Information exchange using the open IFC format from a surveyor's perspective.

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Key words: Geoinformation/GI; BIM; GeoEIR; GIS; Construction Surveyor

SUMMARY

BIM technology is becoming an increasingly significant part in the construction investment projects. In some countries, it is even becoming mandatory. BIM is used for a better and more efficient exchange of information between different stakeholders of the investment process. The main element of BIM is a 3D model together with metadata and standards which regulate the exchange of information or the objects modeling methods. BIM therefore generates new challenges also for the surveyor. The existing work model has to be adapted to the sub-processes carried out during the works conducted in the BIM technology.

The process of information exchange is most often performed using the open data format IFC (Industry Foundation Classes) developed by the buildingSMART organisation and standardised by the ISO 16739-1:2018 standard. Therefore, the focus was on the IFC format when analysing data exchange from a surveyor's perspective. As a result of the research, prototypes of tools, that can support the surveyor during the execution of works using BIM technology and the IFC format, were created and described. Among the proposed tools is a Model View Definition (MVD) adapted to surveying tasks. This tool can also be used by appointing parties as part of the Information Requirements as well as IDS (Information Delivery Specification) or be supported by IDM (Information Delivery Manual). This activity is aimed at more efficient work of a surveyor with the new technology.

The idea of using BIM technology is often also associated with the implementation of surveying work using modern surveying technologies, such as drones with various types of sensors. It also requires surveyors to acquire new skills to operate in three-dimensional space with 3D models of objects and data processing to, for example, compare models. This paper performs a review of available surveying tools in terms of their use with BIM technology.

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1. INTRODUCTION

BIM (Building Information Modelling) is a technology gaining increasing popularity in the AEC (Architecture Engineering Construction) industry. BIM allows for the digitisation of the construction process, resulting in better information management throughout the life cycle of a building based on a 3D model and metadata. The implementation of BIM technology is already taking place in many European countries, and as many reports show, increasing productivity in the construction industry is important for the profitability of the investments made.[1]

This article analyses information exchange in BIM processes from the perspective of a surveyor, with reference to the development of BIM in Poland.

The stage of BIM implementation in Poland is assessed as initial. Various instructions are being introduced to allow the implementation of BIM in Polish realities e.g. the BIM Standard PL [2], plan for digitization of the construction process and roadmap for the implementation of BIM in Poland [3] or adoption by the Polish Committee for Standardization of the ISO 19650 series of standards as binding (they have not been translated into Polish). However, it is important to consider now, how the implementation of the new technology may change the surveyor's work during the execution of surveying works in their entire life cycle. This change takes place on many levels: the use of "new" surveying methods, a different way of performing tasks and new tasks for the surveyor or a change in the approach to information exchange with other stakeholders.

The surveyor as a member of the construction process is assigned new tasks related to the implementation of works in BIM technology. The transition from the classic two-dimensional documentation to the world of 3D models will also cause an evolution in the conduct of surveying works. This will range from changes in legal acts regulating surveying works in the construction investment process to changes in the tasks performed so far (measurement tools used).

The key elements from BIM technology that have the greatest impact on a surveyor's work are four acronyms: EIR (geoEIR), MVD (IDM), IFC and CDE. We will now try, briefly, to introduce each of these acronyms.

EIR (Exchange Information Requirements) refers directly to what information should be provided at different stages of the project and what is the final product of the project. As the integration of BIM data with geospatial data develops, it is likely that a concept such as geoEIR will emerge to define how data should be recorded in global space (georeferencing) and what the process of converting BIM data to formats used in surveying or GIS should look like [4].

IFC (Industry Foundation Class) is a data exchange format that frees information exchange from the native file formats proposed by software vendors. The idea behind the use of IFC is a more effective exchange of information between stakeholders in the investment process. Together with IFC it is possible to use tools such as BCF (BIM Collaboration Format) or MVD. The format is standardised through the ISO 16739-1:2018 standard and developed by the BuildingSmart organisation [5]. The schema of the format represents different instances of classes corresponding to the different components of the model together with attributes, properties or parameters. Currently, it is mainly adapted to record information on building construction. In the future, it should be extended to include class instances specific to infrastructure objects. At this moment, some components used in infrastructure are represented as a default class IfcBuldingElementProxy, which causes difficulties in exchanging and modelling information [6].

MVD (Model View Definition) means definition of what should be exported from the BIM model in IFC format, what information should be included in the model. Not every stakeholder of the construction investment process needs all the information contained in the model, therefore the use of adapted MVD directly for geodetic applications is inevitable and should be defined in IDM (Information Delivery Manual) [7]. It is also possible to validate the information in the model using MVD. The MVD is currently undergoing a transformation towards the creation of an IDS (Information Delivery Specification) that will be tailored to validate the information in the model, and its form will be readable by both humans and machines.

CDE (Common Data Environment) is a platform defined in ISO 19650 to exchange information between stakeholders in the construction process in a structured, standardised and transparent way, so that the right information is provided to the right person at the right time [8]. Currently, the exchange of geospatial data within a single CDE platform is difficult due to the difference in standards used in BIM and GIS technologies.

In the traditional construction process, the surveyor is somewhat removed from the tasks involved in executing design and construction work. In BIM technology, he has definitely more tasks and responsibilities. Of course, this requires having, most often, in addition to the ability to operate surveying equipment, geoinformatics skills to carry out tasks related to simple data processing and creating, for example, comparisons of the current state with BIM models.

Nowadays, there is more and more talk about integrating BIM and GIS (Geographic Information System) to extract more information. This publication will also touch on this problem, but more from the side of the surveyor as a stakeholder providing data and an expert in the location in global space of: the model and the real object. The detailed problems of integrating BIM and geospatial data will therefore not be described, information on this problem can be found, among others, in [9]–[11].

Developments in technology allow data to be extracted using tools of varying technological maturity. A great visualisation of this problem can be found in the GeoBIM maturity model (Fig.1) created by Geospatial Media within the report on GeoBIM in the AEC industry. It presents different kinds of tools that can be used to support the investment process in the whole life cycle of an object from the surveyor's side [12]. Some of these tools will be discussed in more detail later in this article.

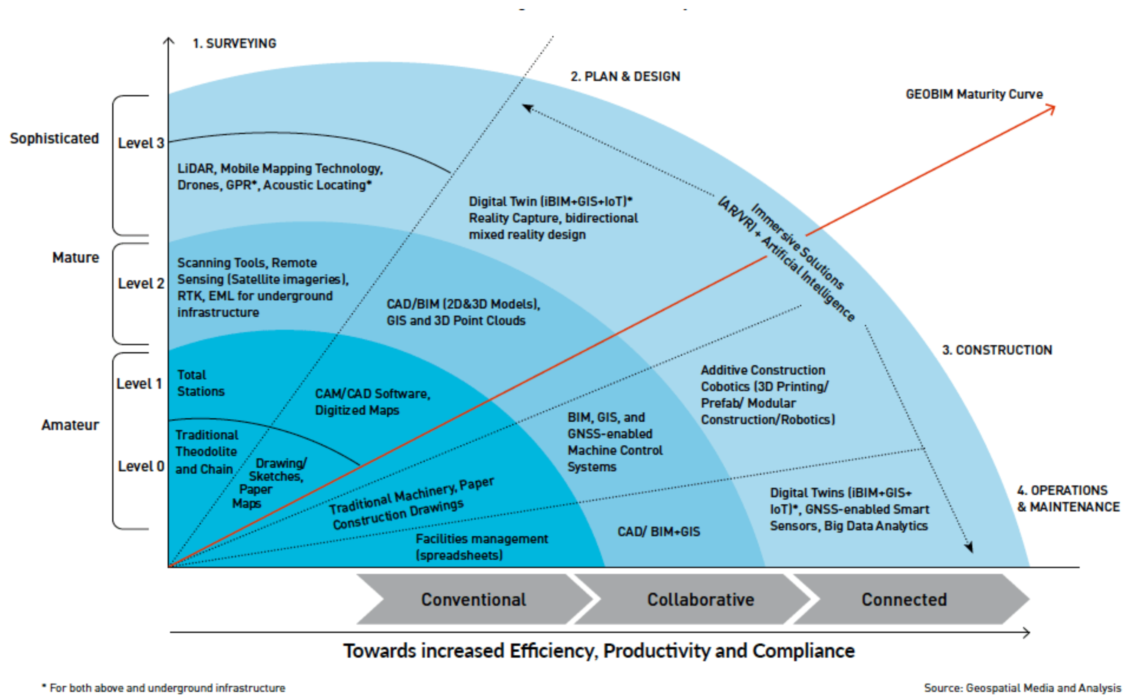

Figure 1 GeoBIM Maturity Model [12]

The aim of this paper is to present the new tasks of the surveyor in the investment processes realized in the BIM technology and to present the concept of MVD adapted to the surveyor's tasks. The article is structured as follows: the first part introduces the topic and presents the current trends; the second part discusses the surveyor's measurement tools, which can be used at different stages of the investment and presents the tasks of the surveyor, as well as presents the concept of View Definition Model adapted to the surveying tasks. The last part discusses the results obtained, presents recommendations, conclusions and plans for future work.

2. SURVEYOR IN BIM

BIM technology is currently, globally, defined mainly by the ISO 19650 series of standards. In Poland, a document entitled BIM Standard PL has been created, which does not have the force of a standard, but in accordance with ISO 19650, can be treated as a national supplement (for buildings) adjusted to national regulations. It is also supported by the Polish Public Procurement Office as a reference document when creating contract descriptions (Terms of Reference) in tenders.

BIM does not appear in the regulations governing the work of surveyors in Poland. By means of the Geodesic and Cartographic Act and the Act on Construction Law, as well as appropriate regulations, the requirements concerning: the work performed by a surveyor, forms of data storage, required documentation or representation of real objects in the form of a digital record (on geodetic maps) are described. These regulations, however, are not adapted to carrying out work using modern solutions - including modeling of information about objects in 3D with high level of detail and use of measurement tools acquiring dense data (laser scanners or photogrammetric products). The number of investments carried out in the BIM technology in Poland is increasing, therefore, it is necessary to consider changing the regulations and creating adapted tools.

The use of geodetic surveying requires the creation of standardising documents governing the possibilities of using the work of surveyors in BIM processes. Such activities are undoubtedly needed because project stakeholders in the AEC industry are not always aware of the potential of using surveying tools. In the literature, the only documents presenting this type of approach are [12] and [13]. Therefore, the publication briefly describes the new tasks of the surveyor together with a proposal of the tools/resources used with reference to the publications cited above.

2.1 MODERN GEODETIC MEASUREMENT TECHNIQUES

More and more proposals are emerging in the literature and industry to combine BIM and geospatial data domains. As an example, the open-source software IfcTerrain allows for a unified terrain record in IFC format [14]. This record is not efficient in terms of disk resources, but allows for the exchange of information in a unified manner. Another example is the open-source Blender with add-ons for BIM and GIS, which allows customisation of the working environment. Another example is the cooperation between developers of software for BIM (Autodesk) and for GIS (ESRI - ArcGIS). As a result, compatibility between existing software is planned, mainly on the basis of native files, but also IFC files [15].

Looking from the technical side of surveying works, the development of technology allows the surveyor to apply modern solutions using: Unmanned Aerial Vehicles (UAV), laser scanners or remote sensing and their integration with BIM technology.

Unmanned Aerial Vehicles can be used for every stage of investment. Their greatest advantage is the possibility of obtaining accurate and extensive information at a relatively low cost. Additionally, it is possible to mount not only optical sensors (for photogrammetric measurements), but also laser scanners. The use of various sensors allows to obtain many products (with a defined geometric resolution): point clouds, orthophotomaps or Digital Terrain Models/Digital Surface Models [16]. Thus, it is possible to realise e.g. the idea of Digital Twins [17], by monitoring objects – inspections [18][19], monitoring the progress of works [20]. Most often, drones provide information needed for design and implementation works [21][22], enriching elements of, for example, Maps for Design Purposes. An overview of the possibilities of using UAV has been made in [23], and some of the tasks described there belong to the surveyor.

Laser scanning can be used to detail the information at the design stage, to acquire data at the construction stage for comparison with the model [24], to check the progress of works [25] or for special purposes such as control of a incremental launching of a bridge [26], assessment of the condition of infrastructure [27] or monitoring of deformation of objects that are difficult to access [28]. It is also often used to measure the current state for objects that do not have a 3D model e.g. for historical objects [29]. An overview of different solutions using laser scanning is described in [30].

Remote sensing can be divided into ground-based and airborne/satellite data. Satellite data allows an area to be tracked in a more dynamic way than the tools described above. Dynamism is based on the fact that sensors on satellites take images of the same area every unit of time (time resolution of the data). This allows, for example, to track the progress of construction works [31]. It is also possible to obtain information invisible when using cameras imaging in the visible light spectrum by using, for example, standardised indicators. The example described above concerned the use of optical data. Radar sensors can also be placed on satellites to observe e.g. the deformation of the terrain around the object [32].

Increasingly, 3D models created by the surveyor (in the case of existing objects) or designer allow the use of Virtual or Augmented Reality. Thanks to this, designers, constructors or teams constructing the object can perform their work in a more efficient way. The advantages of this type of solution were described in [33], where laser scanning was also used.

2.2 SURVEYOR TASKS IN BIM

The result of this part of the research is a table (Table 1) with a description of the surveyor's tasks throughout the life cycle of a facility, together with the proposed tools/resources that the surveyor must provide/obtain/adapt. The assumption was to create a universal task description to be used for both: building construction and infrastructure. Therefore, it should be taken into account that e.g. implementation of tasks for a railway surveyor and one dealing with buildings will be slightly different. The breakdown of the stages was taken from [13], and the proposed surveying tools were described in the previous section.

Table 1 Tasks of the surveyor in BIM at different stages of the object life cycle

Phase	Describtion – new tasks	Tools and resources to do tasks
0 - Strategy	Proposing the spatial data "background" necessary for the design work (e.g. for the purpose of creating the EIR). Selection of reference systems, reference points for the entire project. Description of information requirements for spatial data (e.g. requirement for surveyor's MVD).	Project location and analysis of legal requirements for project location in global space - knowledge of coordinate systems used for the location. Software for definition of information requirements.
1 - Preparation	Provision of data and products (e.g. DTM) with a defined resolution. The quality of the data should provide the situational position of the place planned for the investment together with the information about the land development or the elements of the land utilities. The difference to the classical method of implementation results from the resolution of the data (e.g. the density of distribution of points and their accuracy). Most often, the surveyor provided studies in the vector form (Map for Design Purposes), in the BIM technology these are the Digital Terrain Models or Digital Surface Models..	Open spatial data, resources of state institutions, and if the resolution/quality of the data is insufficient - measurements using: • Unmanned Aerial Vehicle (optical sensor or laser scanner) and as a result: point cloud, orthophoto map with defined terrain pixel • Total Station • GPS satellite receiver • Equipment for measurement of land utility elements (underground infrastructure) e.g. EML or GPR
2 – Concept	Use of data from the Preparation phase. The surveyor may be asked to clarify inaccuracies in the existing data, clarify some spatial information, or perform spatial analyses (more often the task of a geoinformatician). Georeferencing of files and verification of correctness of the global spatial record.	As in the Preparation stage. Tools for georeferencing verification and spatial information modelling/documentation creation.

3 – Design	The surveyor checks and confirms whether the project can be staked out (based on the data received). Execution of further tasks related to detailing of spatial data, spatial information. Cooperation in creation of the model, its components, for placing in the global space, e.g. provision of necessary layers for calculation of earthworks. Validation of project files for correct georeferencing.	As in the Preparation stage.
4 – Construction	Design and placement in the field of the geodetic bench marks connected with the global coordinate system and the model coordinate. Activities: staking, supervision of the works and geometric correctness of the placement of individual components, deformation monitoring. Providing current information on the stage of implementation of the phase in order to: compare the schedule or cost estimates, minimize errors or improve safety on the construction site. Ongoing inventory of elements that are covered in subsequent phases of the investment.	• Total Station or GPS - for staking work - depending on the object staking accuracy required • Laser scanning - for status/progress recording • UAV with laser scanner or optical sensor - for status/progress recording • Mobile scanners - to record the current status of the work/progress • Satellite imagery - to record the current status of the works/progress • GPR/EML - measurement of below surface objects
5 – Handover	Inventory and create an as-built model that can be used to manage resources during the operational phase. Comparison of the current state with the designed one in order to locate possible discrepancies from the design. In case of objects exposed to deformations/displacements, stabilisation of permanent control points or sensors monitoring the technical condition of the object. Creation of appropriate as-built reports.	• UAV with laser scanner or optical sensor • Laser scanners (TLS and mobile) • Total Station and/or GPS • GB-SAR
6 – Operation and Maintanence	Depending on the type of facility, condition monitoring of the facility through periodic measurements. Creation of models of the current state for the purpose of technical condition monitoring of the object. Measurement of geometrical conditions of objects (depending on the type of object). Recording data for verification purposes e.g. for Asset Management/Facility Management systems.	As in phase 5. In addition, possibility to monitor infrastructure using satellite imagery (optical and radar)
7 – Modernisation	Create a current state model and repeat steps 2 to 6.	As in the Preparation stage.
8 – Demolition	Creation of a current state model - spatial analyses to adequately identify e.g. hazardous locations during demolition works	As in the Handover phase.

2.3 MVD FOR SURVEYORS

In this section we would like to present one of the elements of information exchange in BIM, which is the Model View Definition (MVD). The main purpose of using MVD is to adapt the IFC models to the information requirements relevant to the individual tasks inside the investment process [34]–[36], as well as to validate the stored information [37]. BuildingSmart, the organisation responsible for the development of the IFC format makes available for IFC version 4, two main types of MVD:

- Design Transfer View – for the purpose of transferring a model from one device to another. Mainly used when project milestones are reached and milestones are completed, where the entire model must be transferred so that no information is lost.

- Reference View – for the purpose of coordination of IFC models, the geometry is slightly simplified to allow more efficient work on the models and analysis of e.g. clashes.

But there are also MVDs created by different committees (technical rooms) for the following purposes: prefabrication (IFC4 Precast), export to LandXML format that can be used for different tasks in infrastructure projects [38] or COBie - a specific type of MVD that is used for facility management [39]. Thus it can be seen that MVDs are most often tailored to specific applications. This is precisely due to the information need, which depends on the task, project stage or stakeholder. One should therefore also consider, the adaptation of MVDs for surveying purposes. Working with an IFC model that contains too much information that is unnecessary for the surveyor's work causes difficulties in working with the model. The IFC model by the used EXPRESS-STEP recording method is not really efficient in terms of e.g. needed disk space and processing of this type of files. Therefore, minimising the information and adapting the information only to the one required by a given stakeholder allows for more efficient work and greater economic benefits. This type of solution can also be an element of IDM and serve IDS, i.e. an idea that aims to automatically verify the correctness of information content of a model. However, it should be taken into account here that the use of .mvdxml for IDS purposes has some limitations as described in [40]. Therefore, a new standard is being sought [41] but at the moment there is no final version of this type of tool.

The following MVD proposal is its first iteration not yet tested under normal work execution conditions. It is therefore important to note that the MVD proposal still needs to be adjusted in subsequent iterations. It is a concept of what data should be included in IFC files for geodetic applications. The open-sourced software provided by BuildingSMART, Ifc Documentation (IfcDoc), was used to create the MVD (Fig.2). The main purpose of this software is to define information requirements, including the very definition of MVD.

The most important issue for geodetic work is data georeferencing. The different versions of IFC are characterized by different methods of recording georeferencing and, moreover, the recording of data even in the same versions can be done in different ways [42]. In the literature, the levels of georeferencing are described in [43], while, as research shows, the software is not adapted to realize georeferencing at higher levels [44]. In order for surveyors to work more efficiently with IFC pilots, software needs to be developed or extended (e.g. [45]) that is efficient in terms of georeferencing and allows its verification for geodetic work. As research has shown, adequate georeferencing is particularly important for long infrastructure projects. [46][47]. Thus, care should be taken to ensure that files contain adequate georeferencing, preferably at the highest possible level, according to [43].

If we have a model with the right georeferencing (a correctly defined coordinate system), the most important element for the surveyor is the geometry of the object and its individual components. In IFC files the geometry can be stored using various methods. Solids can be represented by using ConstructiveSolidGeometry, Swept Solid or Boundary Representation [48]. Each of these methods generates the need for a different approach when reading coordinates, e.g. for object staking purposes. Additionally, it is necessary to select only those instances of classes that can be useful. In the proposed MVD, it was decided to remove most of the elements that have distribution or facility functions. The focus was mainly on structural elements such as foundations or walls, as this is the part of the model that is most important from the surveyor's point of view.

Another part of the MVD are the properties. For the surveyor, it seems that the most important issues are the quantitative parameters (quantities) and the single most important information, e.g. whether the element is part of a superstructure. Depending on this, the element may be subject to different analyses or staking.

By combining the above elements, an MVD proposal based on the Reference View was made, shown in Figure 3 - the schematic and the effect of the application in Figure 4. The MVD was implemented using the MVD-specific extension of the ifcopenshell library [49]. As previously mentioned, by using the mvdxml file it is also possible to validate IFC files. The use of mvdxml for an IFC file has been Software performing this includes IfcDoc or XbimXplorer with add-on MvdXML [50]. The algorithm has been tested on a model coming from an open repository available at [51].

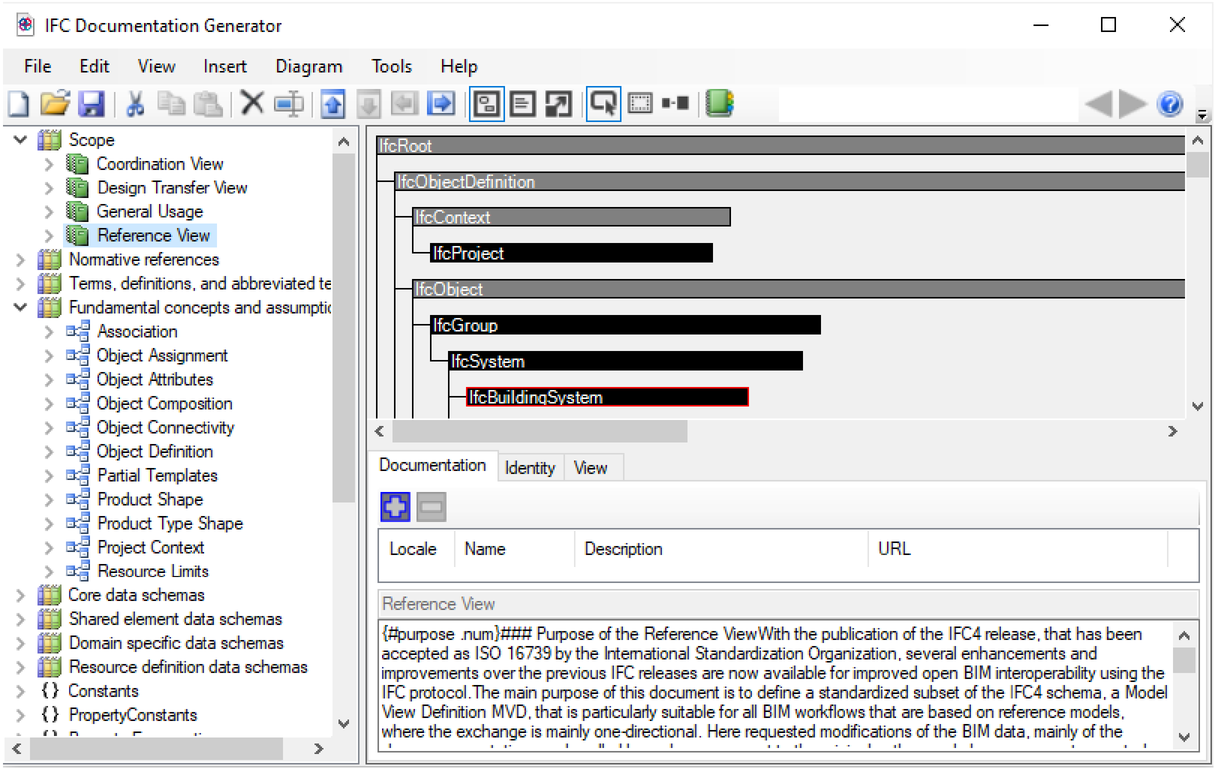

Figure 2 IfcDoc - Information Requirements Definition Software

Figure 3 MVD Schema for proposed MVD

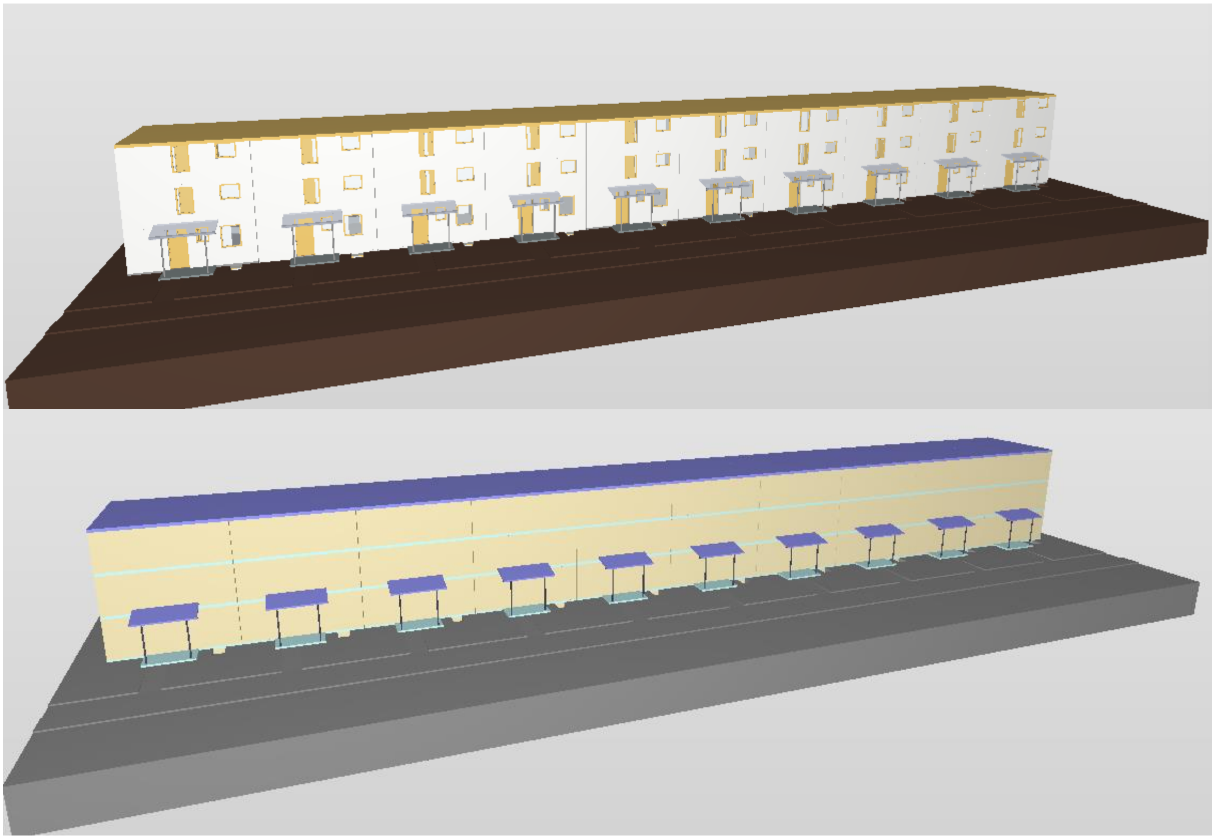

Figure 4 Model before and after application of the proposed MVD (in Solibri software)

3. CONCLUSIONS

Working as a surveyor in a new environment generates the need to adapt the information exchange also for surveying purposes. Emerging IDMs should describe processes and information needs that concern the surveyor.

As part of the work, a prototype MVD was proposed. The authors wanted to point out the need to pay attention to the surveyor's work as part of the processes implemented in BIM, and also show how the surveyor's work will change in a few years. The new method of investment implementation, generates both new opportunities and challenges for surveyors. We are also aware that currently the framework for information exchange using IFC is undergoing evolution and a new format - IDS - will be introduced. The production of the MVD itself was intended to present an idea that can then be adapted to new conditions.

Whether using appropriate measurement tools, resources or standardisation elements, there should be a framework within which it is possible to adjust and adapt to the needs of a particular project.

In the future it is planned to develop tools for information extraction for surveying tasks. In Poland, the currently used 2D documentation will, at some point, most likely be replaced by 3D models. Therefore, the development of tools supporting surveyors both from the information exchange and technological implementation of their tasks is undoubtedly needed.

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