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Possibilities for Building Spatial Planning Using BIM Methodology

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Abstract

The life cycle of a building begins with the planning process. The planning or pre-planning stage is when the most effective decisions are made. Both in terms of time and financial resources, changes made to certain design solutions at this stage are less costly compared to later stages of architectural design, not to mention during the construction process itself. The success of a building's architectural planning solutions, how convenient the site and the building are to use and the economical indicators of constructing the building depend mostly on decisions made during the planning stage. BIM can be used for building spatial planning. This would allow architects to assess the planned building, its influence on the environment and the influence of the environment on the building even earlier and more comprehensively. The paper proposes a model and algorithm for the planning stage of building using BIM. Creating a spatial model for a building using the proposed algorithm will produce a model for specific building and site solutions. The entirety of the solutions used in the building and site design has been considered in compliance with all of the requirements of national law and compulsory regulatory technical documents. The model can then be used for further architectural design.

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Keywords: building information modeling (BIM), building spatial planning, GIS, urban planning, building model.

1. Introduction

The life cycle of a building begins with the planning process. The planning or pre-planning stage is when the most effective decisions are made. Both in terms of time and financial resources, changes made to certain design solutions

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at this stage are less costly compared to later stages of architectural design, and the more so during construction. The success of a building's architectural planning solutions, how convenient the site and the building are to use and the economical indicators of constructing the building depend mostly on decisions made during the planning stage.

Lithuanian law does not provide a definition for the concept of spatial planning. There is also no consistent definition across the member states of the European Union. In standard language, spatial planning refers to certain methods used in the public sector that affect the distribution of people and activity in spaces of varying size. Spatial planning consists of several levels: urban planning (planning of cities), regional (planning of regions), national and international. The most important goal of strategic spatial planning is to link certain aspects of territorial development by integrating economic, environmental, cultural and social policy. In Lithuania, the term 'spatial planning' is used in reference to urban or regional policy and is often related to the Lithuanian term 'territorial planning' [1]. J. Markevičienė [2] defines spatial planning as a process that models the desired urban matrix based on the existing (inherited) matrix of the city's form (by preserving it, continuing it or devaluing it).

This study presents an analysis of spatial planning in buildings and not territories, and the concept of spatial planning in buildings has not previously been defined. However, it is obvious that the life cycle of a building begins with spatial planning, and only later proceeds to more detailed architectural design.

Once the territorial planning documents are acquired for the planned building site, the planning stage for the building itself can be initiated. Planning is the first stage of the life cycle of a building (Fig. 1), during which the concept for the building is established as well as the main qualitative and quantitative parameters.

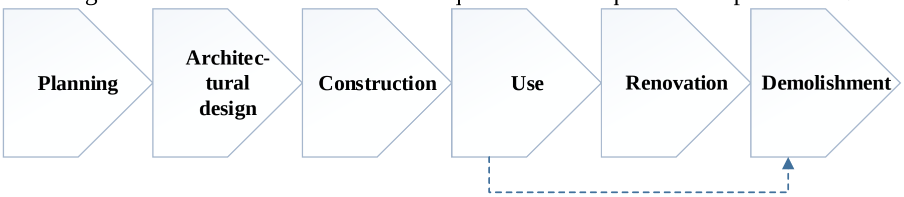

Fig. 1. Life cycle of a building.

In the planning stage of building design, requirements set out in territorial planning documents and site surroundings are used to determine the position of the building on the site, the geometric parameters of the building (height, width, length, or in other words, its spatial form) and the main building materials of its external shell (walls, windows, roof). It is this stage of the construction process that is the subject of this study, and that the study proposes to apply BIM methodology to.

2. BIM and building spatial planning

BIM is a process during which information about a building or group of buildings is generated and managed. However, a substantial amount of information that has an influence on each structure (its planning, design, construction, etc.) is contained in the environment or territory of the planned building. Therefore, the generation and management of information about the building should begin with the generation and management of information about the territory the building is to be built in.

Currently, the possibilities for applying and developing BIM are being widely analysed across the entire world [3, 4, 5, 6]. BIM is investigated from various perspectives: information management during the construction stage [7, 8], the application of online construction work journals [9], creating BIM models of existing buildings by using laser scanning [10], comparisons of the design effectiveness of 4D CAD compared to 2D CAD [11], data exchange according to IFC standards [12], BIM information management model from the state perspective [13].

The two main groups of systems that digitally describe construction environments are GIS (Geographic Information System) and CAD (Computer Aided Design). For the past 30 years, the CAD and GIS systems were developed independently but in parallel. The objective of both systems is to model the real world, however, each system does so differently. Historically, CAD and GIS were invented to solve different problems in different fields. CAD was designed to optimise the modelling of new objects defined in detail. GIS was designed to represent existing objects about which little is known and information is incomprehensive.

The communication process and information exchanges are very important preconditions for the successful development of a project [14]. Some researchers propose the integration of BIM and GIS data [15, 16, 17]. For this purpose, building elements and GIS data would have to be transformed into a semantic web data format [18, 19]. Others propose integration models for BIM and augmented (virtual) reality [20, 21]. Augmented reality systems can link a digital model and an object that exists in the real world [22]. 3D building models can also be used for simulating fire extinguishing operations [23]. The integration of data from these two different platforms results in a synergistic effect that can stimulate the evolution and transformation of technology, the organisational process and collaboration.

In order to access and use comprehensive information about a building, BIM should be linked to geographical and spatial territory information because structures cannot be disassociated from their surroundings and environment, e.g., the distances to various engineering infrastructure objects determine how a building will be used. This is also important from the perspective of sustainable development. For the purposes of sustainable development it is important that all of the information about a city is stored together. This integrated information should include data about specific territories and individual buildings in the city [24]. The application of BIM to spatial planning in building design depends very much on the legislative framework for construction in a given country. This means the specific legal acts (laws, technical building regulations, hygiene norms, rules, etc.) that regulate the construction process and how they regulate it in a specific country. It is well-established that the construction process is regulated differently in different countries. This is why it is crucial that a spatial planning model for building design be developed to meet Lithuanian requirements.

3. A model for building spatial planning using BIM

The model for building spatial planning using BIM consists of three structural elements (Fig. 2).

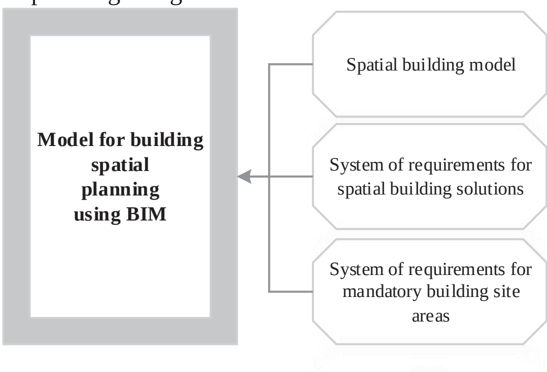

Fig. 2. Three parts of the model for building spatial planning using BIM.

The spatial model of the building is the only element of the building's entire spatial planning model that should be changed. All other elements will remain the same during the planning stage. This means that the system of requirements for building form solutions and compulsory site planning requirements is not changed because these requirements are regulated by law.

3.1. Spatial model of a building

In the spatial planning stage, the first decisions to be made address the position of the building on site, the spatial form of the building, and the main materials of its external partitions (walls, windows, roof) (Fig. 3). Therefore, the planner must establish these solutions in a format compatible with BIM.

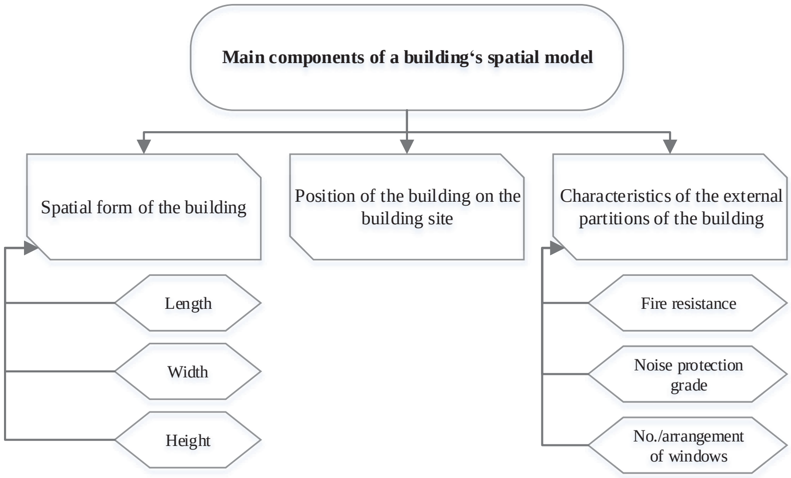

Fig. 3. Main components of a building's spatial model.

Position on-site. The position of the building on-site is a projection of the building onto the surface of the earth (plane), a certain (planned) distance away from the boundaries of the site. This is undoubtedly a very important decision and one of the main questions that needs to be addressed in the initial planning process. The position of the building will determine whether the architectural solution will negatively affect the living conditions of third parties, whether adequate insolation, protection against noise and fire safety are ensured, whether the site will be easy to use and maintain, etc. The position of the building on-site will also determine links and possibilities for various building services.

Spatial form. Space has three measurements or dimensions: length, width and height. Buildings, just like any other object, have three dimensions, i.e., a spatial form. The main coplanar geometric shapes include the triangle, quadrilateral (square, rectangle, rhombus), pentagon, hexagon, circle and ellipse. The main 3D shapes are the pyramid, prism, cube, parallelepiped, cylinder, cone and sphere.

A building can have certain features from one or several of these shapes. During the planning process, it might be difficult at first to decide on its shape. Therefore, the planner should have the possibility to quickly and simply replace one spatial form with another and thus select the most suitable version. In view of this, the spatial form of the building should be described in simple terms in its spatial model. This means that describing the shape of a building by using three-dimensional coordinates is not a suitable option. Setting, entering and changing coordinates takes up a lot of time and is not convenient to use. The coordinates later become irrelevant when a final decision is made regarding the shape of the building.

Characteristics of external partitions. The technical construction regulation STR 2.05.20:2006 "Windows and external doorways" [25] defines the external partition as a building element that separates the interior spaces of a building from the external world or other interior spaces when differences in air temperature either side of the partition are greater than 4 K (°C). The following properties of the external partition structures are important in the spatial building model at the planning stage:

- fire resistance [26];
- sound protection class [27];
- number and layout of windows.

These characteristics are important in the assessment of fire safety issues, insolation, noise protection and parking arrangements.

3.2. Requirements for the spatial solutions in a spatial building model

Requirements for the spatial solutions in a spatial building model are established in territorial planning documents, building safety and use documents as well as other legal acts (Fig. 4).

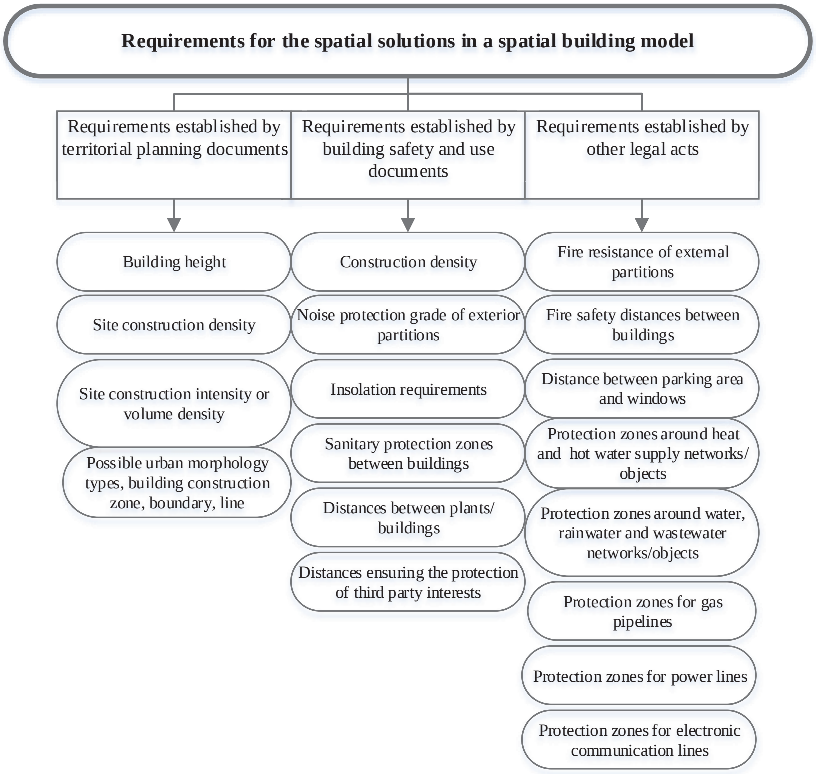

Fig. 4. Requirements for the spatial solutions in a spatial building model.

3.3. Requirements for establishing compulsory building site parts

Depending on the purpose of the building and other characteristics, regulatory documents establish mandatory sections of the building site that need to comply with certain requirements. Spatial building plans should take into account possibilities for planning these mandatory areas of the building site. The technical construction regulation STR 2.02.01:2004 "Residential buildings" [28] defines the following minimum requirements for the structural parts of a building site:

- pedestrian access to the building and driveways;
- parking space;
- green spaces with playgrounds and exercise areas, recreational areas for seniors and disabled individuals;
- bicycle storage;
- area for the temporary storage of domestic waste;
- building service structures (transformer stations, etc.).

4. An algorithm for buildings spatial planning using BIM methodology

The algorithm for the spatial planning stage of building design using BIM created as part of this study is described in Fig. 5.

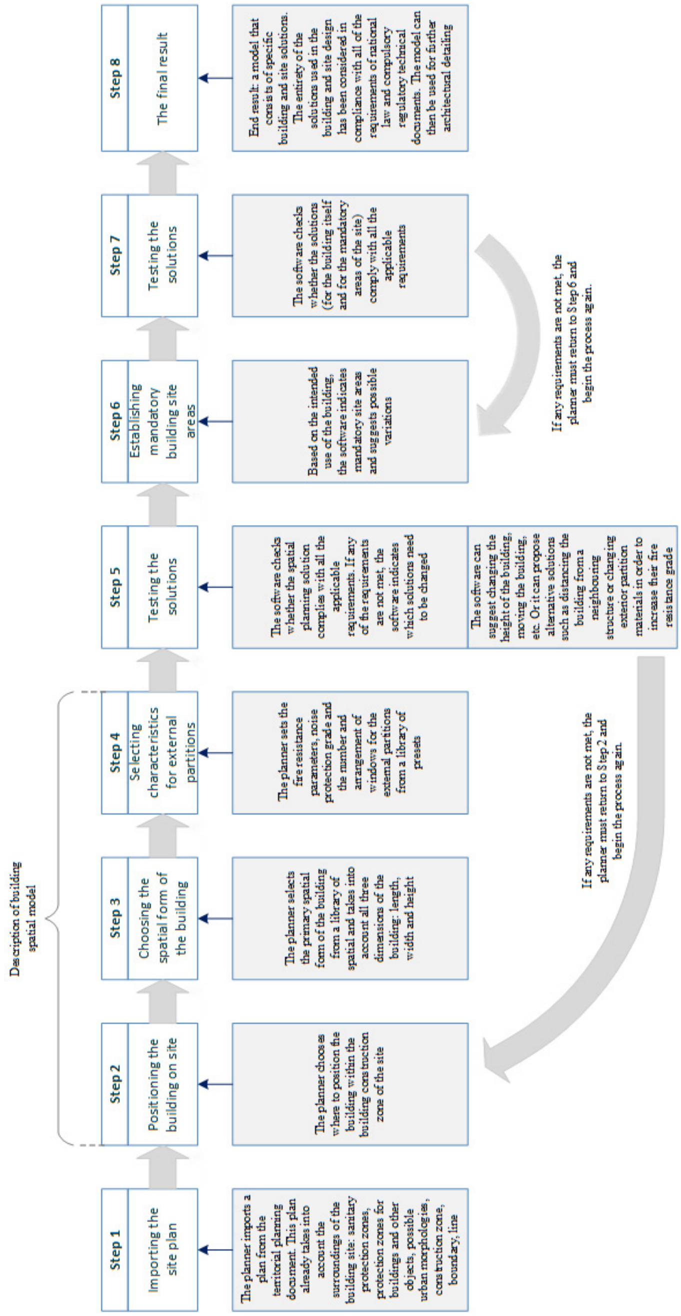

Fig. 5. An algorithm for buildings spatial planning using BIM methodology.

Step 1. Importing the site plan. The architectural planner imports a digital building site plan from the territorial planning document with all its requirements and limitations into their BIM software window. As a component of the territorial planning document, this plan already takes into account the surroundings of the building site: sanitary protection zones for factories, agricultural structures, etc., protection zones for buildings, roads, forests, bodies of water, etc., possible urban building typologies, construction zones, limits, lines. The site plan must also contain information about the allowed construction density.

Step 2. Positioning the building on site. The spatial planning of a building is carried out interactively. The planner chooses where to position the building within the building site in the building construction zone based on the construction boundaries and/or lines.

Step 3. Choosing the spatial form of the building. The planner selects the spatial form of the building from a library of spatial forms offered by the software, simultaneously taking into account all three dimensions of the building: length, width and height.

Step 4. Selecting characteristics for external partitions. The planner sets the following parameters for the external partition structures (walls, windows, roof) from a library offered by the software: fire resistance, noise protection grade, number and arrangement of windows.

Step 5. Testing the solutions. The software checks whether the spatial planning solution of the building proposed by the planner complies with all the necessary requirements. If any of the requirements are not met, the software indicates which requirements are not met and how these parameters should be adjusted in the spatial plan (e.g., by reducing height, moving the building, etc.). The software could also suggest multiple alternatives, e.g., moving the building away from a neighbouring structure or changing exterior partition materials by increasing their fire resistance. If the verification process reveals that the building's spatial solutions do not comply with the requirements, the planner will have to return to Step 2, choose new solutions and check their compliance with the requirements once again.

Step 6. Establishing mandatory building site areas. Based on the intended use of the building, the software indicates mandatory site areas and suggests possible variations. In general cases, mandatory building site areas include: pedestrian access to the site and driveways, parking space, green spaces with playgrounds and exercise areas, recreational areas for seniors and disabled individuals, bicycle storage, an area for the temporary storage of domestic waste, building service structures (transformer stations, etc.). It should be noted that building sites can contain easements. In this context, an easement is considered to be a constant. Their location cannot be adjusted.

Step 7. Testing the solutions. The software checks whether the solutions (for the building itself and for the mandatory areas of the site) comply with all the applicable requirements. If the verification process reveals that the spatial solutions of the building and site do not comply with the requirements, the planner will have to return to Step 6, choose new solutions and check their compliance with the requirements once again.

The final result. A spatial model of a building within the building site. Result: a model that consists of specific building and site solutions. The entirety of the solutions used in the building and site design has been considered in compliance with all of the requirements of national law and compulsory regulatory technical documents. The model can then be used for further architectural design.

5. Conclusions

The planning or pre-planning stage is when the most effective decisions are made. Both in terms of time and financial resources, changes made to certain design solutions at this stage are less costly compared to later stages of architectural design, not to mention during the construction process itself. The success of a building's architectural planning solutions, how convenient the site and the building are to use and the economical indicators of constructing the building depend mostly on decisions made during the planning stage. The study proposes a model and algorithm for the building spatial planning stage using BIM. Creating a building spatial model using the proposed algorithm will produce a model for specific building and site solutions. With this model, planners could assess the entirety of the solutions used in the building and site design and how it complies with all of the requirements of national law and compulsory regulatory technical documents. Using this model and algorithm would allow architects to assess the planned building, its influence on the environment and the influence of the environment on the building even earlier and more comprehensively. The model can then be used for further architectural design.

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