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Chapter

The Data Representations of a Building Project: BIM Model, and IFC or IFCXML Data Standard

Murat Aydın

Abstract

Building regulations in the construction industry are legal documents written in human language. These are interpreted and implemented by people and generally controlled by local governments. Traditional building regulation control and supervision methods emerge as a time-consuming and error-prone process for architects, engineers, and public authorities. Therefore, BIM's effective building regulation control is considered a promising field of study in the construction industry. Automated Code Compliance Checking (ACCC) method is a rule-based method that provides simultaneous control of the computer's building regulations. ACCC takes into account the characteristics of the building elements and related building regulations. BIM is recognized as the most effective platform for information exchange of building projects in the construction industry. It supports the development of various software. It facilitates automated or semi-automated ACCC of the building projects for compliance with building regulations and standards for the participants involved in the building production process. The data of the building project are represented in two ways in the ACCC. These are BIM Model, and IFC or IFCXML Data Standard. In this study, the BIM, IFC, and IFCXML representations of the building project data were explained over the sample housing project in the ACCC process.

Keywords: BIM, IFC, IFCXML, housing project, automated code compliance checking

1. Introduction

Significant advances have been made in building design and construction with technology development in the construction industry. Before constructing the building project, which was drawn on paper, scale physical models are created following the building design through the developing technology. Better quality buildings are started to be built in less time and cost than planned with these models. The use of BIM (Building Information Modeling) for the physical models has been an essential

step for building designs in the construction industry before starting the construction of building projects. There has also been an increase in the use of information technologies with BIM, such as saving data, exchanging data, and verifying the conformity of data according to building regulations among the building project life cycle. Optimum solutions have begun to be obtained with informatics to facilitate the creation, transformation, and use of information to increase the automation of paper-based manually controlled processes in the construction industry [1–4].

Building regulations in the construction industry are legal documents written in human language. These are interpreted and implemented by people and are generally controlled by local governments. Traditional building regulation control and supervision methods emerge as a time-consuming and error-prone process for architects, engineers, and public authorities [5–7]. Therefore, BIM's effective building regulation control is considered a promising field of study in the construction industry. Automated Code Compliance Checking (ACCC) method is a rule-based method that provides simultaneous control of the computer's building regulations. ACCC takes into account the characteristics of the building elements and related building regulations. In this method, each building element is checked for compliance with the rules and conditions of the relevant building regulation. Then, it creates a result report related to the building elements [8–10]. Shortly, ACCC is the answer to how the computer can interpret the building regulations, the computer can create the building regulation rules, and the automated code compliance checking of the building project can be controlled by the computer according to the building regulations [11].

2. Method

BIM is recognized as the most effective platform for information exchange on building projects in the construction industry. It supports the development of various software. It facilitates automated or semi-automated ACCC of the building projects for compliance with building regulations and standards for the participants (designer, architect, engineer, contractor, owner, etc.) involved in the building production process. The data of the building project are represented in two ways in the ACCC [12]. These are:

- BIM Model, and

- IFC or IFCXML Data Standard.

2.1 BIM model

Building Information Modeling (BIM) is a simulation prototyping technology. The definition of the BIM and BIM model according to the US National BIM Standard is "BIM is the digital representation of the physical and functional characteristics of a building project. The BIM model is a reliable source of information where information is shared from conceptual design to demolition of the building project throughout the building project life cycle [13]." BIM, one of the most critical developments in the construction industry, emerges as a technology that enables the management of the building project data in a digital environment by incorporating different tools and

processes into the building design. It is based on the building elements that form the building project. It models the relationships of the building elements with each other. Supporting interdisciplinary integration in the construction industry, BIM effectively changes its role in building design and construction by creating a database of the building elements used throughout the building project life cycle [14, 15].

2.2 IFC data standard

Industry Foundation Classes (IFC) data standard, a new industry foundation class for interoperability, was created by the Industry Alliance for Interoperability (IAI) in 1997 [16]. IFC is an object-oriented data standard developed in the EXPRESS language, and it is independent of any software [17]. IFC is supported by BIM-based software. Therefore, it is accepted that BIM and IFC data standards will significantly advance and facilitate cooperation in the building design process. IFC provides users with comprehensive information and features about the building project. It also represents international standardized object definitions [18]. Objects are also named as the building elements in the building project. The most important feature of the IFC data standard is its rich data structure that allows a building element to be defined by more than one feature. The IFC standard data is divided into different building elements such as the wall, column, beam, floor, window, door, railing, elevator, stair, etc. These building elements have a three-dimensional geometry and parameters, which can be divided into size, material, property, price, quantity, etc.

2.3 IFCXML data standard

IFCXML is a language defined in XML, equivalent to the EXPRESS-based specification of IFC data. The implementation of the IFC data standard using XML is named IFCXML. IFCXML is the ".ifcxml" extension of the current IFC data format. It is an implementation of the ISO 10303-28 standard [18]. This standard provides an automatic conversion feature from IFC's EXPRESS language to an XML language. By representing IFC data in XML language, users can perform many operations such as extracting, transferring, using, and merging IFC data between various applications. The IFCXML representation provides for ease of understanding classes in IFC along with sub-classes. This feature simplifies the use of IFC by reducing the complexity of IFC data. Due to the XML feature, the IFCXML file size is larger than the IFC file size (approximately five times).

3. Sample housing project

In this study, a sample housing project was prepared for the BIM, IFC, and IFCXML representation of the building project data in the ACCC process. The sample housing project consisted of 9 floors, 8 flats, and 2 elevators. Flat plans on each floor were modeled differently from each other. It was completed with 179 rooms, 91 doors, 66 windows, 52 railings, 2 mechanical ventilation, 2 elevators, 8 stairs, 92 walls, 135 columns, 183 beams, and 95 slabs. As shown in **Figure 1**, the procedure for creating the sample housing project with ArchiCAD software are as follows:

- Creating a new building project,

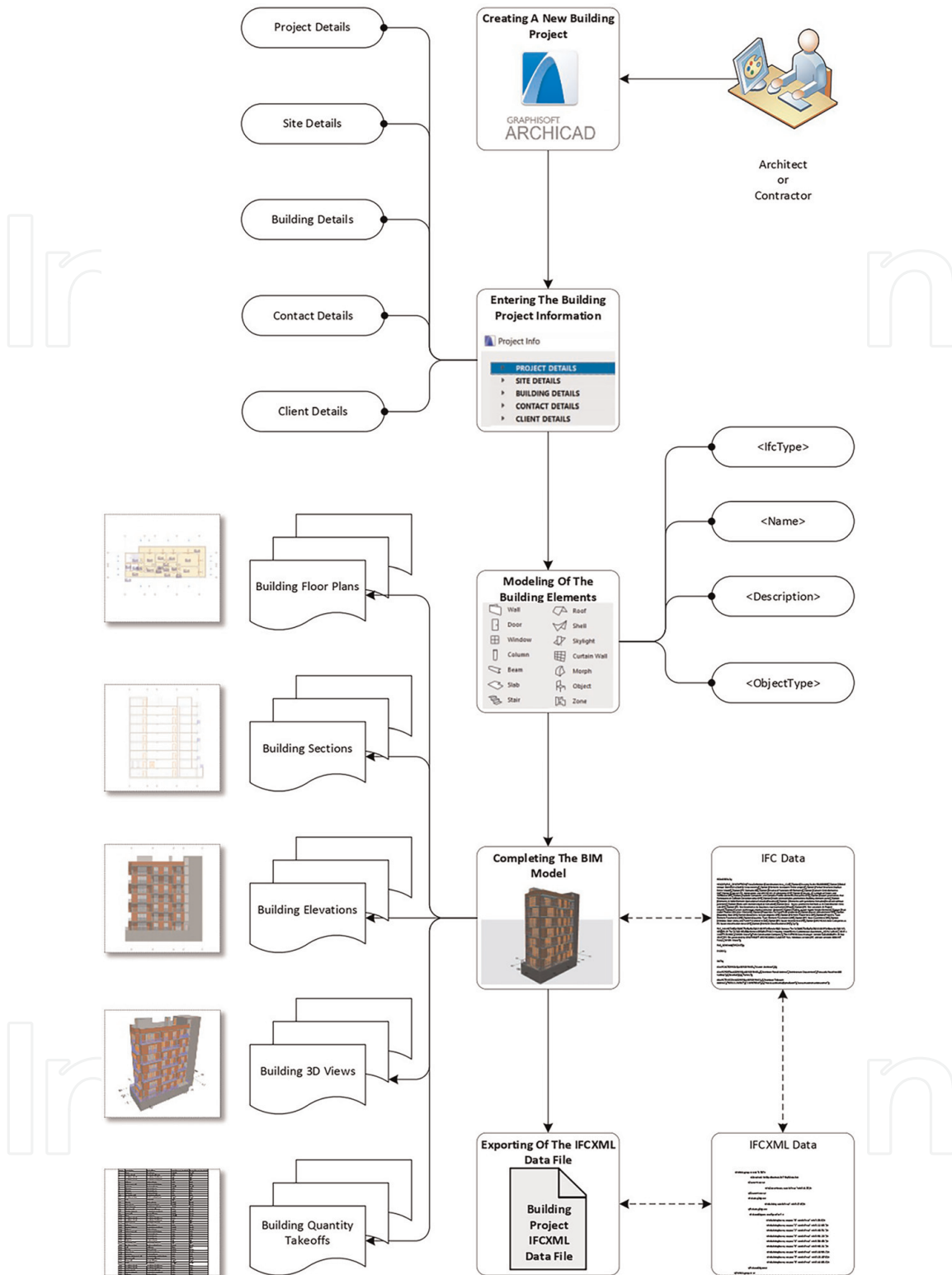- Entering the building project information,

Figure 1.
The procedures in creating the sample housing project with ArchiCAD software [19].

- Modeling of the building elements,

- Completing the BIM model, and

- Exporting of the IFCXML data file.

3.1 Creating a new building project

As shown in **Figure 2**, a new building project named "Sample Housing Project" was created by clicking the New sub-menu under the File menu in ArchiCAD. The default template set was selected for the template option of the new building project in ArchiCAD. First, the working unit settings were set in the sample housing project. "1/50" for the scale unit, "cm" for the length measurement unit, "m2" for the area measurement unit, and "m3" for the volume measurement unit was selected in the working unit settings in ArchiCAD. After the working unit settings were set, the sample housing project's floor information was named respectively -1. Floor, 0. Ground Floor, 1. Floor, 2. Floor, 3. Floor, 4. Floor, 5. Floor, 6. Floor and 7. Floor.

3.2 Entering the building project information

As shown in **Figure 3**, the Project Info option in the Info sub-menu under the File menu in ArchiCAD was selected to add the sample housing project's project information. The project information was entered under five headings on the Project Info page automatically provided by ArchiCAD software. These headings are detailed below:

- Project details,

- Site details,

- Building details,

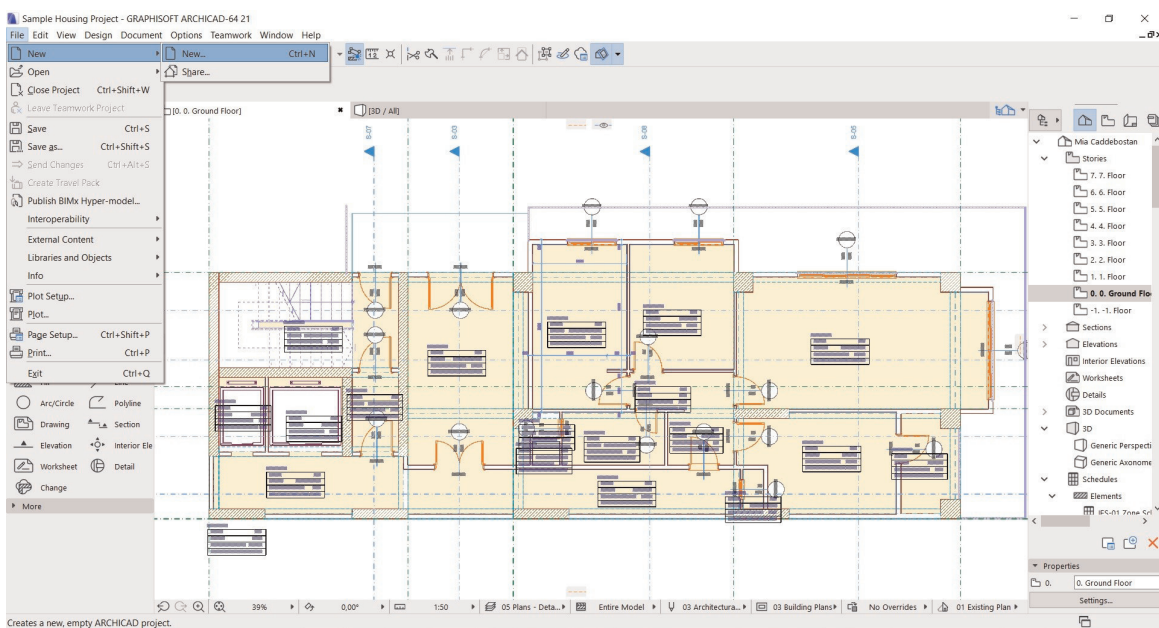- Contact details, and

- Client details.

Figure 2.
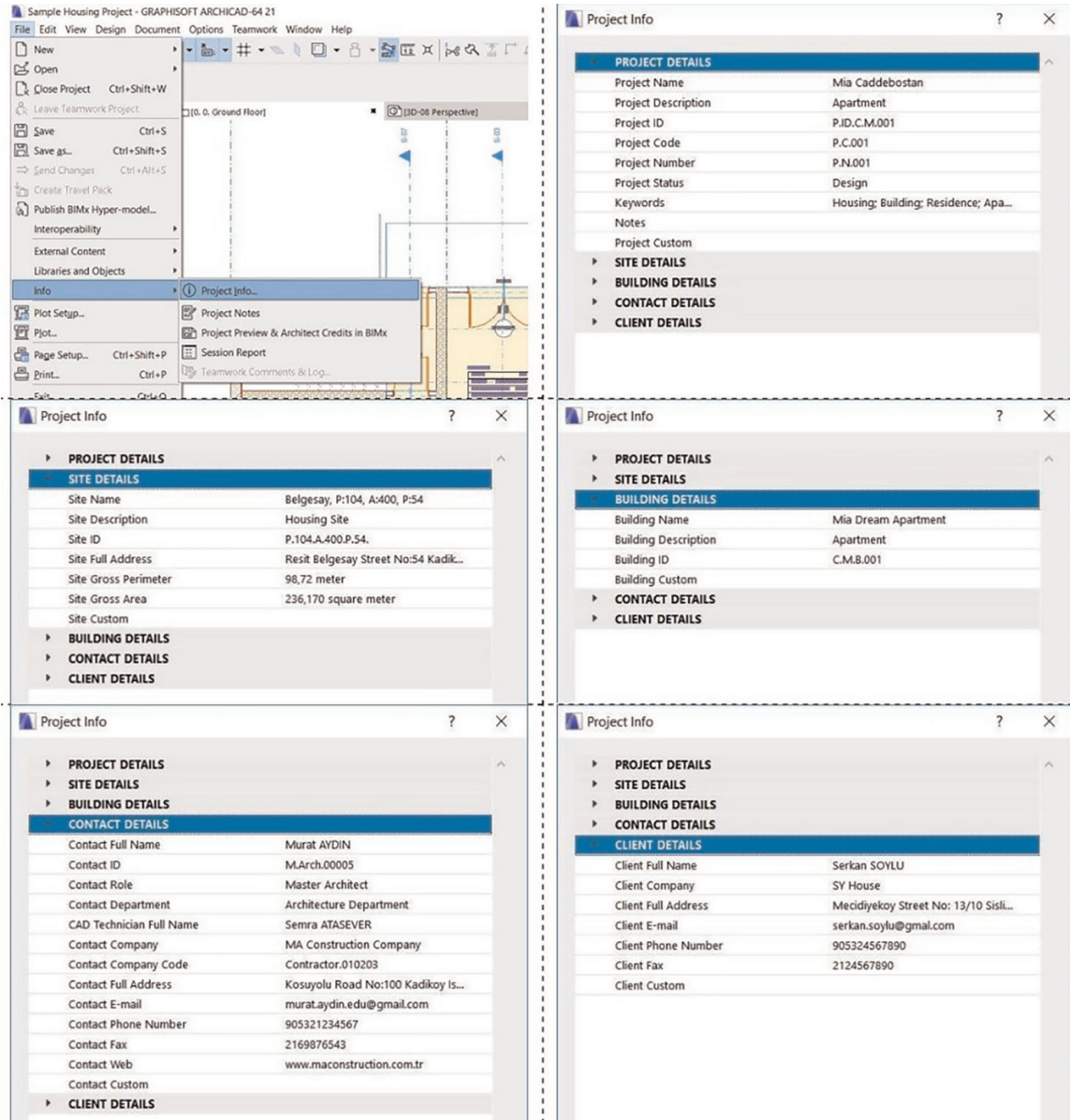*Creating a new housing project in ArchiCAD.*

Figure 3.
Entering the project information of the sample housing project.

3.3 Modeling of the building elements

For the sample housing project's BIM model, different types of building elements such as room, door, window, railing, mechanical ventilation, elevator, stair, wall, column, beam, and slab were modeled. To create the BIM model, the reinforced concrete structure of the project was completed with columns, beams, and slabs of appropriate sizes. Later, the rooms were determined with walls following the project. Doors and windows were placed in the holes opened into the walls. Stairs and elevators connecting all floors were formed under the project. Finally, the safety of stairs, windows, doors, and balconies was provided with railings in appropriate sizes. Toolbox in ArchiCAD interface was used for modeling the selected building elements. Unlike the others, Zone (Space) was chosen for a room from the Toolbox.

As shown in **Figure 4**, the <IfcType> and <Name> attributes of the building elements were assigned automatically by ArchiCAD. The <IfcType> attribute is not

allowed to be changed by the user. However, the <Name> attribute can be changed by the user if required. ArchiCAD gave the <Name> attribute of the building element by automatically associating it with the floor name and sequence number. For example, WD – 003 Living Room Window shown in **Figure 4** is the third window ('WD' – 0'03') on the ground floor (WD – '0'03) of the sample housing project. That is why it

Ground Floor 3D View (IfcSpace Labels)

Ground Floor 3D View (IfcDoor, IfcWindow, IfcRailing, IfcBuildingElementProxy, IfcTransportElement, IfcStair, IfcWallStandartCase, IfcColumn, IfcBeam and IfcSlab Labels)
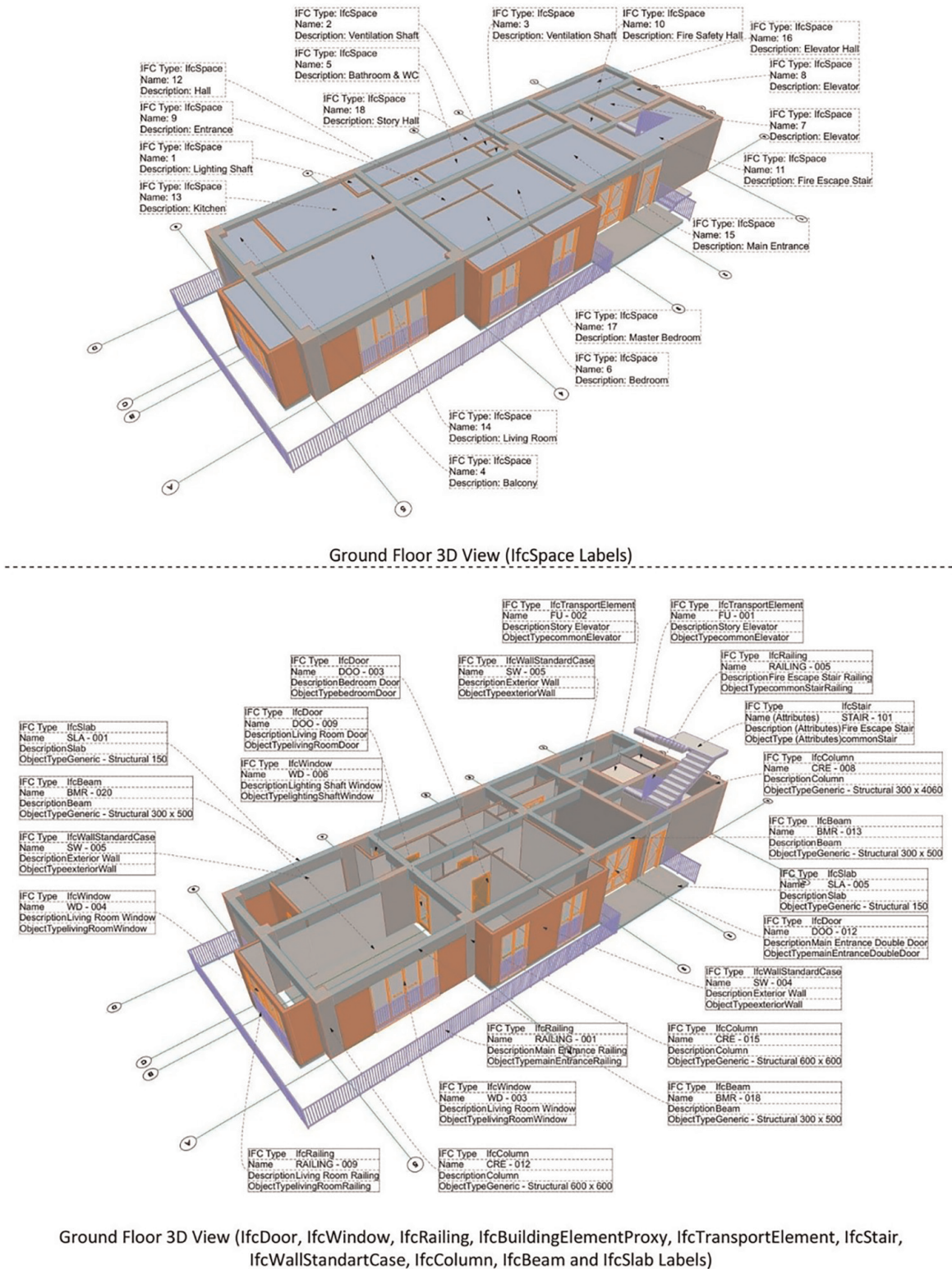
Figure 4.
The representation of the IFC data file of the sample housing project (the building elements on the ground floor with IFC labels).

is named WD – 003. The <Description> and <ObjectType> attributes of the building elements were entered by the user. The <Description> attribute is the appropriate selection of the relevant building element for the room to which it is associated. On the other hand, the <ObjectType> attribute is the programming language equivalent of selecting the relevant building element, which is appropriate for the room to which it is associated.

An example of the building elements whose four attributes were defined with the IFC labels was shown in **Figure 4**. Three-dimensional views of the building elements on the ground floor were automatically prepared with ArchiCAD. The building elements were shown with the <IfcType>, <Name>, <Description>, and <ObjectType> attributes in **Figure 4**. The room (space) labels of the building elements on the BIM model's ground floor were shown in the top view. The window, railing, mechanical ventilation, elevator, stair, wall, column, beam, and slab labels of the building elements on the BIM model's ground floor were shown in the bottom view.

3.4 Completing the BIM model

In this study, the working unit settings were set first. Then, the floor information of the sample housing project was named. The project information was entered under five headings; different types of building elements were modeled. Thus, the BIM model of the sample housing project was completed with all these procedures. The
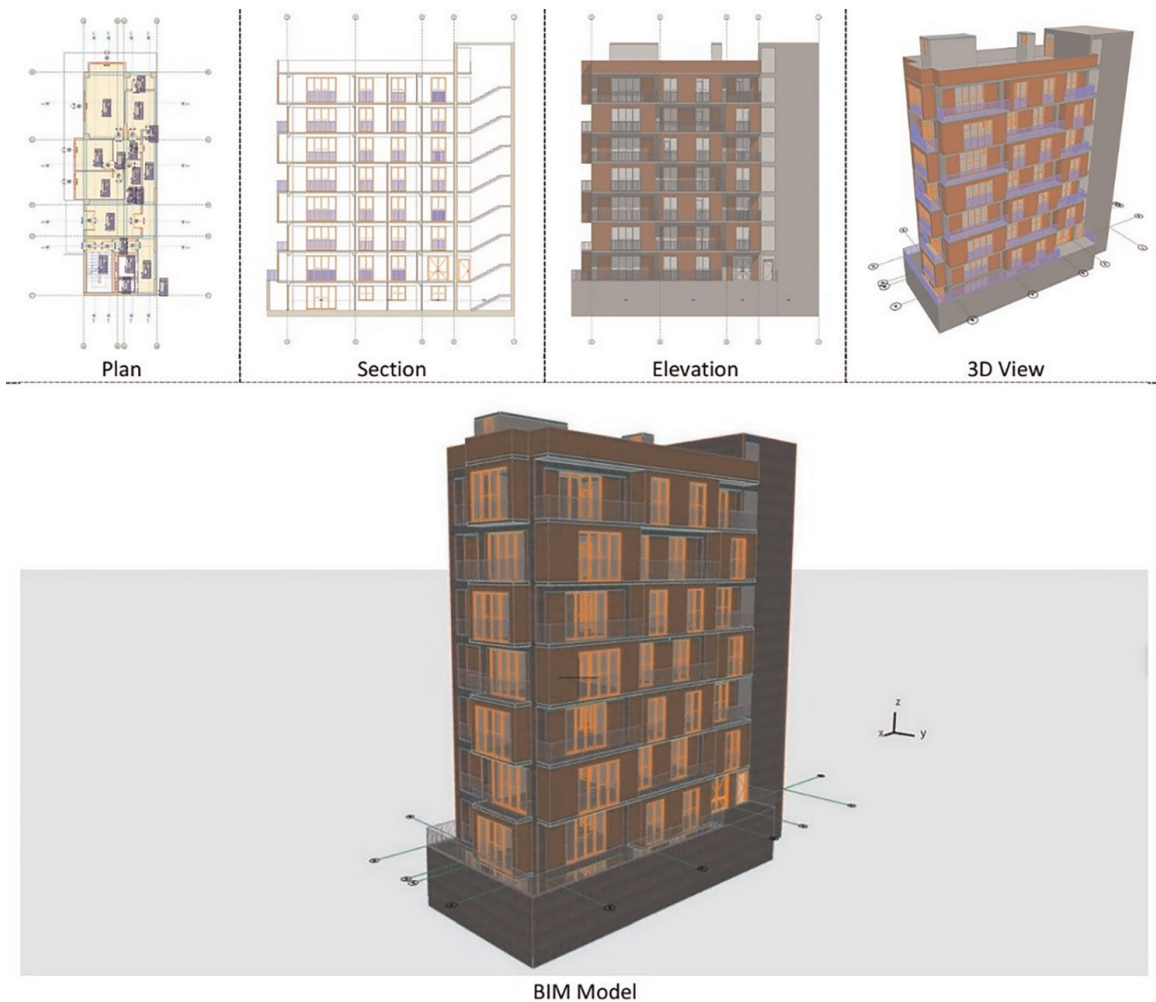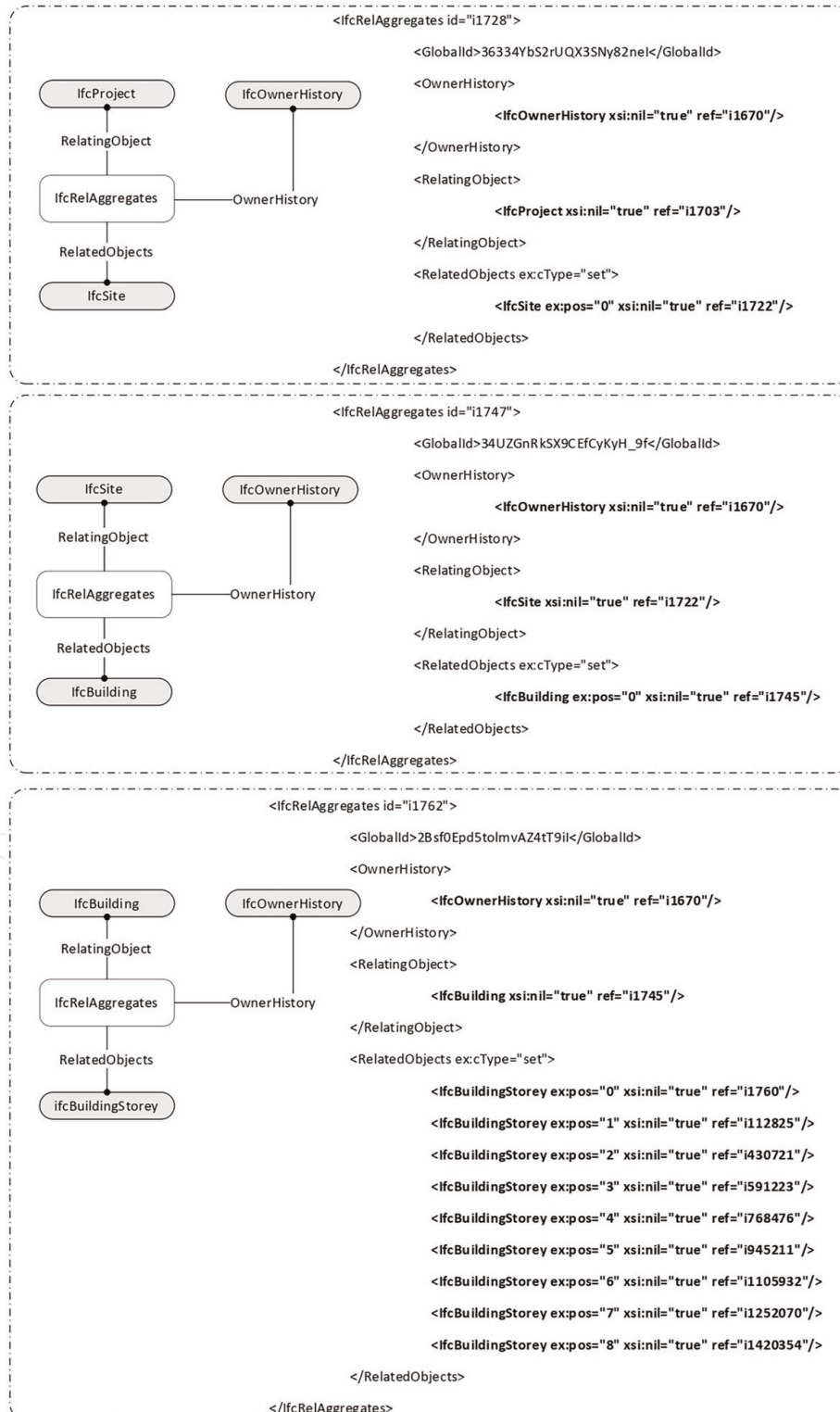

Figure 5.
The representation of the BIM model of the sample housing project.

BIM model consisted of 9 floors, 8 flats, and 2 elevators. Except for the 7. Floor, which was shaped as a terrace, each floor was designed as one flat. Apart from the vertical circulation, mechanical ventilation, and installation spaces, each floor's flat plans were formed differently from the others. Finally, the representation of the sample housing project's BIM model was shown as a three-dimensional view in **Figure 5**.

As seen in **Figure 5**, the sample housing project's project documents were automatically prepared with ArchiCAD software. The project documents of the project were printed with the default publisher settings in ArchiCAD. These are:

- Building floor plans,

- Building sections,

- Building elevations,

- Building 3D views, and

- Building quantity takeoffs.

3.5 Exporting the IFCXML data file

The IFCXML data file was exported with the completion of the BIM model of the sample housing project. The Save As Type option was selected as IFCXML, and the Export option was selected as Entire Project by clicking the Save As sub-menu under the File menu in ArchiCAD. After selection, the IFCXML data file of the sample housing project was exported. The first page of the IFCXML data file consisting of approximately 5.700.000 strings is shown in **Figure 6**.

In IFCXML, the data starts with the "Ifc" prefix, just like in the IFC data representation. According to the CamelCase naming convention, the first letters are

Figure 6.
The representation of the IFCXML data file of the sample housing project.

capitalized, and English words are without underlines. The word must be shown in a string ($< \ldots >$). Each class has an ID number in a string. ID number is given mainly for each class, and it is specified in the string with ref = " … ". ID numbers are required to provide, clarify and verify relationships between classes. The logical relationship between IfcProject and IfcBuildingStorey of the sample housing project is shown in the IFCXML language in **Figure 7**.

A superclass matches one or more subclasses with $<$IfcRelAggregates$>$ in IFCXML. The superclass is specified with $<$RelatingObject$>$ and its number is always one. Therefore, it is not represented by the ex: pos = " … " number. Subclasses or classes are
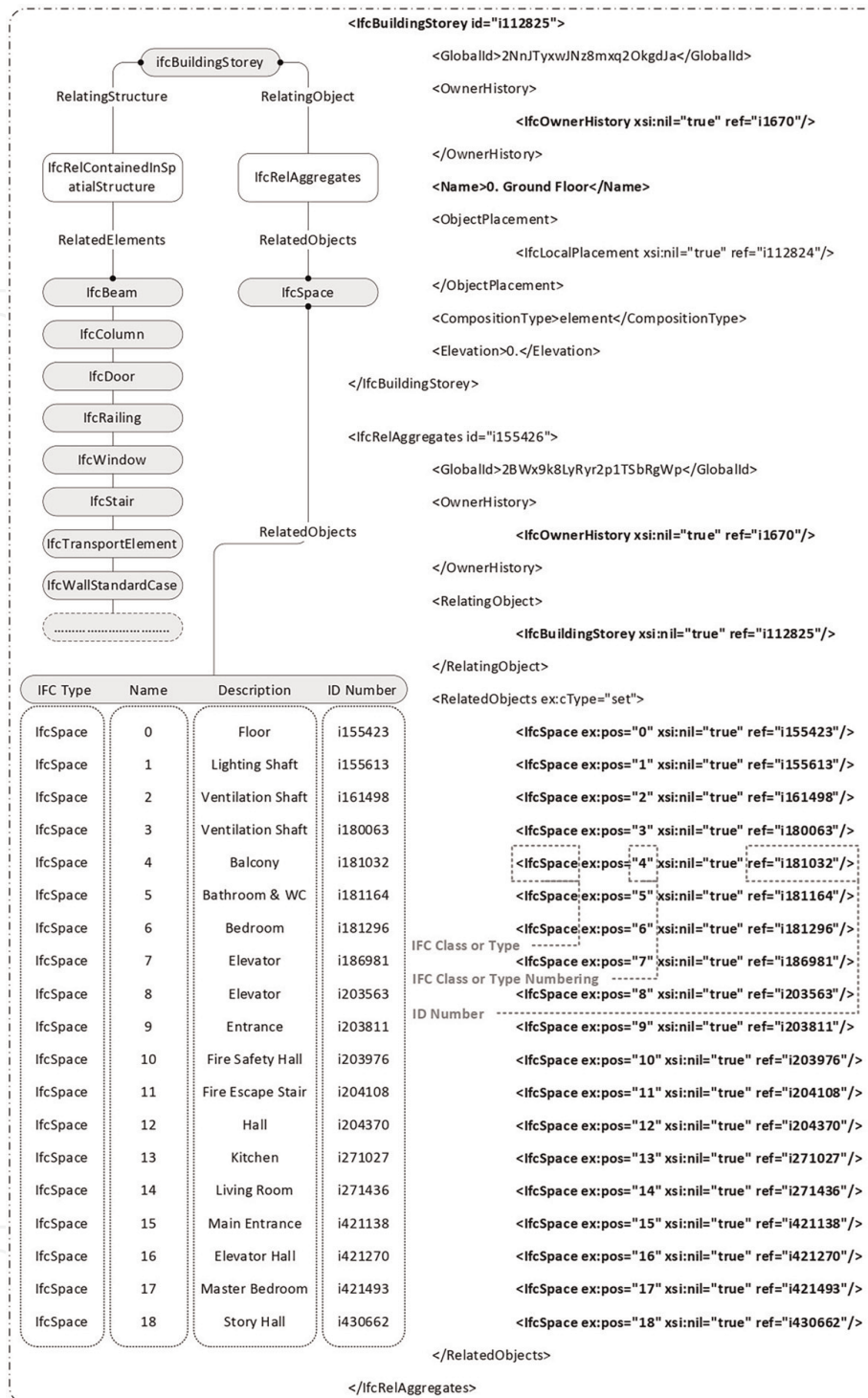
Figure 7.
The representation of the IFC class, the IFC class sorting, and ID number in IFCXML.

sorted with <RelatedObjects>. If there is more than one subclass, they are sorted by sequence number in the string like ex: pos = "0", ex: pos = "1", ex: pos = "2", etc. <RelatingObject> and <RelatedObjects> are always linked to <IfcOwnerHistory>. An <IfcRelAggregates> is used to sort and present all these relationships. An example of sorting subclasses in strings in IFC is shown in **Figure 7**.

An example of a hierarchical scheme of the IFC is shown in **Figure 7**. The abbreviations of the IFC data are given according to the IFC standard in **Figure 4**. The first equivalent of the sample housing project is IfcProject in IFC data. The logical

relationships between IfcProject - IfcSite, IfcSite - IfcBuilding, and IfcBuilding - IfcBuildingStorey are provided IfcRelAggregates. IfcRelAggregates is where the data is sorted between the two IFC types. Since this data belongs to the building project, IfcRelAggregates is always linked to the IfcOwnerHistory representing the project owner. IfcRelAggregates makes the previous IFC type's logical relationship with RelatingObject and the next IFC type with RelatedObjects.

IfcProject contains necessary information about the building project. The IfcProject number must be one because the BIM model always represents a building project number. On the contrary, it is not possible to mention IFC for situations other than this. IfcSite contains information about the site, area, or plot on which the building project will be built. The building project can be built on more than one site. Therefore, the number of IFC types can be more than one except IfcProject. IfcBuilding involves the information of the building or buildings included in the building project. On the other hand, IfcBuildingStorey gives each floor information by sorting the number of floors in the building project. Finally, the information of building elements named IfcBuildingElement is listed.

The list of building elements included in the building project is put in order in two ways:

- IfcSpace represents a building element such as a room, space, or zone. IfcRelAggregates provide the logical relationship between IfcSpace and IfcBuildingStorey. All IfcSpace(s) are listed here via IfcRelAggregates.

- IfcBuildingElement represents all building elements except IfcSpace in IFC. The logical relationship between IfcBuildingElement and IfcBuildingStorey is provided by IfcRelContainedInSpatialStructure. Apart from IfcSpace, all other building elements such as IfcBeam, IfcColumn, IfcRailing, IfcSlab, IfcStair, IfcDoor, and IfcWindow are listed here via IfcRelContainedInSpatialStructure.

4. Conclusion

In this study, the BIM, IFC, and IFCXML representations of the building project data were explained over the sample housing project in the ACCC process. The sample housing project consisted of 9 floors, 8 flats, and 2 elevators. Flat plans on each floor were modeled differently from each other. It was completed with 179 rooms, 91 doors, 66 windows, 52 railings, 2 mechanical ventilation, 2 elevators, 8 stairs, 92 walls, 135 columns, 183 beams, and 95 slabs. The procedures to create the sample housing project with ArchiCAD software were described, respectively. The four attributes of the building elements of the sample housing project were defined with the IFC labels. The BIM model of the sample housing project was modeled. Finally, the IFCXML data file of the sample housing project was exported.

Before exporting to the IFCXML data file, all information regarding the building project must be modeled appropriately. When the BIM model is transformed into an IFC or IFCXML data file, building elements can be translated into the relevant IFC types. Transforming a building model into an IFC or IFCXML data file also provides the detailed information required for automated code compliance checking. This convenience allows the building regulation control, which the traditional method implements, to be controlled by the computer. It also brings the advantage that the building regulation control is checked over the IFC data file where the BIM model is

exported, not on paper-based manually. This advantage is realized only in information technology systems and databases.

The IFC data standard is currently being developed, updated, and maintained by buildingSMART International [18]. buildingSMART develops open standards for BIM and openBIM. These open standards are related to data models, processes, and terms. Feature terms defined in the IFC specification depend on the terms defined in the buildingSMART data dictionary. buildingSMART collaborates with ISO to develop international, regional, and national standards. Today, when global standards are being accepted as national standards, both financial and technical support are provided to innovative studies in the field of automated code compliance checking by buildingSMART [20]. It is aimed to achieve the following objectives by buildingSMART:

- Developing and maintaining international standards for BIM such as IFC, IFCXML,

- Increasing the use of automated code compliance checking in building projects according to the building regulations,

- Providing low-cost data sharing and exchange, and

- Spreading and accelerating the use of buildingSMART technology throughout the building project life cycle in the construction industry.

Conflict of interest

The author declares no conflict of interest.

Notes/thanks/other declarations

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