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Original Research Article

INTEGRATION OF BIM AND GIS DATA OF A HERITAGE BUILDING USING FME

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Abstract

BIM and GIS technologies are used in both planning and investment and construction processes. GIS is more often used in the former, where one operates on a macro scale and information about the environment is essential for decision-making. BIM, on the other hand, is increasingly implemented in investment and construction processes (micro scale). The BIM model as a resource of knowledge and information about the construction object is the basis for decision-making, while data from GIS systems are necessary to obtain reliable information about the environment and the prevailing spatial, social or economic conditions. The basic information from GIS systems are attributes related to geographic location (coordinate system, angle to true north, elevation ordinate). Unfortunately, both technologies use different programming paradigms. GIS is mainly a relational database based on multidimensional tables, while BIM uses so-called encapsulation, polyform, hierarchy or instantiation, which enrich semantically stored data. There are many benefits to integrating geospatial data with building object information. The problem of compatibility and interoperability of the two technologies is the subject of many considerations of basic science and the problem of practitioners during application work. Georeferencing of BIM models is conferred in several ways, however, most of them require relatively expensive commercial tools or extensive digital skills or even programming. Rarely, however, are tools such as FME used for data conversion, management and visualization. Thus, the purpose of the present work was to attempt to properly georeference a BIM model of a historic building, located at Constitution Square in Warsaw, in a GIS environment, and then convert the data to shapefile output format using FME software. The results of the experimental work indicate that the BIM data can be embedded quite accurately in the space of a given coordinate system and displayed against various contextual data, but the 3D geometry itself loses its detail and quality. The paper discusses the limitations of the procedure and future research directions.

Keywords: BIM, GIS, FME, 3D visualization, georeferencing, heritage, integration

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1. INTRODUCTION

BIM (Building Information Modeling) is defined as a digital representation of the physical and functional characteristics of any building object that provides a reliable basis for decision-making throughout its life cycle [1]. It is also the process by which information about a building or group of buildings is generated and managed [2]. A BIM model contains highly detailed and semantically rich information about a structure [3]. Building information modeling has become one of the latest trends in the construction industry, which is constantly evolving [4]. BIM has quickly become the primary approach to digitally integrating data and information about the design, implementation and management of building structures [5]. It has allowed stakeholders to capture and share information in an efficient and productive manner [6]. BIM is being used to bridge the interoperability gap between different industries, increasing its popularity among clients and designers [7]. BIM is now considered to facilitate integration, interoperability, collaboration and process automation in the construction industry [8]. The implementation of BIM in Poland is progressing [9], and BIM models in modern architecture and building management are an essential prerequisite for the successful emergence of construction projects. Thanks to the semantic richness of the data (geometric and non-graphic), BIM applies in the design of new buildings, in the retrofitting of existing buildings [10], ensuring safety on site [11] or the efficient implementation of projects [12]. Highly detailed geometric data is generated during BIM processes and can be integrated with GIS (Geographical Information System) data structures. However, the compatibility of the two worlds is fraught with many questions and problems [13].

There are many benefits to integrating geospatial data into the design process [14]. A GIS represents various aspects of the real world in a digital environment, ranging from a variety of geodetic information in different coordinate systems to infinite datasets updated in real time. GIS technologies have evolved significantly over the past decade [15]. A GIS can be defined as a system designed to store, retrieve, manage, display and analyze all types of geographic and spatial data. GIS information combines with attributes of geographic locations to show what is properly located in a specific area [16]. GIS technology is used in many different fields. For example, in the construction industry, GIS is used in the construction planning process or reviewing the project schedule for gravity dams, where topography plays an important role. Without the geospatial data provided by GIS, the implementation of such a project would be impossible [17]. GIS also enables planners and designers to quickly and efficiently create and test alternative development scenarios for a given site. It also determines their likely impact on the future environment, e.g., land use analyses and related population and employment trends, enabling informed planning decisions [18]. The BIM conceptual model is designed for a different purpose than the GIS models currently in use. The key role in it is played by classes that model the construction of objects, such objects as wall, beam, column, while in GIS models these types of classes are usually not present [19].

The topic of BIM and GIS integration has been an area of research for many years, especially at the level of combining data from these systems [20]. The integration of BIM and GIS enables a better understanding of the relationship between different elements of urban infrastructure and their impact on the surrounding area. The digital models created by BIM-GIS integration can represent conditions of the past and present and take into account the procedures required to restore cultural heritage sites. They can be used in managing the spatial distribution information of ancient buildings to establish a consistent relationship between geometric information and non-geometric features, and they can provide detailed HBIM models for daily maintenance and specific aspects of preservation and restoration [21]. In some studies, commercial tools such as FME (Feature Manipulation Engine) developed by Safe Software are used for data conversion, management and visualization. Such a tool is capable of handling data conversion tasks, such as geometry assignment and georeferencing or data semantics [22]. For example, the software given above was used in a study aimed at visualizing a 3D model made in IFC (Industry Foundation Classes) format of the Church of Santa Maria dei Miracoli in Venice in a GIS environment, in order to digitize 3D documentation of historical cultural heritage [23]. Another example of application was a study done on integrated modeling between CityGML (City Geography Markup Language) and IFC formats for the analysis of urban microclimates for urban development and neighborhoods. FME was then used to convert data from IFC format to CityGML format [24]. However, there is a lack of applications for existing buildings that could be digitized into a digital model, which in turn could feed GIS spatial reference databases (in Poland, for example, the Land and Building Register). The correct location of the BIM model in GIS space also enables reliable analyses and simulations (e.g., insolation) . Such studies have already been conducted on the feasibility of using a pair of Autodesk Revit and ESRI ArcGIS GeoBIM applications [25]. Also interesting is Trimble Quadri, which enables the creation of BIM models for infrastructure projects. It enables designers to efficiently design all aspects of roads, railroads, bridges, water and sewer systems, and places models in the context of GIS data. It uses a proprietary data management system that enables quick calculations, facility type searches, networks and area searches [26]. The fundamental question is what such georeferencing looks like for the Autodesk Revit and FME pair.

Hence, the purpose of this work was to attempt to give proper georeferencing to an existing BIM model of a historic site in a GIS environment, and then convert the data to Shapefile format (which can feed reference databases), using FME software.

2. METHODOLOGY

The BIM model used was a building located on Constitution Square in Warsaw, Poland. The model was obtained from an internal repository of BIM models maintained by Warsaw University of Technology. A topographic map from the ESRI geoportal and 3D building geospatial layers with the CityGML LOD2 level of detail (Fig. 1) in Shapefile (.shp) format were used as reference data. The data were placed in the 1992 coordinate system.

Fig. 1. The building model used. Source: own elaboration based on the model obtained from the repository of BIM models maintained by the Warsaw University of Technology

Tools from three software vendors were used to achieve the goal: Safe Software (FME), Autodesk (Autodesk Revit), and ESRI (ArcGIS Pro). The BIM model made in Autodesk Revit was uploaded to

FME software, which allows the appropriate coordinate system to be assigned and the file to be converted to Shapefile (.shp) form. ArcGIS Pro was used to locate the BIM model (.rvt) in GIS space and later present the data after assigning the appropriate georeferencing (Fig. 2).

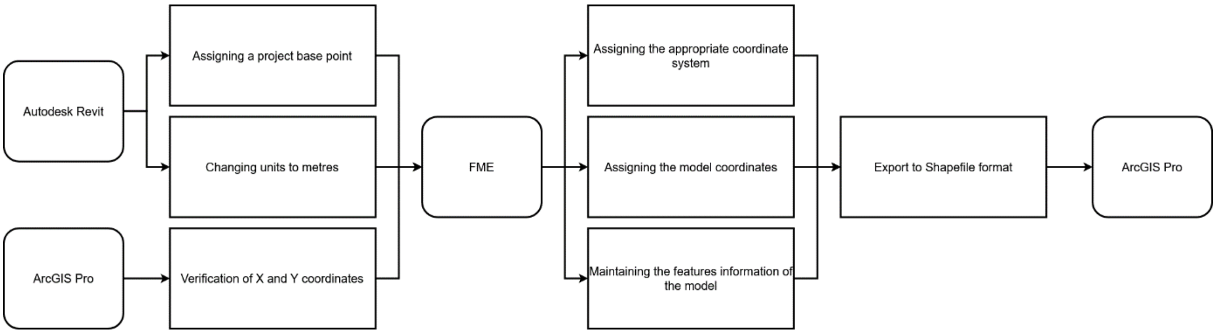

Fig. 2. Flow chart of the procedure process. Source: own development

To integrate the BIM data into the GIS environment, first the assignment of a suitable base point and the change of the unit of work to meters was performed in Revit software. Next, the X and Y coordinates of the points for which the assigned base point would be located in the GIS environment were checked in ArcGIS Pro (Fig. 3).

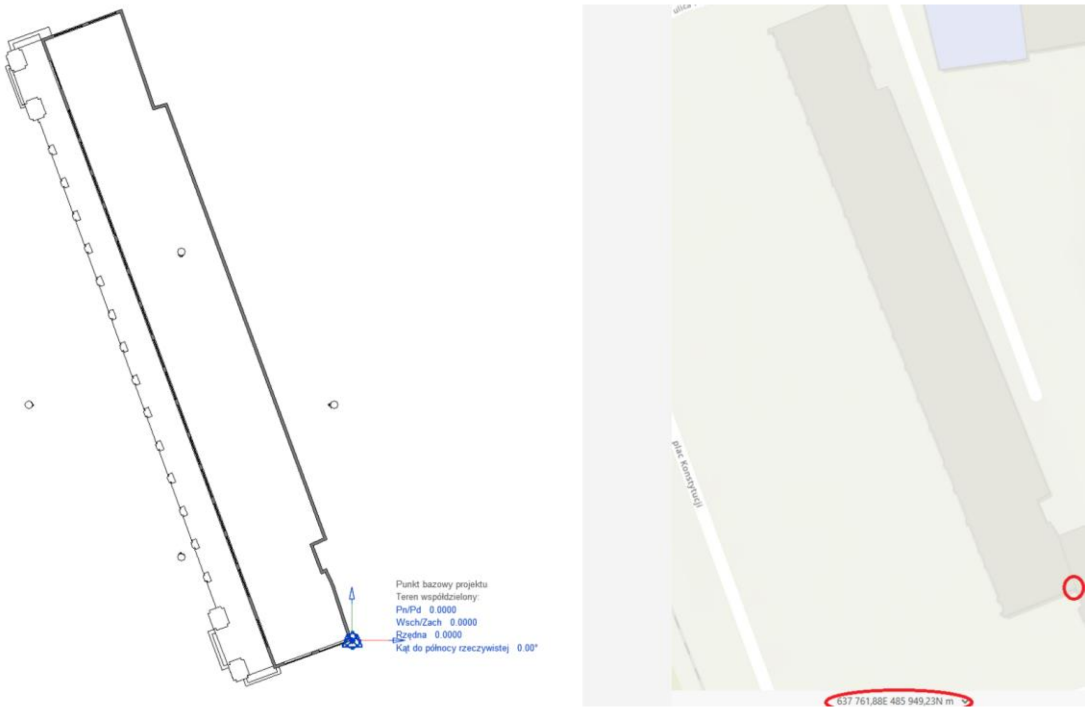

Fig. 3. Setting the base point to a known base point and checking the X and Y coordinates. Source: own development

The next step was visual programming in FME software (Fig. 4). After uploading the Revit file to FME, 3 tools were used to give the BIM model the proper georeferencing and coordinates:

- "Offsetter" - used to set the reference point to 0,0 coordinates,

- "3DRotator" - used to rotate the object towards true north if required,
- "LocalCoordinateSystem" - used to give the appropriate coordinate system and coordinates of our building (base point).

In addition, 3 more tools were used to retain information about the features of the model:

- "AttributeManager" - used to export attribute information from the BIM model to a new attribute table in the Shapefile,
- "AttributeExposer" - used for possible modification, copying or renaming of attributes,
- "AttributeRemover" - used to select the data to be visualized in the output file.

In the last step, the file was exported to Shapefile (.shp) format using the "FeatureWriter" tool. Such an exported file was already ready to be displayed in ArcGIS Pro.

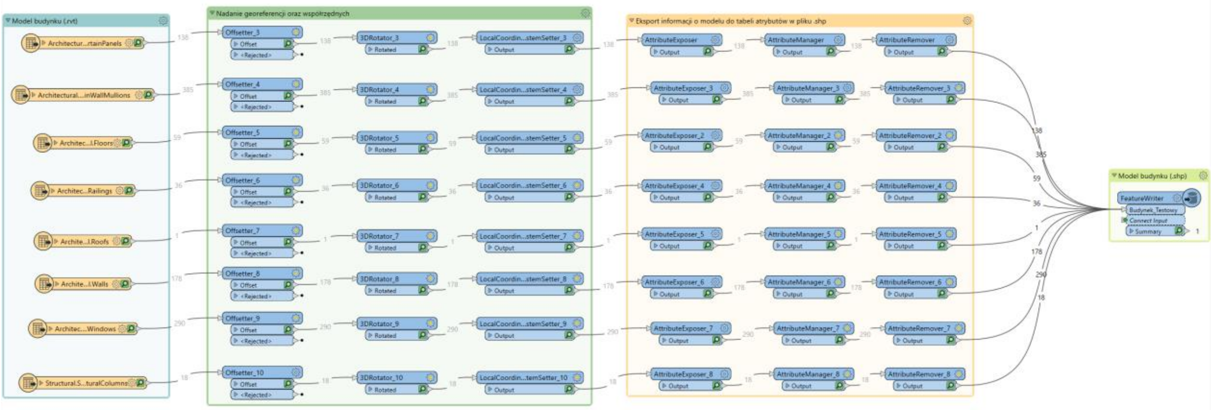

Fig. 4. Diagram of model construction in FME software. Source: own development

3. RESULTS

Transformation processes performed in FME it was possible to display the processed building model into shapefile format in ArcGIS Pro. The corresponding tools enabled correct georeferencing and appropriate geographic coordinates in the specified coordinate system (Fig. 5). Thus, the building outline agrees with the actual state within the required margin of error that the land and building registry assumes (up to 10 cm). On this basis, the boundaries of the building property can be plotted into reference databases.

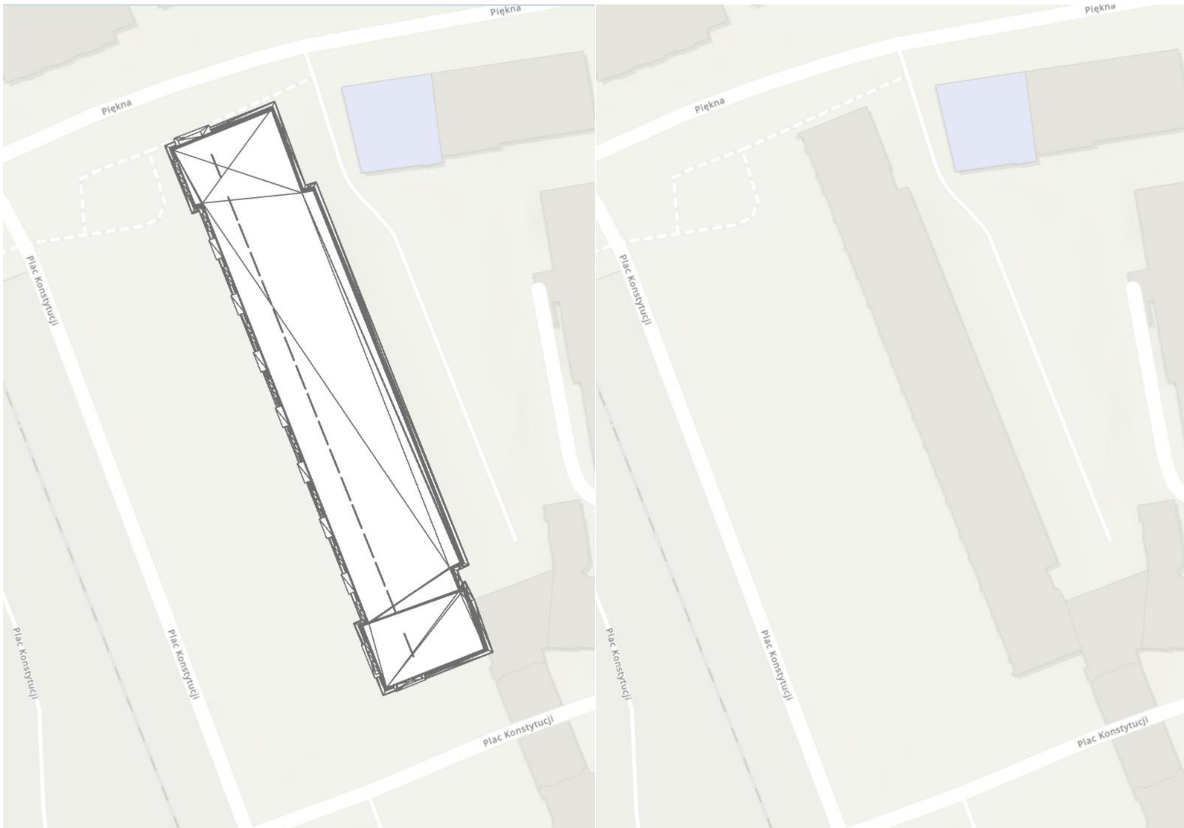

Fig. 5. The building model in 2D view after georeferencing and coordinates (left) and the location of the building against a topographic map from ESRI (right) in ArcGIS Pro. Source: own development

The imported model in shapefile format adopts "multipatch" geometry and can be displayed in two-dimensional and three-dimensional views (Fig. 6). Thanks to the integration of the building model with the ArcGIS Pro environment, all available functions in this program can be used in conjunction with BIM data.

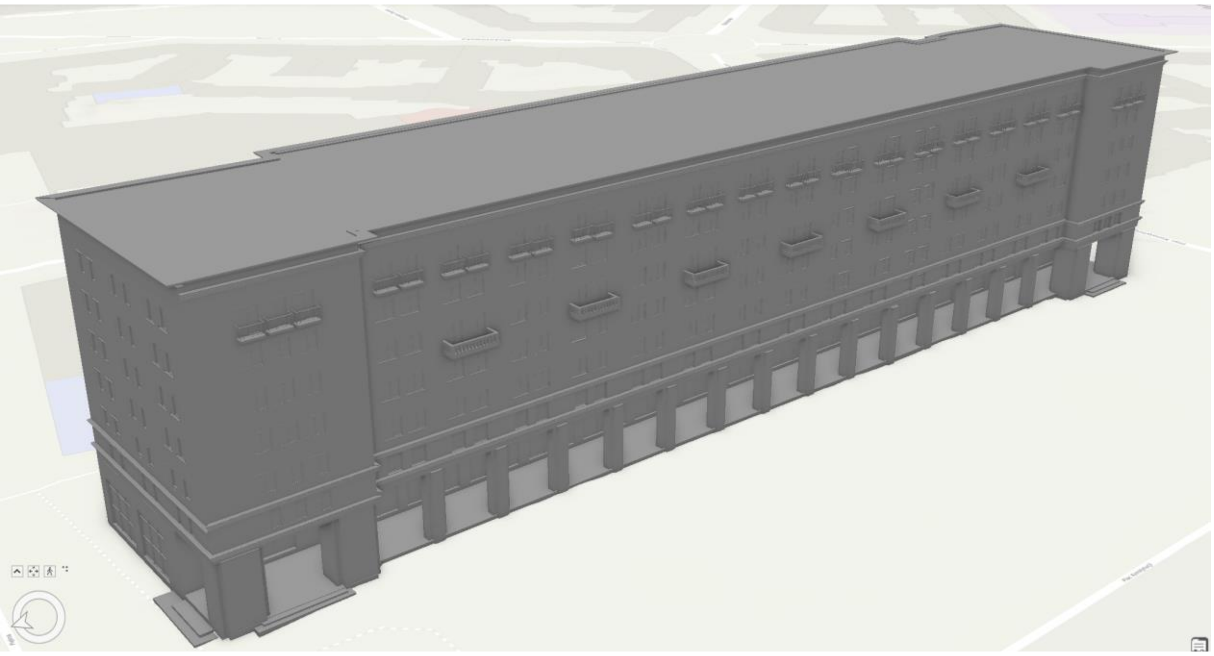

Fig. 6. Building model in 3D view in ArcGIS Pro. Source: own development

Fig. 7. Building model in 3D view against the background of buildings with CityGML LOD2 level of detail. Source: own development

The building in ArcGIS Pro, compared to the model in Revit, retained a relatively good level of detail (Fig. 7). When zoomed in, detailed elements such as stairs, balconies and windows, among others, are visible in the Shapefile model (Fig. 8 and 9).

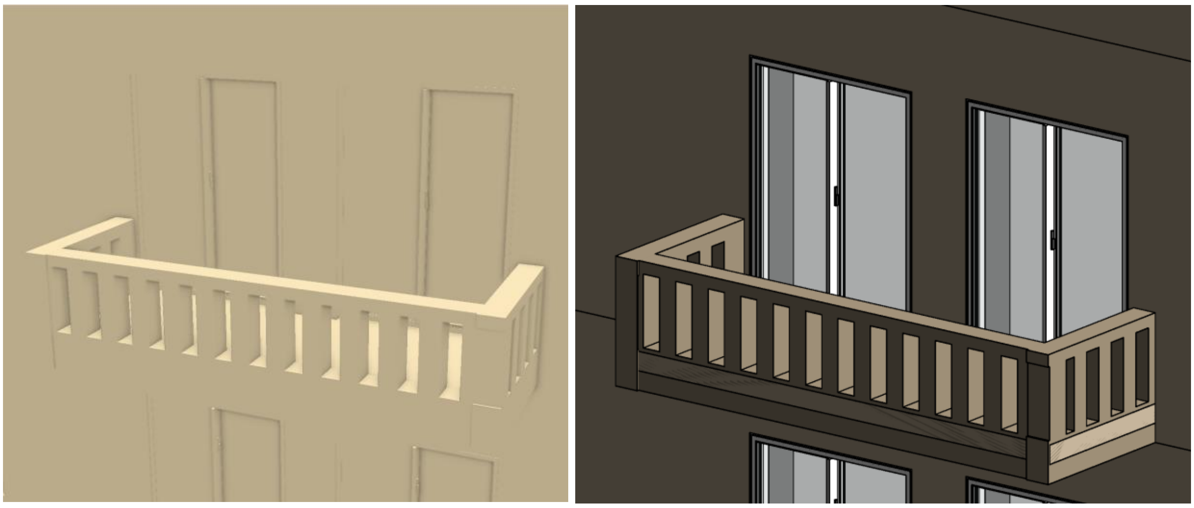

Fig. 8. Balcony with windows in ArcGIS Pro (left) and Revit (right) software. Source: own development

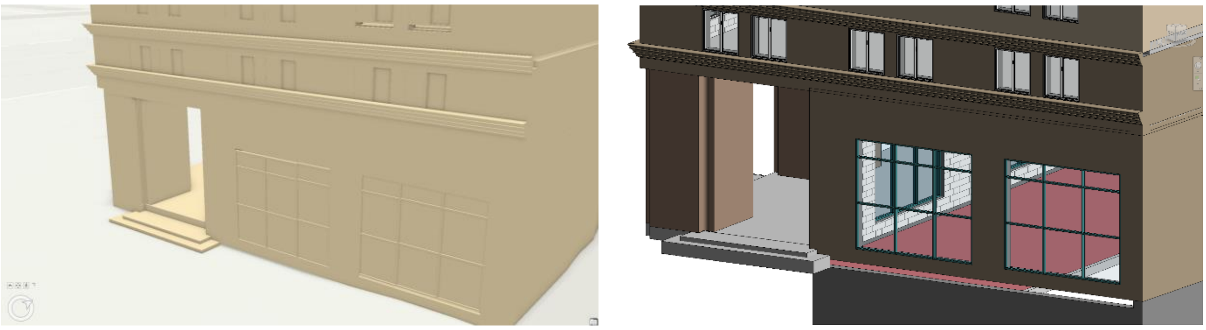

Fig. 9. Comparison of 3D models in ArcGIS Pro (top) and Revit (bottom) software. Source: own development

Exporting data from a BIM model to a table in a Shapefile also makes it possible in ArcGIS Pro software to select elements based on data in an attribute table. For example, it is possible to color-code a building based on Revit families or display families of interest (Fig. 10).

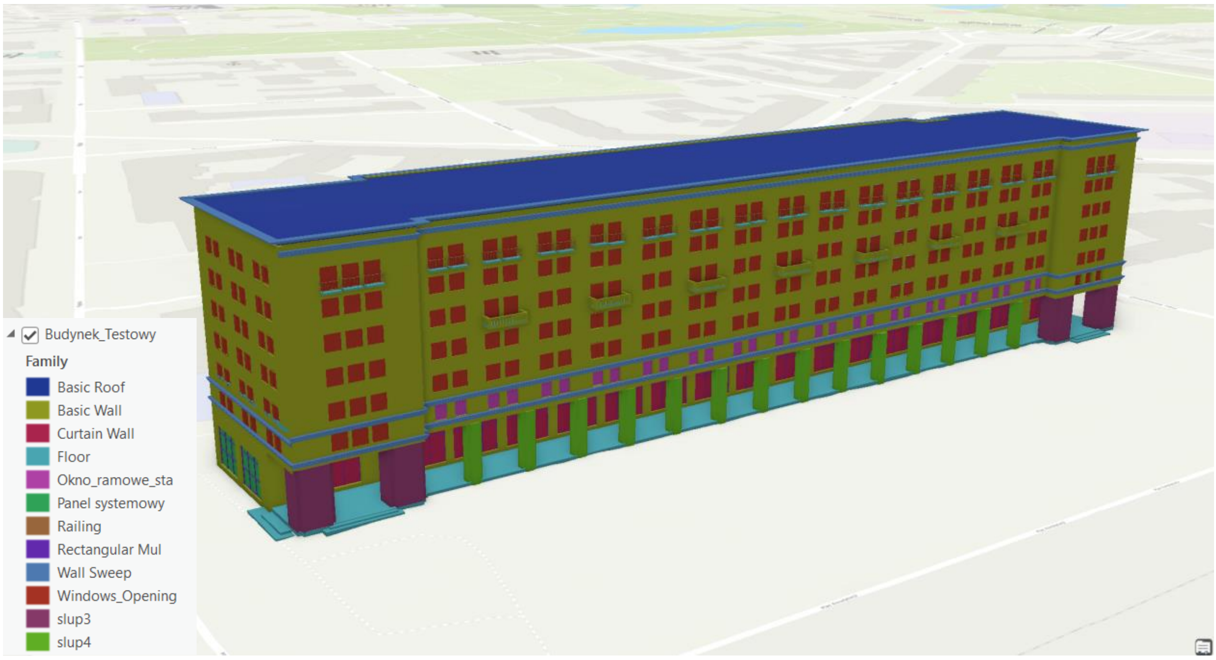

Fig. 10. Color breakdown of the building model based on Revit families. Source: own development

However, the building model in Shapefile format does not reflect the BIM model 100 percent. In some places, "holes" in the model can be seen, probably resulting from errors in data transformation or in the FME software's reading of the data. This error is hardly noticeable and only noticeable at close approximation (Fig. 11). The color of materials or visibility of building materials used in Revit is also lost.

Fig. 11. Example of a "holes" in the model in ArcGIS Pro software. Source: own development

4. CONCLUSION

The presented method of integrating BIM data into a GIS environment showed that it is possible to interact between two theoretically dichotomous formats, avoiding data loss regardless of their typology. The 10-centimeter building embedment error indicated in the paper, assuming that the BIM model being entered is accurate, does not appear to be so large as to make it impossible to determine the sunshine hours of rooms or analyze the shading of surrounding buildings, which is something that designers with projects located in urban centers and downtowns face on a daily basis. The steps presented in the paper ensure the correct georeferencing of BIM models in GIS. The FME software used contains the key functionalities necessary for this topic in assigning the appropriate coordinate system and converting data from Revit file (.rvt) format to Shapefile (.shp) format. A future research direction, which is already being carried out by one of the authors, is to compare the 3 solutions (Revit-ArcGIS GeoBIM, Revit-FME, Revit-Civil3D) and the accuracy of georeferencing obtained in these software pairs. Another interesting thread is the economic (financial) gain that could be gained from such integration. The progressive integration of BIM and GIS systems increases the spectrum of challenges facing practitioners and researchers. The work presented here is one of several examples of the implementation of such a topic and also one of the less expensive solutions. The future application of one or another BIM AND GIS data flow is already dependent on the organizational and financial issues of the company. Nevertheless, a realistic three-dimensional view of models in an appropriately localized area enables better preparation of analyses and simulations or problem solving for future investments. To improve the accuracy of BIM-GIS data integration and enhance data interoperability between IFC and CityGML, both types of models need to be updated, and software (FME, ArcGIS GeoBIM or Quadri) needs to keep up with the development of these standards. In order to broaden and deepen the application in urban management, some standards for 3D modeling of urban buildings and policies to support effective sharing of BIM and GIS data with construction participants must be formulated. In conclusion, highly integrated visualization, bi-directional interactive data flow, open standards and specifications, customization, and user-friendly experiences are fundamental aspects to be addressed in future BIM-GIS integration.

ADDITIONAL INFORMATION

The authors declare no conflicts of interest.

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