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Using BIM for the development of accessibility

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Abstract: Accessibility in today's reality is becoming an increasingly important issue as it affects every individual. We are observing the progressive ageing of the Polish population. By applying the principles of universal design, all needs related to mobility, vision, hearing, and other issues are met, thereby creating inclusive spaces that eliminate social exclusion and enhance the quality of life. This article aims to demonstrate the usefulness of BIM in building urban accessibility. For this purpose, a point cloud acquired from laser scanning of a single-family building was utilised. Based on this, a digital BIM model of the actual building was created in Revit and subsequently modernised. This modernisation aimed to remove barriers from the building, as stipulated in the relevant regulation. The paper refers to the theory of ageing in place, a response to the steady increase in average age. The BIM model is not merely a geometric representation of the building, but a digital reconstruction of the object using elements equivalent to those used in reality, allowing for efficient data management.

Keywords: BIM, accessibility, universal design, point cloud, inclusiveness

1. Introduction

BIM is an ever-evolving process of modelling and information management [1]. Simultaneously, it can be regarded as a technology that is part of the Industrial Revolution 4.0 in construction and as a methodology for conducting construction investment, effectively utilising the saturation of the model with information (geometric and non-graphic). Currently, BIM is most often used during the design and construction phase of the investment process. In Poland, it is still in the early stages of adoption [2]. However, it is increasingly being used in what is known as reverse engineering of facilities - models of existing building structures must be geometrically accurate and semantically predictable [3] to be useful for various purposes, such as ongoing maintenance, preservation, and repair planning. The operations phase appears to hold the greatest potential for using BIM. This phase is the most costly in a building's life cycle [4]. According to various sources, the maintenance of a property throughout its life cycle consumes about 70% of the investment outlay relative to the cost of implementation, which includes design and construction [5]. These costs grow depending on the time perspective. The possibilities for using BIM in management are manifold: analysis and variants [6], evacuation planning and simulation, traffic organisation, space planning [7] and leasing, waste disposal organisation, greenery and landscaping design, statement generation, planning the course of renovations, upgrades and remodelling [5], and the effects include: reduction in the time of work performed, access to information from mobile devices, possible calculation of disposal of construction materials or recycling recovery, simplified process for obtaining BREEAM and LEED type certificates, simulation of applying newer technologies, maintenance and administration of the facility, usability of virtual and augmented reality, lower costs of repairs and preparation of renovation documentation, transparency of the investment process, and lower demolition costs [8]. Nevertheless, in order to achieve the benefits that BIM offers, it is necessary to properly manage the property in accordance with current legislation [9-11], which involves collecting asset data from earlier phases of the building's life cycle, analysing it, and using it to make decisions about its maintenance [12]. The key to success is information, which to be useful must be [13]:

- unambiguous,
- current,
- complete,
- accessible,
- protected,
- easily to modify,
- appropriate to the needs,
- concise.

Additionally, the data should be accessible, searchable, interoperable, and reusable, in accordance with FAIR's principles. BIM models display varying levels of geometry saturation with non-graphical information, such as attributes and metadata. The geometry of the building can represent simple solids or form advanced component families. This article aims to show that BIM is suitable for both infrastructure and volumetric design, as well as for visualising accessibility in these facilities. Visualisation, besides producing images of the model, involves the representation of reality and its digital examination prior to construction. In this context, making changes is cost-effective and easier due to the use of machine learning algorithms, automatic calculations, or even artificial intelligence. Accessibility is often associated with the special needs of wheelchair users, the visually impaired, or the blind, yet any space user can face mobility challenges, for example, when travelling with a heavy, bulky suitcase, walking a dog, due to extreme height, walking with a child in a stroller, or riding a bicycle. According to Polish law, the Law on Revitalisation emphasises the need for municipalities to consider the principles of universal design in line with the Convention on the Rights of Persons with Disabilities [14]. Universal design is defined as "designing products, environments, programmes and services to be usable by all, to the greatest extent possible, without the need for adaptation or specialised design. It does not exclude assistive devices for specific disability groups, if needed" [15]. Building architectural accessibility involves removing barriers from a space, with a barrier being "an architectural, digital, or information and communication obstacle or limitation that prevents or hinders people with special needs from participating in various spheres of life on an equal basis with others" [16]. Disability or temporary injury is a common cause of exclusion due to barriers. Universal design eliminates the stigma of vulnerable groups, the emphasis on disability and special treatment, while enhancing the quality of life. With the rapid pace of ageing, universal design assists seniors in maintaining their independence and activity for as long as possible in their current residence.

Therefore, the purpose of this paper was to present the possibility of applying BIM in building accessibility, using the example of single-family residential development, although the analysis also considers broader aspects.

2. Methodology

Several steps were undertaken to achieve the set goal. The first step involved the acquisition and analysis of a point cloud derived from laser scanning. The second step was creating a BIM model based on the cloud. The third step entailed retrofitting the building for architectural accessibility. The fourth step focused on visualising the building to demonstrate the possibilities of implementing changes in reality. The process culminated in a description of the various ways BIM can be used in building accessibility, not limited to single-family housing, in accordance with current legislation [17].

The choice of housing development was informed by the current demographic situation in Poland. People are living longer, and the birth rate is declining [18], which indicates that not every senior will have access to third-party care, especially in rural areas. Moreover, an appropriately adjusted residence reduces the need to create new neighbourhoods dedicated to the elderly, thereby avoiding social enclaves. The necessity to move is eliminated, allowing the elderly to maintain as much effective activity in their own apartment as they did when fully functional. Consequently, the space becomes inclusive, fostering neighbourhood relations and increasing social capital.

The acquired point cloud of the building (Fig. 1) was continuously inspected and compared in ReCap Pro software for a more accurate representation in the model.

Fig. 1. Point cloud of a single-family residential building, source: *own study*

3. Results

The building was modelled based on the point cloud uploaded to Revit. The first activity involved determining the levels, followed by modelling the walls, ceilings, and roof. Windows, doors, and stairs were then added. The model utilised free components available on the Internet and custom local model blocks were created for complex roof geometries or chimneys (Fig. 2).

Fig. 2. BIM model from a point cloud, source: *own study*

The resulting model was compared with the point cloud at a density of 2 cm (Fig. 3). In terms of the model's geometry detail level, achieving British LOD4 was the benchmark [19]. Equally popular classifications include AIA or CityGML [20]. The digital model is consistent with actual dimensions and allows for the recognition of the material and type of component. The LOD4 level is sometimes equated with the approval of the design phase, but in this case, we are not dealing with the design, nor even with the documentation of the object. However, mere possession of documentation does not guarantee the accuracy of dimensions – the drawings might be outdated. The point cloud reflects the existing condition unequivocally. Elements such as the turret, chimney flashing, or planks in the balustrade were not modelled. Such detail could only slow down work with the model and would not contribute significantly to the subject under development.

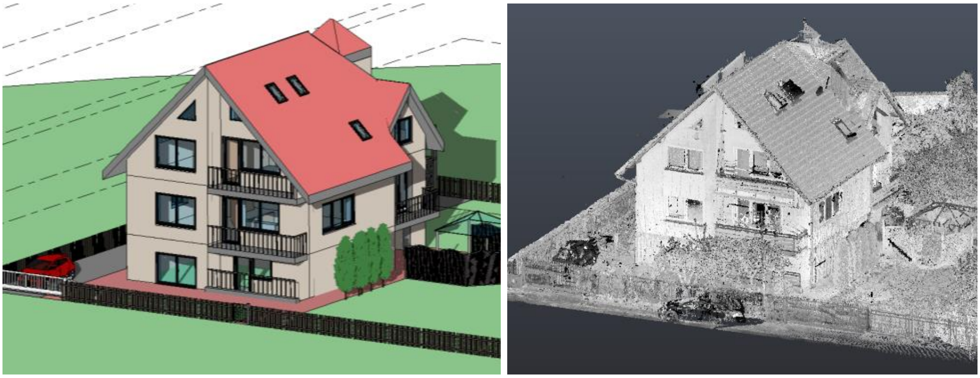

Fig. 3. Comparison of model and point cloud, source: *own study*

The provisions of the Regulation of the Minister of Infrastructure from April 12, 2002, regarding the technical conditions to be met by buildings and their location [21], apply primarily to construction work based on building construction, but are also applicable to reconstruction. In the prepared model, stairs present a significant barrier to overcome (Fig. 4).

Fig. 4. Architectural barriers of the building – stairs, source: *own study*

To ensure accessibility to the building from ground level, the existing stairs to the basement were replaced with a ramp featuring a gentle descent, and the installation of an elevator was proposed for the front door stairs. According to the regulation, the slope of the ramp should not exceed 8% for a ramp height exceeding 50 cm. The level difference between the basement and ground level is approximately 70 cm. For the ramp to reach ground level, its length should be 866.7 cm. In this case, more than half of the ramp would extend beyond the house's outline, leading to the creation of a ramp consisting of two runs (Fig. 5). The length of the first run is 508 cm (the maximum permissible length for one run is 900 cm), and the second run is 358 cm, with the ramp's width being 120 cm (the minimum required).

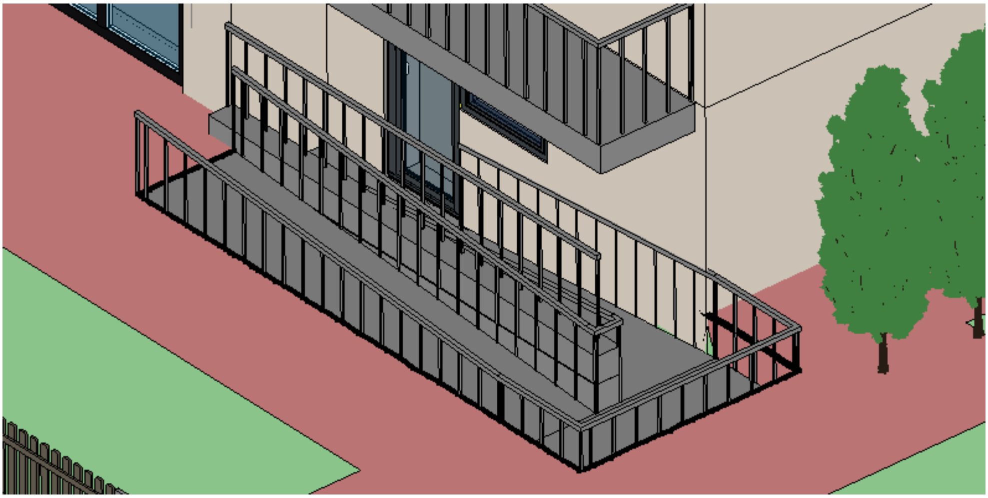

Fig. 5. Ramp model to replace basement stairs, source: *own study*

In the second case, part of the handrail at the entrance door was removed, and a specialised elevator was proposed for installation on the rear side of the ceiling (Fig. 6).

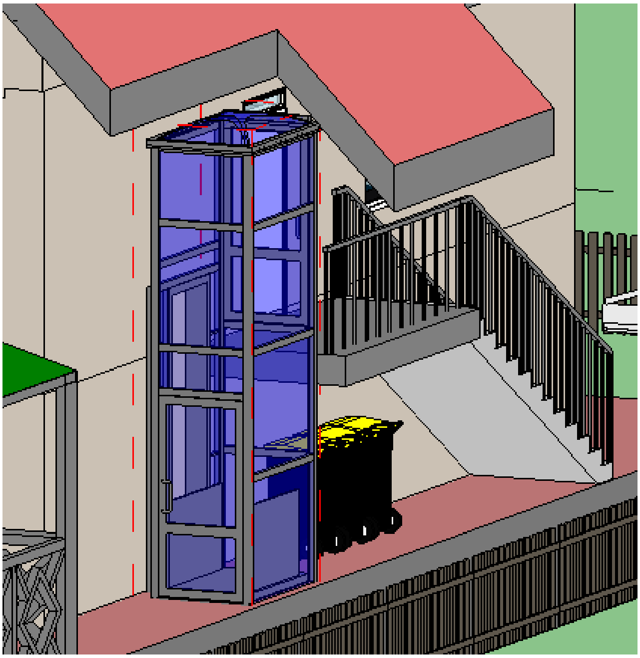

Fig. 6. Elevator proposed for the front door, source: *own study*

The Lumion 2023 program was used to visualise the created digital 3D model, utilising a real-time graphics engine. The user sees the image in real time, combined with graphic effects [22]. Available live-link plugins allow for direct importation of the BIM model from the modelling program into the graphics engine, with automatic updates. The software includes ready-made libraries of objects and materials that enable users to achieve satisfactory, realistic visualisation in a relatively short time, even without experience in rendering [23]. In Lumion, low and high vegetation from the uploaded library was added, and the appearance of materials was altered. The ground area under the ramp was lowered, and the ground cover was varied (Fig. 7). The visualisation of the effects of the remodelling in building adaptation provides a realistic view of the changes to the space user [24]. This form of presentation is the most accessible, also for changes to an existing building. Non-geometric or geometric 2D information does not fully convey the object's scale, despite given dimensions, the appearance and colour of materials in natural light, and can be misunderstood by non-specialists. Visualisations often influence the client's decision, for whom technical data alone may not demonstrate the accuracy of the realisation. By adding visualisation of the surroundings, the designer can create a uniformly accessible space and access to that space. Viewing from above, for example, a planned accessible housing development, at least makes the traffic layout within it more apparent. Sometimes pedestrian routes are poorly routed, lengthening the journey. Pedestrians then create their own paths through the grass. Therefore, it's important to consider the investment from the perspective of its users. Virtual and augmented reality can be utilised for this purpose.

Fig. 7. Visualisations of a single-family residential building model, source: *own study*

4. Conclusions

BIM facilitates better planning and anticipation of the consequences of actions taken. It is gaining popularity, which justifies the costs of its implementation in companies over time (including the costs of purchasing software, equipment, and conducting training). There is increasing awareness and knowledge among Polish architects, civil engineers, and industry professionals about BIM, fostering hope for the development of digital construction.

Accurate BIM parameter lists enable the calculation of the cost and volume of materials needed for a project. The geometry created, along with the non-graphical information assigned to it regarding the characteristics of components, materials, and manufacturers, is a key enhancement of the documentation, extremely useful for facility management.

The use of BIM in building accessibility is particularly beneficial in the case of a detached single-family building, considering accidents, illnesses, or an ageing population. Everyone is susceptible to unexpected injuries that impair mobility, such as fractures, regardless of their age. This can be a temporary or permanent situation, necessitating mobility on crutches or in a wheelchair. A development of a single-family home estate by a developer, using the model concept created in BIM and replicating it, would bring significant benefits to both parties.

Accessible buildings enhance the overall quality of life for a city's residents, who do not feel excluded due to their disabilities, age, or gender. Spaces also become more attractive to visitors. Furthermore, designing accessible housing contributes to urban sustainability and reduces the negative impact of construction on the environment. Adapting existing buildings and constructing new ones according to universal design principles allows for long-term fulfilment of residents' needs, without the necessity of demolishing and rebuilding. Additionally, a well-planned building leads to an increase in property value, contributing to local economic development. Above all, the most important aspect is the positive impact of adapted buildings on the health and safety of their occupants, thereby reducing the burden on healthcare systems.

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