

The insistence of the ISO 19650-1 standard (ISO 2018) that the creation of an information requirement must be the first step in the entire information management process in a BIM environment represents a significant step towards understanding the use of information. Unfortunately, a lot of people in AECO sector still do not understand the significance of that process. Analyzes show that many participants in the BIM process use existing completed information requirement templates and only change the data according to the new project, and often this work is done by consultants, and not by the party initiating the project. Also, the final stage of the process is not sufficiently supported and models are accepted without checking and are often not even used later, but new models are made instead (Ford 2020).
The Level of Information Need standard (ISO 2023) clearly specifies requirement that question why, when, who, and what shall be considered for information exchange. The recent review of techniques for information requirement specification (Tomczak et al. 2022) shows that idmXML and Level of Information Need provide full support for the description of purpose and involved actors, while IDS provide full support for description of purpose and partial for actors.

Since the IDM is oldest method to describe information requirements, when only IFC was the method to exchange information it was oriented toward developing reduced sets of IFC specification that suits particular needs (MVD) and as such was reduced to classes and properties that IFC provides. The IFC data schema contains numerous representations of actors. The ifcActor is a general concept that defines all stakeholders involved in a project. It refers to concepts of ifcPerson, ifcOrganization, and ifcPersonAndOrganization. The ifcPerson contains all formal data that identify a person, and roles that are assigned to them. The roles are related to design, construction and management tasks that occur during the life of the building, like architect, civil engineer, construction manager, manufacturer, facility operator, client, etc. The subclass of ifcActor is the concept ifcOccupant that defines the form of occupancy of a property, with the roles mostly related to the type of ownership. It is also possible to assign user defined role. Since IFC4 ways to express time resources in IFC was significantly modified. Concepts like IfcDate, IfcTime, IfcDateTime, and IfcDuration have been added and concepts from fcTimeSeriesResource were merged and now it is possible to express many time related concepts in IFC. Until recently, the ability to use all the resources provided by IFC was limited by the support provided by commercial applications for importing and exporting IFC files. With new developments such as CDE and ICDD that allow the storage and exchange of different information formats while providing open BIM principles, it is possible to use the full expressive power of IFC to provide all kinds of support for information requirements and this expands the possible use of IDM.

In contrast to IDM that is methodology to describe whole workflows, the IDS (buildingSMART 2023b) is methodology to express requirements for particular information exchange. The extent of IDS is not predefined. It can have a metadata an only one specification that defines information requirements for one particular object in the model, and it can also define information requirements for whole phase in the project. This flexibility and rich metadata content makes it perfect candidate for expressing information requirements that express why the information is needed, by whom, where and when it is applicable, how it will be applied, in addition to the "what" that is currently the only preoccupation of majority BIM users. The standard is under development and to meet the above requirements it would be practical to develop predefined classes for use in metadata instead of the current plain language.

ICDD technology, developed to support effortless access to archived documents, provides many more possibilities. As metadata provides access to components within individual documents, it is possible to use ICDD to dynamically create containers for specific use cases. Since it enables connection with external ontologies, the use of Link Data technologies can significantly expand the scope of usable information beyond the scope of data on the construction object itself. The only drawback of Link Data technology is the high effort in implementation.

From the presentation so far, it is clear that all current BIM technologies support traditional workflows based on documents just in digital format. Current IFC is optimized for file-based exchange and each file contains data about the entire structure of the construction object. Also, current CDEs support container-based federation rather than data-based federation. The shortcomings of the existing approach have been noticed and efforts are being made to overcome them. BIM Maturity Level 3 envisages distributed, web-based, interoperable, interdisciplinary exchange of information between stakeholders throughout the life cycle of buildings. Instead of monolithic data structures more flexible structures are needed allowing smaller discrete exchanges. Current efforts to develop the IFC5 version are directed in that direction (van Berlo 2021).

At the current level of BIM development, exchange of information is just exchange of information containers, not particular information that is valuable to someone, at specific time and for specific purpose. Since the development of BIM technology is moving towards a modular architecture that would allow access to specific data, the topic of information use is gaining importance.

5 Conclusion

Technologies that enable properly structured set of required data to be delivered at the right time to the right person are still under development. In the meantime, attention should be paid to defining information requirements and using all available techniques to create structures that computers can process, such as IDS or idmXML. Also, with completed models, it is not only necessary to check the presence of all the required data, but also whether the model can be used for everyday needs. In this way, the need to provide data in the models that can be used to obtain relevant information will be strengthened and it will be possible for various, now experimental, technologies to become available on the market.

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