Aspects Of Architectural Design Using BIM Technologies

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Summary
In this article, we look at the application of BIM (Building Information Modeling) in sustainable infrastructures. In response to global warming, energy shortages, and environmental degradation, people are trying to build eco-friendly, low-carbon cities and promote eco-friendly homes. A "green" building is the entire life cycle of a building that includes maximizing the conservation of resources (energy, water, land, and materials), protecting the environment, reducing pollution, providing people with healthy, comfortable, and efficient use of space, and establishing harmony between nature and architecture. In the field of ecological and sustainable buildings, BIM modeling can be integrated into buildings with analog energy, air flow analysis, and solar building ecosystems. Using BIM technologies, you can reduce the amount of waste and improve the quality of construction. These technologies create "visualization" of digital building models through multidimensional digital design solutions that provide" modeling and analysis "of Scientific Collaboration Platforms for designers, architects, utility engineers, developers, and even end users. Moreover, BIM helps them use three-dimensional digital models in project design and construction and operational management.

Key words:
BIM technologies, design, construction, architecture, digital twins.

1. Introduction

Despite the fact that the architect's tool for design can be a drawing board and pencil, modern architectural and construction practice is complicated, includes in circulation based on IT-technology new tools, methods, design technologies, new building structures, devices and mechanisms, new construction and finishing materials, new forms of Organization of construction and installation works (which provide acceleration of time, improvement of Assembly accuracy, reduction of collisions). The search for new solutions is carried out in terms of planning and architectural appearance of the object, from the point of view of environmental approach, energy and resource conservation, security, neuromarketing and cognitive maps. These principles provide for a conceptual approach to the creation of new facilities, and at each stage of the design process, integration and optimization of environmental, technological, social, and economic factors should be carried out, energy-saving technologies should be used, a closed cycle of resource consumption, minimizing the harmful impact of human activities on the environment, which allows not only to preserve nature, but should also be economically profitable, since the cost of maintaining and operating the building is significantly reduced [7].

On an emotional and subconscious level, architecture can be considered as a synthesis of plastic images that touch our feelings, which will always be of fundamental importance for a person. The plastic harmony of space in the historical part of the city, its artistic expressiveness created at a certain time, will always differ in its stylistic expressiveness of architectural plasticity. The onslaught of general urbanization in the third millennium has increased many times, the risks of man-made disasters, and the demographic crisis has led to the over-compaction of megacities, the happiness of city residents is becoming an increasingly ephemeral concept. In a city, especially in a large one, the danger to people is not only transport accidents, chemical explosions, fires, floods, landslides, air and water pollution, increased levels of radiation and noise, but also an unnatural, and therefore potentially dangerous visual environment. "Scanning" the urban environment, we constantly get information about the degree of potential danger, or vice versa – the security that the architectural environment carries with its visual qualities. The tone of its sound in architecture and its perception by a person depends on a professional understanding of the complexity of this problem [16].

Architectural activity in the process of designing an object includes the search for architectural solutions that reflect the originality of the creative idea, the rationality of

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the characteristics of the object, which is designed in specific conditions and under given requirements; the development of materials that determine the architectural section of the project documentation, including visual representation (external and internal appearance), spatial organization and functional characteristics of the projected object, planning scheme and ergonomic component.
Object design is a multi-stage process that includes stages of analytical research, geometric modeling (with layout options, structural organization), calculation (according to the criteria of strength, stability, ballistics, hydraulic - and air-characteristics, economy, etc.), optimization of object characteristics (physical, geometric, functional, cost, etc.), visualization, decision-making when choosing options (including taking into account the conditions of project implementation).

Although initially the concept (idea, idea) comes from the project architect (his vision of the object, general idea), but at the same time the creative process of finding a solution is influenced by a number of factors, including planning, structural, engineering, environmental and economic. And here it is important to choose an information model of the object from the point of view of organizing the process of design and construction work, since this affects (and determines during project implementation) the effectiveness of the entire process chain. Today, environmental rational design develops together with building information modeling (BIM) and shares a common basis with the concept of Sustainable Development (Sustainable Development), and the latter closely interacts with BIM technology. Building design using BIM involves the initial collection and further complex processing in the design process of all architectural, design, technological, economic and other information about buildings, with all relationships, external factors, in order to consider the building as a single object [7]. Moreover, the correct definition of relationships, classification of all components of the project, structuring the data used at the initial design stage determines the key to successful BIM modeling. In addition, BIM technologies allow you to put together all the components of the future building created by various specialists in virtual mode, check their functional and operational qualities, allowing you to avoid errors throughout the entire life cycle of the building, as well as reduce project completion times, improve the quality of construction and save budget funds [10].
Moreover, construction needs to evolve from BIM to embrace digital twins as the promising area of upcoming research in the field of sustainable infrastructure.

2. Theoretical Consideration

Use of BIM in other countries.
BIM is just beginning its rapid development and demand, only the richest countries have been actively using information modeling for the last decade.

Great Britain.
The UK is still not just the first, but also the absolute leader in the use of BIM. This became possible thanks to support at the state level: since 2016, all budget construction projects are required to apply BIM of the second level, not lower. So, as a trial implementation, the technology is used for the project of the Ministry of Justice – the expansion of Cookham Wood prison in Kent. And this made it possible to significantly reduce capital expenditures and implementation time.

USA.
In the United States, the Office of General Services has developed a BIM program for all public building maintenance projects since 2003. Today, in the United States, about 72% of construction firms use BIM to significantly save money on projects. A number of US states, universities, and private organizations also apply BIM standards. So, the state of Wisconsin has made it mandatory to use BIM for government projects, if their total budget starts from 5 5 million.

France.
In France, since 2017, they have started building with the help of BIM, and today half a million residential buildings have already been built in the country. The Le Plan Transition Numérique dans le Bâtiment working group is responsible for the French BIM strategy, which aims to ensure environmental friendliness and reduce costs.

Germany.
In Germany, the government also influences the promotion of BIM technology. The focus is more on commercial and residential buildings in order to implement BIM in all infrastructure projects as soon as possible.

Spain.
In Spain, BIM has been used for public sector projects since 2018, and since 2019, it is mandatory to use the technology in infrastructure projects. A separate commission has been set up to assist in the implementation of BIM in the Spanish construction sector.

Finland.
The Scandinavian countries were among the first to start using BIM. For example, Finland started using information modeling of buildings back in 2002. BIM was used to create complex infrastructures, such as the Helsinki metro line.

China.
Chinese specialists from the Atomic Energy Commission and several organizations have integrated a high-level

BIM implementation policy for digitizing and distributing the technology. BIM has become a key element and is used in most of their projects. The Chinese government has not yet introduced mandatory use of BIM in construction, but its use is welcome. In general, BIM works in an experimental form even in economically strong countries – the process of introducing digital technologies in construction is not fast for a number of reasons. However, there is still an acceleration in the digitization of the industry and a great interest of developers in modern long-term solutions, such as construction information modeling [2].

BIM modeling software.

To implement a successful project using BIM modeling, you must immediately resolve the issue of information completeness of the object model. How fully architectural, design, technological, economic, and other data about an object with all its relationships and interdependencies are presented in the model. At the same time, you need to determine in which software environment the object model will be created (with the possibility of different specialists participating in the project to work in the same information space), because, in fact, the BIM model is databases.

For example, Autodesk Revit allows you to create a set of moduli – in the form of ready-made components-rooms with various finishing options and taking into account the necessary engineering systems and content, while all modules can carry all the necessary information: specifications for all elements, their quantity and even cost. Such modules will be developed separately and only then loaded into the base model. By selecting from the ready-made options those modules that carry the necessary data on the repair of specific parts of the building in each specific case, we can get the necessary combination, from which the project itself will then be compiled. Thanks to the built-in functions of Autodesk Revit, the program itself notifies about collisions that have occurred, for example, the mismatch of modules and their parts with each other and between the main carrier model. Such functions will allow you to avoid making mistakes when developing design solutions and displaying specifications. Thanks to the use of BIM technology in the development of a major repair project, labor costs are reduced without losing the quality and accuracy of the initial data.

Dynamo is a tool that allows designers to fully implement all the necessary tasks in the Revit model space, starting from creating elements of the object's geometry, and ending with the design and simplification of the process of working with the model. Thanks to this program, designers, customers, contractors, and related specialists get the opportunity to use the information model as efficiently as possible, get not only a set of drawings with information about elements, but also any other information contained in the project.

The construction calendar plan is developed in Primavera and Microsoft Project.Navisworks allows you to make it as detailed as possible.

You can develop an estimate section in the Nemetschek Allplan, Autodesk Revit, or Renga Architecture Environment.

ArchiCAD, 3d Max, and other programs allow you to create a full-fledged 3D model of a building, simplify the preparation of estimates and other documentation, as well as simplify the exchange of Information, its analysis, ensure security, and so on.

Stages of working with the BIM model.

Working with the BIM model is carried out in several stages:

1. design. First, create a 3D model of the structure with plans, sections, and views. With the help of a special constructor, this model is entered into a program that calculates the parameters of all elements of a construction object. A large database allows you to get all working drawings, specifications, information about the scope of upcoming work, and planned costs. At the design stage, engineering and Power Networks, heat losses, and the level of natural light are also calculated, taking into account the characteristics of the terrain, terrain, soil, etc. The initial information model of the building is supplemented with logistics data that determine the delivery time of materials and the most favorable delivery options. BIM modeling also allows you to plan the social infrastructure and transport network in the development area. At the final stage of design, a detailed work plan and schedule of their implementation are drawn up, and the required amount of equipment and resources for performing the work is determined.
2. construction. At this stage, BIM design allows you to track the status and progress of work. With its help, it is possible to control the expenditure of funds and the extent to which the budget is implemented. BIM provides real-time information about all management decisions and changes in construction.
3. Operation. After construction is completed, the information model can continue to collect the necessary data about the building using sensors, monitoring its functionality and predicting potential emergencies. Using BIM, you can keep records of equipment, monitor warranty obligations, and monitor resource consumption. Integration with the object's BMS system is possible. Moreover, BIM modeling can also be useful for real estate management: this model allows you to keep records of rentals, rental of premises, scheduled repairs, and interactions with various authorities. Management assessment, technical audit, development of a construction

project development plan – this and not only is possible with the help of BIM design [2].

Green BIM modeling.

The need to reduce tension, anxiety, and fear is directly related to architecture, which is designed to protect a person from external adverse conditions. Architecture is able to remove the feeling of anxiety, comprehensively revealing the regularity of construction, strength, stability of the building, and its compliance with the person by conventional means of expressiveness. In this aspect, three main categories of fear are also considered – biological, social and existential. But in this case, in terms of the protective properties of the architecture, biological safety is natural. Biological fear is caused by a certain situation and threatens one of two biological laws: the preservation of one's own life and the preservation of the life of a species. In the visual perception of architecture, it includes such concepts as fear of heights, stability, strength, etc. Also, biological fears can include the threat of meeting the simplest physiological needs such as: the need for food, water, air, shelter, that is, those that a person must satisfy in order to maintain his body in a vital state. The architecture is constantly scanned by the recipient for potential hazards. Huge, empty asphalt-concrete spaces with their small planes are perceived as places with a weak or completely absent protective base and the inability to hide in case of danger, thereby provoking an unconscious fear of hunger and the need to escape. The need for physical comfort is so programmed in humans that even when all basic needs are met, we will still try to improve them [17]. But today, our biological fears are becoming even broader, given the generally unfavorable ecological situation of our only planet. We humans have destroyed everything we could destroy, today we live in debt, we have used up all the resources of the Earth, and today we are on the verge of destroying our species altogether from the planet. And at this time, one of the most relevant BIM models in architecture and construction is the so – called "GREEN BIM" strategy-a fusion of two strategies for environmental rational design and BIM technologies [7]. The Ukrainian-language name of this strategy – "green construction" – immediately reveals to us its semantic essence. This project strategy necessarily takes into account the following factors: economic and environmental, features of specific geolocation time of design and development of cities, as well as such the latest resource and energy - saving technologies as nanoantennas in solar windows, vortex type thermogenerator, heat exchangers in the ventilation system, solar activity of the building, solar collectors, Rotary wind turbines, underwater power plants, recycled water supply, etc. It is clear that all of the above factors were previously components of the designer's scenario preset. For Example, N. P. Travin designed residential buildings, a kindergarten and a boiler room, where the guiding idea of solving facades was the principle of maximum possible use of sunlight [1].

Since GREEN BIM technology is based on an environmental component, the future perspective of GREEN BIM in combination with the tasks of BIM is to continue to improve in the "green" direction, to contribute to improving the environmental friendliness of projects. For the effective implementation of such technology, environmental issues should be identified by the architect and engineer at the initial stage of working on the project. Further work in this direction is divided into several stages, such as: a comprehensive assessment of the placement conditions of the building under construction (Geodetic studies are carried out, orientation to the cardinal directions is carried out, the degree of solar shading is estimated, the possibilities of using wind energy are determined); development of the building concept (the number of people, the volume of water consumption, the quality and quantity of materials are estimated); modeling of engineering structures taking into account thermal comfort for each specific room. Since ecological buildings are not standard projects, and all decisions made are individual in each specific case, factors that indicate the environmental friendliness of the project should be taken into account, namely: maintaining the temperature regime of the premises, using ecological materials and renewable natural energy sources, natural and climatic conditions, The Shape of the building (compactness), zoning of premises, the use of energy-saving engineering communications, etc. [5]. This allows you to combine the activities of many specialists, including architects, engineers, and specialists in related professions working with different software products and using different tools. With proper and clear application of GREEN BIM, it becomes possible to get a number of solutions and choose the most optimal and eco-friendly one. I would especially like to note that the relevance of mastering the GREEN BIM tools for an architect lies not only in the ability to design a unique ecological building, but also gives advantages over competitors – adherents of the traditional construction approach, since GREEN BIM technologies are an effective marketing tool for obtaining prestigious green construction certificates.

Example of using GREEN BIM in practice.

1. Analysis of the construction site.

The location of the construction site and its analysis are the main factors affecting the condition of buildings. These factors determine the spatial orientation of buildings and their facade, as well as the relationship between the construction process and the surrounding landscape. In the planning process, the topography of the site, vegetation and weather conditions are important components. Traditional analysis of the locations of future buildings has

drawbacks – for example, lack of quantitative analysis, excessive subjective factors, inability to work with a huge amount of data and information. Taking advantage of BIM and GIS, we can create simulation models of spatial data and building scenarios. At the planning stage, using BIM to assess the conditions and characteristics of the construction site, you can make ideal key decisions, organizational relationships of traffic flows and building planning.

2. Project Overview.

A practical example is based on the International Design Competition The Tent Hotel. Such hotels can be adapted to different climatic conditions, they are quite easy to design, fill them with details of local cultures and inspire a new style of recreation. The place of implementation of the project we are considering is the mountain village of Hengshan Nashan (550 m above sea level), 12 km from the top of Zhu Rongfeng peak. Hengshan city is 4.5 km away, Changsha City (the capital of Hunan province) is 130 km away, and Huanghua airport in Hunan province is about 150 km away. [17] Since the hotel, its construction and operation, have a huge negative impact on the ecology of the environment – energy consumption, air, soil pollution and carbon footprint during and after construction, the main task of this construction and further operation of the hotel was to minimize its impact on nature. The border of the plot is 10 hectares.

Figure 1. Tent Hotel in Henshan Nashan village. Bird's eye view

3. Requirements for Tent Hotel.

- Mobile: mobile and convenient, virtually unaffected by the environment.
- Culture: reflects elements of local culture, providing a unique life experience.
- Eco-friendly: compliance with LEED standards, full implementation of the principles of eco-friendly and low-carbon design.
- Create a BIM model for Project Coordination. Then use the BIM model modeling software to analyze the green building.
- Analysis by modeling daylight, sunlight, shadow, sub-environment.
- BIM can provide a framework for further green building projects and environmental measures based on the results of this analysis.

4. location analysis.

- The AutoCAD Civil 3D ® program was used to create the project [13; 14]. Initial modeling was performed using the following data: site location, climatic conditions, environmental value, site information, and transport infrastructure. The AutoCAD Civil 3D ® program will be used primarily for creating 3D visualizations. Subsequently, the same model was used in the environmental analysis of the project. For reasons of resource sustainability, the authors (Wojciech Bonenberg, Xia Wei [17]) chose flat plots of land as planning plots. Layout of a land plot of 3 hectares, flat plot, with swimming pools, tea shoots and streams. The plot for planning is located on the southern slope of a small height near the road to the city.

Before coming to a conclusion, numerous options are tested during the design process. This allows you to fully understand the site and start designing buildings that fit into the surrounding green landscape.

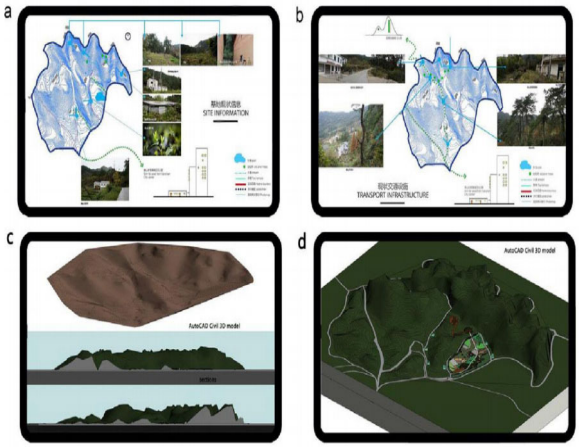

Figure 2. Tent Hotel in Hengshan Village Nashan. (A) location information; b) transport infrastructure; (C) AutoCAD Civil 3D @ model and parts of the location; (D) AutoCAD Civil 3D model

5. Organization of Tent Hotel.

- Sustainable development design using the energy-saving and eco-friendly features of the Tent Hotel. The creation of a magnificent park on the embankment contributes to the hotel's plan.

- Create three functional zones, each of which relates to a coastal park.
- Deviation of roads to water. All buildings connect the districts with the park on the embankment. In Chinese garden planning, water is the most important part. A "courtyard" is traditionally defined as an architectural space located near a mountain and surrounded by water. In Chinese, this is called "feng shui".
- Daylight analysis. Various building functions are created according to the analysis of sunlight, which avoids mutual overlap between buildings to guarantee lighting.

Analysis of 3D models. Using the analysis, it is more convenient and appropriate to evaluate the site conditions and project characteristics at the planning stage, which helps to make ideal key decisions, plan new projects, traffic flows, linear organizational relationships, building planning. After constant adjustment and analysis, the final conclusions are obtained.

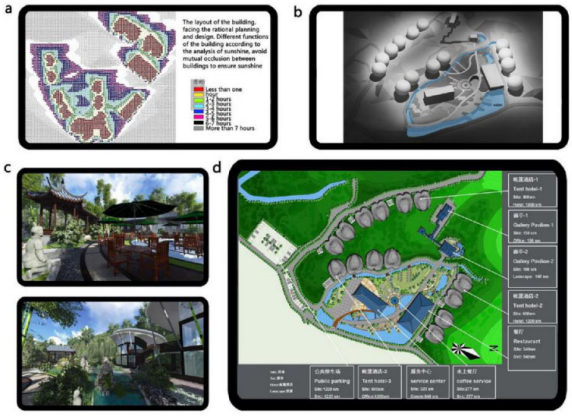

Figure 3. Tent Hotel in Hengshan Village Nashan. a) daylight analysis; (B) analysis of three-dimensional models; (C) visualization modeling; (D) Master Plan

6. GREEN BIM with building design and layout analysis.

- Use of natural ventilation, natural light and natural shadows.
- Use of solar energy.
- Rainwater recycling and waste management.
- Use of soil outdoors.
- Use of green materials.
- Focus on Environmental Services.
- Application software for energy-efficient computing; use of natural ventilation and performance analysis.

In the master plan, the main facade faces south so that there is enough natural light. The information model of the building allows you to find the most suitable position, installation guide, direct light scattering in the interior space, allowing you to get a lot of natural light in the room due to scattering and bright, energy-saving lighting. Solar power generation is integrated with outdoor shading capabilities to get a double benefit – power generation and energy saving.

The roof of the hotel is made of solar panels as an external material. The solar panels will not have a battery, and they can be directly connected to the power supply. During the operation of the building, the panels can also be turned off,which means that more energy can be saved. When designing the interior lighting of a building, LED lamps are mainly used. LED lights are powered by solar panels.

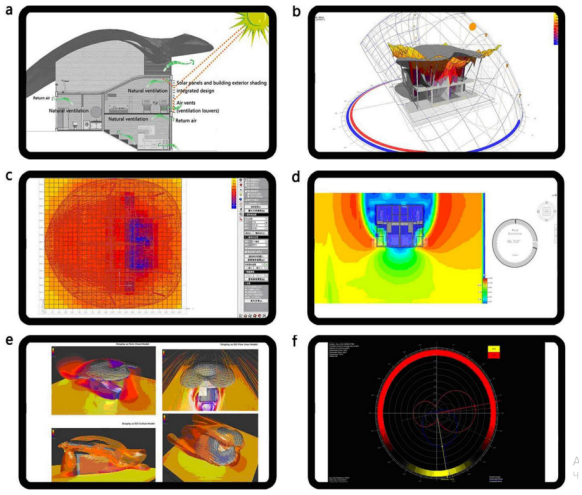

Figure 4. Tent Hotel in Hengshan Village Nashan. a) natural ventilation analysis; b) Natural Light; c) natural light and illumination; (D) wind rose modeling (e) wind analysis; (E) optimal orientation

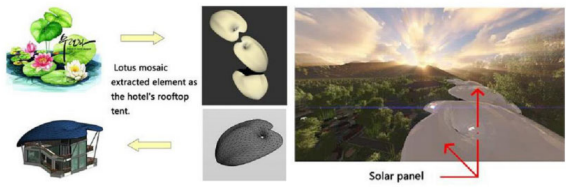

Figure 5. Tent Hotel in Hengshan Village Nashan. Analysis of solar energy

Figure 6. Tent Hotel in Hengshan Village Nashan. Wind rose analysis

The tent-shaped roof is used to collect rainwater. The building located at the bottom of the rainwater collection system is designed to store large amounts of water. The collected rainwater will be used for irrigation of outdoor plants or for other purposes.

The presented example shows that the use of BIM (Building Information Modeling) is an effective tool for integrating natural and technical systems into architectural design. The multidimensional digital model of the Tent Hotel in Hengshan village made it possible to quickly coordinate an interdisciplinary project in accordance with the principles of green design.

Conclusions

Object design is a multi - stage process that includes stages starting with analytical research, geometric modeling (with layout options, structural organization), calculation (according to the criteria of strength, stability, ballistics, hydraulic - and air-characteristics, economy, etc.), optimization of object characteristics (physical, geometric, functional, cost, etc. D.), visualization, decision-making when choosing options (including taking into account the conditions of project implementation) ending with the stages of analyzing the future cognitive perception of the structure, perception of the architectural environment, as a source and as a means of protection from human fears and anxieties. In the design process, it is necessary to solve problems related to the correctness of the description of the final result, which represents a consistent representation of the detailed qualities of the future object. The project prepared for further reproduction should allow for an unambiguous understanding of the design of the object and ensure its technological implementation (production). In the design process, the target problem is reduced to a cumulative system of optimization tasks: it is necessary to choose a solution (and in accordance with the architectural plan) that provides a comprehensive solution to functional, structural and aesthetic requirements, as well as social, economic, sanitary and hygienic, environmental, engineering and technical aspects. The design result is presented in the form of a technical description containing geometric and graphic materials and generated documentation (technical, construction, etc.). Providing such a description is the formation of coordinated, internally coordinated, systemically calculated information about the projected object, as well as a visualized model as a digital prototype of the projected object. Such a digital prototype as a single information object is defined on the basis of building information modeling (BIM) technology. In terms of creativity, BIM technology helps to integrate the efforts of specialists in various fields involved in creating a new architecture.

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