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Landscape Information Model (LIM): a case study of Ołtarzew Park in Ożarów Mazowiecki municipality, Poland

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Abstract: BIM is penetrating more and more areas of human activity. Currently, it is not only volume or infrastructure objects that are being digitised, but also public spaces such as parks. To achieve this, a number of BIM tools are used to build a LIM model. The LIM model can contain a quantum of information necessary for the park management process. A municipality, for example, can use the LIM model to perform ongoing maintenance or plan rearrangements of the park space. The model itself can serve as a database for the reconstruction of a park in the event of its destruction, e.g. by forces of nature. This paper presents the LIM model of Ołtarzew Park in Ożarów Mazowiecki (Poland), which can serve as a model for building similar models in other cases. In addition to the construction methodology, examples of analyses are presented and the benefits and advantages of using a LIM are described.

Keywords: BIM methodology; BIM technology; LIM; landscape information modelling; Ołtarzew Park; Ożarow Mazowiecki;

1. Introduction

BIM methodology is increasingly being used in the modelling of landscape structures and land development components. While it has great potential to streamline and improve a product or service, it is a relatively new and still maturing concept that is becoming an essential tool for the design, implementation and management of built structures [1]. However, tt can be noted that most efforts have looked into the impact of BIM at a micro scale so far (e.g. buildings and developments) [2], [3] with limited focus on the macro scale (e.g. landscape design and climate change) [4]. Research to the date has also shown that there are limited efforts to explore landscape and urban design and the ways in which digitalisation can support sustainability in open spaces [5]. In the literature and practice of BIM, the acronym LIM, or *Landscape Information Modelling*, is becoming increasingly common,

which is, among others, an adaptation of BIM technology focusing on landscape architecture, development design, landscaping and vegetation, [6]. BIM technology is most often associated with buildings and infrastructure, but in fact all these buildings are accompanied to a greater or lesser extent by landscaping in the form of greenery, pavements or landscaping. With the increasing importance of the aesthetic and functional development of small fragments of space in towns and cities, as well as the design of open and multifunctional green public spaces, designs are becoming more and more sophisticated and accurate. Attention is also drawn to the increasing need for landscape architects and planners to use BIM [7] to streamline and rationalise design tasks. The LIM model enables the integration of land-use objects and building volume models to create a complete picture of a given space [8]. This, in turn, also enables the creation of digital twins not only of the buildings, but also of their surroundings, which are already gaining recognition for their functionality. The LIM provides the possibility to model the entire surroundings of a project, perfectly fitting in with the aforementioned trends. Thus, the aim of this article was to build a LIM model of the Ołtarzew Park in Ożarów Mazowiecki at a high level of detail.

2. Research methodology

The working methodology for the project involved a variety of design stages, each focusing on a different aspect of LIM model development. The stages listed mainly involved working in a BIM environment. Then, the analysis was carried out on the finished model, and technical documentation was prepared. An analysis of overshadowing and shading was also developed, as this is an important issue for the operation of leisure facilities, covered with a lot of greenery and sports and leisure facilities, as well as an analysis of the height of the terrain and the slope of the terrain, for which dedicated BIM tools were used to demonstrate the possibilities of extracting information and, therefore, knowledge from the digital model. The comprehensive LIM model produced as part of the work can be of key importance in future activities, not only for renovation, but also to a large extent to enable the storage and processing of information about the number, size, manufacturer or supplier of landscaping and landscaping facilities, which allows the creation of statistics and summaries as well as facilitates and automates design work.

3. Study area

Ołtarzew Park is located in the urban area of the municipality of Ożarów Mazowiecki, which is situated in the Warsaw West district, in the central part of the Mazowieckie Voivodeship (Poland). It is one of the more significant greenery complexes on its territory, especially in the intensively developing area of the city. Ołtarzew Park is a manor landscape park. It is an important element contributing to the identity of the surrounding area and its users. The idea of presenting it using LIM technology modelling tools can create many opportunities for the development of the park and also for preserving its identity and creating a digital model that could serve as an inspiration and a tool for future changes and modernisations taking place in its area. The project area (Fig. 1) was delineated on the basis of the boundaries

Fig. 1. Boundaries of the study area on the sub-plot of the neighbouring registered plots and buildings (source: own development based on data of the Central Office of Geodesy and Cartography and drawings of the project "Increase of biodiversity as an element of sustainable development of the area of Ożarów Mazowiecki - stage II, under the Operational Programme Infrastructure and Environment")

of the cadastral parcels downloaded through the 'Cadastral Parcel Finder' tool, operating through the ULDK service launched by the Central Office of Geodesy and Cartography, and the boundaries developed under the project 'Increasing biodiversity as an element of sustainable development of Ożarow Mazowiecki city area - stage II, under the Operational Programme Infrastructure and Environment'. The modernisation works were carried out thanks to funding under the Operational Programme Infrastructure and Environment 2014 - 2020, under the title 'Increasing biodiversity as an element of sustainable development of the area of the town of Ożarow Mazowiecki - stage II'.
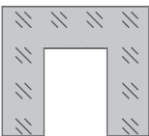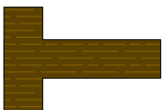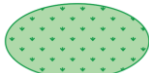
4. Construction of the LIM model
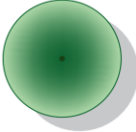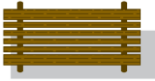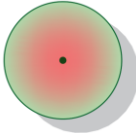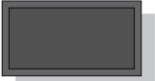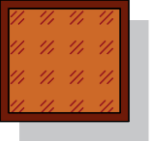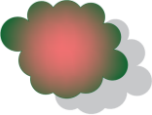
The creation of the Ołtarzew Park landscape information model took place in two stages. The first stage included a site inventory, research of available data sources and a field visit. In the second stage, a model was built based on the available data. During the construction of the model, an important element of working in BIM was to ensure proper hygiene in accordance with good practices [9]. Maintaining a high level of hygiene is one of the most important aspects of working in CAD and BIM environments, so it is right to develop determinants that should guide the user throughout the model building process. A number of digital tools have been used to achieve this goal, which together build a so- called 'tool ecology' [10]. The logical use of tools from different CAD, BIM and GIS

environments has made it possible to integrate data from multiple sources. Both direct links between programmes, intermediary plug-ins or open standards can be used for this purpose [11].

Work on the model began by georeferencing the LIM model in the appropriate geographic coordinate system (GIS). This was crucial during the project, as it allowed it to be positioned at the appropriate point in space. Consequently, it was possible to further utilise the relevant part of the topographic model, to carry out analyses in the corresponding geographical zone of the project location (taking into account the height of the sun in a given month of the year). The registration plots, which were correctly placed in space, made it possible to match the design drawings obtained from the Public Information Bulletin of the Municipal Office in Ozarow Mazowiecki and to vectorise the elements contained therein in the CAD environment (Tab. 1). Each element was placed on an appropriately named layer, which greatly improved the work on the project and ensured readability and clarity. This also made it possible to subsequently place each object in the correct coordinates on the topographic model in the BIM software.

Table 1. Layers containing vectorised objects in CAD software (source: own development).

Lp.	Name of facility	Example of an object in CAD software	Lp.	Name of facility	Example of an object in CAD software
1	Design development boundary		19	Flowerbeds	
2	Walking routes		20	Water locks	
3	Place		21	Flower meadow	
4	Bridge		22	Grass	

5	Existing deciduous tree		23	Rugs - Retail	
6	Existing conifer		24	Bench	
7	Deciduous design tree		25	30 L basket	
8	Coniferous design tree		26	100 L basket	
9	Existing shrub		27	Pots	
10	Deciduous shrub design		28	Tables	
11	Coniferous shrub design		29	Grill	

12	Existing shrub group		30	Lanterns	
13	Group of existing trees and shrubs		31	Chapel	
14	Group of deciduous projected shrubs		32	Information boards	
15	Group of coniferous projected shrubs		33	Registered plots	
16	Projected perennials		34	Escarpment	
17	Projected grasses		35	Ponds	
18	Design discounts				

The next step was to download and develop the landform model. This was done using CAD (Autodesk AutoCAD [12]) and BIM software (Autodesk Revit [13], SketchUp Pro [14] and the plug-ins Enscape [15] and Environment for Revit [16]) as well as GIS (ArcGIS Pro [17]). Originally, the terrain model was built as a triangulated irregular network (TIN),

which was then converted to points by editing the terrain model. Subsequently, the model was indicated as an imported element, which generated a terrain point cloud. The imported .dwg file was removed, so that only the model created from the terrain points was displayed in the software. This resulted in a finished terrain model of the park and surrounding area (Fig. 2). However, the depressions that form the ponds were not present on the resulting terrain model. Therefore, it was necessary to create these areas independently. Canals connecting the ponds were also added, as well as a section of the Ożarów canal running through the northern part of the study area. The main part of the design work focused on modelling in a three-dimensional environment in Revit using the Enscape application object library (with a plug-in that creates a bridge with Revit software).
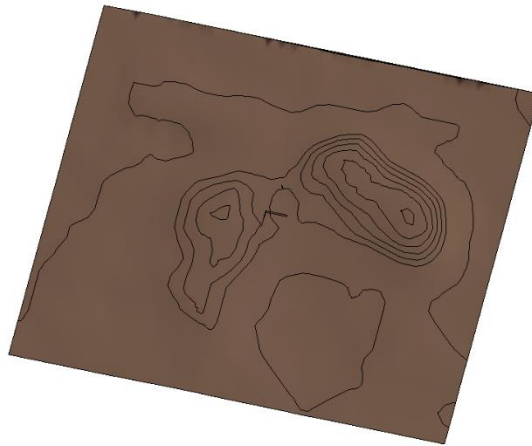
Fig. 2. Landform model (source: own development).

With the AutoCAD objects vectorised, using the CAD Link function, it was possible to connect a drawing with specific layers to Revit and use them as a reference to place three-dimensional objects. Revit allows areas to be drawn on top of the terrain topographic model using a Sub Area. This area can be superimposed on the terrain to form another layer of coverage and given a separate material. In this way, sub-areas of land cover (Fig. 3) are added to the created model at the locations indicated on the design maps, and each is given a unique material that resembles the actual appearance of the cover as closely as possible.

Fig. 3. Visualisation of the grass-covered area and the bark flowerbed (source: own development).

The next stage of work on the model involved the creation of pavements and footpaths consistent with their actual alignment and with finished materials (Fig. 4). These facilities include both the areas covered by the upgrades carried out and those left as they were. Within the Park, there is a diversity of pedestrian routes in terms of their coverage. This creates a very interesting aesthetic experience, as the types of surface interweave with each other depending on the part of the Park.
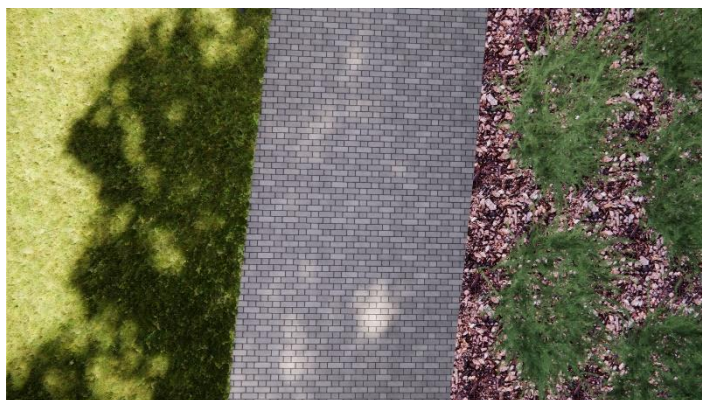
Fig. 4. Light grey paving (source: own development).

A key part of the process of creating a digital model of Ołtarzew Park was the creation of accurate models of small architecture. It constitutes the peculiar character of the place and gives separate character to its individual parts. Due to the fact that the work focused on a detailed and accurate representation of the actual state, the use of ready-made models of small architecture available in the library of popular applications and Internet sources was abandoned, and unique models of land development components were created in accordance with their parameters specified in the design documentation. A significant problem in creating landscape information models, such as the one exemplified by the Ołtarzew Park model, is the low availability and low diversity of landscape components compared to other three-dimensional elements. This can often be an obstacle to faithfully depicting the characteristics of the space or, in the case of designing a new area, a limitation in the selection of small architecture or plant species. With the development of space

management object bases, ways of managing them efficiently will develop analogously. Small architecture in the Park consists mainly of repetitive objects - benches and waste bins, lanterns, benches with tables, information boards, barbecues, gazebos, as well as objects unique to the Park, such as a chapel, fitness equipment, a table for playing table football and chess tables, bridges and footpaths. Each component of the landscaping was designed in Revit, creating a separate so-called 'family' (a parametric component of the BIM model). A family defines each component created in the design, so it could be a bench (Fig. 5) or a gazebo (Fig. 6). Repeated elements constituted one family, which was placed a certain number of times in the project. All families were created based on the system's general metric model and centimetres were used as the units, as this was how the design drawings were described. The generic model was chosen for its versatility, as the elements created in the Family Editor were diverse. The Graphic Family Editor in Revit allows each element created to be given a separate material and edited as required, so that the actual appearance of the objects can be reproduced very accurately.

Fig. 5. Bench family (source: own development)

Fig. 6. The gazebo family on the square with a bonfire (source: own development)

All the created families of small architecture objects were placed on the created model of the Park in their places of occurrence according to the vectorised design drawings. In this way, the model was equipped with elements that create the unique character of the place.

Supplementing the LIM model with trees required a meticulous analysis of the design drawings and the list of vegetation present in the Park. The vegetation was divided into groups: perennials, ferns and grasses, shrubs, trees, wet meadow plants and undergrowth plants (Fig. 7). It should be mentioned that, in the project, the assumption was made not to include the exact plant species in the model, but those that are available in the open family libraries and visually resemble the actual plants as closely as possible. This was prompted by the fact that most plant species do not have a family equivalent with the ability to be freely placed in the project. This is a problem that needs to be solved in the future for the efficient creation of LIM models and the development of this area of BIM design.

Fig. 7. Development of the study area with families of trees, shrubs and flowers and perennials (source: own development)

5. Comparisons of LIM model visualisations with the real state

The visualisations produced, juxtaposed with the photographs (Fig. 8, 9, 10) obtained through the site visit, illustrate the high level of detail in which the LIM model was made and also make it possible to observe what limitations affect the accuracy of the model.

The final element of the LIM model created was to supplement the study area with additional elements to make the area dynamic. These included models of animals and also people extracted from the Enscape object library. In this way, the created model, containing all its component elements, could be considered complete.

Fig. 8. The bonfire square: visualisation (left, source: own development) and reality (right, source: author's photo)

Fig. 9. Pond bridge: visualisation (left, source: own development) and reality (right, source: author's photo)

Fig. 10. Recreational path: visualisation (left, source: own development) and reality (right, source: author's photo)

6. Analyses carried out on the model and documentation

The digital twin of a model that exists in reality allows analyses to be carried out on it, which can provide important information on the management of a building or building objects or even entire spaces. The use of digital representations of physical objects allows to simulate phenomena and predict behaviours [18]. Thanks to the development of programmes working in BIM, including the Revit programme used to create the model, they have many functions as well as dedicated add-ons that allow various analyses to be carried out. The basic analysis that can be carried out in Revit is the analysis of natural lighting, i.e. sunlight and

shade on a given day or during a given period [19]. In fact, Revit has extensive sun and shade settings, so it is possible to adjust them within the project according to the needs. The natural lighting settings allow the analysis to be carried out for a precisely defined location using geographical coordinates and to select the position of the sun. Many GIS (ESRI ArcGIS) or CAD/BIM (Autodesk Civil 3D) applications enable similar analyses. The results can help in strategic planning, but also in the day-to-day management of space or building facilities.

Using the discussed function, insolation and shading analyses were created for the LIM model of Ołtarzew Park (Fig. 11, 12).
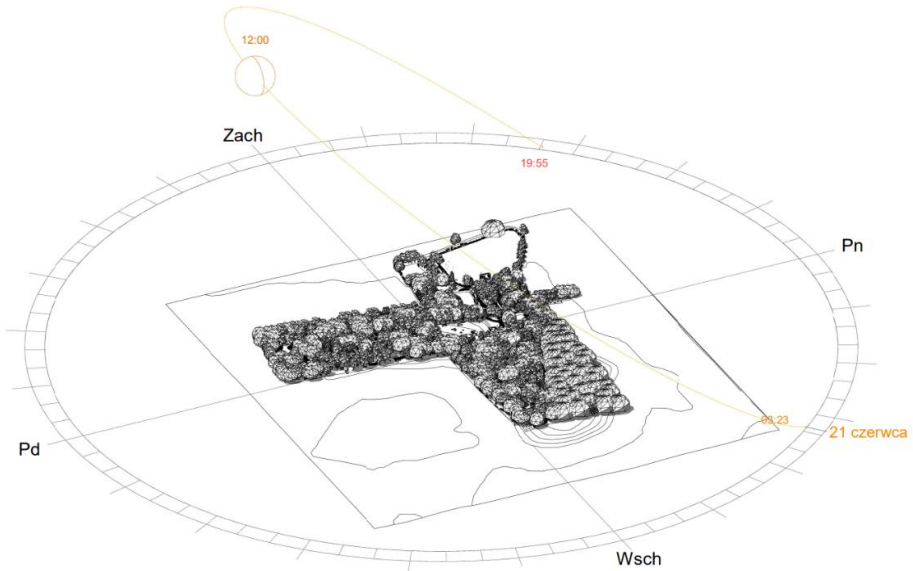

Fig. 11. Insolation and shading analysis for the summer solstice (21 June 2022, 1200 hrs) (source: own development)
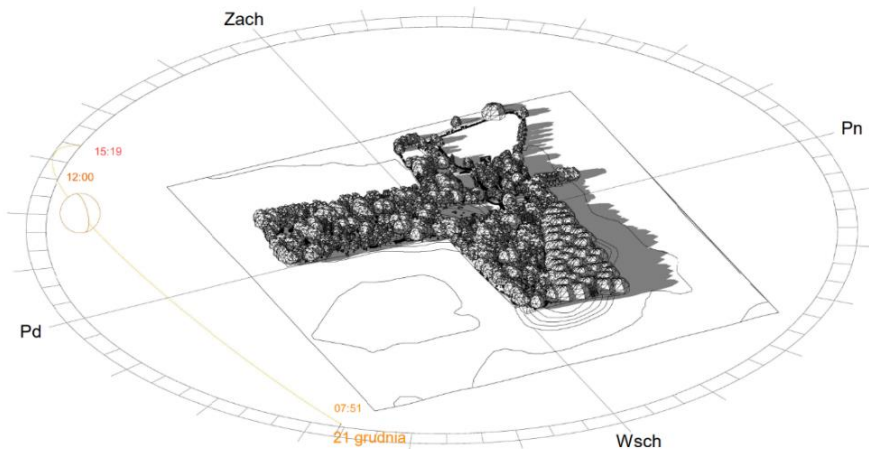
Fig. 12. Insolation and shading analysis for the winter solstice (21 December 2022, 1200 hrs) (source: own development)

Another analysis that can be carried out in the BIM software for the Park's study area is that of heights and slopes. A specialised Environment for Revit plug-in, managed by Arch-Intelligence, was used for this. It is a tool that offers additional functions visible in the software, particularly for modelling and editing topography and creating and managing ground surfaces. It also has tools for carrying out terrain elevation and slope analysis. This is an uncomplicated analysis that is of particular value in projects where the terrain itself is an important aspect. In the case of the Park, this analysis can be used in the planning of new recreational infrastructure projects, as a detailed study of the slope of the terrain can help to select the optimum location for the facilities in question, or even to manage the vegetation that is found on steep slopes and can pose a potential danger to visitors.

Elevation Analysis was carried out using the Elevation tool of the Environment for Revit plug-in. This function creates a colour visualisation of the terrain model according to the selected value ranges. The analysis focused on reading the lowest and highest elevation above sea level of the area under study and the average elevation above sea level, as well as creating a visualisation in the adopted colour scheme to illustrate the results of the analysis (Fig. 13).
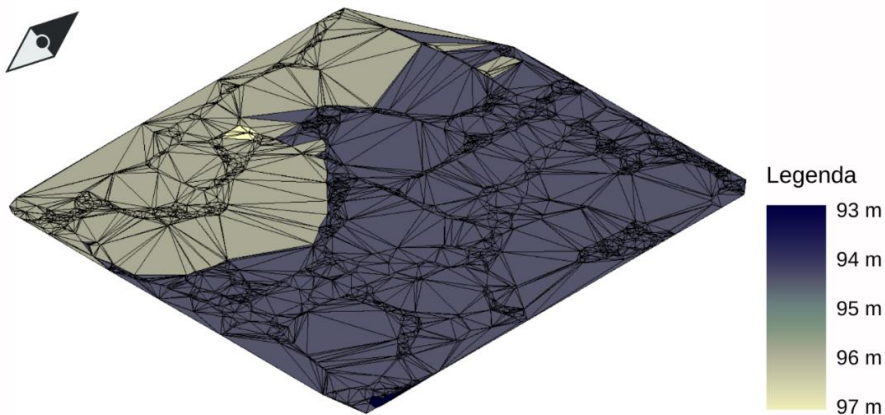
Fig. 13. Land elevation analysis (source: own development)

The development area is between 93 and 97 metres above sea level with an average elevation of 95 metres above sea level. There is definitely a slight downward slope to the east, but there are no drastic changes in the elevation of the area, so it can be described as flat and suitable for a variety of development towards recreational development.

Another part of the analysis was the Slope Analysis, which was also carried out using the aforementioned plug-in. It consists of creating a colour visualisation of the slope of a specific area based on selected intervals (Fig. 14).

Fig. 14. Analysis of land slopes (source: own development)

Based on the analysis performed, it can be concluded that the site is largely flat and does not have a steep slope. This situation is also conducive to the development of a recreational function in the area, as it does not pose a threat to people and property and does not pose a challenge to potential planners.

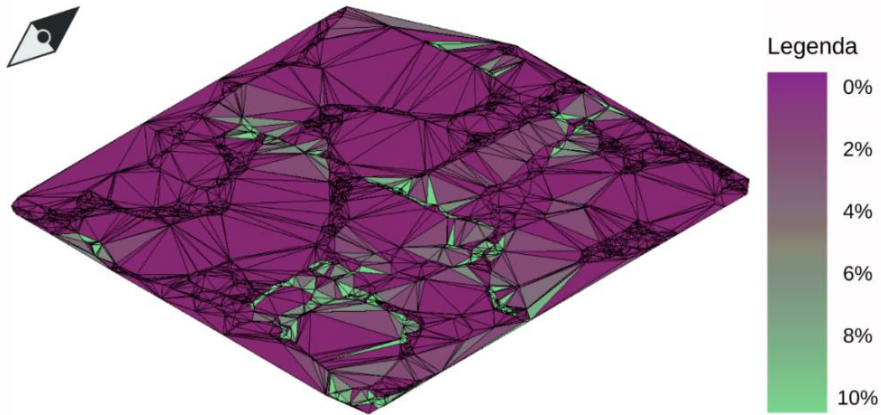Thanks to the analyses offered by tools running on BIM technology, it is possible to gain a more detailed understanding of the site being developed, which can be of significant importance in the future decision-making processes. This also shows the great potential of the aforementioned technology in the further development of the design of digital terrain and landscape models.

The creation of a digital twin of the Ołtarzew Park allowed documentation to be extracted from the model. The Revit programme allows for the creation of various types of documentation, although the documentation creation tools are specifically designed for buildings. However, it is also possible to create it for the landscape model. Sections in Revit are mainly dedicated to buildings, but it is also possible to create a landscape section. Due to its complexity and the size of the area being developed, a cross-section was made through a smaller section of the Park (Fig. 15).
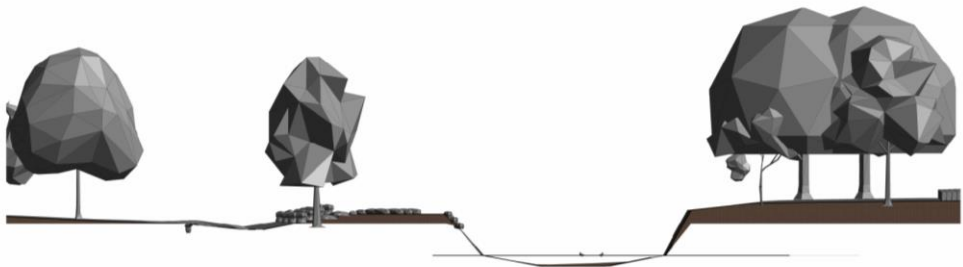
Fig. 15. Example cross-section of the Park - fragment of the pond in the north-western part (source: own development)

BIM tools are required to assess sustainability criteria. There is an ongoing need to improve the interoperability of BIM software and analysis and simulation tools. The use of BIM needs to be emphasised in various aspects of refurbishment and retrofitting, and an innovative procurement system is needed to adopt social sustainability in projects [20].

7.   Conclusion

The landscape information model allows for a comprehensive presentation of many aspects of land use that are described in the example of the Park: topography, land cover, materials that make up pavements or paths, landscaping or high, medium and low vegetation. Each of these site components is of great value and should be presented in as much detail and accuracy as possible when creating a digital twin of an existing site.

In the absence of the necessary models that provide a good representation of the real situation, it is a good idea to create them yourself or to obtain as similar objects as possible if you want a realistic representation of the object under development. The LIM model makes it possible to carry out a variety of analyses, including analysis of natural lighting (sunlight and shade), elevation and slope analysis, as well as obtaining documentation in the form of lists or cross-sections of the site. These elements are extremely important for the correct management of the site, and are an aid to planned upgrades or design decisions.

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