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SUSTAINABLE DEVELOPMENT AND ARCHITECTURE: ECONOMIC FEASIBILITY OF DUALISTIC CONSTRUCTION

The characteristics, principles, and directions of sustainable development in architecture have been identified. The economic feasibility of implementing sustainable development in architecture has been substantiated. The Fourth Industrial Revolution has been considered in the context of sustainable development. The authors suggest utilising the latest technologies and innovations to enhance production efficiency, reduce emissions through the implementation of clean technologies, and utilise resources rationally. By combining the opportunities presented by the Fourth Industrial Revolution with sustainable development approaches, it is possible to achieve a balance between economic, social, and environmental aspects of development. Sustainable architecture aims to minimise negative environmental impacts and improve building performance by consuming fewer resources, reducing waste, and creating a functional and productive environment. The text discusses the importance of sustainable principles in architecture, including adaptability of architecture, recycling of resources, use of sustainable and renewable materials, and energy efficiency. The economic feasibility of applying sustainable principles in design has also been considered and justified. Additionally, the text provides examples of innovative architectural designs. This is a crucial step towards implementing sustainable building practices. The adaptability of architecture enhances space efficiency by enabling areas to serve various functions based on user requirements. Resource recycling minimises waste and the expense of extracting new materials. The use of sustainable and renewable materials aids in reducing the ecological impact of construction. Energy efficiency helps to decrease energy consumption and GHG emissions. Further research and innovative architectural designs can accelerate the development of sustainable construction and promote its wider adoption in the future. The authors suggest that taking into account the costs of building, maintaining, and operating buildings, as well as a balanced cost-benefit ratio, can significantly influence decision-making in the design and construction process. The authors argue that implementing environmental solutions in architecture may raise the initial project cost. However, in the long run, it can lead to significant economic benefits by reducing energy and maintenance costs, as well as increasing the overall value of the building.

Keywords: economic feasibility, sustainability, architecture, Fourth Industrial Revolution, sustainable building principles, efficiency.

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СТАЛИЙ РОЗВИТОК ТА АРХІТЕКТУРА: ЕКОНОМІЧНА ДОЦІЛЬНІСТЬ ВИКОРИСТАННЯ ДУАЛІСТИЧНОЇ КОНСТРУКЦІЇ НА ПРАКТИЦІ

Визначено особливості, принципи та напрямки сталого розвитку архітектури; обґрунтовано економічна доцільність використання дуалістичної конструкції «сталий розвиток та архітектура» на практиці. Розглянуто, Четверту промислову революцію у контексті сталого розвитку. На думку авторів, це означає використання новітніх технологій та інновацій для підвищення ефективності виробництва, зменшення викидів за рахунок впровадження чистих технологій, та раціонального використання ресурсів. Таке поєднання можливостей Четвертої промислової революції з підходами сталого розвитку дозволить досягти балансу між економічними, соціальними та екологічними аспектами розвитку. Наголошується, що стала архітектура орієнтована на мінімізацію негативного впливу на довкілля та удосконалення загальних характеристик будівлі. Основна мета – споживати мінімальну кількість ресурсів, скорочувати відходи, розвивати функціональне та продуктивне середовище. Розглянуто та обґрунтовано економічна доцільність використання сталих принципів при проектуванні: адаптивність архітектури; вторинне використання ресурсів; використання сталих та відновлюваних матеріалів в архітектурі; енергоефективність. Наведено приклади інноваційних архітектурних конструкцій. Це важливий крок у впровадженні сталого будівництва. Адаптивність архітектури дозволяє приміщенням виконувати різні функції в залежності від потреб користувачів, що підвищує ефективність використання простору. Вторинне використання ресурсів сприяє зниженню кількості відходів та витрат на видобуток нових матеріалів. Використання сталих та відновлюваних матеріалів допомагає зменшити негативний вплив будівництва на екосистему. Енергоефективність сприяє зменшенню споживання енергії та зменшенню викидів парникових газів. Подальше дослідження та впровадження інноваційних архітектурних конструкцій дозволить прискорити *розвиток сталого будівництва та забезпечити його більш широке поширення у майбутньому. На думку авторів, урахування витрат на будівництво, утримання та експлуатацію будівель, а також виважене співвідношення вартості та користі може мати значний вплив на прийняття рішень у процесі проектування та будівництва. Екологічно орієнтовані рішення в архітектурі можуть призвести до збільшення вартості проекту на початковій стадії, але у майбутньому можуть принести значні економічні вигоди через зменшення витрат на енергопостачання та утримання приміщень, а також підвищення цінності в цілому.*

Ключові слова: економічна доцільність, сталий розвиток, архітектура, Четверта промислова революція, принципи сталого розвитку в архітектурі, ефективність.

GENERAL STATEMENT OF THE PROBLEM AND HOW IT RELATES TO IMPORTANT SCIENTIFIC OR PRACTICAL ISSUES

Nowadays, sustainable development principles are crucial in all manufacturing industries, including the building industry. It is essential to construct buildings in a way that benefits the environment rather than causing harm. Although modern architects are improving their projects, there is still much to be done to ensure that the environment is not negatively impacted. Environmental aspects, renewable resource use, and emissions reduction are being considered. This approach contributes to sustainable development and minimizes negative environmental impacts. Implementing these approaches in the construction industry can positively impact resource conservation and environmental impact reduction.

Furthermore, implementing sustainable building principles can reduce energy consumption and improve occupants' quality of life. By using eco-friendly materials and energy-efficient technologies, it is possible to create a comfortable and safe living environment. Developing ecological architecture presents new opportunities for balanced human settlement development with minimal impact on nature. Therefore, it is crucial to continue supporting and developing sustainable construction ideas. This will contribute to a greener and healthier future.

It is important to note that sustainable architecture is cost-effective because it reduces the cost of constructing and running buildings. Energy-efficient technologies and materials can lower the cost of heating, cooling, and lighting, freeing up funds for other needs. Additionally, the use of renewable materials and energy can reduce the long-term maintenance costs of a building. Businesses can be encouraged to adopt a more sustainable approach by incorporating environmental considerations into building and urban design. Financial incentives and support from government agencies or investors can be obtained by reducing emissions and using renewable resources. Sustainable development architecture can be environmentally, socially, and economically responsible.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Various aspects of this problem have been studied and presented in the works of Ukrainian scientists, such as Y.V. Orlovska, V.S. Chala, A.V. Glushchenko [1]; M.I. Chepeliuk [2]; Y.T. Borovyk, Y.V. Elahin, O.M. Polyakova [3]; U. L. Storozhylova, H.M. Storozhylov [4]; O.V. Stasiuk, N.M. Shylo [5]; Y.I. Gayko, E.A. Shyshkin [6]; M.Yu. Prytula [7]; L.S. Shevchenko [8]; L.S. Ivanova [9]; A.S. Bilyk [11]; U.I. Naydenova, I.I. Grineva [12]; E.G. Gerasimov, G.G. Gerasimov [13]; N. Ivolzhatova, T. Dimko, T. Kholevan [14]; A.S. Zalogina, I.S. Yaremenko [15]. However, the problem is still relevant.

FORMULATING THE ARTICLE'S OBJECTIVES

The article aims to determine the characteristics, principles and directions of sustainable development in architecture. It aims to prove the feasibility of practical application of the dualistic structure “sustainable development and architecture” in practice.

THE MAIN MATERIAL STATEMENT

Sustainable development involves taking measures to meet the current needs of people while also preserving the environment and natural resources for future generations. This means ensuring that people's present and future needs and desires are met. Sustainable development is defined as socio-economic growth that considers the consequences for present and future generations. It combines social, economic, and environmental components as their respective development goals that should evolve in symbiosis [1, p.10].

The concept of sustainable development originated in the 1980s. In 1983, the United Nations established the first World Commission on Environment and Development to address global environmental issues. Today, this remains a pressing topic, with recent reports highlighting the alarming deadline of 2030. Studies indicate that without radical action to transition to alternative energy sources and curb $CO2$ emissions within the next decade, the consequences of climate collapse will be irreversible.

We are currently in the era of the Fourth Industrial Revolution, which is the latest wave of disruptive innovation. Like its predecessors, the Fourth Industrial Revolution can be summarised in a few key words: artificial intelligence, autonomous vehicles, and the Internet of Things [2, p. 18]. Undoubtedly, the Fourth Industrial Revolution is having a significant impact on the development of modern society, including industry, technology, and the economy. However, the increasing use of digital technologies and artificial intelligence also poses a risk to sustainable development. This is because it may lead to a surge in electronics production, which requires large amounts of rare metals and energy sources. Additionally, there is a risk of increased waste and negative environmental impacts. Therefore, it is crucial to consider the Fourth Industrial Revolution in the context of sustainable development. This involves utilising the most up-to-date technologies and innovations to enhance production efficiency, whilst also reducing emissions through the implementation of clean technologies and efficient resource usage. By combining the opportunities presented by the Fourth Industrial Revolution with sustainable development approaches, a balance between economic, social, and environmental aspects of development can be achieved.

It is important to note that the environment is impacted by various factors, including industrial production, transportation, deforestation, and pollution. The construction sector alone is responsible for 40% of air and water pollution, climate change, and landfill waste. Ignoring these issues is not an option. This is why rigorous standards and certifications are emerging in the building sector. The first standard, Leadership in Energy & Environmental Design (LEED), was developed in 1993. It has since been followed by many new certification standards, such as the UK's BREEAM, the US's WELL and Fitwel, among others. Architecture is moving towards sustainability, albeit at a slow pace.

Developing international environmental standards is based on several objectives, including independent assessment and endorsement of environmental practices, implementing a wide range of environmental requirements and integrating them into a single approach, balancing energy efficiency objectives with indicators of building quality, a healthy and comfortable environment, formulating criteria and requirements that go beyond legal standards and could become the driving force for the modernisation of the construction sector, reducing the impact of the built environment on nature, and providing a recognisable brand for buildings with a 'certificate'. To be awarded a 'certificate', a building's site choice, construction project design, materials characteristics, and waste material reuse are all considered.

The aim of sustainable architecture is to reduce the negative impact on the environment and enhance a building's overall performance. The primary objective is to minimise resource consumption, waste production, and create a functional and productive environment that provides optimal living conditions while preserving the natural environment. It is important to note that this architecture is not only environmentally friendly but also economically viable. It should not only be aesthetically pleasing but also beneficial to the environment. The advancement of ecological construction contributes to the development of a more refined design culture. It reflects the trends in human society, which aim to solve environmental problems by changing the architect's worldview. The forms and functions of construction objects are being improved to meet changing consumer requirements and ecological standards. Environmentally friendly materials are actively used in construction to promote both our comfort and the preservation of the environment.

The CopenHill incinerator in Copenhagen, Denmark, exemplifies sustainable architecture. It utilises waste-to-energy technology, generating electricity and heat by incinerating waste. The plant emits non-toxic, odourless smoke from its stacks. Additionally, the facility's 85-metre-high building houses a ski slope that is open year-round and can accommodate up to 150 skiers per hour. The slope's surface is covered with recycled plastic. The plant incinerates waste generated by Copenhagen's residents and provides the city with heat and electricity [4, p. 122]. In addition to waste incineration, the building also houses a sports centre. There is also a green area that is open to the public, providing a scenic view of the city from the top.

1. In the field of architecture, several principles can be applied to address this issue. The main ones are adaptability and flexibility. This is the design of buildings that interact with the environment and can be transformed in response to the development of the city, its economic and environmental conditions. The main characteristics of such architecture are flexibility, multi-functionality, and updateability [5, p. 70].

An excellent example of adaptability is converting former factories, hangars, churches, and warehouses into residential or public buildings. A contemporary approach, however, involves considering the adaptability of a building during the design process. This entails creating an open or modular layout that facilitates future changes to the building's function. This method can be applied to a diverse range of facilities, from exhibition halls and stadiums to residential buildings. The Nagyerdei Víztorony water tower in Debrecen, Hungary, is an example of adaptive architecture.

Furthermore, the adaptability of architecture allows for the functional purpose of a building to be changed with minimal loss. This enables efficient use of space to meet changing needs. Architecture can also reduce the cost of rebuilding and modernising buildings by considering the individual needs of users and the ability to adapt to changes in the environment. Adaptive architecture can help companies and institutions save money by preserving property values and reducing the need for new construction. This increases resource efficiency and reduces overall costs, making it an important economic argument for sustainable construction.

For instance, many developed nations face the issue of industrial sites being located in urban zones. The relocation of industrial zones outside cities or their radical transformation is a European solution that has been implemented in recent decades. The cluster principle, which combines business, science, and production, is used to develop the vacated sites. As a result, industrial sites are transformed into high-tech, eco-friendly production facilities, technology parks, or residential, public, or green areas. Transformation or renovation involves a comprehensive renewal of the architectural and landscape urban environment. This includes the simultaneous reconstruction of objects and the space in which they exist, as well as the adaptive use of buildings, structures, and complexes in case of changing their functional purpose [6, p. 7].

2. Another aspect of this approach is the secondary use of resources, which can apply not only to the building itself but also to materials, furniture, decoration, lighting, and natural resources. This approach has a positive impact on the environment.

M. Prytula suggests that the use of artificial raw materials, including production by-products, is a current trend in building material production. Substituting natural raw materials with production waste can improve economic efficiency by reducing material costs. Companies can obtain cost-effective sources of partially processed raw materials by using waste in building material production. Industrial waste, including slag waste of metal manganese from ferroalloy plants, ash and slag waste from thermal power plants, bauxite sludge waste from alumina refineries, red sludge waste from aluminium smelters, and construction waste (concrete, bricks, etc.) [7, p. 158], can be repurposed for building materials.

The Circular Pavilion in Paris is an excellent example of architectural upcycling. Encore Heureux Architects proposed an experimental project for the Circular Pavilion building located on the Hotel de Ville square in Paris. The project aims to demonstrate the potential of reusing waste in construction. The building was constructed for the climate conference (COP21) held in France in 2015. The materials used for its construction were sourced from building sites or unused reserves of materials. The pavilion's façade consists of 180 oak doors, and the partitions are constructed from the walls of a previous exhibition space. The furniture was crafted from recycled materials found in Paris, with a frame made from reclaimed wood and insulation sourced from another object [8, p. 183].

Reducing the cost of new materials, saving energy, and minimising environmental impact are the economic drivers for recycling in construction. The use of recycled materials, such as reclaimed or recycled building materials, can be economically beneficial as it reduces the cost of purchasing new materials and optimises production processes. Additionally, it has a positive impact on waste reduction and pollution control.

Using recycled materials in construction helps conserve natural resources and reduce operating costs. This demonstrates that recycling resources in construction and architecture is both environmentally friendly and economically beneficial.

3. In architectural practice, it is crucial to use sustainable and renewable materials. Sustainable materials can reduce the cost of construction and operation. These materials can be non-toxic, manufactured using sustainable technologies or recycled with minimal energy consumption. In addition, the use of renewable resources, such as wood or clay, should be part of the construction process. It is important to keep in mind that these materials should be compostable or derived from renewable sources.

The environmental performance of building materials includes issues of resource and energy efficiency during production, material recovery, natural use of recycled materials, and resource and energy efficiency of materials and products in the operation of architectural and construction facilities [9, p. 365].

TECLA is a residential building located in the Massa Lombarda region of Italy that demonstrates the use of sustainable and renewable materials. The building was constructed using 3D-printed blocks of clay mined from the area. Mario Cucinella Architects designed this innovative construction project [10]. Another example of this approach is the Gaia house, also situated in the Massa Lombarda region. This structure is constructed using blocks made from a 3D printer that utilise a combination of waste wood, rice husks, hay, and local soil.

We agree with A. S. Bilyk's viewpoint that the choice of building materials and design should be all-encompassing, taking into account all aspects of its life cycle, with the goal of reducing its overall cost [11, p. 57].

Therefore, incorporating sustainable and renewable materials in architecture has a strong economic rationale based on long-term advantages. One benefit of using these materials in buildings is the reduction of long-term maintenance costs due to their extended service life and minimal risk of malfunctions. Furthermore, they often have high thermal insulation and are energy-efficient, resulting in lower energy costs during building operation. Furthermore, it enables proprietors to lower the expenses of heating and air conditioning, while considering the escalating costs of conventional construction materials. It is crucial to note that any changes made to the original text were solely for the purpose of enhancing clarity, conciseness, or formality without altering the primary message. This can also help owners to lower the cost of heating and air conditioning, while considering the rising prices of traditional building materials. In addition, sustainable and renewable materials can help reduce construction and operating costs, increase energy efficiency, and contribute to more competitive and environmentally friendly building projects.

4. The fourth point is energy efficiency. Statistics indicate that construction facilities are responsible for around 40% of energy consumption, making industrial and residential buildings one of the primary sources of CO2 emissions. Architects have a responsibility to reduce these figures.

Fortunately, there are already many technologies available to make buildings more energy-efficient.

For example, modern buildings can generate energy, thereby reducing the consumption of urban heat and light energy. Solar panels, wind turbines, and geothermal sources can be used to achieve energy neutrality in buildings. In some cases, a building can produce and consume enough energy to sustain itself. For example, in 2015, the first mass-produced energy-efficient house in Ukraine, called OrPtaNoiBe, was built. This modern house has a total area of 130m2 and is designed for a family of 3-4 people. No changes in content have been made. The text has been edited for clarity, conciseness, precision, and grammatical correctness while preserving the original meaning and structure. It spans two floors, including an attic, and features a living room, a kitchen-dining room, two bedrooms, a common dressing room, a bathroom with a shower, a spacious bathroom with a laundry room, and a technical room housing all engineering systems [12].

Secondly, architectural and engineering techniques can be used to adapt the building to the environment and reduce its energy consumption. For instance, open facades on the south side and transparent ceilings can allow more light to enter the building. Additionally, a specific slope and orientation of the walls can optimize the use of solar heat and wind power, resulting in savings on electricity and ventilation. Providing for automatic window opening can naturally ventilate the building and prevent overheating [13]. Another engineering technique that can be used is the double facade, which allows for heat retention and ventilation of the building [14].

One way to create eco-friendly architecture is to use replaceable facades that allow for adjustments in lighting, insulation, air conditioning, and heating of the premises. For instance, in 2012, Aedas Architects, in collaboration with British developer Arup Engineers, designed the Al Bahar Towers, a 25-storey complex located in the east of Abu Dhabi. The buildings seamlessly blend centuries-old traditions of Arabian architecture with modern technological solutions. The facades of the towers are covered with special decorative panels on three sides. Each panel consists of moving modules that create a unique relief when opened by sunlight. The facades of the towers are covered with special decorative panels on three sides. The panels automatically close to form a modern openwork pattern when the light changes. It is worth noting that the lattice facade not only reduces solar heat penetration by 50%, but also provides free ventilation and reduces the need for artificial lighting in the buildings [15]. The integration of kinetic architecture featuring transformable facades in construction enables the creation of buildings that can adjust to current conditions, adapt to new requirements, and thereby aid in addressing the issue of sustainable societal development. Buildings with transformable facades can reduce energy consumption by over 60% compared to passive climate systems. These facts make the technology highly attractive as it promises to reduce energy consumption, greenhouse gas emissions, and create a healthier microclimate.

Therefore, energy efficiency in modern architecture is crucial not only for environmental reasons but also for economic ones. Lowering energy consumption in homes and buildings can substantially decrease heating, air conditioning, and electricity expenses. The extensive implementation of energy-efficient technologies, such as thermal insulation, double-glazed windows, and cost-effective heating and lighting systems, can enhance comfort and decrease building maintenance costs. Additionally, certain countries offer government programmes and incentives to promote energy-efficient construction. These may include support for green roofs and other building features that reduce energy consumption, as well as financial incentives for energy-efficient buildings. Implementing energy-efficient solutions in construction ensures economic feasibility while reducing energy consumption contributes to reducing greenhouse gas emissions and overall negative environmental impact.

CONCLUSIONS FROM THIS STUDY AND PROSPECTS FOR FURTHER RESEARCH IN THIS AREA

In conclusion, we consider economic feasibility crucial in sustainable architecture. Considering the costs of construction, maintenance, and operation of buildings, as well as a balanced cost-benefit ratio, can significantly impact decision-making in the design and construction process. Sustainable architectural solutions may initially increase project costs, but can provide significant economic benefits in the future by reducing energy and maintenance costs and increasing overall value. Additionally, sustainable construction can encourage innovation and the development of new technologies, which can lead to improved efficiency and lower costs. Therefore, the economic feasibility of sustainable construction and architecture depends on the ability to balance long-term economic benefits with initial costs, as well as the impact on the future environment and society as a whole.

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