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USE OF DIGITAL INFORMATION IN ARCHITECTURE, ENGINEERING, CONSTRUCTION AND OPERATION: STANDARDIZATION EFFORTS

UPOTREBA DIGITALNIH INFORMACIJA U ARHITEKTURI, GRAĐEVINARSTVU I EKSPLOATACIJI: NAPORI KA STANDARDIZACIJI

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Abstract

Today, BIM (Building Information Modelling) is the basic technology used to create models and documentation in architecture, engineering, construction and in the operation (AECO) sector. Although the whole sector is experiencing an intense digital transformation based on information technologies, few people pay more attention to the very concept of information. The paper analyses the basic aspects of the concept of information and demonstrates how they are gaining increasing support in BIM technologies through the development of standards. An overview of all current BIM standards is given, as well as a selection from those in the process, showing how the role of information is defined in them. The paper summarizes aspects of standards and gives a proposal on how they should be used in everyday AECO practice in order to achieve a new way of expressing and using information.

Izvod

Danas je BIM (informaciono modeliranje zgrada) osnovna tehnologija koja se koristi za kreiranje modela i dokumentacije u sektoru arhitekture, građevinarstva i eksploatacije. Iako ceo sektor doživljava intenzivnu digitalnu transformaciju zasnovanu na informacionim tehnologijama, malo ljudi obraća više pažnje na sam koncept informacija. U radu se analiziraju osnovni aspekti koncepta informacija i pokazuje kako oni dobijaju sve veću podršku u BIM tehnologijama kroz razvoj standarda. Dat je pregled svih aktuelnih BIM standarda, kao i izbor onih koji su u procesu razvoja, koji pokazuje kako je u njima definisana uloga informacija. Rad sumira aspekte standarda i daje predlog kako ih treba koristiti u svakodnevnoj praksi da bi se postigao novi način izražavanja i korišćenja informacija.

NATURE OF INFORMATION

Today, the term 'information' is so prevalent in everyday communication that few people even think about its meaning. However, more and more jobs are moving to a complete replacement of traditional ways of working with information technology based work. In order have a better understanding of this transformation, it would be advantageous to understand the very nature of information.

Foundations of the development of today's information technologies were laid at the beginning of the 20th century by the works of Ralph Hartley /1/ and Claude Shannon /2/ that initiated the mathematical theory of information. The papers dealt with the problem of transmitting meaningful signals through the communication systems of the time and gave precise mathematical methods to quantify information that led to further developments in information technology. Among many contributions is the definition of bit as the most basic unit of information in binary systems. These models treat information as a signal that is coded on one side, then transmitted through communication channels and decoded on the receiving side. Although they have enabled the development of information technology, they do not go further into explanation of what information is.

It is interesting that other disciplines did not give a single and generally accepted definition of the concept of information, but the definition differs significantly from discipline to discipline, /3/.

One notion that is common is that information reduces uncertainty. The mathematical theory contrasts information to randomness, in communication there is distinction between signal and noise, and in everyday speech we can come across the statement that something is not information but noise.

Another common notion is that information is about something, that it is a representation, a physical or energy pattern that denotes something in the world. As such, it can be recorded or transmitted in some medium, processed by humans, and recently also by computers. A medium can introduce interference or degradation to message (noise or entropy). In digital systems information it is a collection of symbols represented as strings of 1's and 0's that carry a meaning.

Information always has some purpose that lies behind its creation, communication and processing. It is expected that it creates some effect (action or state of mind) on the receiving side /4/. Connected to this notion is the need for infor-

mation to be relevant to the receiving party. If no uncertainty exists on the receiving party upon the content of the information, then information does not fulfil its function, instead it is treated as noise.

Related to this aspect of information is the concept of 'seven elements of circumstance' or the need to answer to seven questions: Why, Where, When, What, With Whom, By Whom, and How in order to provide valuable information or argument. This concept has been applied since classical antiquity and originates from the works of Aristotle /5/. Today it is known as a Five Ws (or Five Ws and How) principle in journalism.

A concept that is also often used to explain what is information is relationship between data, information, knowledge, and wisdom, known as DIKW pyramid /6/. The data consist of raw, unorganised symbols (patterns) that simply denote some objects or concepts in the real world. The information presupposes some structure (organisation) of data that gives some additional meaning that transcends basic references to objects or concepts (Fig. 1). The other two aspects of the scheme, knowledge and wisdom, represent higher levels of the organisation which at this moment exceeds the needs of information systems in the architecture, engineering, construction and operation (AECO) sector.

Natural language

Data - wall color blue

Information - The color of this wall is blue

Information technology

Data - wall color blue

Information - ConstructionObject: wall;
color: blue;

Figure 1. Relation of data and information in natural language and information technologies.

INFORMATION IN AECO

Historically, architecture, and later other engineering disciplines, emerged as professions in the early Renaissance, when the traditional craft principle of design and construction directly at the construction site was replaced by documentation that provided information on what will the future building look like and how it should be built. Drawings like scale plans, sections, elevations and details, and written documents containing program, schedules, and calculations, have become the standard way of transmitting information in the AECO sector.

The digital transformation of the AECO sector began with the use of CAD programs that replaced hand drawing. Still, traditional paper based documents remained as the final products. Next step was digitization, i.e. conversion of paper based drawings and documents into digital form. In this way, both the method of creation and the final product are based on digital technologies, but the way of representing information does not change and remains based on a century-old tradition.

Things began to change with the arrival of programs that made it possible to create consistent project documentation

through the creation of 3D building model. In order to speed up the process of creating 3D models, parametric models of building elements such as walls, windows, stairs, etc. have been developed. Instead of developing the whole 3D model, the user defined the parameters for the elements corresponding to his project and then combined the elements to get the whole 3D model. To enable the combination of elements that do not require user intervention for each individual combination, the geometry parameters are enriched with parameters that determine materials, layers, relationships, etc., so that the program itself could properly connect elements into the entire 3D model, and automatically create sections and schedules. Programs that have successfully implemented this concept are ARCHICAD and Revit, originally developed for architectural design purposes. With the commercial success of these programs, other manufacturers of 3D modelling software have developed their own solutions and such an approach has been called Building Information Modelling (BIM) /7/.

At the same time, parametric approach has been used in applications covering other aspects of AECO practice like construction an MEP design, and it became obvious that by adding parameters describing all possible aspects of building a larger functionality can be achieved. But after initial enthusiasm it became obvious that a process requires standardized approach in order to achieve real benefits.

The standardization effort is mainly driven by the International Organisation for Standardization (ISO), European standardisation body (CEN) and buildingSMART. Within ISO the TC 59 in charge of regulations in buildings and civil engineering works charged SC 13 to standardize organisation and digitization of information in AECO sector with reference to the BIM. The ISO/TC 59/SC 13 has published 19 standards and has 8 standards under development. Within the European standardisation body CEN, the Technical Committee TC/442 was set up to take charge of the standardisation regarding structured semantic information in the built environment that encompasses full life-cycle of the asset. The CEN/TC 442 is responsible for the adoption of ISO standards as EN standards and the development of standards, specifications and reports on the organisation of information in the built sector. The CEN/TC 442 plays a major role in development of both ISO and EN standards. The buildingSMART started its work as an industry consortium with the goal to define interoperability format to provide seamless connection between AECO applications. The goal was achieved by developing the IFC format, which later became the ISO standard. The buildingSMART still supervises the development of IFC format, whereby individual stages of development are validated as an ISO standard. In addition, buildingSMART is developing both the Information Delivery Manual (IDM) and the BIM Collaboration Format (BCF) standards.

MODELLING INFORMATION ABOUT BUILDING

The idea of developing a standard format for the exchange of information between programs intended for architectural or construction design emerged with the development of the first such applications /8, 9/. Only with the formation of an industrial consortium in 1994 that first included US compa-

nies and then grew into an international effort - International Alliance for Interoperability, the conditions were created for that idea to come true.

The first version of IFC standard appeared in January 1997 /10/. The v1.0 had a limited scope, focusing mostly on architectural part of the model. It was intended only as prototype platform and soon it was replaced with the new 1.5 version in November 1997. This version was intended for implementation in commercial software, but after some implementation problems were detected it was replaced with version 1.5.1 that was successfully implemented in several software in 1998. Since then, the IFC standard has been constantly improved and has undergone numerous versions. In certain stages of development, certain versions were submitted to obtain the status of ISO standards. The first one was IFC2x3 TC1 where only stable core received status of ISO/PAS 16739:2005, which was followed with IFC4 that attained status of the ISO 16739:2013, and IFC4 ADD2 TC1 that obtained status of ISO 16739-1:2018 /11, 12/.

The IFC can be seen both a conceptual data schema and an exchange file format. From the perspective of the conceptual data schema it 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 as walls, columns, and windows), processes (event, procedure, task), actors (designer, supplier, owner), and controls (cost, performance, action request). Since it is not possible to predict all the parameters that comprise certain classes, only common ones are part of the IFC data model, and new parameters 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 /13/, Extensible Markup Language (XML) file format, RDF/OWL formats (Turtle and RDF/XML), and JSON JavaScript Object Notation.

From the beginning, IFC was developed to enable the highest level of interoperability among applications, to support all available applications and possible future uses, but still to be independent from any actual software implementation. The IFC gives a high level data model but does not prescribe any implementation method. At the time after publishing IFC v2.0, the problem with the approach is that standardization effort is oriented only toward development of data model and that the ways on how to use IFC are left to industry became obvious with the lukewarm industry acceptance and the general view of the IFC as an unreliable way to achieve interoperability, /11/.

It was clear that in order to achieve streamlined collaboration in the AECO sector, it is necessary to regulate the processes and ways of using developed standard. Attention is focused on developing specifications that use the minimum resources provided by IFC and that provide a predictable and efficient exchange of information for specific cases. The result was the development of Information Delivery Manual (IDM) as the method to structure processes in AECO and determine what information is needed and at what times, and Model View Definition (MVD) as a way to define the subset of the full IFC data schema which includes only those data that support one particular workflow in AECO sector. This approach enabled efficient certification of software solutions for IFC import and export. Both technologies will be presented in more detail later in the paper.

As the changes in the way IFC data models have been implemented have led to successful interoperability, the IFC4 version has been used to improve and extend the standard. Among extensions are support for parametric exchange of shape, material and element type for building elements, support for b-spline surfaces and curves, support for energy calculations and advanced simulations, standardized base quantity, enhanced support for building services domain, linking of IFC property definition to the buildingSMART Data Dictionary, and implementation of conditions for the extension of IFC to infrastructure.

The IFC standard is under constant development. Latest official version is IFC4.3 /14/ that is submitted for ISO certification, and work is underway for version 4.4, /11/.

The Model View Definitions (MVD) /15/ is a technique to define subset of full IFC schema suitable for particular case and includes only those data that support one particular workflow in the construction sector. It defines the mapping of process maps and exchange requirements from IDM onto an IFC data model. The MVD is the core of IFC import and export certification of the software. The IFC 2x3 has only one certification MVD, the Coordination View 2.0, but since no software could achieve 100 % full compliance, green, yellow and red levels of satisfaction have been introduced for certain aspects which led to the fact that despite the certification, there are still some cases in which there are errors in the exchange of information. It is envisaged that IFC4 has two more strict MVDs: 1) the Reference View that is similar as Coordination View 2.0, but strictly covering only coordination aspects, and 2) the Design Transfer View which covers aspects of exchanging models, so that they can be further modelled by other applications.

MODELLING INFORMATION ABOUT CONCEPTS AND BUILDING PRODUCTS

The IFC data format is conceived as the way to structure data about one built asset during its conception, design, construction or operation phase. But there is a lot of information outside of the particular built asset, like information about products, standards, local regulations, etc. that are important in all phases of the life of built asset. Also, since IFC was developed to enable efficient exchange of information between software applications, it was not practical to include all the parameters that describe the building. It has also been shown that the free definition of properties in IFC using IfcPropertySet leads to inefficient interoperability. In order to define and give a structure to all information in AECO sector, it was necessary to create a new information model that corresponds to such a purpose.

The ISO 12006 series of standards considers the organisation of information on construction works. Part 2 /16/ provides a general framework for development of classification systems in AECO sector. It gives recommendations on classification tables and table titles to structure construction information on results, processes, resources, and prop-

erties. From the time of first edition in 2001, several modern building classification systems like OmniClass and Uniclass are aligned in accordance with this standard.

The ISO 12006-3 standard /17/ defines data structure to develop a taxonomy model. It enables concepts to be defined by properties, and provides methods to group concepts and to define relationships between concepts. Each concept has a specific calculated global unique ID number (GUID) that uniquely specifies it in IT systems, name defined in different languages, version, version date, and description that can link concept to external documents. Objects, collections and relationships are the basic entities of the model. Every object is defined by the set of associated properties. Properties have values that can optionally be expressed in units. The data structure defined in ISO 12006-3 can be used to store different AECO information resources in computer systems, like dictionaries, standards, classification systems, ontologies.

The high level of adoption of BIM technologies has posed the problem of creating a standardized model for the representation of information on construction products. The ISO 12006-3 provides a suitable structure, but lacks the concept of classification, which is crucial for information on construction products. For that purpose, an ISO 23387 standard was developed /18/. It uses concepts from ISO 12006-3 and extends them with the concept of classification and 5 new relations.

Data templates define how data on construction products are structured to include data from 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 and the process of creation is driven by domain experts. Data templates do not store any actual data on construction objects. They are just generic objects, structures that manufacturers can use to create data sheets that provide concrete description of specific product with actual parameter values. Using a verified data template stored centrally in some data dictionary, the manufacturer can select from their data bases about products only the data that suits actual information needs and can format them according to the requirements of standards and classification used on actual projects. Having data sheets with required data and in right units enables comparison of products and informed decision making.

The data dictionary is the way to provide centralized repository of information related to AECO sector, to store in computer interpretable way all concepts, their properties and relationships to other concepts, and to record their origin, usage and format.

The Data Dictionary (bSDD) /19/ is an online service provided by buildingSMART based on the principles set out in ISO 12006-3. It stores concepts from many classification systems (CCI Construction, ETIM, NL-SfB, Uniclass 2015, etc.) and all IFC concepts. From the IFC2x3 the buildingSMART began to include the standardized IfcPropertySet definitions into the bSDD for better administration. Currently it hosts classifications and properties. It provides links, mappings and federation between concepts that enable

concepts from one domain to be represented in another domain. Each concept is uniquely identified with URI namespace. The possibility of bSDD to define concepts in different languages provides multilingual definitions.

Cobuilder Define /20/ is the data dictionary system based on the ISO 12006-3 principles. It has a goal of building a common language in AECO sector. It enables creation and management of concepts like properties, groups of properties, measures, units, values, construction objects, and data templates. It also enables concepts to be linked with documents and classifications, and supports full management process in accordance with ISO 23386.

INFORMATION CREATION, USE AND MANAGEMENT

Initially, the digitization of the AECO sector was directed toward developing a data structure that would support the full lifetime process, resulting in the IFC data model. It was considered that only the development of a data model that supports all aspects of the AECO sector would be the solution to successful interoperability. But it soon became clear that this was not enough and that it was necessary to standardize the ways in which information is created, used and managed.

Among the first findings was that the full IFC specification confuses those who use it and that for practical application it should be limited to segments that support one specific AECO process, /10/. The Information Delivery Manual (IDM) was developed by buildingSMART as the method to define how the full IFC specification should be segmented to achieve effective interoperability. A goal has been set to determine where processes fit, why they are relevant, who the actors are, what information is used, and how the information is supported by software /21/. These questions strongly resemble the classical 'seven elements of circumstance.'

The IDM has a status of full ISO standard /22, 23/. The part 1 of the standard /22/ defines a methodology for creating documents describing particular AECO processes and required data. It defines an IDM format consisting of an interaction map, a process map and one or more information exchange requirements. The process map is structured in Business Process Modelling Notation (BPMN) /24/ and it is used to set boundaries of information contained in processes and to establish activities and their order. Exchange requirement is a document written in understandable language that describes particular information exchange and later serves to develop technical requirements for implementation in MVD. The part 2 of the standard /23/ gives a detailed overview of how the interaction map is structured. The interaction map lists all the roles and transactions between them that make up a specific AECO process. Each transaction has only one role that triggers the request and one role that gives effect to the request. IDM is a formally structured description of a particular AECO workflow that allows the implementation of the MVD for a concrete workflow.

At the start of development, it was also expected that a simple exchange of IFC files would be sufficient for successful cooperation. This was later expected from BIM

servers. Finally, the solution was found in the development of the BIM collaboration format (BCF) /25/. BCF is developed as a standard for the BIM model issue management. It can be implemented either as file-based collaboration using XML-based data format, or as the server-based service using a bcfAPI.

Using the BCF, the participant in the process creates a topic that describes particular issue in the model. The topic is defined by mandatory title and contains description, assignment, milestone, deadline, priority and other information that define issue. Each topic is automatically linked to a particular view position within the BIM model and the unique identifiers (GUIDs) of the building elements that are contained in the view. That way the issue is uniquely linked to the model and it is not necessary to exchange elements of the model, but only information on the issue. Each participant in the project can create, sort out, explore and solve issues in their BIM models.
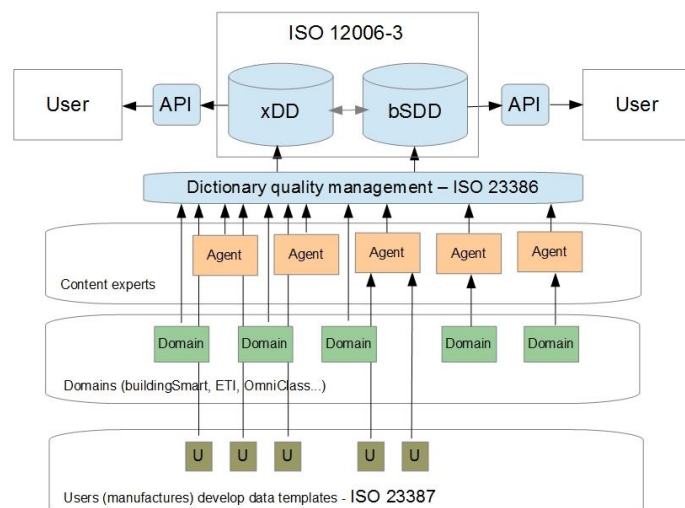

Figure 2. Relation between ISO 12006-3, ISO 23386, and ISO 23387 standards.

At the beginning of the development, the implementation of data dictionaries was based only on the standards that describe the information structure. Over time, it has become clear that this goal cannot be achieved without standardized management of the entire process. In order to achieve that different data dictionaries can link information to each other, in order to avoid different definitions of the same terms and to achieve credibility of data stored in the data dictionary, the ISO 23386 standard has been developed /26/.

In order to achieve compatibility of terms defined in interconnected data dictionaries this standard specifies a precise list of attributes to be used to describe properties and groups of properties. Mandatory attribute to describe both properties and groups of properties is a global unique identifier that enables all concepts to be machine-readable.

The standard also defines rules for authoring and maintaining properties and groups of properties 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 organised.

ISO 19650 set of standards

Recently, the standards from the ISO 19650 series attract most attention. This series of standards regulate the information management process during all phases of a building's life cycle. The standard currently contains four parts, with two more in development. Part 1 /27/ defines the basic concepts and principles used in all other parts, part 2 /28/ deals with information management during the delivery phase which includes design and construction of the building, part 3 /29/ deals with information management during operational phases of the construction site, and part 5 of the standard /30/ discusses the security of the information. The parts under construction cover a detailed description of the information exchange process and health and safety requirements.

These standards are based on best practices and are the result of almost a decade of BIM implementation in countries where a legal obligation to implement BIM in AECO sector has been introduced. The standards are an attempt to summarize in one place all the solutions that have been developed during the application of BIM technologies, especially in connection with the experience that only data structures and software solutions do not achieve full interoperability and effective cooperation among stakeholders. The content of the standard can be viewed as a checklist of activities that should be carried out during the planning, contracting and implementation of BIM information in order to achieve an efficient flow. The standards also specify the types of documents that should summarize the results of planning and contracting, and which are part of the contract documentation.

According to ISO 19650 standards, information is 'reinterpretable representation of data in a formalised manner' (ISO 19650-1 3.3.1) /27/ that can be processed either by humans or machines. Information is collected in information containers that are named and permanent sets like files, folders, documents, chapters, locations on the Internet etc. The information containers can be structured or unstructured. The naming should be consistent with a predetermined naming convention. The information model is a set of information containers. The project information model is used in the delivery phase (design and construction) of the asset, and asset information model is used in the operational phase.

ISO 19650 standards distinguish two information flow directions that appear in both the delivery and operational phases of the asset. The party initiating the process (the so-called appointing party) should prepare documents that clearly state the information requirements. These requirements are divided into four categories: 1) organisational (OIR)- related to the company's general information management policy, 2) asset (AIR) - defining the company's needs for asset information management, 3) project (PIR)- defining information requirements for specific project, and 4) exchange information request (EIR) - defining the precise scope and level of information for each decision point (milestone) in the project or asset operation. The role of these documents is to determine in advance what information, to what extent, at what defined time, in what format, and for

whom, is needed during the life cycle of the building. These documents form the basis for the contracting process of each phase of the project or event during the operation of the building. For each event in the life cycle of the building, a number of information management activities are carried out, which include tendering, information planning, and information production.
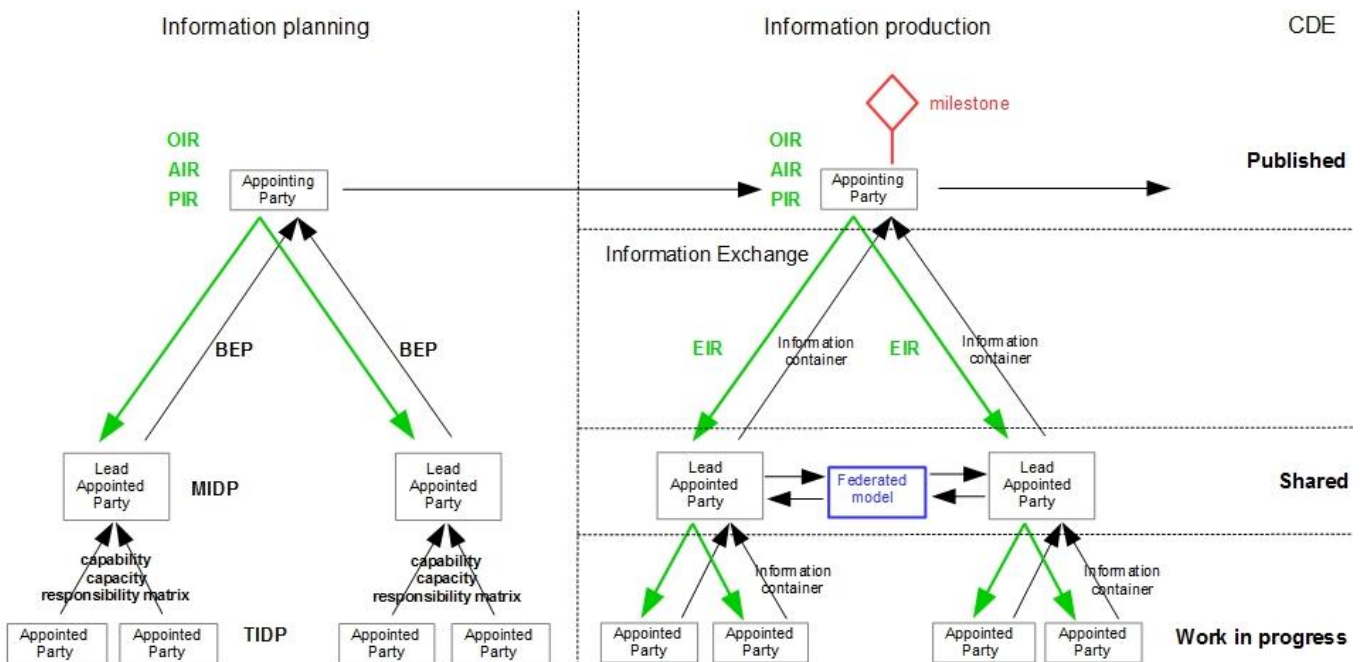

Figure 3. Relation of some concepts appearing in ISO 19650 series of standards.

The second direction of information flow is initiated by the information delivery team consisting of the lead appointed party and appointed party. Based on the information requests they develop a BIM implementation plan (BEP) in the tender process. The BEP is a document that states how the delivery team will take into account the tasks of information management and information production and also provides a clear insight into their BIM capacities and capabilities. The information delivery team defines how it will meet the requirements of AIR or PIR, how to ensure precise information delivery time, defines the federation strategy and breakdown structure for information containers, describes how information will be coordinated with other teams and establishes a precise responsibility matrix. These statements are documented as the Master Information Delivery Plan (MIDP).

In traditional documentation, the detail of the information is resolved through the scale of the drawings. However, a digital model can also contain geometry and attributes at different levels of representation. The first solution was Level of Development (LOD) a concept that describes precision of BIM information according to predefined levels with assigned numerical levels where higher number designates higher precision. LOD is the document that enumerates all building elements, and for each LOD level gives precise definition of geometry details and attributes that should be included in the model. ISO 19650 standards do not use the concept of LOD, but state that the exchange of information should be in accordance with the level of information need. Standard EN 17412-1 /31/ defines concepts and principles for the level of information need as the framework to identify extend and granularity of information. The standard differentiates between geometrical information, alpha-numerical information, and documentation, and actual level of information need is the document that specifies preferred presence and granularity of these information types at a defined information delivery milestone or at specified time, for the particular purpose, and for the specific actor.

An important aspect of the ISO 19650 standard is the requirement that all information containers should be accessed and managed through a common information environment (CDE). In order to be consistently managed all containers should provide information on their role and have a unique ID. In addition, containers should have attributes that determine their suitability (status), revision and version, and classification. The CDE must allow information containers to switch between states, provide secure access to containers, guarantee ownership of the container even in the event that the author of the container leaves the project, and allow the user name and date of transition to be recorded. Information containers can have four states: 1) work in progress - which contains information containers that are visible only to the actors working on them, 2) shared - information containers that have been checked and approved for sharing with other actors in the project, 3) published - information containers accepted by the client, and 4) archive - information containers stored after the project.

The CDE is both a process and technological solution. It is important to first clearly define the guiding process and then to search for technical solution that supports it. It is the role of the appointing party to define and set up CDE. Often, one technical solution will not satisfy all requirements and in large projects the use of multiple CDEs can be expected. To support seamless transition of data between different

CDEs, a building Smart is developing OpenCDE Documents API standard, /32/.

According to ISO 19650-1 /27/, at the end of the project information containers in the CDE should be reviewed and those that fit that purpose should be translated into the asset information model, and the rest should be archived. At the moment it is the manual process that assumes that each information container is opened and reviewed in native application. The ISO 21597 series of standards provides a solution for automation of this process. It generally provides a solution for easier information exchange in all circumstances where it is necessary to exchange multiple documents and their relationships. The part 1 of the standard /33/ defines a container format consisting of a header file and optional link files that define the relationships between documents or elements within them. The information in the header and link files are defined using the semantic web standards. The part 2 /34/ defines the further specialization of the generic connection types listed in ISO 21597-1 by adding common connection types that allow inclusion of additional information that enables human understanding.

FUTURE DEVELOPMENT

The process of standardization of various aspects of the use of digitized information in the AECO sector is in constant progress.

The IFC expands domains that it covers and includes an increasing number of infrastructure systems like road, rail, bridge, and tunnel. Since all these domains heavily rely on the digital representation of terrain, IFC also expands its ability to represent geospatial information. Also, the need for a broader understanding of the structure of the data model itself has been recognized so that one of the goals for IFC4 is improvement of readability and ease of access to the documentation /35/. Plans for IFC5 are much more ambitious /36/. The development of new domains has led to the introduction of many new classes and ways of representing geometry which made the already intricate data model even more complex. On the other hand, it is clear that in the current model only certain parts are used intensively, while there are parts that are extremely rarely used. Therefore, a modular architecture is envisaged for the IFC5 model. It is also envisaged that the modelling language and implementation techniques will be updated and aligned with modern methods.

The new version of the 12006-3 standard which includes aspects of data dictionary management is adopted and in the process of publishing.

Due to the growing demand for the support of specific BIM use cases, ISO 29481-3/37/ is being developed, which enables the representation of IDM in a computer interpretable way.

The set of ISO 19650 standards is expanding with parts 4 and 6. The part 4 of the standard /38/ describes process and criteria for the information exchange based on information containers that have proper identifier and metadata and are stored in CDE. The part 6 /39/ is going to specify how information on health and safety is going to be integrated with other information and managed in CDE.

An Information Delivery Specification (IDS) /40/ is the computer interpretable version of the exchange information requirements (EIR). It enables information requirements to be generated in applications according to the levels of information need, automatically verified against software capabilities, linked to the external information resources (data dictionaries) and enables automatic verification of the results of the information production against information requirements.

The Semantic Web is long standing project of the World Wide Web Consortium (W3C) with the goal of developing Web of data (Linked Data) based on neutral common format to represent data on the Web and technologies to access the data /41/, enabling all data stored on the web to be linked in one global network. The EN 17632 standard /42/ defines ways how to use Semantic Web and Linked Data technologies in AECO sector in order to enable all data in AECO sector to be findable, accessible, interoperable end reusable (FAIR) and vendor neutral. It does not replace any of existing data models, but provides additional level of interoperability. The standard specifies data model, data language, and linking approach for interlinking data sets.

The EN 17549-1 standard /43/ considers digitization of AECO information down the whole supply chain. It defines the structure to exchange construction product data using the specific IFC MVD (construction objects data view). The standard enables implementation of catalogues of configured construction objects based on data templates as they are defined in ISO 23387 and data sheets with actual data on building products with all properties authored and maintained according to ISO 23386.

CONCLUSION

Today, BIM is the basic technology used to create AECO models and documentation. It completely dominates in the development of architectural, engineering and MEP models and plans. With the advent of numerous 4D and 5D applications, BIM technology is gaining ground in the field of construction planning and budgeting and financial forecasting. BIM is increasingly becoming the basis for designing energy efficient and sustainable buildings, /44/. An increasing number of applications for facility management and building operation monitoring also support the use of information from the BIM system. BIM has also led to the emergence of disciplines that were not possible before, such as clash detection, but also to tasks that are a consequence of the still inconsistent view of the nature of the BIM model, such as the model checking.

From the beginning, the application of information technology in the AECO sector has been based on standards /45/ but mainly with a focus on the development of data structures with the assumption that only technical solutions will contribute to successful digital cooperation in the AECO sector. Later, the focus of standardization was extended to the ways of applying these technologies.

Today we can witness that there is a widespread recognition of the importance of information. In many standards we can see echoes of the 'seven elements of circumstance' through differently structured requirements that information

in addition to the appropriate structure must also satisfy conditions of why, where, when, what, who, and how. It is assumed that the correct definition of these conditions and the ability to process these requirements by computer will lead to better collaboration, data alignment, transparency, automation of tedious tasks. Standards are seen as the needed way to provide trust in technology.

Numerous standards that regulate the field of BIM technologies today are an exceptional contribution to the digital transformation of the AECO sector. However, if understood only as an obligation to be fulfilled, it will only be an additional administrative task. Therefore, it is very important that all participants in the process understand the role of information in BIM technologies and the ways in which standards regulate their structuring and use.

Digital transformation of AECO sector gradually removes information structures on which all stakeholders relied for centuries, and which allowed them to feel safe and have confidence in the information obtained. Because what we think information is, shapes how we use it, a clear understanding of new standardized digital information structures is imperative for their successful use. And since people are practice oriented and learn by doing, it will also determine the level of trust they will have in the new way of expressing and transmitting information.

It should be understood that standardized digital information structures represent a new way of expressing, exchanging and using information. A new language is used in the digitized AECO sector whose goal is not to create models that meet predefined requirements, but to develop more successful AECO practices and cooperative work on creating better buildings and infrastructure facilities that benefit people. The digitally transformed AECO sector serves people who in new way share trustworthy information in order to create a better built environment for people.

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