Information in Architecture in the Digital Age

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ABSTRACT

Information technologies are so ubiquitous these days that we rarely question ourselves about what information is. Historically, the architecture became a profession when medieval master builders stopped the practice of designing and constructing the facility directly on the construction site and instead began to make plans for the future building, leaving the job of construction to other professions. Those drawings, plans, sections, elevations, details, represented information about future building.

Today, like many other professions, architecture is facing a digital transformation. All information that has been traditionally used is now converted to digital form, and information technologies are becoming the basic tool for their creation, modification, maintenance and updating. The whole process takes place on the assumption that there is a general agreement on what information represents.

The paper analyzes the concept of information and shows that there is no single definition that all professions accept. A review of different definitions is given with the main focus on the architectural information and its current use in digital technology. A detailed overview of the use of information in BIM technology and the efforts to unify it through the development of numerous standards is given.

As the transition of architectural practice to the use of digital technologies becomes a necessity, it is useful to create a better understanding of the nature of information and information technologies. New ways of creating, transmitting and using information need to be mastered in order to achieve a successful digital transformation of architectural practice.

Version accepted for publishing.
Svetel, I., (2022) Information in Architecture in the Digital Age, in Bogdanović, R., (Ed.) On Architecture Philosophy of Architecture Proceedings, STRAND, Belgrade, pp. 71-78 ISBN 978-86-89111-28-6

INTRODUCTION

Today, when we use information technologies in almost all areas of life, we rarely ask what information is. However, if the question is asked, it is revealed that a single and generally accepted definition of the concept of information does not exist, and the definition differs significantly from discipline to discipline (Bates 2010). Today, like many other professions, architecture is facing a digital transformation. All information that has been traditionally used is now converted to digital form, and information technologies are becoming the basic tool for their creation, modification, maintenance, and use. In light of that, this paper analyzes the concept of information and ways the digital information is structured and used in the AECO (architecture, engineering, construction and operation) sector.

NATURE OF INFORMATION

The interest in information started in the first decades of the 20th century. The rapid development of communication technologies at that time led to the practical problem of comparing the transmission capacity of certain technologies. To achieve this, it was necessary to develop a theory that would base the quantification of information on purely physical properties without any psychological aspects. The first steps towards a mathematical theory of information were made by Harry Nyquist (1924) in a paper that studied the best shape of signals and the choice of codes to achieve higher communication speed without the influence of interference. The work laid down the basic mathematical principles without going into the issues of the very nature of information.

The first paper that explicitly dealt with the concept of information was written by Ralph W. R. Hartley (1928). The paper connects definition of information with communication. In order to communicate, participants use symbols, abstract patterns that, based on previous agreement, convey a meaning to communicating parties. When the sending party selects one symbol and sends it over the communication channel it does not only designates particular entity, but also excludes all other available symbols that can be chosen. As more symbols are added, more and more possible symbol combinations are excluded and information becomes more precise. Since the number of available symbols in ordinary communication depends on whether the participants speak the same language, on their level of knowledge and various other factors, for mathematical theory it is necessary to free symbols from any psychological aspects. Treating all possible combinations of symbols a mathematical equation is devised that relates amount of information with the time and frequency of the transmission.

The work of Claude Shannon (1948) gave the final form to the theory by extending available theories to include effects of noise, statistical structure of message, and the nature of the final information destination. The paper introduced the term “bit” as the information content of the single binary symbol, which is later accepted as the basic unit of information in digital computing and communication.

While for the purposes of defining a mathematical theory it was necessary to deprive information of any meaning, for everyday use it is necessary to add meaning to the strings of 1's and 0's that make up digitally encoded information. Just as in natural languages there is an established agreement that certain letters represent certain sounds and that certain words refer to corresponding objects or phenomena in the world, so in digital technologies agreements are established that certain strings of 1's and 0's refer to certain elements of the world. One of the oldest such conventions was the ASCII standard, which defined how a string of seven 1s and 0s determined numbers, letters of the Latin alphabet, and special characters. It was later enhanced by the UNICODE standard which defines the binary encoding of any character of any alphabet and any special character. Standards are also developed for images, sound, video, and various other representations. In this way, most phenomena in the world received their standardized digital representation.

But merely assigning digital symbols to entities still does not constitute information, but merely defining the digital representation of the data that describes the world. A concept that is often used to explain relationship between data and information is DIKW (data, information, knowledge, wisdom) pyramid (Ackoff 1989). The data consist of raw, unorganized symbols that only denote some items in the real world. Information assumes organization of data in structure that gives additional meaning that goes beyond basic references to objects or concepts.

No matter how precise the theories and computer structures that model information are, in the end, information only serves humans. Douglas Hofstadter (1979) distinguishes three levels of information: the frame message, the outer message, and the inner message. The frame message is defined by the very structure of the message and provides the basic instructions on how to decode the message. In modern computer data structures, for example, at the very beginning, it is explicitly declared which scheme was used. The outer message is conveyed by the content of the symbols contained in the message and the way they are structured. The inner message is the meaning intended by the sender. While the frame and outer message are dependent on the technology, the inner message is completely dependent on humans.

Often mentioned as "the founder of modern management", Peter F. Drucker (1970) emphasizes that information and communication are inseparable and that the increasing formalization and impersonalization of information will require better communication. The formal and impersonal information processes will separate people and will require much greater efforts to restore the human relationship reflected in communication. He also notes that the person receiving information is the one who communicate. Without receiver there is no communication, no information, but only physical manifestation of sending signals. And ability of receiver to communicate depends on his/her perception, experience, expectations and involvement. The conclusion is that the communication is on the receiver's side, that it is reaction rather than action. Since information is encoded there must exist some prior agreement on the code that is used to establish communication. Second, it must take into account motivation (values, beliefs, aspirations) of the intended recipient. Information should be relevant to the receiver; otherwise it is treated as noise.

In the field of rhetoric, the principle of "Seven Elements of Circumstance" dates back to classical antiquity and originates from the works of Aristotle (Sloan 2010). It states the need to answer to seven questions: Why, Where, When, What, With Whom, By Whom, and How in order to provide valuable argument. The same concept is present in the Five Ws principle in journalism which determines the questions who, what, when, where, and why as essential in information gathering.

INFORMATION IN ARCHITECTURE

Along with letters and words that represent the generally accepted traditional representation of information, architectural practice is characterized by the use of drawings as a medium for the representation of information. The oldest preserved examples of sketches of architectural plans engraved in stone or clay date from the Sumerian period and are more than 4000 years old. The ancient Romans used full-size plans engraved on the ground of construction site as representations of parts of architectural buildings (Haselberger 1995). The oldest surviving architectural plan that is drawn on paper and in relative scale to the depicted object dates from the early 9th century. It is considered that the first architectural plans in the modern sense were preserved in the "sketchbook" of Villard de Honnecourt (Philipp 2020). However, it was only with the development of precise geometric projection techniques at the beginning of the Renaissance period that modern architectural documents were created, which enabled the development of architecture as a discipline separated from the building process.

Over time, detailed conventions have been developed that determine views (floor plan, section, elevation etc.), scales, types of lines and hatching, annotations, and many other components of documentation which enabled architectural drawings to become a medium through which all necessary information is transmitted. The drawing enables both the creation and development of the idea, explaining the concept to the investor, creating documentation for obtaining construction approval, managing the construction process and finally documenting the built state. Also, the drawing has become a basic element of the architectural language through which ideas are transmitted among professionals, registered for theoretical review and preserved as a basis for learning.

In accordance with the importance that drawing has acquired in the architectural profession, the first commercial applications of computers in architecture were aimed at simulating the process of drawing with computers. Also, the programs that today represent the basis of the BIM process, such as ARCHICAD and Revit, were originally developed with the aim of obtaining consistent drawing based project documentation from the 3D model of the building. Originally, information contained in parametric objects used to create a 3D model was aimed at automating the connection of objects into a consistent whole in order to obtain high-quality drawings (e.g. erasing lines between parts of different objects that are of the same material).

Today, the most common level of understanding of BIM in architectural circles is that it is a 3D model with information. However, such a way of thinking is related to the time when the term BIM was associated with a single application. In the meantime, a great effort has been made in networking the various participants in the entire AECO process. The initial steps were aimed at creating standard data structures that would organize information in a unique way during building's life cycle. Over time, it was realized that it is not enough to standardize the structuring of information, but also the ways of its use. Today, BIM applications are only part of the whole BIM process in which standard ways of presenting information and using it are a key element.

STRUCTURING DIGITAL AECO INFORMATION

The first step towards linking together the computer applications used in the AECO sector was the creation of the IFC data format (ISO 2018). The intention was to create standard format for the exchange of information between AECO applications that will cover whole building life cycle. The project started in 1994 with the formation of an industrial consortium that first included US companies and then grew into an international effort - International Alliance for Interoperability, later renamed to buildingSMART. The first version of IFC standard appeared in 1997 and has subsequently undergone many revisions until today's current version 4.

Although it was developed primarily as an interoperability format the IFC can be seen both a conceptual data schema and an exchange file format. As the conceptual data schema IFC defines classes that represent all concepts related to the built assets during their lifecycle, their parameters and relationships. Concepts include objects (both space objects like site, building, and storey, and construction objects like walls, columns, and windows), processes (event, procedure, task), actors (designer, supplier, owner), and controls (cost, performance, action request). Since the development of IFC is an industrial project aimed at practical application, when determining the parameters that IFC includes, those that are supported by all stakeholders and all software manufacturers were chosen. Other parameters that are specific to certain types of projects or geographic regions can be added using a mechanism of the IfcPropertySet class. As the exchange file format the IFC uses plain text file format based on STEP standard, Extensible Markup Language (XML) file format, RDF/OWL formats (Turtle and RDF/XML), and JSON JavaScript Object Notation.

At the beginning, it was thought that only the development of a standardized data structure would be sufficient to achieve interoperability between applications. But the experiences with the first implementations of the IFC format quickly showed that it is necessary to predefine the ways of its use. Although the number of parameters included was limited, the IFC included a large number of domains and it was not clearly demarcated where certain data should be recorded. It was also pointless to require applications to support import and export of data that will never be used. The solution was to create a Model View Definition (MVD), a subset of the entire IFC format that would support a specific AECO process (buildingSMART 2021). In order to determine what information needs to be supported by the appropriate MVD, the Information Delivery Manual (IDM) was developed. The IDM is a formally structured document that describes particular AECO workflow through the definition of the process and the required data (ISO 2016). The IDM format consists of an interaction map, a process map and one or more information exchange requirements. The process map is used to set boundaries of information contained in processes and to establish activities and their order. The interaction map lists all roles and mutual transactions that are characteristic of a specific AECO process. Exchange requirement is a document written in understandable language that describes particular information exchange. Until recently, information requirements in IDM were formatted as a plain text document, but a specification based on the XML format (idmXSD) was recently developed, which enables creation of a structured computer interpretable document format (ISO 2022c). According to new format IDM consist of use case, business context map (process map, interaction map), and information requirements. The use case contains unified overviews that were previously part of each individual IDM component. The attributes in IDM focuses on many aspects of information like 'why' (aimAndScope), 'how' (use), 'by who, for whom' (actor), 'when, for what' (ProjectPhase), and covers other aspects like limitations, required resources and competencies. The scheme gives an extensive description of information requirements, but it is directed toward implementation of MVD and the final realization of the information requirements depends on the MVD implementation.

The IDM is targeted toward definition of information requirements for the development of software solutions that support particular MVD. However, in daily work of creating information to meet requirements, it is useful to have a computer interpretable representation that would enable automatic verification. With this aim, the Information Delivery Specifications (IDS) is being developed as a buildingSMART standard (buildingSMART 2022) for the specification and verification of simple information requirements based on the IFC model covering particular information exchange as defined in the ISO 19650 series of standards. The IDS is XML formatted file that contains metadata part and list of specifications. The metadata contains title, copyright, version, author, date, description, purpose, and milestone fields. The description is plain text that details who will possibly use the IDS, why it is created, for what projects, etc. A purpose is a sentence that explains what the IDS will achieve. Each specification describes single entity (wall, window, etc.) in the model and contains metadata, applicability and requirements sections. The specification metadata contains fields for name, description that explains why the requirement is important to the project, and instructions that defines who is responsible to provide information and how. Applicability defines what information an entity needs to have in order for the specification to be applicable to the entity. The requirements section describes information that an entity needs to have in order to conform to the specification.

The ways of structuring information presented so far relate to an individual construction project. A data dictionary was developed for the purpose of structuring general information in the AECO sector. The structure of data dictionary is defined in ISO 12006 Part 3 standard (ISO 2022a). The standard specifies information model which can be used to create a computer based dictionary of terms in the AECO sector. The structure of the information model enables the definition of other relations between concepts so that it can be used for development of ontology, taxonomy, meronomy, lexicon and thesaurus. The information model enables concepts to be defined using subjects and properties, to describe subject by properties, and provides means to define relationships between concepts. The set of properties defines the subject and its behaviour. Properties can have values and associated units. The model is intended for development of multiple dictionaries. Each concept belongs to one dictionary and can be linked to concepts in other data dictionaries. The model enables different information resources like standards, classifications, data templates, object and process models to be cross-referenced in a common framework.

In order to enable the structuring of information about construction products, an ISO 23387 (ISO 2020c) standard was developed that defines the structure of the data template. The data template allows interlinking of separate information relevant for a specific building product such as standards, classifications and manufacturer specifications in a way that suits specific information needs and local requirements. Data templates are implemented within a data dictionary based on ISO 12006-3 standard and the process of creation and maintenance is driven by domain experts. Data templates are just generic objects without any actual data on construction objects. Manufacturers can populate them with actual parameter values to create data sheets that provide concrete description of specific products. Using a verified data template stored centrally in some data dictionary the users can get data about construction products that suits actual information need and can format them according to standards and classification used on actual project. Having data sheets with required data and in right units enables comparison of products and informed decision making.

USING DIGITAL AECO INFORMATION

At the beginning of the development of BIM technologies, it was assumed that only the development of information structures would solve the problem of interoperability in the AECO sector. But already the first experiences with the IFC format and the need to introduce MVD have shown that it is necessary to define the conditions for using BIM technologies. During the past years, various approaches were developed, and in the end, the most successful solutions were summarized in the set of ISO 19650 standards.

An important fact is that the standards recognize the need for information to be structured according to the needs of the recipient. The whole process is initiated by the party that will use the created information. In order to determine their needs, the so-called appointing parties create documents that describe their organizational (related to the general company's information policy), asset (defining the company's needs for asset information management), project (defining information requirements for specific project), and exchange information requirements (defining the precise scope and level of information for each decision point in the project or asset operation). These documents are foundation used throughout the stages of procurement, planning, production, and approval of information. Based on the information requirement, the qualified participants in the project are selected, the level and amount of information that should be created are determined, and they represent the basis for the verification of the delivered information. The basic terms and principles of the process are defined in the ISO 19650-1 standard (ISO 2018b), while the processes in the design and operation phases of the asset are elaborated in the ISO 19650-2 (ISO 2018c) and 19650-3 standards (ISO 2020a). The process of creating information is divided into stages that are determined by milestones, and in each stage a specific exchange information requirement (EIR) is created that defines what the appointing party expects from information in specific stage. The EIR is the basis for creating and verifying information in each phase and that process is called information exchange. The ISO 19650-4 (ISO 2022b) standard defines process and provides quality assurance and quality control criteria for each information exchange event. All parts of the standard treat information as "reinterpretable representation of data in a formalized manner" (ISO 2018b) regardless of whether it is digitized classic documents or information structured in a computer interpretable scheme (Svetel 2020).

The ISO 19650 series of standards require that information should be consistent with the level of information need. Until now, numerous methods have been developed to determine level of information need, but they mostly inherited the practice from traditional drawings of defining the level based on the degree of detail of the geometry so they where focused on the characteristics of the object. Such an approach required that the elements must contain all the data that a certain level requires, regardless of the application, which in some cases led to an excessive amount of information. The EN 17412-1 standard (CEN 2020) aims to provide a framework that is more sensitive to particular use of information. The standard specifies four prerequisites that shall be considered: purpose of information (why), milestones (when), actors (who), and objects in breakdown structures (how, what). These topics represent only the areas that should be taken into consideration when determining the level of information need, while the standard itself does not specify the purposes, milestones, actors or objects. Those prerequisites are used to specify granularity of information, while the level of information need should be defined using geometrical information, alphanumerical information and documentation. The level of information need provides framework for verification and validation of information content. The verification process ensures the completeness of information, checking that all requirements are satisfied, while validation ensures that the ways of using information are met. Part 3 of the standard that will provide the XML schema is under preparation.

Another area for which the need to define the creation and maintenance process is recognized is the development of data dictionaries. The information structure itself was first formally published in 2001 as ISO/PAS and then as a full ISO standard in 2007. But the actual implementations of the technology did not take off. Only with the development of the methodology for describing, authoring and maintaining properties in interconnected data dictionaries, that is described in the ISO 23386 standard (ISO 2020b), conditions were created in which there were both concrete implementations of the dictionary and the emergence of interest in the development of technology support in applications by software developers. The standard ensures compatibility of terms defined in interconnected data dictionaries through a precise list of attributes to be used to describe properties and groups of properties. The standard defines rules for authoring and maintaining properties and groups of properties that are expressed as BPMN diagrams, as well as list of attributes that define each management request. The standard also describes how the governance of data dictionary and networks of data dictionaries should be organized.

CONCLUSION

In recent years, the development of BIM technology has been marked by the development of new and improvement of existing standards. The development is so intensive that often after short time new standards become uncoordinated with other standards because they cause changes that were not counted on when they were created. Although this leads to confusion, the progress that has been made overcomes such shortcomings. The development has made it possible that the techniques of connecting different BIM technologies are no longer just experiments, but potentially permanent solutions based on standards (Son et al. 2022). Also, it is now possible to make valid comparisons of different approaches in the use of BIM technologies (Tomczak et al. 2022).

However, there are still remnants of old beliefs that slow down technology adoption. One of the most prominent outdated beliefs is that BIM is a 3D model plus information. The fact is that the first BIM applications were not developed with the aim of manipulating information structures, but to create consistent project documentation based on 3D building models. Related to this is the view that BIM is one application. However, the development of BIM technologies has advanced so much that even a group of applications that seamlessly exchange information about a construction project can no longer be treated as BIM.

BIM is increasingly becoming a set of techniques and tools for creating, exchanging, modifying and using digital information about construction objects. Recent study (Tomczak et al. 2022) shows that there are seven standardized techniques to define information requirements. However, no single technique meets all the criteria that the authors of the study established. One of the reasons is that orientation toward information is a topic that has only recently emerged.

Among BIM practitioners, there is still an orientation towards characteristics of the building objects, elements, properties and attributes. Most current efforts on information management in BIM are orientated toward checking content of models coded using different information structures. The focus of the BIM community is on “shared digital representation of a built asset” (ISO 2018b) or “model of the facility in virtual space” (BIM Dictionary 2022). Computer systems, on the other hand, enable the structuring of huge amounts of data, which exceed the human ability to understand them. Although this negative trend has long been observed (Drucker 1970), computers are still used to justify spending time on control, instead of freeing people from control by providing them with information. A new view is needed that will allow information to be relevant instead of complete. In order to perform actual tasks on the construction site or during maintenance, it is necessary to provide information about what, where and who should do it, while information about the structure of elements are less important. Still, the existing mindset that is preoccupied with the object itself, its elements, quantities, prices and checking whether all parameters are present in the model is aimed at control instead of using information.

However, the situation is gradually changing. In order for BIM technologies to become the basic way of working in the AECO sector, it is necessary for all participants to understand why they use them. Currently, the basis of digital expression in the AECO sector is defined by standardized information schemes. Only with an understanding of those schemes can one start comparing them and deciding when and for what they will be used. Based on that, a set of applications that support a workflow can be determined. This process will take time. As we can see from the development so far, it was only the use of certain technologies that led to an understanding of the advantages and disadvantages and caused the development of new solutions, which in turn led to a new perception of the entire field. Psychological experiments on the topic of category formation (Vygotsky 1962) showed that this process is possible only in the presence of some interruption in thinking or communication. Philosophers who belong to the hermeneutic school of thought insist that objects and their properties exist only in the context of the breakdown of our everyday activities related to those objects (Heidegger 1962). As long as we use an entity without trouble, we do not pay attention to it. Only when there is some deadlock in daily use we become aware of that entity. At the same time, our understanding of that entity does not focus on the essence and study of what that entity really is and what it consists of, but it is entirely determined by the ways in which that entity can be used.

There are other areas where there is an opportunity to improve BIM technologies. In his work, Professor Yehuda Kalay (2013) proposes the extension of information model to include form, function, and use. The current practice of modelling information structures is inspired by models in other disciplines that focus on consumer products. Unlike such products that function independently of the culture or context in which they are used, architectural objects are inseparable from the context, habits and expectations of those who use them.

However, there is an increasingly noticeable shift in orientation to the ways in which information is used. Today's standards that define information structures and ways of using them, as well as those that will be developed, describe a new way of structuring and using information in the AECO sector. It is a new way in which all concepts are expressed, exchanged, explored, developed and used. An architect in the modern digital environment is as much an architect as he is able to express his ideas through digital information structures.

ACKNOWLEDGEMENT

The results presented in this paper are the result of research supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia under the Agreement No: 451-03-68/2022-14/200213 from 4.2.2022.

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