

CONSTRUCTIVE AND ESSENTIAL CHARACTERISTICS, ECONOMIC ADVANTAGES AND POSSIBLE CHALLENGES OF USING ADAPTIVE ARCHITECTURE IN MODERN URBAN PLANNING

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Kubanov R. A., Makatora D. A., Mykhalko A. O. Constructive and Essential Characteristics, Economic Advantages and Possible Challenges of Using Adaptive Architecture in Modern Urban Planning

The study provides a comprehensive analysis of the constructive and essential characteristics of adaptive architecture. The study identifies the economic advantages and possible challenges of using this methodological conception in modern urban planning. The authors examine in detail the key principles of adaptability, such as: the city as a living organism; flexibility and multifunctionality; renewability and interaction with the environment. This provides a deeper understanding of the conception of adaptability in architecture and its ability to respond dynamically to changing human and environmental needs. A thorough study of the economic benefits of adaptive architecture has been undertaken. Reduced running costs, extended building life, increased rental income and reduced disposal costs are some of the significant benefits highlighted in the article. This demonstrates the significant economic potential of this approach. It also demonstrates its ability to ensure long-term efficiency and relevance. Furthermore, the study identifies and analyses in detail the potential economic challenges that may arise. Key difficulties are identified, such as high up-front costs, the need for specialist skills and the uncertainty of future changes. This makes it possible to provide a comprehensive assessment of the economic risks and challenges that may be faced in the use of an adaptive architecture. A comprehensive set of recommendations aimed at optimising costs, developing human resources, increasing the predictability of change, introducing innovation and strengthening collaboration with stakeholders are developed to address these challenges. These practical tools provide effective ways to ensure the successful implementation of adaptive projects. Overall, the study shows that provided existing economic challenges are fully addressed, adaptive architecture has significant potential to create more sustainable, efficient and resilient urban spaces. Further research in this area, as well as the development of effective implementation strategies, will be key to the promotion of adaptive architecture in urban planning practice.

Keywords: adaptive architecture, economic advantages, economic challenges, flexibility, energy efficiency, sustainable development, urban planning.

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Kubanov Ruslan A. – Candidate of Sciences (Pedagogy), Associate Professor, Associate Professor of the Department of Economics, Management and Territorial Administration, Separate structural subdivision "Institute of Innovative Education of the Kyiv National University of Civil Engineering and Architecture" (4 Osvity Str., Kyiv, 03037, Ukraine)

E-mail: kubanov12@gmail.com

ORCID: <https://orcid.org/0000-0002-0121-4858>

Researcher ID: <https://www.webofscience.com/wos/author/record/L-6715-2018>

Makatora Dmytro A. – Candidate of Sciences (Engineering), Associate Professor of the Department of Machines and Units for Printing Production of the Educational and Scientific Publishing and Printing Institute, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute» (37 Beresteiskyi Ave., Kyiv, 03056, Ukraine)

E-mail: makatora_d@ukr.net

ORCID: <https://orcid.org/0000-0002-1909-900X>

Researcher ID: <https://www.webofscience.com/wos/author/record/AHB-4079-2022>

Scopus Author ID: <https://www.scopus.com/authid/detail.uri?authorId=58572089000>

Mykhalko Anastasiia O. – Candidate of Sciences (Engineering), Associate Professor of the Department of Mechanical Engineering, Kyiv National University of Technologies and Design (2 Mala Shiiianovska Str., Kyiv, 01011, Ukraine)

E-mail: nastyia_franchuk16@yahoo.com

ORCID: <https://orcid.org/0000-0001-8203-7488>

Researcher ID: GYD-4871-2022

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Кубанов Р. А., Макатьора Д. А., Михалко А. О. Конструктивно-сутнісні особливості, економічні переваги та можливі виклики використання адаптивної архітектури в сучасному містобудуванні

У дослідженні проведено всебічний аналіз конструктивних і сутнісних особливостей адаптивної архітектури, визначено її економічні переваги та можливі виклики використання цього методичного концепту в сучасному містобудуванні. Автори детально розглядають ключові принципи адаптивності, а саме: місто як живий організм; гнучкість та багатofункціональність; здатність до оновлення; взаємодія з навколишнім середовищем. Це дозволяє глибоко зрозуміти концепцію адаптивності в архітектурі та її здатність динамічно реагувати на зміни потреб населення та умов навколишнього середовища. Проведено ґрунтовне дослідження економічних переваг адаптивної архітектури. Виокремлено такі вагомі переваги, як зниження експлуатаційних витрат, продовження терміну служби будівель, збільшення доходів від оренди та зменшення витрат на утилізацію. Це демонструє значний економічний потенціал даного підходу та його здатність забезпечувати довготривалу ефективність та актуальність. Водночас дослідження детально ідентифікує й аналізує можливі економічні виклики. Визначено такі ключові

складнощі, як висока початкова вартість, необхідність залучення спеціалізованих фахівців та невизначеність майбутніх змін. Це дозволяє всебічно оцінити економічні ризики та проблеми, з якими може стикатися використання адаптивної архітектури. Для подолання зазначених викликів автори розробили комплексні рекомендації, спрямовані на оптимізацію витрат, розв'язок людських ресурсів, підвищення передбачуваності змін, впровадження інновацій та посилення співпраці із зацікавленими сторонами. Ці практичні інструменти надають дієві шляхи для успішної реалізації адаптивних проєктів. Загалом дослідження демонструє, що адаптивна архітектура має значний потенціал для створення більш стійких, ефективних і життєздатних міських просторів за умови комплексного вирішення наявних економічних викликів. Подальші дослідження в цьому напрямку, а також розробка ефективних стратегій впровадження, відіграватимуть ключову роль у просуванні адаптивної архітектури в містобудівній практиці.

Ключові слова: адаптивна архітектура, економічні переваги, економічні виклики, гнучкість, енергоефективність, сталий розвиток, містобудування.

Бібл.: 25.

Кубанов Руслан Анатолійович – кандидат педагогічних наук, доцент, доцент кафедри економіки, менеджменту та управління територіями, Відокремлений структурний підрозділ «Інститут інноваційної освіти Київського національного університету будівництва і архітектури» (вул. Освіти, 4, Київ, 03037, Україна)

E-mail: kubanov12@gmail.com

ORCID: <https://orcid.org/0000-0002-0121-4858>

Researcher ID: <https://www.webofscience.com/wos/author/record/L-6715-2018>

Макатьора Дмитро Анатолійович – кандидат технічних наук, доцент кафедри машин та агрегатів поліграфічного виробництва Навчально-наукового Видавничо-поліграфічного інституту, Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського» (просп. Берестейський, 37, Київ, 03056, Україна)

E-mail: makatora_d@ukr.net

ORCID: <https://orcid.org/0000-0002-1909-900X>

Researcher ID: <https://www.webofscience.com/wos/author/record/AHB-4079-2022>

Scopus Author ID: <https://www.scopus.com/authid/detail.uri?authorId=58572089000>

Михалко Анастасія Олегівна – кандидат технічних наук, доцент кафедри механічної інженерії, Київський національний університет технологій та дизайну (вул. Мала Шияновська, 2, Київ, 01011, Україна)

E-mail: nastya_franchuk16@yahoo.com

ORCID: <https://orcid.org/0000-0001-8203-7488>

Researcher ID: GYD-4871-2022

Architects and urban planners need to find new approaches to planning and developing cities in today's world, where the number of urban dwellers is increasing. Adaptive architecture, which allows cities to adapt comfortably to changes in the global socio-economic environment, is proving to be one of the most promising areas.

One of the key benefits of using adaptive architecture is the ability to respond flexibly to changing human and environmental needs. This allows urban designers to create innovative spaces that meet modern needs and are comfortable for those living and working in them. In addition, adaptive architecture contributes to the preservation of the historical heritage and the cultural value of the cities. It creates a harmonious blend of past and future by combining old buildings with modern infrastructure.

Implementing adaptive architecture, however, poses certain challenges. One of these is the need to involve a large number of specialists from different disciplines. This can involve significant costs in organising communication and collaboration processes. There is also a risk that innovative solutions will be unpopular with the public and government agencies, which can make it difficult to implement projects using adaptive architecture. Influencing public opinion and finding compromises requires serious work. In many cases,

there is also the question of how to finance projects using adaptive architecture. This can be a barrier to implementation as these projects typically require significant investment.

Given these advantages and challenges, it is important to continue research in the field of adaptive architecture and to develop strategies to address the existing problems. Only by taking an integrated and applied approach, and by working closely with all stakeholders, will it be possible to create cities that meet current and future needs.

In the works of Ukrainian and foreign scientists various aspects of this problem have been studied and presented, e. g. H. Fesenko [1]; B. Goy, H. Katola [2]; S. Kudria [3]; T. Tkachenko [4]; I. Potapchuk, L. Bychkovska [5]; L. Hnatiuk, I. Nesteruk [6]; H. Osychenko, N. Kryvoruchko, O. Shushlyakova [7]; V. Zelensky [8]; B. Pleskach, E. Novak [9]; R. Glushchenko, T. Tkachenko [10]; O. Pona, B. Gulai [11]; A. Bessonova, L. Bezugla, M. Beloborodova [12]; U. V. Petrenko, S. G. Buravchenko [13]; A. S. Bilyk [14]; V. I. Deshko, I. Y. Bilous, M. V. Gureev [15]; I. G. Olishevsky [16]; D. V. Gulay [17]; O. R. Popovych, Ya. M. Zakharko, M. S. Malyovanyi [18]; O. A. Streltsov, A. O. Shkarupa [19]; P. O. Kachanov, O. M. Yevseenko [20]; S. P. Ivanyuta, O. O. Kolomiets, O. A. Malynovska,

L. M. Yakushenko [21]. However, there is great potential in modern urban planning for adaptive architecture, which adapts to changes in the environment and user needs.

The use of this approach can help to create more flexible and cost-effective spaces. These spaces can be easily adapted to current needs and urban changes. The issue is therefore relevant and important in terms of application.

The purpose of the research is to examine the design and main characteristics of adaptive architecture, to study its economic advantages and to identify possible challenges in the use of adaptive architecture in modern urban planning.

The following tasks must be carried out to achieve this objective:

1. To analyse in detail the design features of adaptive architecture and to determine which of them contribute to its flexibility and ability to adapt to changes in the environment.
2. To study the economic advantages of using adaptive architecture, including reduced maintenance costs, energy savings and stimulation of innovation in construction.
3. To identify possible challenges, such as economic constraints, the need for skilled labour and market instability, associated with the use of adaptive architecture in urban planning.
4. To develop proposals on how to overcome these challenges and maximise the benefits of using adaptive architecture in urban planning.

The outcome of the study will be systematic information on the design and key characteristics of adaptive architecture, economic benefits and potential challenges in the use of this approach in urban planning. Recommendations will help to improve the quality and efficiency of urban planning by overcoming challenges and optimising the benefits of adaptive architecture.

Adaptive architecture is an important concept in modern urban planning, involving the design of buildings that can respond to environmental changes. In the context of globalisation, climate change and rapid urban development, architecture must not only meet the needs of the present. It must also be ready for the changes of the future.

There are some adaptive architectural features and principles:

1. The city as a living organism.
2. Flexibility and multifunctionality.
3. Upgradeability.
4. Interaction with the environment.

The city as a living organism. Modern cities are constantly evolving. They change and adapt to new challenges. Architecture that cannot 'breathe' with the city is at risk of obsolescence and inefficiency. The answer to this challenge is adaptive architecture. It allows the city to change dynamically. It responds to the needs of its inhabitants and evolves with them.

The idea of continuous development and transformation of the city is at the heart of the principle of adaptive architecture. To respond effectively to changes in society and the environment, buildings that follow these principles can provide the necessary flexibility.

Not only current needs but also future development prospects are taken into account in the design of adaptive architecture. Buildings are designed in such a way that they can be modified and extended in the future [12]. Adaptive architecture also contributes to the creation of viable and sustainable cities. It allows urban structures to adapt to change, so that they remain relevant and attractive places to live and develop. The ability to evolve on its own is an important feature of adaptive architecture. Buildings can be modified and upgraded in response to needs and opportunities, and can be used for a variety of purposes.

Regarding flexibility and multifunctionality. With the aim of creating innovative and efficient facilities that can easily adapt to changing conditions and needs, flexibility and multifunctionality are certainly key aspects of adaptive architecture. Adaptive architecture is not just about creating buildings. It is a platform for the life and development of the city as a whole.

Buildings that embrace the concept of flexibility have the ability to change their function or structure according to changing socio-economic environments [13]. For example, a residential building can be transformed into office space or a hotel, allowing for efficient use of available resources and maintaining the city in harmony with the needs of its inhabitants.

The ability to perform different functions simultaneously or sequentially is the multifunctionality of adaptive buildings. This allows them to create interactive and vibrant environments for city dwellers, while optimising the use of space and resources.

Architecture that makes the most of the space and capabilities of buildings creates a welcoming and comfortable environment for those living in the city. Flexibility and multifunctionality allow adaptive architecture to maintain the mobility and dynamism of the urban environment, helping the city to develop and interact. Architecture that is based on flexibility and multifunctionality can work for the benefit of the whole city and contribute to the solution of problems that arise in modern development conditions. Such

buildings can become social centres, cultural hubs or spaces for innovating and creating.

Flexible and multifunctional architecture offers the possibility of continuous updating and modernisation of buildings, so that they remain relevant and competitive over the long term [25]. This is important to ensure that buildings remain valued and performing. Adaptive architecture creates unique and innovative objects that contribute to sustainable urban development by integrating flexibility and multifunctionality into the design and implementation of buildings. They contribute to a creative and dynamic city by creating new opportunities for interaction and cooperation in the urban environment.

The ability to renew is an important characteristic of adaptive architecture, which distinguishes it from traditional building standards. Adaptive architecture is seen as a dynamic organism that can change and improve over time, adapting to the needs and demands of the present.

Renovating buildings can be achieved by using modular structures that can be easily replaced or modified to meet new needs [14]. This approach is an important step towards the conservation of valuable resources and the reduction of waste, which is an important step towards sustainable construction. The use of modular structures in adaptive re-use architecture makes it easy to change the functionality of a building without the need for major alterations. This means that only specific modules need to be replaced or modified, rather than the entire building structure, making the renovation process more efficient and cost-effective.

The ability of adaptive buildings to be renovated is key to ensuring that they continue to function and remain relevant. Renovation ensures that an existing facility can adapt to new conditions and change with the times, keeping pace with changing needs, technologies and market demands. Adaptive architecture is based on the ability to upgrade. It helps to improve the quality and functionality of buildings in line with current needs and technological possibilities. This allows the building to retain its relevance and value for a longer period of time. It does not have to be completely rebuilt or reconstructed.

The renovation of adaptive buildings can be carried out on a variety of scales - from minor alterations and replacement of individual elements to complete rebuilding and modernisation. This ensures new life and relevance for the future by bringing the facility up to modern standards and needs. Adaptive architecture updates also allow for the introduction of new technologies and innovations. These improve the quality of life in the building and ensure its competitiveness in the market. This contributes to the creation of inno-

vative and efficient facilities. Facilities that can stand the test of time and change as needs and technologies evolve.

Since buildings have an impact on the environment and need to work in harmony with nature, interaction with the environment is a fundamental aspect of adaptive architecture. Ecological adaptive architecture not only minimises its own negative impact on the environment, but also makes active use of natural resources and creates a space in which people can live.

Modernity demands new ways of development and interaction with the natural environment in the city. A key area in the development of urban space is the strategy of 'growing' nature and creating balanced ecosystems in cities. It is important to have an understanding that the city is not separate from nature, but is a necessary part of its life cycle. Ecological urbanism aims to create a viable environment for people and nature, where the preservation of ecosystems and biodiversity is a priority. It is an approach that aims to create a reciprocal and enriching interaction between the city and nature, while maintaining an ecological balance [1].

Green roofs, for example, are one of the ways in which adaptive architecture can interact with the environment. They improve indoor temperature regulation and reduce energy consumption, thereby reducing a building's impact on the urban environment. Green roofs also contribute to the improvement of air quality and the reduction of CO₂ emissions, which is important for the maintenance of the ecological balance [2].

Another effective way to make buildings green and use renewable energy sources is through solar panels. They reduce dependence on coal and other inefficient energy sources by generating electricity from the sun's rays. Solar panels also contribute to the reduction of CO₂ emissions and the impact of buildings on the climate [3].

Another important aspect of sustainable adaptive architecture is rainwater harvesting. They reduce the amount of freshwater used and help to replenish soil and green spaces. Collecting and using rainwater helps minimise wasted water and improves the quality of life in the surrounding area [4].

One more key aspect of sustainable adaptive architecture is energy efficiency. Energy consumption and greenhouse gas emissions can be reduced by using high-efficiency windows and ventilation systems, environmentally friendly insulation materials and translucent structures. Energy efficiency helps to conserve natural resources and reduce the impact on the climate, as well as saving money on heating and cooling buildings.

Landscaping within ecological adaptive architecture is an important aspect of ensuring that buildings are integrated with the natural environment. It helps to create a vibrant and healthy environment for people and plants by using native plants, creating ecosystems and recreational areas. Landscape design also contributes to the enhancement of biodiversity and the maintenance of the ecological balance of the area [5].

There is no doubt that adaptive architecture, which considers ecological principles, contributes to the creation of sustainable living and working environments that promote the health and well-being of people. It reduces the negative impact on nature and contributes to the creation of healthier and more environmentally friendly dwellings through the use of environmentally friendly technologies and practices in construction. The urban planning concept of adaptive architecture involves intelligently planning and developing human settlements to ensure environmentally sustainable and viable conditions for people and nature. This includes creating green spaces, cycling and walking paths, improving public transport and other measures that contribute to sustainable urban development. An important task in the development of cities and towns is therefore the sustainable improvement of ecologically adaptive architecture. Incorporating the latest environmental technologies and practices into building allows us to create a healthier and more sustainable environment for those living in, and to ensure the preservation of natural resources for future generations.

Adaptive architecture is a field that is constantly evolving towards the creation of buildings that can change their configuration on demand. Such buildings are equipped with practical sliding walls that can be easily adapted to different conditions and provide the highest level of comfort for the occupants.

Here are a few examples of this:

1. Another example of adaptive architecture that improves the quality of life in a city is buildings with green roofs. Green roofs clean the air of pollutants, reduce the temperature of the city and improve the micro-climate. They contribute to the development of urban flora and fauna [6] and provide green spaces for residents to relax.
2. Modular residential complexes are one more interesting example of adaptive architecture, as they can be easily reconfigured and adapted to suit the changing needs of those living in them. Depending on changes in the number of residents or their needs, these complexes can change the layout of rooms and add or remove modules [7].

3. Smart materials that can change their structure or colour according to external conditions are also used in modern buildings. For example, to make efficient use of natural light and energy, smart glass can change its degree of transparency depending on the ambient light [8].
4. Structures with integrated renewable energy systems, such as solar panels or wind turbines, are another important aspect of adaptive architecture. These systems provide a sustainable source of energy for the building's operation and help to reduce the building's environmental impact [9].
5. Buildings can reduce freshwater consumption and contribute to the efficient use of water resources by incorporating rainwater harvesting and reuse systems. This helps to reduce the negative impact on groundwater and water resources, as well as conserving water that is normally used for external sanitation [10].
6. Passive solar systems, such as solar panels and solar pipes, use solar energy to heat and cool buildings. These systems can reduce CO₂ emissions [11] and reduce dependence on traditional energy sources.
7. The use of efficient thermal insulation and ventilation systems with heat dissipation contribute to the reduction of energy consumption in buildings and to the creation of comfortable conditions for the occupants. Energy efficiency technologies can help to reduce the costs of heating and cooling, while maintaining the temperature of the premises at an optimal level [23].
8. Reducing pollutant emissions and creating a healthy living environment can be achieved by using natural and environmentally friendly building materials [24]. The use of bamboo, core bricks, lime materials and other environmentally friendly options can reduce the environmental impact of construction and provide a comfortable living environment for the occupants.

Incorporating natural elements into architectural design, such as water, green spaces and natural materials, helps to create harmonious spaces for people to live in and improves the quality of the environment. At the same time, buildings are integrated into the natural landscape and create favourable conditions for man and nature to coexist.

The main question facing developers, architects and economists is how much economic benefit can be gained by implementing adaptive architecture. Obviously, the efficiency and lifecycle of buildings can be

significantly influenced by adaptive architecture. This approach conserves resources and reduces both construction and maintenance costs by creating spaces that can change and adapt to different user needs. One of the key economic benefits of adaptive architecture is the ability to use space efficiently without the need for constant rebuilding. This makes buildings more versatile and durable, as they can be adapted to different functions and needs.

We believe that the main economic advantages of adaptive architecture are:

1. Reduced operating costs: adaptive buildings can be more energy efficient because of their flexibility. Sliding walls reduce heating and cooling costs by allowing natural light and ventilation [15]. In the summer, they can be opened to allow for natural ventilation and cooling, and in the winter, they can be closed to keep the heat in, thus reducing heating and cooling costs.

Another example of such energy efficiency is the use of solar panels and water recycling systems. Adaptive buildings can be equipped with advanced technologies to collect solar energy and recycle used water, providing a significant level of energy efficiency and reducing utility costs. For example, water consumption can be significantly reduced and the use of this resource optimised by using a rainwater harvesting system for domestic use or irrigation systems. The use of energy-efficient materials and structures is another important component of adaptive architecture. For example, heating and air-conditioning costs can be significantly reduced by using renewable materials or materials with high thermal insulation properties. In addition, the building's acoustic performance and resilience to negative environmental factors can be improved through the right choice of materials. Adaptive architecture also provides for the ability to reconfigure spaces in a quick and efficient manner to meet the changing needs of the users. For example, open spaces can be converted into rooms or vice versa without significant cost and time. This allows the building to be more functional and efficient in its operation.

2. Extending the life of buildings: adaptive architecture allows buildings to be easily renovated and modernised, extending their life. This reduces construction and demolition costs by reducing the need to build new buildings. For example, a building's performance can be improved and the need for reconstruction or restoration avoided by replacing outdated heating systems with more energy-efficient ones or by installing modern building management

technologies [16]. Adaptive architecture also contributes to the preservation of historical and cultural values, as upgrading existing buildings can preserve their authentic architectural heritage and historic character. For example, converting old factories into modern office space preserves the atmosphere of the past while giving them new life and purpose without losing their value.

3. Rental increase is another important benefit of adaptive architecture, as buildings can generate more rental income due to their ability to easily change their function. For example, a building that was originally adapted to provide office space can easily be converted to provide residential or commercial space, depending on consumer demand and changing property markets [17]. In addition to increasing rents, flexibility and the ability to respond quickly to changes in the external environment can help adaptive buildings attract and retain tenants. For example, tenants who value innovation and comfort in their work and lives are attracted to buildings that can adapt to new technologies and safety standards. In addition, adaptive architecture can help diversify a property portfolio and minimise risk by encouraging collaboration between different types of businesses and attracting diverse tenants. For example, a wide range of tenants can be attracted and demand for space stimulated by mixed-use developments that can combine offices, retail and leisure facilities. The use of adaptive architecture can also have a positive impact on the local economy. Higher rents stimulate investment in local infrastructure and increase the competitiveness of the property market. For example, business development in a city can be boosted and new investors attracted by projects to restore and adapt old factories for use as office space.
4. Reducing disposal costs is one of the key benefits of adaptive buildings, as they are made up of modular elements that can be easily replaced or recycled [18]. This reduces the amount of waste that pollutes the environment and saves money on the disposal of building materials. For example, without the need to dismantle and rebuild, modular buildings can easily adapt to changes in function or size. Modular construction reduces waste and optimises the construction process by allowing the interior of the building to be changed quickly and efficiently. Adaptive buildings can also reduce disposal costs and conserve

natural resources by using recycled or renewable building materials. The use of such materials can be both a sustainable solution for construction and help reduce future waste. Adaptive buildings can also minimise waste and disposal costs when changes to the building are required, as they can be designed to be reconfigured and expanded in the future. For example, the functional purpose of a building can be easily and quickly changed through the strategic placement of foundations or internal partitions. The use of adaptive technologies in the construction of buildings can also help to extend the service life of a building and reduce the need for reconstruction throughout the life cycle of a building. The result can be a significant reduction in the amount of waste and the cost of waste disposal in the future. In this way, adaptive architecture has a key role to play in the reduction of recycling costs in the construction sector, thereby contributing to the economic efficiency and sustainable development of the industry. Implementing these approaches is an important step towards creating environmentally friendly and efficient buildings for future generations.

5. Adaptive architecture attracts investors with the promise of a high return on their investment. Investors see this approach as an opportunity to create long term and sustainable projects that will generate a stable income and a high level of value. In addition, adaptive architecture allows investors to be confident that they are making efficient use of financial resources and benefiting from innovative building solutions.

For example, investors may be attracted to the adaptive re-use of old factory buildings into modern micro-apartments. In this way, you can make use of existing structures to create unique and modern properties that meet the needs of the modern market and attract buyers. Such projects can be highly valuable due to their historic value and unique design, while generating a stable income from the rental or sale of apartments. Projects with adaptive architecture that incorporate innovative technologies to improve energy efficiency, reduce operating costs and increase comfort for residents or office workers may also be of interest to investors. For example, buildings that use solar panels to generate electricity or renewable heating and cooling systems may be attractive to investors because of the potential to reduce operating costs and to increase demand for such facilities by creating favourable conditions for occupants or users [19]. Adap-

tive architecture offers investors significant opportunities for creating profitable, environmentally sustainable projects which stand out for its innovation and adaptability. Because of the competitive advantages that this approach offers, investors who invest in adaptive building projects can be assured of steady income and high returns.

Adaptive architecture faces a number of economic challenges that require an integrated approach and innovative solutions, as well as environmental and social challenges. In particular, these are *First sector*. Compared to traditional buildings, adaptive buildings often have higher initial costs. This stems from the use of the latest technologies and materials, which may have higher up-front costs. For example, significant equipment and installation costs may be required to introduce energy efficient heating, ventilation and air conditioning systems [20]. Increased design and engineering costs are another factor contributing to the higher initial cost of adaptive buildings. In comparison to traditional buildings, the design of an adaptive building may require additional resources to consider the unique requirements of energy efficiency, sustainability and other aspects of adaptability. In addition, the need to integrate a variety of sensor technologies and control systems to ensure efficient use of resources and optimal comfort for occupants or users may contribute to the higher cost of adaptive buildings. These technologies also affect the overall cost of the building as they can be more expensive to install and maintain.

It should also be considered that the needs of adaptive buildings may change over time, which may require additional costs to upgrade and modernise infrastructure systems. For example, changes requiring additional resources may be required due to changing climate conditions or to expand the functionality of a building. Adaptive buildings can be more efficient and sustainable in the future, despite higher initial costs. They can have significant economic benefits in the form of reductions in operating costs, increases in staff productivity or new opportunities for space use. Thus, over the life cycle of the building, the higher initial cost of adaptive buildings can be offset by greater efficiency and durability.

Second sector. Designing and constructing adaptive buildings requires specialised skills and experience. This can increase the cost of producing and implementing the project. In general, adaptive buildings require specialists with a broad range of skills, covering not only design and construction, but also engineering networks, energy efficiency, automation and the Internet of Things [22]. The need to hire costly external experts or even provide additional training and

education for staff may arise from a lack of specialists in these areas.

For example, the selection of energy-efficient materials, heating and air-conditioning systems, and the use of natural light and ventilation are all skills required by green architecture professionals. These professionals are able to integrate environmental considerations into their designs thanks to their knowledge of sustainability and sustainable development. Engineers who are specialists in energy efficiency and renewable energy are also important players in the process. They design energy supply systems, energy monitoring systems and electronics for consumption optimisation. The implementation of these technologies can be complex and require specialist skills, which has a knock-on effect on installation costs. In the implementation of adaptive buildings, information management and digital technologies also play an important role. Using advanced building management systems, smart sensors and the Internet of Things can require specific digital engineering and data analytics skills. These technologies provide the ability to collect and analyse data to optimise operations, as well as providing efficient building management. In addition, innovative architectural solutions and designs that consider user needs, comfort and functionality are often required for modern adaptive buildings. In order to create innovative environments that can be selectively rewarded, architects and designers specialising in adaptive projects must have a unique approach.

The successful design and construction of adaptive buildings therefore requires specialist skills and expertise from a range of disciplines including architecture, engineering, energy, digital technology and design. Working with multiple specialists and engaging experts can increase the cost of the development process. However, the right approach and investment in quality development can be key to ensuring the success of an adaptive building project.

Third sector. One of the key challenges facing managers and developers of adaptive buildings is the uncertainty of the future. Adaptive architecture is based on the ability of a building to adapt to future changes. However, these changes can be very difficult to predict, which can create economic risks and complicate the design and construction process.

For example, changes in technology can occur at a rapid pace and place new demands on the infrastructure and functionality of the building. The use of outdated technologies or a failure to anticipate future needs can result in the need for costly changes in the future, which can increase costs and delay the commissioning of the building. Climate change can also affect the adaptability of a building. New energy effi-

ciency and insulation requirements may result from climate change. A worsening climate may require major changes to heating, air conditioning and ventilation systems, which will require additional investment and time to implement [21]. The adaptability of a building may also be affected by socio-cultural changes.

Changes in the layout and design of a building may be required due to changes in lifestyles, working practices and comfort requirements. For example, an increase in the number of older people in the population may have an impact on the accessibility and safety of a building. Other factors that may affect the adaptability of a building are economic and political changes. A building may need to be rebuilt or modernised due to increased energy costs, changes in legislation or the economic situation. Failure to consider these issues at the design stage can result in additional costs in the future, which may be unpredictable and have a significant impact on the financial performance of the project.

In order to avoid negative consequences in the future, all these factors highlight the need for a careful planning and design strategy for adaptive buildings. The successful operation of adaptive buildings in the future can only be ensured through a thorough analysis of potential risks and the development of flexible and progressive solutions.

Recommendations for the management of the challenges and optimisation of the benefits of adaptive architecture.

1. Optimisation of design and construction cost:
 - ✦ the use of integrated design approaches to reduce project costs and increase efficiency;
 - ✦ implementation of effective project management systems for the reduction of construction costs.
2. Human resources and skills development:
 - ✦ recruitment of skilled professionals from a variety of disciplines for integrated design and construction;
 - ✦ implementation of training programmes for the improvement of staff skills in the field of adaptive architecture.
3. Improvement of the predictability of future changes:
 - ✦ during the design process, carry out a detailed analysis of risks and possible future changes;
 - ✦ the use of analysis and forecasting tools for the prediction of possible scenarios.
4. Integrating innovative technologies and materials:
 - ✦ continuous updating of knowledge of new technologies and their implementation in projects;

- ✦ collaboration with suppliers of the latest materials in order to optimise costs and improve construction efficiency.
- 5. Engagement with the community and stakeholders:
 - ✦ involvement of local communities and other stakeholders in the decision-making process for adaptive architecture projects;
 - ✦ collection and analysis of user feedback to further improve projects.

The overall aim of these guidelines is to contribute to the optimisation of costs, the increase of efficiency and the preparation of adaptive architecture projects for future challenges and changes. Implementing these recommendations will help to reduce design and construction costs, increase efficiency and ensure that adaptive architecture projects succeed in the face of economic challenges.

CONCLUSIONS

Adaptive architecture, which enables the creation of buildings that can respond to environmental changes, is an important concept in modern urban planning. Flexibility, multifunctionality, upgradeability and interaction with the environment are its key principles. These characteristics make adaptive architecture an effective solution for the creation of urban spaces that are sustainable, resilient and dynamic.

The economic advantages offered by adaptive architecture are considerable. Adaptive designs help to reduce running costs through energy efficiency, to extend the life of buildings and to increase rental income through the flexible use of space. In addition, adaptive architecture has the potential to stimulate innovation in the construction industry and to create new market opportunities.

However, there are economic challenges associated with the implementation of adaptive architecture. Investment in research and innovation is an important aspect of the implementation of adaptive concepts in construction, but can be a significant cost. The increased cost of staff with the necessary skills and knowledge to implement adaptive technologies, which can increase project costs, is also a major economic challenge. Other economic challenges for adaptive architecture include market instability and competition in the construction industry. However, by stimulating the production of innovative materials and technologies, adaptive architecture can create new opportunities for economic development. This can create new markets and employment opportunities. Optimising design and construction costs, developing human resources and skills, increasing the predictability of fu-

ture changes, introducing innovative technologies and materials, and strengthening collaboration with stakeholders are important to overcome these challenges.

Despite the economic challenges, adaptive architecture has significant potential for the creation of more sustainable, efficient and resilient urban spaces. Adaptive architecture can become a key factor in the development of modern cities by addressing existing challenges in a holistic way and maximising the benefits of this approach.

For its successful implementation and dissemination in urban planning practice, further research into the economic aspects of adaptive architecture and the development of effective strategies to overcome existing challenges will be crucial. This will contribute to the creation of more flexible, sustainable and innovative urban environments that can adapt to changes in population needs and environmental conditions. Integrating advanced digital technologies is key to advancing adaptive architecture. The adaptability and efficiency of adaptive buildings can be significantly enhanced through the introduction of intelligent building management systems, sensor networks and artificial intelligence technologies. This will not only allow for a better response to changes, but will also optimise the use of resources, reduce operating costs and create more comfortable conditions for the users.

Another important aspect is the development of a legal and regulatory framework that encourages and supports the implementation of adaptive architecture. Developing appropriate standards, regulating the use of innovative materials and technologies, as well as providing government support, can contribute to the wider adoption of this approach in the construction industry. This will help overcome existing barriers and create an enabling environment for implementing adaptive architectural projects. It is also important to involve local communities and stakeholders in developing and implementing adaptive solutions. More popular and efficient urban spaces will be created by considering the needs and preferences of users and by actively interacting with them.

This will not only increase the economic efficiency of the projects, but will also ensure that they are socially and environmentally sustainable. Finally, an important area is to develop interdisciplinary cooperation between professionals from different fields – architects, engineers, economists, urbanists and local authorities. Only an integrated approach, based on the synergy of different areas of expertise, will ensure the successful implementation of adaptive architecture projects and maximise the economic, social and environmental benefits they bring to cities. Such co-operation will result in more flexible, sustain-

able and innovative solutions that are in line with the needs of modern and future cities. ■

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