Article

Not peer-reviewed version

Semantic Enrichment of Non-graphical Data of a BIM Model of a Public Building from the Perspective of the Facility Manager

Andrzej Szymon Borkowski * and Marta Maroń

Posted Date: 25 July 2024

doi: 10.20944/preprints202407.1975.v1

Keywords: semantic enrichment; non-graphical data; management; building information modeling (BIM); model; Industry Foundation Classes (IFC)

Article

Semantic Enrichment of Non-Graphical Data of a BIM Model of a Public Building from the Perspective of the Facility Manager

Andrzej Szymon Borkowski [1,*] and Marta Maroń [2]

[1] Faculty of Geodesy and Cartography, Warsaw University of Technology, 00-661 Warsaw, Poland; andrzej.borkowski@pw.edu.pl
[2] Faculty of Geodesy and Cartography, Warsaw University of Technology, 00-661 Warsaw, Poland
* Correspondence: andrzej.borkowski@pw.edu.pl

Abstract: Building Information Modeling (BIM) is undeniably the most important trend in the digitization of the construction sector in recent years. BIM models currently being built are extremely geometrically rich, that is, they are modeled at a high level of detail in terms of geometry. Thanks to object-oriented programming paradigms, BIM models include high-level relationships to ensure interactions between objects, rapid view generation and documentation. However, these models are not always equally rich in non-graphical data. This is true for parameters at the library object level, with which building object models are saturated, but also at the project, site, building or floor level according to the structure of the interoperable Industry Foundation Classes (IFC) format. For this reason, experimental work was undertaken on semantic enrichment in non-graphical data of a public building (Public Kindergarten, Secemin, Poland), which has its BIM model at a high level of geometric detail but is poor in non-graphical data. As a result of the research and development work, all levels of the IFC structure were saturated with non-graphical data, validated, and the possibilities of their use were shown from the perspective of the facility manager. The article contributes to the discussion on semantic enrichment from CAD3D to BIM by presenting a detailed process for entering non-graphical data into a BIM model.

Keywords: semantic enrichment; non-graphical data; management; building information modeling (BIM); model; Industry Foundation Classes (IFC)

1. Introduction

When working on the construction of a building, contracts, certificates and other documents are issued, to which there should be constant and easy access for participants in the investment process. Often such documentation is kept in paper form, and this results in the fact that at some point it may be overlooked, for example, in the building management phase [1]. Therefore, it is important to implement BIM (Building Information Modeling) in the design and during the implementation of the investment, to have full access to geometric data, which presents the visual part of a given building, as well as insight into non-graphical data, which plays an important role, especially at the stage of maintenance and upkeep of the building object. Unfortunately, the aspect related to enriching BIM models with non-graphical data is consistently overlooked or neglected. Inaccurate and erroneously entered parameters can result in the accumulation of many problems, which consequently lead to a re-examination of the construction object. This usually results in additional financial costs on the part of the owner/manager. It should be borne in mind that today's buildings, especially public facilities, require very advanced and precise management due to the fact that they are among the places where people permanently or temporarily reside. The use of BIM in this case allows for effective management of such buildings, and access to all the most necessary and up-to-date data, especially non-graphical data, provides increased safety and comfort for users [2].

Wang, Sacks, Ouyang, Ying and Borrmann present the possibilities for semantic enrichment of BIM models using multiple applications and novel techniques [3]. The developed semantic enrichment processes enable effective management of construction resources. The aforementioned study also uses a modern approach that allows for the integration of different programs, thus improving interoperability issues. Semantic enrichment is an essential process that adds new values such as geometric, non-geometric and topological information to existing models to enable multidisciplinary applications in fields such as construction, management or urban planning [4]. Although considered a relatively new area of research, semantic enrichment and semantic web services are among the most important topics and trends in BIM application research [5]. Difficult automatic and semi-automatic methods are presented in the prescriptive and gray literature. Practitioners and innovators in the market report the need for simple, manual methods to saturate BIM models especially in the operation phase, which is dynamic and the changes that occur in it imply further changes to the BIM model, which according to the idea should be up to date.

For this purpose, innovative experimental work was undertaken with the BIM model of a public facility - a Public Kindergarten in the municipality of Secemin (Poland). The facility has a geometrically very detailed BIM model, which is poor in non-graphical data at all levels of the Industry Foundation Classes (IFC) structure. The model is saturated from the highest level - design, to the lowest level - library objects. Thanks to the data at multiple levels, it is possible to generate a number of statements necessary for property management. In addition, thanks to the data entered, it is possible to analyze or simulate events and phenomena. For this purpose, some tests were carried out - evacuation simulation, equipment analysis, etc. The purpose of the study was also to present the current state of the art in semantic enrichment in the BIM environment.

2. Semantic Richness of BIM

2.1. Definition of Semantics and Enrichment

Building Information Modeling (BIM) is a key aspect in digitization and thus brings great value to planning, design, construction, operation and all processes throughout the building lifecycle. Despite various initiatives to promote the BIM methodology, it requires continuous improvement and further development in order to be fully integrated and to be based on collaborative opportunities between involved and interested stakeholders. Among the whole range of applications of BIM, semantics can be distinguished, which is derived from various sources, databases and rule sets that provide access to the information of individual models [6]. Thus, the stakeholder involved should be able to search the BIM model for all relevant information, and perhaps provide comments that are more relevant from his point of view. A BIM model can be colloquially understood as a semantic database of a building object [7]. Semantics (i.e. geometry, topology and meaning), which is the foundation of BIM, facilitates things that CAD (Computer Aided Design) is unable to do.

The expression "enrichment," on the other hand, can be defined as the process of improving the quality or power of something by adding something else. Semantic enrichment, on the other hand, refers to a process that is related to and used for various operations in many fields. In the field of computer science, semantic enrichment is presented as one of the methods for ensuring interoperability between different databases. This process provides an opportunity, first of all, to provide the most important and necessary information about an entity without additional work. In reverse engineering of objects, semantic enrichment can be used in 3D reconstructions from a point cloud. One example of the use of semantic enrichment, for example, is the ability to process internal 3D point clouds to identify all building elements. In BIM, semantic enrichment is defined in several ways and by many researchers. One definition defines the phrase as a process that enables and aims to automate the processing and addition of all information [8]. It can also mean the process of adding missing or new information [9]. Another definition indicates that semantic enrichment refers to the process during which, new acquired information is automatically or semi-automatically added to given models using specific and specified techniques. One definition developed by Bloch and Sacks defines semantic enrichment as building object classifications, aggregation and clustering, uniquely identifying and filling in missing objects [10]. It can be concluded that semantic enrichment is an oriented process, as requirements are defined by the intended use of information. It is a means to ensure easy communication of construction-related information between different environments [8].

Semantic enrichment in BIM, for example, can be divided into two categories. One concerns individual model elements. In this case, semantic information can be organized in terms of geometric features, such as shape, location, or non-geometric features - types, functions, specifications. The other is semantic information about the relationships between components - neighborhood, hierarchy, inheritance, etc. [11]. Modern BIM tools, are constantly changing the way information about building objects is created, stored and exchanged, and thus guarantee a three-dimensional environment for designing models with geometry, alphanumeric data and semantics. However, it is important to consider that these tools constantly encounter misinterpretation of information that is not always clearly represented in the model. BIM models are often created from 2D documentation or point clouds, and the results are purely geometric. Thus, inadequate and insufficient semantics can affect the quality of the exchange of selected data in the first place and make it difficult or even impossible to use a number of solutions and applications that are used for building analysis [3]. The exchange of information during design work between several people involved in the project can face interoperability barriers. IFC is one of the most popular standards that are used to exchange geometric and topological information, which still suffers from the problem of information loss or distortion when it is exchanged between multiple applications. IFC's hierarchical structure: (i) project, (ii) site, (iii) building, (iv) building floor, (v) component, provides a degree of interoperability at the application or database level. However, the IFC schema, despite its rich and broad scope, still faces the challenge of increasing the level of semantics in models [10].

2.2. Importance of Non-Graphical Data

BIM is generally equated with a 3D model that contains the geometric data of an object. It is known that such a model significantly facilitates the work of designers and allows the introduction of newer and newer design possibilities. The 3D model is the key to effective design. On the other hand, in the construction process, non-graphical data are indispensable at the stage of construction and subsequent operation of the building object. The model can contain data, for example, on the cost of each element that is created on the construction site, as well as on the elements that are ready to be installed in the construction facility, or on equipment and fixtures. The model can also include information on the completion time of each individual construction stage or scheduled other activity [12]. Nowadays, it is becoming more and more common to experience the creation of any analysis to check the environmental impact of a construction facility during implementation, as well as during operation. This information is becoming paramount, and thanks to BIM models that are properly "data-enabled," we can have access to a huge amount of information, and thus the ability to monitor, for example, energy consumption, heat in the facility, calculate various types of energy indicators [13], or track and calculate the amount of carbon footprint that is produced in all scopes. It is important to note that there is a very large number of different types of information that is associated with a building in all phases of its life. Data is extremely important to manage effectively and efficiently. Therefore, to facilitate and systematize the data used, their categorization has been adopted [12]. The BIM model is extended by further dimensions and thus it is multidimensional and can include all specialized data. In addition to 3D modeling, BIM is also defined in other dimensions: 4D - data for delivery and construction schedules, 5D - data to develop cost estimates and budgets, 6D - data for sustainability, 7D - data to assist in facility management.

There is a huge amount of non-graphical information associated with every construction facility in operation. These can include manuals, warranties, inspections, certificates, information about materials. Users and owners of the facilities in question have always collected such data, as it is essential for effective management and operation. The data is usually stored in binders, CDs with PDF files, spreadsheets or files in other formats. It should be added that sometimes this data was not

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

collected and archived during the construction of a facility or other work related to upgrades or renovations but was only recreated when the need for it arose [12].

Among other things, the most important data includes the equipment of the building facility with a complete set of information about each item: technical parameters, origin, prices, product sheets, inspections, equipment warranties, maintenance plans, installation and inspection dates, lists of variable parts, etc. This is information that is of extraordinary value and essential for the use of a construction facility [14]. All data is linked to the objects in the 3D model and supplementary data. BIM models are not only used to transfer data to FM (Facility Management) systems but are also used to exchange information between different parties. The most important task is that any interested party should be able to obtain non-graphical data of the required scope and a certain level of detail, so that it corresponds to their expectations and the presented purposes of use: during the construction process, modernization, renovation or ongoing use [12].

By the irreplaceable role of non-graphical data in the model, it should be borne in mind that incomplete, fragmentary, outdated data can result in inefficient management, incomprehensible results, and wasted time or even money [15]. Non-graphical data should be updated and added to all the time to avoid confusion. Non-graphical data can play a significant role in space management of public facilities. With BIM, a summary of each room can be created, complete with data on the area, purpose, name of the room, number of equipment, furniture, toys, educational items located in each individual room. Such information gives an idea of the size of the space and provides an opportunity and opportunity to implement new ideas when managing [16]. Along with the above-mentioned parameters, each room can be supplemented with relevant data to control the occupancy of rooms such as teaching rooms. They can be used to control the space and be modified according to the occurrence of activity in the space. The data provided will allow to show information about the available number of seats. These parameters can be assigned based on the number of desks. By adding information about the characteristics of each room, a data sheet can be created to reflect the current state that each of the listed rooms is adequately equipped. The database can be based on information on, for example, manufacturers of equipment, furniture, certificates, materials from which the item was made, year of manufacture, place of manufacture, user manuals, warranties, contacts, etc. Staff managing the facility, will have an overview of the entire database, and thus will be able to react, prevent and, for example, replace obsolete items. The use of non-graphical data, in addition to being used for management inside, can also be used to manage elements outside the kindergarten, namely: playground components, vegetation, paving, landscaping elements, etc. All the information contained in the model, can be used for upgrades, renovations, inventories. Assigning the right parameters already during construction, will help reduce errors later. Sound technical knowledge related to data on building and finishing materials will allow sustainable development of materials. That is, access to non-graphical data during renovation or other work, will avoid the use of materials or components that are defective, have poor performance or are unsustainable [17].

When saturating non-graphical data, it is worth following FAIR's four basic postulates, and using standardized solutions wherever possible. Data should be findable, accessible, interoperable, and reusable. Inaccurate or outdated non-graphical data, such as costs, schedules, or even the properties of individual materials, can negatively affect the quality of the entire project, and thus lead to inefficient management. It is also important to make judicious use of the entire model with its wealth of non-graphical data. Sometimes adequate training is needed to meet the challenges of effective and sustainable BIM implementation in an organization [18].

2.3. Non-Graphic Data Saturation Levels

The detail of BIM models in terms of information should be minimal enough to achieve the specified goals. The use of variable detailing in individual models and components at a given stage is crucial in accomplishing the task. Levels of model detail determine the accuracy in mapping the object at each phase of design and implementation of a particular project. By this it should be understood that the detail refers to the graphical representation, but also to the saturation with non-graphical data of the design and individual model components [19]. Different geometric detailing can be used for each model and element - LOGD (Level of Graphical Development), or geometric LOD (Level of Development), and LOI/LOMI (Level of Information/Level of Model Information), or non-geometric LOD [20].

It is worth highlighting how information delivery planning affects the implementation of a project using the BIM methodology. According to the ISO 19650 standard, which quite accurately uses the previous achievements of the specification and standards of information delivery planning brings, however, a substantial reconstruction of the previous system. The standard does not use the term LOD/LOI but replaces it with the term Level of Information Need, and forbids abbreviating it. According to the Level of Information Need standard, it is not a classic metric like LOD or LOI. The standard specifies that the Level of Information Need has to be earned, and that means it has to be done by the customer or the developer. Ideally, it should be the clients who define their information requirements, behind before the project starts. In many cases, you will find that typical LOD metrics will be sufficient but note that every project is different. You may find that off-the-shelf standards won't meet the requirements, and this involves then describing your own standard. ISO 19650 describes that it is up to the contracting authority to make the effort and determine what information it needs. One of the primary goals of defining the level of information needed, in the first place, is not to provide too much information [21].

The level of saturation of non-graphical data can refer to the quantity as well as the quality of data. This is all the information that is used to comprehensively manage a building facility. Throughout the life cycle of a building, data is collected, the volume of which should increase after each stage of work. At the very beginning, the data that pertains to the building/building/infrastructure facility itself should be identified. The identified data is intended to show, for example, what function the facility has, what area it is located on, the characteristics of the building, floors, rooms and zones. Nomenclature and numbering usually follow standard naming conventions given by manufacturers and organizations. Identified data that pertains to component group and type should also be classified based on industry standards [22]. The three most widely used systems for classification, costing, etc. are Uniformat, OmniClass and MasterFormat. The first refers to building components related to materials and where they were built. The second system is useful for creating material libraries, organizing product literature and project information. It contains a combination of the other two systems and is used as a basis for MasterFormat or Uniformat, for example. Omniclass is considerably expanded and consists of construction information on objects, separated spaces, products, work results, materials. MasterFormat, on the other hand, is used for institutional and commercial projects in Canada and the United States. The system primarily presents cost data and with related information contained in the design, estimates and specifications [23]. Next in importance is the classification of data on equipment, materials and finishes. This data provides knowledge of any parameters that relate to product manufacturers, models, serial numbers, acquisition dates, dealer leads, any warranties and information on their use or expiration dates. Subsequently, specifications and attributes can be linked to any data on types and other values, as well as detailed data on weight, power, energy consumption or spare parts. The last non-graphical data should relate to the operation and maintenance of the facility itself. The model should be supplemented with data on maintenance statuses and their history, as well as data on space occupancy [24].

Using all data resources minimizes the risk of errors. However, with a high level of non-graphical data saturation comes certain risks. First, too much data can cause, for example, problems in interpreting the design and difficulty in maintaining the data. To avoid problems, a thoughtful and sensible approach to data entry is paramount.

3. Materials and Methods

The materials for the study were mainly paper documentation collected in many volumes (Figure 1). It concerned material resources, mainly equipment, installations and mobile elements. Originally, the BIM model did not contain information on such elements. Hence, it was decided to

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

perform detailed semantic enrichment in the non-graphical data of the BIM model using available paper materials, archival materials or current information from the manager (director and management team).

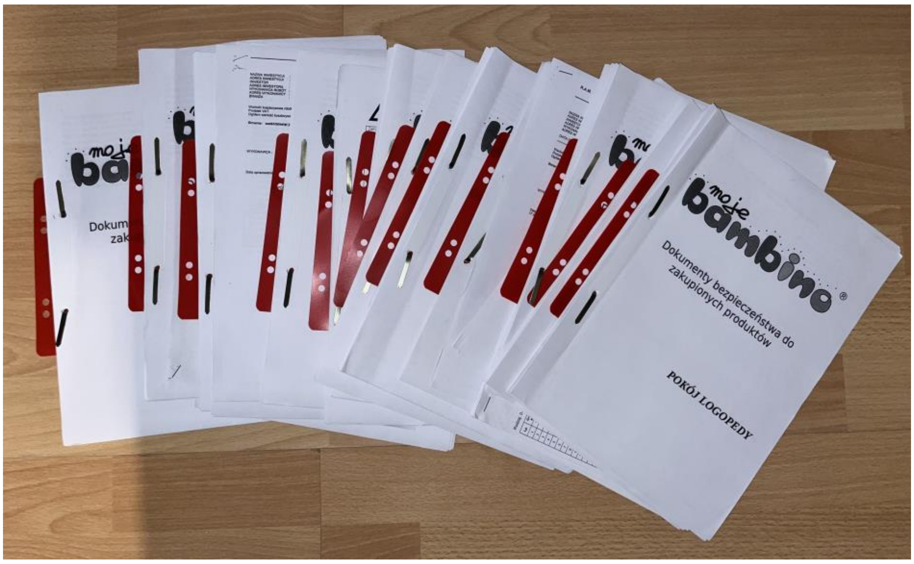

Figure 1. Documentation of material resources of the entire construction site.

The BIM model was developed in Autodesk Revit software and the semantic enrichment process took place there. The rest of the study used BIMVision, BricsCAD BIM and Autodesk Tandem software. The first two were used to validate the results, while the latter simulated the manager's activities.

4. Semantic Enrichment in Non-Graphical Data - A Case Study

4.1. BIM Model - Site and Project Level

Completing the entire project with non-graphical data is an extremely important and crucial aspect. The Autodesk Revit program, which was first used to create a model of the Public Kindergarten in Secemin (Figure 2), was then used to supplement the resulting model with non-graphical data.

(**a**) (**b**)

Figure 2. A photograph of the Secemin Public Kindergarten (a) and a BIM model with a high degree of geometric detail (b).

The BIM software gives you the ability to fill in so-called "project information" in the dialog box, i.e. all the most necessary parameters, which will also be visible in the drawing tables of the project sheet. Revit software has built-in parameters that apply to a project. However, they are not very

 doi:10.20944/preprints202407.1975.v1

extensive, and BIM modelers rarely extend them (Table 1). The basic parameters relate to data such as building name, project author, client name, project name and project number.

Table 1. Basic information about the project.

Parameter	Value
Identification data	
Name of the organization	
Description of the organization	
Name of the building	
Author	
IFC parameters	
IfcSite GUID	
IfcBuilding GUID	
IfcProject GUID	
Other	
Project release date	Release date
Status of the project	Status of the project
Customer name	Owner
Project address	Enter the address here
Project name	Project name
Project number	0001

Nevertheless, it is possible to add your own parameters, which allow you to complete the project in detail with the most necessary information. Therefore, the first step taken was to create shared parameters. These are parameters that can be added to library components and BIM models. One of the key types of information about the parameters in question is that they are stored in a standalone file, and thus this allows them to be used in multiple components and projects.

Thus, almost 30 shared parameters were created, with them divided into four groups. The first one includes information about the location of the building. In it you can find parameters such as the locality, the local zoning plan (the plan, resolution and extract from the resolution regarding the area covered by the local plan), as well as the plot numbers on which the investment was created. Another group concerned parameters related to the technical conditions of the kindergarten. It included parameters, i.e.: the length of the building, the width of the building, the maximum height of the building, the number of floors, the gross cubic capacity, the net area, the area of the cubic project site, the usable area, the development area, the development intensity and the biologically active area. The third group contained parameters related to the entire construction project, and the parameters found there included the price, the dates of: acceptance of the building, the announcement of the contract, the start and completion of execution, the selection of the most advantageous offer, the opening of the offer, and the name of the contractor, the name of the contract, the warranty and guarantee period. There was also a parameter, related to the website, where all the construction documentation is located. The fourth group contained parameters related to the director of the kindergarten, the head of the municipality and the kindergarten's phone number.

The created shared parameters were then imported into the project parameters. It selected the shared parameter from the corresponding parameter group, added the parameter to the group in which it should be displayed and the categories, i.e. "Project information". After opening the corresponding dialog box, the list of newly added parameters was displayed. Each of them was supplemented with relevant data extracted from the documentation provided by the Municipality of Secemin. The result was a table containing a detailed set of data at the IFC structure project level (Table 2).

Table 2. Non-graphic data enrichment at the IFC project level: Public Kindergarten in Secemin, Poland.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

Parameter	Value
Dimensions	
Length of the building	56,64 m
Maximum building height	8,95 m
Width of the building	32,64 m
Identification data	
Name of organization	Secemin municipality I Struga street 2 I 29-145 Secemin
Name of the building	Public kindergarten in Secemin I Poland
Author	Sepagroup - Sebastian Palczynski I 51-361 Wroclaw I Wilczyce 15/5 Szkolna Street I Poland
Kindergarten director	Danuta Lentas
Head of the municipality	Tadeusz Piekarski
Phone number	606364639
IFC parameters	
IfcSite GUID	
IfcBuilding GUID	
IfcProject GUID	
Results of the analysis	
Building intensity	0,17
Biologically active area	54,83%
General	
Area of the cubic project site	6148,00 m^2
Number of floors above ground	1
Usable area	710,94 m^2
Development area	1060,7 m^2
Net area	910,97 m^2
Gross cubic capacity	6490,00 m^3
Date	
Date of order announcement	2017-05-11
Implementation start date	2017-09-04
Date of selection of the most advantageous offer	2019-06-13
Completion date	2017-07-25
Contractor name	"R.A.M. BUJAK Construction Company "FUBIT" s.c."
Order name	Construction of a kindergarten in Secemin
Warranty and guarantee period	from 2018-09-04 to 2024-09-03
Bid opening	2017-05-31
Gross price	PLN 4,830,715.17
Date of building acceptance	2018-09-03
Other	
Project release date	-
Project status	Completed
Customer name	Secemin municipality
Project address	Koniecpolska 2A Street
Project name	Design of the building of a 6-branch kindergarten along with the necessary land development
Project number	532268-N-2017
Local Zoning Plan	https://cdn02.sulimo.pl/media/userfiles/secemin.pl/pobierz/Plan_1_nr_uchwaly.jpg
Local Spatial Development Plan	https://cdn02.sulimo.pl/media/userfiles/secemin.pl/pobierz/Uchwala_X_80_19_2019_08_06.pdf
City	Secemin

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

Plot numbers	2818/3, 2818/4, 2818/5, 2818/6, 2818/7, 2819/8, 2819/9, 2819/10, and 2819/11 | precinct 26135_2.0013 Secemin
Website with documentation	https://bip.secemin.pl/prawo-lokalne/

It should be noted that the Public Kindergarten in Secemin is not a large public facility. It has only one floor, and the area itself is about 1000 m². Thus, generating such a number of parameters about the project itself should be sufficient for efficient management by the director or the municipality. Nevertheless, facilities that are larger in size should be detailed with additional parameters. This is related to the fact that a given building may be managed by more people, and each of them may be responsible for a different area in the project. Then the information can be made more specific and tailored to the existing dependencies found throughout the project.

4.2. Ground Floor - the Floor Level of the Building

The Secemin Public Kindergarten, due to its purpose, should be equipped with a range of data and information for efficient and responsible management. A properly prepared BIM model allows the generation of statements that present all selected parameters. The building, by its use specification, should have a detailed list of rooms and a division into selected zones. This will allow the manager, in this case the director of the kindergarten, to control, for example, the conditions that should prevail in a given space (temperature, humidity, lighting, etc.).

In the work, it was decided to produce a summary of zones. But before doing so, a division of the facility into spaces was generated, which in the future can be supplemented with information on energy analysis, e.g. heating load, cooling load, air flow, lighting, etc. Then naming each space and assigning it a number, they proceeded to combine them into individual zones. Five of them were specified in the facility: the care zone, the staff zone, the parent zone, the food zone and the PM zone, or fire zone, and each zone was given an individual color (Figure 3).

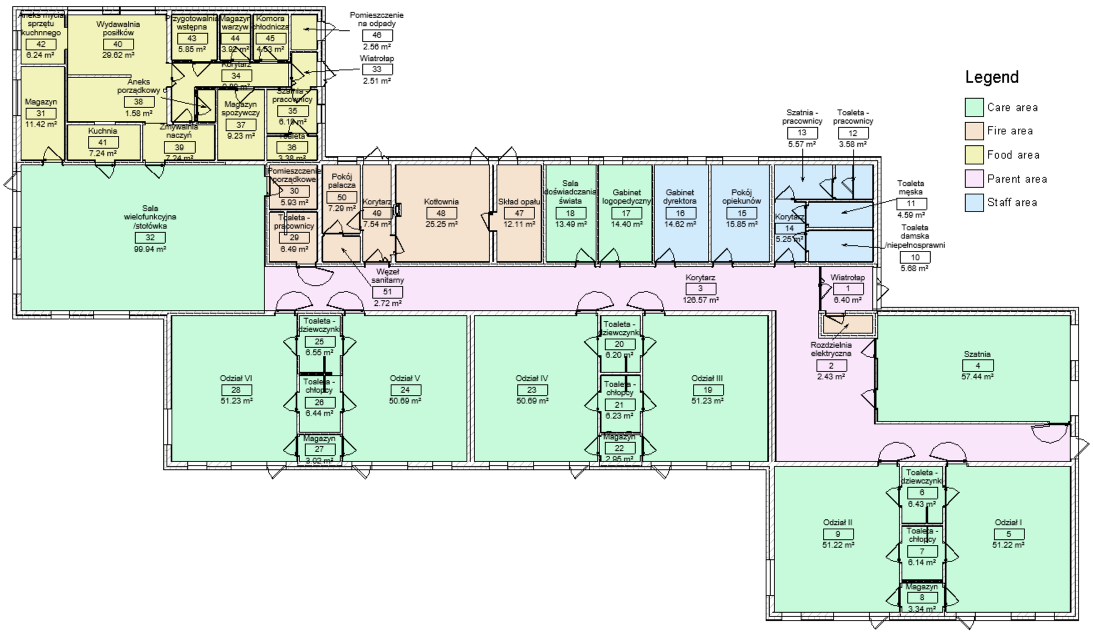

Figure 3. Zoning.

The creation of the zones made it possible to generate summaries (Table 3), where the first showed the names of the zones, the perimeter of the zone, the total area of each zone, the number of zones and at what level each zone is located. The lowest possible temperature and the highest possible temperature in each zone were also given.

Table 3. A quick tabular summary generated in the BIM model.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

Summary of zones						
Name	Lowest temperature	Highest temperature	Circumstance	Total area	Number	Level
Care zone	20 °C	22 °C	31611	538.84 m²	1	Level 1
PM Zone	20 °C	24 °C	4854	69.75 m ²	1	Level 1
Employee zone	20 °C	22 °C	6335	55.14 m ²	1	Level 1
Parent Zone	20 °C	22 °C	11517	132.96 m ²	1	Level 1
Food zone	20 °C	22 °C	15354	111.37 m²	1	Level 1

Also exported are summaries by zone: care zone (Table 4), staff zone, parent zone, food zone and PM zone, including the spaces present. Additional parameters have been added, such as number, areas and the level on which the space is located. Each table was given a color that corresponds to the color scheme of the zoning. The number of rooms located in each zone and their area were also summed up.

Table 4. Tabular comparison of parameters from the care zone.

Summary of space-care zone				
Space number	Name	Zone	Surface	Level
4	Checkroom	Care zone	57.44 m²	Level 1
5	Division I	Care zone	51.22 m²	Level 1
6	Toilet - girls	Care zone	6.43 m²	Level 1
7	Toilet - boys	Care zone	6.14 m²	Level 1
8	Magazine	Care zone	3.34 m²	Level 1
9	Division II	Care zone	51.22 m²	Level 1
17	Speech therapy office	Care zone	14.40 m²	Level 1
18	World experience room	Care zone	13.49 m²	Level 1
19	Division III	Care zone	51.23 m²	Level 1
20	Toilet - girls	Care zone	6.20 m²	Level 1
21	Toilet - boys	Care zone	6.23 m²	Level 1
22	Magazine	Care zone	2.95 m²	Level 1
23	Division IV	Care zone	50.69 m²	Level 1
24	Division V	Care zone	50.69 m²	Level 1
25	Toilet - girls	Care zone	6.55 m²	Level 1
26	Toilet - boys	Care zone	6.44 m²	Level 1
27	Magazine	Care zone	3.02 m²	Level 1
28	Division VI	Care zone	51.23 m²	Level 1
32	Multipurpose room/canteen	Care zone	99.94 m²	Level 1
Grand total: 19			538.84 m²	

BIM is also used in conducting simulations that can be used for thoughtful management during life-threatening situations. Due to the presence of such many children in the kindergarten, it is important to conduct analyses that will help ensure their safety and reduce damage in the event of a fire, for example. One of the simulations that was performed on the Secemin Public Kindergarten model concerns the availability of fire extinguishers. It is extremely important, as it allows us to determine the location of each fire extinguisher and whether this arrangement is correct and provides quick and easy access.

The next step was to run a simulation to analyze the distance between the two locations (Figure 4). The path generated, for the units located in the nursery, had the route start next to the caregiver's desk. On the other hand, in the other rooms, the longest possible distance to the fire extinguisher was selected. The result that was obtained were paths to the fire extinguishers. It should be added that the paths themselves were based on elements present in the model, i.e. components that were treated

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

as obstacles (such as benches). Revit, when determining the paths, bypasses them by 0.3 m, considering the value of 0.25 m for the radius of the body and 0.05 m for ensuring free movement. The speed of the access path is calculated based on the walking speed, which is about 4.828 km/h. All routes have been marked in green, indicating that the managers follow the rules and take care of the safety of the wards.

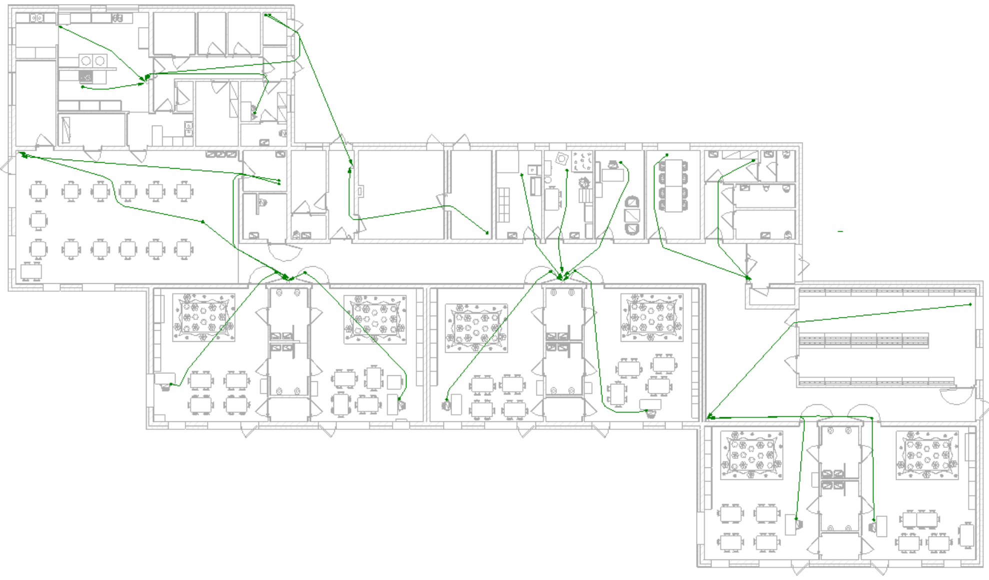

Figure 4. Access paths to fire extinguishers.

After generating the possible routes to the fire extinguishers, a summary was made that shows all the paths, along with their length, access time and the name of the room from which the route starts. The conditional formatting used gives a green color to records (Table 5) that meet the applicable guidelines in this regard. This increases the manager's understanding and confidence in the correct placement of fire extinguishers.

Table 5. Summary of routes to fire extinguishers.

Summary of routes to fire extinguishers			
From the room	Time	Length	Track number
Meal dispenser 40	2.7 s	3.6 m	4
Meal dispenser 40	4.4 s	5.9 m	3
Multipurpose room/canteen 32	4.5 s	6.0 m	8
Speech therapy office 17	4.5 s	6.0 m	14
World experience room 18	5.0 s	6.6 m	13
Director's office 16	6.1 s	8.1 m	15
Locker room - employees 13	6.6 s	8.8 m	18
Locker room - employees 35	7.2 s	9.6 m	22
Division VI 28	7.5 s	10.1 m	9
Waste room 46	7.6 s	10.2 m	1
Housekeeping room 30	7.7 s	10.3 m	6
Division IV 23	7.8 s	10.5 m	12
Division V 24	8.2 s	10.9 m	10
Keepers room 15	8.4 s	11.2 m	17
Division II 9	8.5 s	11.4 m	21
Fuel depot 47	8.6 s	11.5 m	11
Division III 19	8.8 s	11.8 m	16
Multipurpose room/canteen 32	8.9 s	12.0 m	7
Waste room 46	9.5 s	12.7 m	2

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

Housekeeping room 30	11.2 s	15.1 m	5
Division I 5	11.5 s	15.5 m	20
Checkroom 4	13.3 s	17.8 m	19

4.3. BIM Library Objects - Component Level

In BIM, the level of library elements plays a significant role, as the components themselves provide a lot of relevant information. This translates into effective modeling and, at a later stage, effective management of the entire construction site. Library components can be equipped with precise as well as accurate information that can be updated on an ongoing basis. These include, for example, physical properties, costs, certificates, manufacturers, inventory numbers, etc. For this purpose, non-graphical items of furnishings have been enriched with data. Shared parameters were created, which were then assigned to the corresponding BIM components (in Autodesk Revit - families).

The built-in and added parameters created a table that was populated with the appropriate values. For one type of chair (Figure 5), the table contained information on the dimensions, which were in the dimensions group, and information in the identification data on the certificate number, cost, manufacturing location, model, article number, design number, description, manufacturer, certification program, certificate expiration date and URL page (Table 6). Each value corresponded to a paper version of the document.

Figure 5. 3D geometry of the BIM library component - children's chair.

Table 6. Completed parameters of the children's chair.

Dimensions	
Depth	27.10
Width	36.10
Height	57.90
Identification data	
Certificate	TM 62000783 040
Cost	88.68
Place of production	St-Majewski Spółka Akcyjna S.K.A. ǀ ul. Krzemowa 16Aǀ 19-320 Ełkǀ Poland
Model	Bambino 2 chair
Article number	133524
Project number	26201477 001
Description	Chair for educational institutions
Manufacturer	My Bambino
Certification program	PVCU-3
License holder	Moje Bambino Sp. z o.o. Sp. k. ǀ Graniczna St. 46 ǀ 93-428 Lodzǀ Poland.
Expiration date of the certificate	from 14.03.2019 to 17.01.2020
URL	https://mojebambino.pl/?gad_source=1&gclid=CjwKCAjw5ImwBhBtEiwAFHDZx6QDUjjg6qxrJNHQeAXDccuatiMFC3665X2RZhWT4qtvEEg_7YwLlhoCQ-QQAvD_BwE

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

With the method presented, each piece of equipment in the facility was completed, and a list of furniture located in all the wards in the care zone was created. Listings were also made for the other rooms located in the care zone and the staff area. However, due to their complexity, their presentation in the paper was omitted.

5. Verification of Compliance

5.1. Tests in Applications

Those on the management team can use a variety of applications. From sophisticated CDE (Common Data Environment) environments to user-friendly solutions like Autodesk Tandem, to primitive yet simple desktop/cloud IFC viewers. To check how the created model of Secemin Public Kindergarten enriched with non-graphical data displays in other applications, it was exported to IFC format. A number of tests and ways of saving the file were carried out to ensure that all the most important information was displayed correctly in the selected programs.

The first application for compliance verification was the free BIMvision viewer, which allows visualization of BIM models in commonly used formats: IFC2x3 CV 2.0, IFC4 Reference View. The intuitive tool provides the ability to easily present any model elements. Thanks to the fact that the application is free, it saves the costs associated with buying other commercial software. BIMvision allows you to present the project in a schematic way, but very clearly. At the very beginning, the entire model was exported from Revit to IFC. The saved file was then easily imported into BIMvision (Figure 6). The properties displayed a list of assigned data. A review of the table revealed that all the non-graphical data with which the project was enriched had been imported into BIMvision. Only the order of displaying the data had changed. A user viewing the structure of an IFC project can check the information he needs at any level.

Figure 6. The model displayed in the BIMvision viewer.

In addition to exporting the entire project, Revit also exports the furniture itself in the object. Such a procedure, allows access to information related only to the furnishings, without unnecessary geometrical and non-graphical data. The IFC file can serve not only the person managing the furnishings of the facility, but also people who are interested in buying the same furniture. To check whether all the most important information about the furniture was imported, one of the tables was selected (Figure 7) and the table associated with it was displayed (Table 7). Comparing the data stored in the table created in Revit software (Table 8) with the table imported in BIMvision, all the information was correctly transferred, along with the ability to open web pages via hyperlinks.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

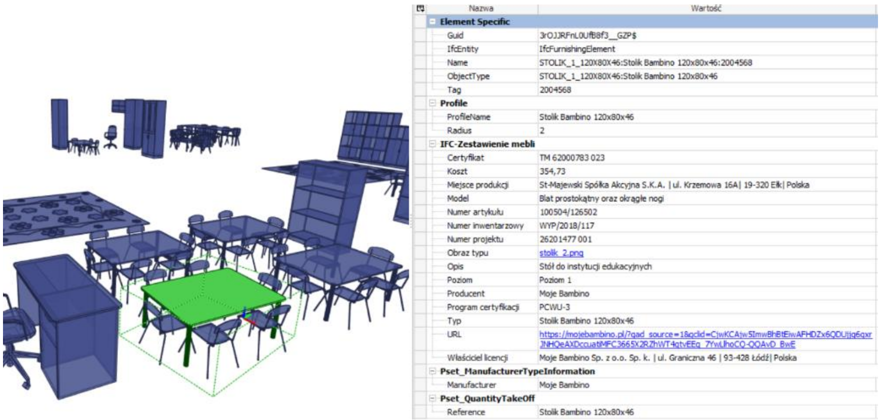

Figure 7. A table with an assigned table in BIMvision.

Table 7. BIMvison table parameters.

Identification data	
Certificate	TM 620000783 023
Cost	354,73
Place of production	St-Majewski Spółka Akcyjna S.K.A. | ul. Krzemowa 16A| 19-320 Ełk| Poland
Model	Rectangular top and round legs
Article number	100504/126502
Project number	26201477001
Image type	table 2.jpg
Description	Table for educational institutions
Manufacturer	My Bambino
Certification program	PVCU-3
License holder	Moje Bambino Sp. z o.o. Sp. k. | Graniczna St. 46 | 93-428 Lodz| Poland.
URL	https://mojebambino.pl/?gad_source=1&gclid=CjwKCAjw5ImwBhBtEiwAFHDZx6QDU-jjg6qxrJNHQeAXDccuatiMFC3665X2RZhWT4qtvEEg_7YwLlhoCQ-QQAvD_BwE

Table 8. BIMvison table parameters.

IFC - Overview of furniture	
Certificate	TM 620000783 023
Cost	354,73
Place of production	St-Majewski Spółka Akcyjna S.K.A. | ul. Krzemowa 16A| 19-320 Ełk| Poland
Model	Rectangular top and round legs
Article number	100504/126502
Inventory number	WYP/2018/117
Project number	26201477001
Image type	table 2.jpg
Description	Table for educational institutions
Level	Level 1
Manufacturer	My Bambino
Certification program	PVCU-3
Type	Bambino table 120x80x46
URL	https://mojebambino.pl/?gad_source=1&gclid=CjwKCAjw5ImwBhBtEiwAFHDZx6QDUjjg6qxrJNHQeAXDccuatiMFC3665X2RZhWT4qtvEEg_7YwLlhoCQ-QQAvD_BwE
License holder	Moje Bambino Sp. z o.o. Sp. k. | Graniczna St. 46 | 93-428 Lodz| Poland.

For interoperability purposes, compliance verifications were also carried out with another BIM program, BricsCAD BIM. For compliance verification of parameters assigned to equipment, the same table was used as in the previous case (Figure 8). In Table 9, a difference can be observed in terms of the order of the parameters (compared to Tables 7 and 8) however, the information has not been changed in any way.

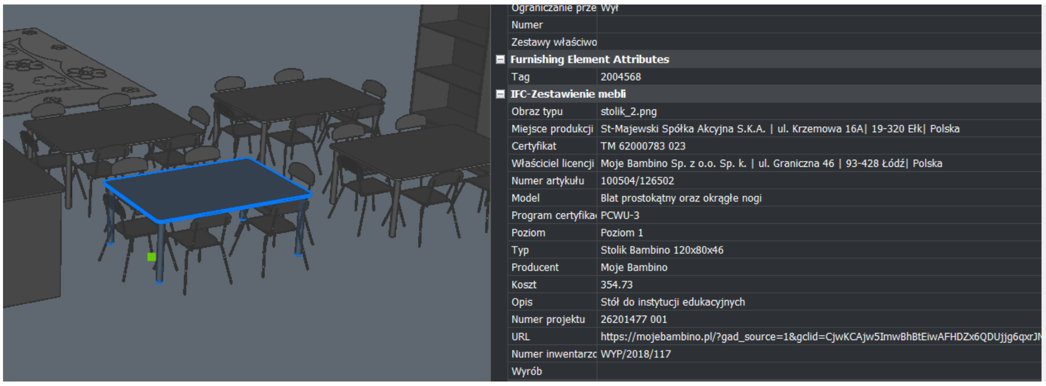

Figure 8. A table with an assigned table in BricsCAD BIM.

Table 9. table parameters in BricsCAD BIM.

IFC - Overview of furniture	
Image type	table 2.jpg
Place of production	St-Majewski Spółka Akcyjna S.K.A. ǀ ul. Krzemowa 16Aǀ 19-320 Ełkǀ Poland
Certificate	TM 620000783 023
License holder	Moje Bambino Sp. z o.o. Sp. k. ǀ Graniczna St. 46 ǀ 93-428 Lodzǀ Poland.
Article number	100504/126502
Model	Rectangular top and round legs
Certification program	PVCU-3
Level	Level 1
Type	Bambino table 120x80x46
Manufacturer	My Bambino
Cost	354,73
Description	Table for educational institutions
Project number	26201477001
URL	https://mojebambino.pl/?gad_source=1&gclid=CjwKCAjw5ImwBhBtEiwAFHDZx6QDUjjg6qxrJNHQeAXDccuatiMFC3665X2RZhWT4qtvEEg_7YwLlhoCQ-QQAvD_BwE
Inventory number	WYP/2018/117

Comparing the two applications for opening IFC files, it can be concluded that the first one, BIMvision, is designed for people who do not have high digital skills and thus can take an active part in the management process. For more sophisticated programs like BricsCAD, broader digital skills and some knowledge of BIM are required.

5.2. Management using BIM

The use of BIM during the operational phase of a building allows for a more streamlined management process, which includes safety assurance, ongoing maintenance, inspections, repairs and upgrades. However, this requires access to a range of information, which, thanks to the BIM models created, is in one place. Many applications, programs, viewers can be used to manage the facility. One of them is Autodesk Tandem, which, above all, is ideal for sites that do not want to have expensive software and specialized knowledge. The available form of cloud platform gives the opportunity to intelligently and sustainably manage the building's resources, thereby ensuring the

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

continuity of the facility's operations and maintenance. The program is free to manage 1,000 (thousand) entities in the model.

Autodesk Tandem can find application in efficient management of spaces located in the facility. The manager can modify the view of the project so as to have an overview of all the necessary parameters, with the ability to check the status of their completion. For example, the names of dozens of pieces of furniture in the facility were completed in an additional table, which allows the creation of various lists. Thus, a view of the object's furnishings was created, divided into sections so that each room could be clearly seen (Figure 9). On the left side, a dialog box appeared, which tells us how many items any parameters have assigned. Underneath is a table that shows the completeness of the data, along with its percentage and color, which is assigned to complete, in-progress and unfinished parameters, respectively.

Figure 9. Autodesk Tandem dashboard with equipment.

One very useful option is the ability to integrate software with IoT, or Internet of Things, devices [25]. Digital twin management is a smart and undeniably important solution that allows you to monitor and control all building processes in real time. Combining various devices (sensors, actuators) with Autodesk Tandem makes it possible to measure a number of signals identifying noise, temperature or CO_2 levels in each of the rooms in the facility. The collected parameters are presented, for example, by means of colors placed on a digital twin or graphs. The application allows threshold values to be set to check performance in real time and to detect upcoming anomalies.

6. Limitations and Future Directions of Research

BIM models often contain incomplete and insufficient data that affect project quality and performance. Despite the great potential of BIM, contemporary practices have a gap between graphical and non-graphical information, highlighting the seriousness and need for semantic enrichment. This raises issues and difficulties that result in the full potential of this technology not being realized. A serious limitation that needs to be improved is the aspect related to the huge amount of non-graphical input into projects, especially extensive ones. Often such parameters are implemented manually, and this leads to a time-consuming (hundreds of hours of data entry) and costly (large number of people entering data) process. However, too many parameters can pose huge organizational challenges and lead to mismanagement of facilities. The lack of common standards can lead to interpretation difficulties and to incorrect decision-making. Another limitation is the lack of competence of data entry personnel. Semantic enrichment of non-graphical data is a difficult task, so to do it properly one must have the necessary skills and knowledge in this area.

However, despite the many benefits of using BIM, the potential of the technology has not yet been fully realized. One major limitation is the compatibility problem that exists between different programs and systems. The IFC format, which was introduced to streamline the exchange of information between many applications, despite its continuous development, constantly carries many inconveniences and errors. The evolution of the standard, which has been decades in the making, still faces the problem of interoperability across all application domains, and the process of creating the MVD (Model View Definition) itself is still tedious and labor-intensive. IFC files do not always capture all the information present in each project, such as non-graphical data, and when generated into another program, the information may turn out to be outdated, fudged or erroneous. Keep in mind that a complex data exchange consists precisely of geometric and non-graphic elements found in a project. Parameters relating to properties, materials, certificates, expiration dates, etc. are no less important during the design and operation of the facility. They are the key to taking correct and efficient action. However, there are constantly problems with their exchange between different systems, and this causes many complications. One of the risks is also the prioritization and overriding of graphical data. Often, the exchange of data may concern only the geometric part of the project, and the part with non-geometric data, which is considered unnecessary, is omitted. This can prove detrimental and expose the entire investment process to increased expenses, management problems and exposure to complications during multi-discipline cooperation. However, the problem is not just in the IFC standard itself. The root of the interoperability problem is also linked to human error. The lack of qualified personnel has a significant impact on how all information is communicated. Lack of knowledge related to the interoperability process and any human shortcomings can lead to ineffective use of technology, thus hindering work between different industries.

Nevertheless, BIM technology is constantly evolving, overcoming the difficulties encountered. One direction to address the limitations is integration with ML (Machine Learning). Incorporating Artificial Intelligence (AI, Artificial Intelligence) and ML into BIM means increasing the accuracy of models and managing the entire facility more effectively throughout its life cycle. Practical implementation of innovations leads to improvements in traditional methods. For now, the combination of ML or AI and BIM will be most effective in a high-tech environment. Continuous development of standards, including interoperability, is also a key direction to properly maintain data semantics. Work continues to improve formats that will enable forecasting, design and management of building assets with automated simulations. It is important to improve the process of data exchange between multiple applications. BuildingSMART continues to address the challenges of optimizing the undertaking of activities and increasing automation. It is also important to keep in mind that the development of technology, also depends on the skill level of the people involved. Employees should continually increase their skills and adapt to changing conditions in BIM.

7. Conclusion

Semantic enrichment in non-graphical data provides effective monitoring and control of the progress of activities, which are key elements leading to effective management of a building facility. BIM provides a comprehensive as well as accurate symbolic representation of a building insofar as it includes not only geometry or spatial relationships, but primarily non-graphical data. The AEC industry is undergoing sweeping changes, reducing errors and increasing efficiency. Significant changes are making it possible to improve design, management and, above all, improve collaboration and communication. Building information modeling solves several problems in many industries. It facilitates the process of exchanging building information related to geometric as well as non-graphic features. A BIM model that is enriched with non-graphical data improves the use and control of a building facility. BIM allows for fast and interactive real-time management of the building. A design in which built-in parameters are defined, and those created and specified by the user, provides a powerful database that helps increase the efficiency of the entire facility. However, it comes with many limitations and problems that need further improvement and development. The evolution of BIM is ongoing and semantic enrichment is a constant challenge for researchers, innovators and practitioners.

Author Contributions: conceptualization, A.S.B. and M.M.; methodology, A.S.B.; validation, A.S.B.; formal analysis, M.M.; resources, M.M.; data curation, M.M.; writing-original draft preparation, A.S.B. and M.M.; writing-review and editing, A.S.B.; visualization, M.M.; supervision, A.S.B.; funding acquisition, A.S.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

 doi:10.20944/preprints202407.1975.v1

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to (restrictions towards the public customer).

Acknowledgments: Thanks to the Faculty of Geodesy and Cartography (Warsaw University of Technology) for their support during the research and development work.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Garagnani, S. (2013, October). Building Information Modeling and real world knowledge: A methodological approach to accurate semantic documentation for the built environment. In 2013 digital heritage international congress (DigitalHeritage) (Vol. 1, pp. 489-496). IEEE.
2. Edirisinghe, R., & Woo, J. (2021). BIM-based performance monitoring for smart building management. Facilities, 39(1/2), 19-35.
3. Wang, Z., Sacks, R., Ouyang, B., Ying, H., & Borrmann, A. (2024). A Framework for Generic Semantic Enrichment of BIM Models. Journal of Computing in Civil Engineering, 38(1), 04023038.
4. Xue, F., Wu, L., & Lu, W. (2021). Semantic enrichment of building and city information models: A ten-year review. Advanced Engineering Informatics, 47, 101245.
5. Dinis, F. M., Poças Martins, J., Guimarães, A. S., & Rangel, B. (2022). BIM and semantic enrichment methods and applications: A review of recent developments. Archives of Computational Methods in Engineering, 29(2), 879-895.
6. Ouyang, B., Wang, Z., and Sacks, R. (2022). Semantic Enrichment of Object Associations across Federated BIM Se-mantic. Trondheim: Virtual Construction Lab., p.1.
7. Borkowski, A. S. (2023). Evolution of BIM: epistemology, genesis and division into periods. Journal of Information Technology in Construction Vol. 28, p. 647.
8. Bloch, T. (2022). Connenting research on semantic enrichment of BIM - review of approaches methods and possible applications. Journal of Information Technology in Construction, pp. 417-418
9. Xue, F., Wu, L. & Lu, W. (2021). Semantic enrichment of building and city information models: A ten-year review. Advanced Engineering Informatics, p. 2.
10. Bloch, T., & Sacks, R. (2018). Comparing machine learning and rule-based inferencing for semantic enrichment of BIM models. Automation in Construction, 91, 256-272.
11. Dinis, F. M., Martins, J. P., Guimarães, A. S. & Rangel, B. (2021). BIM and Semantic Enrichment Methods and Ap-plications: A Review of Recent Developments. Archives of Computational Methods in Engineering, p. 880.
12. Kasznia , D., Magiera, J. & Wierzowiecki, P. (2017). BIM in practice: standards, implementations, case studies. Warsaw: PWN SA, p. 150 (in Polish).
13. Borkowski, A. S. and Maroń, M. (2023). Application of a digital twin in the management of a public facility - a case study of a kindergarten in the municipality of Secemin. Builder, p. 9 (in Polish).
14. Kacprzyk, Z. (2020). Designing in the BIM process. Warsaw: Oficyna Wydawnicza Politechniki Warszawskiej pp. 64-6.5 (in Polish)
15. Volk, R., Stengel, J. & Schultmann, F. (2013). Building Information Modeling (BIM) for existing buildings-Literature review and future needs. Automation in Construction, p. 110.
16. Muñoz Pavón, R., Arcos Alvarez, A. & Alberti, M. (2020). BIM-Based Educational and Facility Management of Large University Venues. Applied Sciences, pp. 10-13.
17. Becerik-Gerber, B., Li, N., Jazizadeh, F. & Calis, G. (2012). Application Areas and Data Requirements for BIM-Enabled Facilities Management. Journal of Construction Engineering and Management, p. 438
18. Kensek, K. M. & Noble, D. E. (2014). Building Information Modeling - BIM in Current and Future Practice. New Jersey: Wiley, p. 60Author 1, A.; Author 2, B. *Book Title*, 3rd ed.; Publisher: Publisher Location, Country, 2008; pp. 154-196.
19. Kochanski, Ł., & Borkowski, A. S. (2024). Automating the conceptual design of residental areas using visual and generative programming. Journal of Engineering Design, 35(2), 195-216.
20. Park, J. J., Kim, E., & Jun, H. J. (2022). Development of an Open Government Data (OGD) evaluation framework for BIM. Buildings, 12(4), 490.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 July 2024 doi:10.20944/preprints202407.1975.v1

21. EN ISO 19650-1: Organization and digitization of information about buildings and civil engineering works, including building information modelling - Information management using building information modelling: Concepts and principles.
22. Gelder, J. E. (2015). The design and development of a classification system for BIM. Building Information Modeling (BIM) in Design, Construction and Operations, WIT Transactions on The Built Environment, 149, 477-489.
23. Afsari, K., & Eastman, C. M. (2016, April). A comparison of construction classification systems used for classifying building product models. In 52nd ASC annual international conference proceedings (Vol. 10, p. 2016).
24. Ilter, D., & Ergen, E. (2015). BIM for building refurbishment and maintenance: current status and research directions. Structural Survey, 33(3), 228-256.
25. Borkowski, A. S. (2024). Low-Cost Internet of Things Solution for Building Information Modeling Level 3B-Monitoring, Analysis and Management. Journal of Sensor and Actuator Networks, 13(2), 19.