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Sustainable Design in Architecture (The Case Study of the Educational Process at Universities in Poland and Ukraine)

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Abstract A large part of the capital, both financial and natural, is being invested in modern construction. The role of construction and architecture in creating conditions for sustainable development as industries involved in shaping this space is extremely important. Harmonization of architecture with the environment was and remains an important component of urban planning and architectural design. The purpose of this study is to highlight the theoretical and methodological foundations as well as practical solutions (based on the examples of students' works at architectural universities in Ukraine and Poland) regarding the formation of a sustainable architectural environment. The research is based on a systemic approach, which allows considering the architectural environment as a hierarchically arranged functional and spatial integrity. The methods of modeling, historical, comparative, and typological analysis and field surveys were widely used. Due to the lack of complex theoretical and methodological workings in this field, the scientific novelty of the article consists of a systematic approach to the formation of a theoretical and methodological basis for designing a sustainable architectural environment. This research was conducted at different levels of spatial integrity. The article considers the concept of the formation of a balanced architectural and urban environment. Theoretical and methodological foundations of designing at different hierarchical levels of its spatial integrity (city, building, interior) are outlined. Attention is paid to the problem and methods for assessing the balance and environmental efficiency of architecture. Standards in balanced design and modern interior design trends using innovative ecological building materials are also considered.

Keywords Sustainable Development, Architectural Environment, Design, Methodological Principles, Students' Projects

1. Introduction

The ecological trend of sustainable development is gaining more and more relevance in the context of making contemporary architectural and urban planning decisions. Sustainable progress is a development that can go on for a relatively infinite period without disturbing the ecological and social balance. Studying sustainable development principles and policies is becoming the main goal in EU countries. The leading role in the development management programs of urban planning and architectural and construction systems belongs to national and local authorities.

The Concept of Sustainable (balanced) Development basics was laid out in 1987 in the report 'Our Common Future', which was prepared by the World Commission on Environment and Development of the United Nations, also called the report of Gro H. Brundtland. This report defines sustainable development as 'development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs and provides a list of risks to future human development. The main theme of the report was the sustainable development concept and the problem of meeting the peoples' needs at the expense of nature, the needs of the rich at the expense of the poor, and the needs of the present generation at the expense of future generations. It was also stated that the principles of sustainable development should be implemented by all countries, because only then will it be possible to satisfy the aspirations of current and future generations [1].

Architecture is an integral part of human life. It is difficult to imagine modern and future life without buildings and structures. It should also be noted that the quality of architecture significantly affects all life processes. Based on this, it is important to train architecture students to design their projects and concepts, taking into account the principles and provisions of sustainable development. In this article, the authors share their international experience in introducing the designated pedagogical approach into the educational process.

To determine the main principles of sustainable development in the formation of a balanced architectural environment, the following theoretical methods of scientific research were applied:

- a systematic approach that allows considering the architectural environment as a hierarchically arranged functional and spatial integrity;
- methods of systematization and generalization, modeling, and working by analogy;
- historical, comparative, and typological analysis, and field surveys.

2. Results

According to the Sustainable Development Concept of the architectural environment, modern world construction practice shows that now the most promising is the formation of settlements and buildings designed based on energy-efficient and environmentally friendly technologies [2]. Thus, the most well-known is the concept that provides the construction of energy-efficient, bioclimatic, 'passive', 'healthy', and 'smart' buildings. At the same time, architecture in a balanced environment should be harmonized and integrated into the surrounding space, should positively influence its elements, and create optimal conditions for human life [3, 4].

The accumulated material regarding the practical use of these and other concepts [5, 6], as well as relevant contemporary urban planning and architectural solutions, especially during the rapid development of scientific and technical progress, requires their analysis and generalization, which is what this study is dedicated to [7, 8]. Its overall goal is to present a comprehensive picture of modern urban planning and architecture in a sustainable environment, at different hierarchical levels of spatial integrity (city, building, interior), taking into account various determinants, such as ecological, economic, social, aesthetic, ethical [9, 10]. Architecture in a balanced environment is not only a requirement of the present but also a postulate of the future, which determines the current world trends of urban planning, architecture, and construction [11, 12].

The need to create a harmonized environment and solve various and complex aspects related to its formation and development by the sustainable development concept is the main and urgent task of urban planning, architecture, art, and construction sciences. Galloping urbanization, the rapid development of various technologies and technical means of creating an artificial environment, on the one hand, natural disasters occurring in the world due to the depletion of the environment, caused by the above-mentioned development, on the other hand, create new requirements and conditions for contemporary architecture and design. The modern architectural environment design, which is an integrated creative work on the formation of a harmonized object-spatial environment, cannot be considered outside the context of social, economic, ecological, technical, aesthetic, and other factors and aspects. Each of them in one way or another affects both the conceptual decision and the final implementation of the design objects.

Modern dynamic changes in various factors and conditions of the architectural environment formation, the diversity and universality of environmental systems, objects, and approaches to their typology and design make it necessary to clarify the understanding of the environment quality and the methodological foundations of its creation in project activities. The formation of various urban planning objects and the existing methods of their design are determined by the typology of the architectural environment, which is generated from the spatial and subject features of the environment condition

and, in fact, of the greater part of this condition (environmental atmosphere), which exists as a conceptual unity and integrity.

Many works of various researchers are devoted to issues of environment typology [13, 14]. Based on the System Approach Concept, the architectural environment is considered the integrity of the conditions of the material human world, which is changing during the transition from one system level to another. With all the appropriateness of certain classifications, the understanding of the environment quality and its compositional and spatial organization for architectural and design activities lies in the plane of open (exterior), that is, space without a cover or roof, and closed (interior) – the room space. This corresponds to the already established division of the environment into the external and internal design [15].

These forms of the environment differ in the degree of openness to the natural environment; their common function (for example, recreational) will be solved by completely different artistic and compositional means. In the future, such a typological division should be differentiated into corresponding open and closed subsystems, which will also be divided into smaller-scale elements. At the same time, each element of the system or subsystem should be considered a complete system of a certain level.

The first hierarchical level of architectural systems' open spaces will be the urban structural block. It determines the place and role of the environmental object in the space of the settlement and its development, taking into account the various natural, climatic and urban conditions of the area, and the characteristics of the natural and artificial environment surrounding it. Urban planning conditions for the location of design objects, together with natural and geographical factors, play a primary determining role in the formation of both open and closed (interior) spaces of the environment.

Furthermore, this hierarchical level has several structural sub-levels or subsystems:

- the first is the level of the general scheme of territory planning and regional planning (the territorial development concept), taking into account the location of the country in the European space;
- the second is the level of regional planning (planning of the territories of an oblast or a group of oblasts);
- the third is the level of city master plans; the fourth is the level of detailed territory planning;
- the fifth is the level of development projects of districts, blocks, quarters, residential and public urban planning entities, and ensembles, taking into account the appropriate improvement of streets and squares.

The following – second hierarchical level of open spaces is the environment organization level of individual buildings and structures subordinated to the corresponding urban planning formation, and the surrounding external environment as a whole. At this level, the following structural and organizational subsystems can also be distinguished:

- determination of the basic functional and planning structure of the urban planning object in the context of the general environmental concept;
- its compositional and spatial organization, color, and light solutions.

The third structural block includes the surrounding buildings of the territorial fragment's environment, such as various outdoor areas (for example, quiet and active recreation), entrance groups, open terraces, operating roofs, atriums, parking spaces, etc. At the same time, this hierarchical level has a subsystem of already separate primary structural elements, such as specific elements of landscaping and improvement and arrangement, small architectural forms, means of visual information, various temporary and mobile devices, and the like. For example, for the entrance group, the objective filling of its environment and the artistic solution of the main system-forming elements and fragments, the synthesis of the design of the entrance group with decorative, applied, and landscape art are envisaged. It is also important to use appropriate building materials and products.

As for closed (interior) spaces, they should also be divided into the corresponding hierarchical levels of the architectural environment. The first hierarchical level of closed spaces is the organization of the internal environment of a building or an ensemble of buildings and structures, uniting the complex into a single internal space. At this level, the general architectural and spatial design and ideology of the internal environment of the entire interior space, the conditions of its interconnection, and interaction with the open space of the architectural environment are resolved.

The second hierarchical level will be the internal environment of specific premises of a building or complex, taking into account the connection with other open and closed elements of the environment. At this level, as well as at the previous one, functional zoning, architectural-spatial composition, and a general color solution are resolved, but not of the generally enclosed space of the building, just a separate room. The third structural block of closed spaces is a compositional and artistic solution of the main system-forming elements, furniture, and interior fragments with elements of decor and art synthesis of a specific room in the context of its general environmental design. Finally, the use of appropriate building materials and products is a separate final level for both indoor and outdoor spaces. Skillful use of traditional building materials (stone, ceramics, wood, glass) and their texture provides special natural artistic characteristics of the environment.

2.1. Features of Designing at the Urban Level

The study of sustainable, environmentally balanced

urban areas development issues, such as Ecological Urban Planning Systems (EUPS) 'population ↔ environment' in different levels of their spatial integrity, revealed several principles that outline the conceptual foundations of a new direction in the theory of urban planning – 'wave urbanism' [16, 17]. Within this direction the Department of Urban Planning of the Kyiv National University of Construction and Architecture (KNUCA) is forming an ecologically oriented 'Sustainable Urbanism' Scientific School, which is based on:

- perception of urbanization as a natural link with the ecosystem self-regulation law[1], which, as it turned out, is a manifestation of the fundamental law of sustainable development of open systems – the law of conservation of energy [8, 16, 18];
- consideration of urban planning activity as a constructive space environment of 'homo sapiens' species existence [16];
- apprehension of the environment as a theory of a big unification of various interactions for the sake of sustainable development and successive overcoming of growth limits in conditions of limited resources of the planet [8, 9, 10, 16, 17, 19, 20].

It was found that the EUPS dominant aspect of sustainable development is defined by a triad of complementary principles, namely:

- 'Variability of the unchanging'[2] – the spatial and energetic foundations of human development, such as the surface area and biological capacity of the planet, which determines the balancing and harmonization of the population interaction with the environment in the multi-level environmental space of urbanization processes deployment;
- multi-level unity of urban processes oscillatory development of dynamic structures, which, with evolutionary acceleration, contribute to increasing the local EUPS potential;
- inverse change in EUPS components parameters at the combined spatial levels of the urban planning object integrity (city ↔ region ↔ country ↔ world), which causes the self-organization processes at the level of cities (regions, countries) and self-regulation at the level of regions (countries, world) [9, 16, 19].

Consideration of the triad of sustainable development fundamental principles and the power of positive feedback joint action, make it possible to determine the adaptive management urban planning principles of urban areas sustainable development, using the potentials:

- 'Mosaic nature of asynchronous development' of territories, which is determined by the different levels of EUPS development and the presence of separate areas at earlier stages of development, that is, those that have a reserve of demographic capacity (the author developed and tested the methodology for calculating this capacity);
- 'Spatial kaleidoscope inertia' of changes in urban areas, the effect of which is determined by the rate of acceleration/dynamics deceleration of the wave process of the EUPS functional components development in the multi-level environmental space of the population interaction with the environment [9, 16, 17].

The environmentally oriented principles of 'sustainable urbanism', which have been laid out, are being worked out by master's students of the Department of Urban Planning of KNUCA in the ECOPOLIS Conceptual Modeling [25], as a way of Being, in which human activity stands together with natural cycles and determined by a careful attitude to Life.

The general features of the works are a harmonious combination of the advantages of 'High-Tech' and 'Eco-Low-Tech' technologies in construction; alternative sources of renewable energy and innovative eco-friendly productions; 'Aquaponics System' in urban 'closed soil' agriculture and ecological transport. To achieve compact space planning and compensation for the loss of the area of natural landscapes, the works propose the creation of 'urban biotopes' – artificial natural landscapes supported by humans and imitating pristine primary ecosystems in yards and squares, on facades and roofs. It is also proposed to use a 'vertical forest' or a 'network of attic parks' with viewing platforms, elements of social infrastructure, and recreation. Another interesting proposal is the use of the latest urban greenhouses or 'aquaponics' farms to provide residents with flowers, fresh fruits, berries, vegetables, herbs, fish, and work. The key triad of ECOPOLIS sustainable development is formed by such interconnected spheres of human activity as scientific, industrial, and educational.

Modeling of the Phoenix Bird ECOPOLIS is aimed at reviving the cultural and historical heritage of the site. The village of Vozdvizhenskoe (Yampil district of Sumy region of Ukraine) is a metamorphosis of the former (from 1880 to 1929) M. Nepliuyev Khrestovozdvizhensky Labor Brotherhood. At the end of the 19th century, Vozdvizhenskoe had telephone connection, and at the beginning of the 20th it was electrified. More than a century ago, the mechanized 'industrial-agrarian and educational cluster' of this labor brotherhood was already turning into an information one, and the main product here was the newest technologies of agriculture, breeding and education[3]. The concept of restoring the ethnogenesis memory of a place, which lies in the cyclical plane of multi-level spiral development: birth → formation →

1 According to this law, each territory, depending on the climatic conditions of the area, has certain dimensions of demographic capacity. The reserve of this capacity contributes to the growth of the population, and its depletion – to the reduction of the population (with a certain delay in time).

2 The author's presentation of the dialectic's synthesis by H. Hegel: 'Everything changes and remains unchanged,' according to which all real concepts used by the mind are necessarily internally contradictory [8, p. 84, p. 111].

3 L.H. Melnyk. 'Green' Economy (the EU experience and the practice of Ukraine in the light of the 3rd and 4th Industrial Revolutions), Sumy State University: Sumy, Ukraine, 2018.

flourishing → decline → ⋯ revival → flourishing, emphasizes urban synergy (nature + place + people, ideas and actions). This is marked in the project model by sinusoidal landscape lines and illustrated by citing similar projects, including an urban settlement in a modern city (Tokyo, Japan); eco-complex Lucien Rose (Rennes, France); BedZED eco-district (London, Great Britain); Ecopolis-Valencia self-sufficient city (Valencia, Spain) and others (Figure 1).

The simulation of 'Urban Being Fabric – Borodyanka Metamorphoses' ECOPOLIS is aimed at the revival of Borodyanka (Bucha district, Kyiv region), which, after its liberation from the Russian occupation, was disfigured by rocket and bomb attacks, infrastructure and residential buildings destroyed. The concept of city regeneration, which was first mentioned in 1190, derives from a fundamental quality of the Living - its ability to regenerate its damaged parts and lost structures. We are talking about the restoration of the urban fabric and planning the structure of Borodyanka from the ruins. As a visualization of the deep metamorphoses of this city - from its deliberate destruction by the Russian troops to its revival and flourishing in the future ECOPOLIS is chosen the model of the successive 'Hippodamus network' transformation in the newest Toyota Woven City (Figure 2). In the revival of the city of Borodyanka, the idea of turning a negative into a positive comes to the fore and the goals and means change places here. The goal of restoration, in a certain way, is to obtain 'ecological profit' from the urban fabric mutilated by craters – artificial lakes, which become 'epicenters of urban biotopes', have been chosen as a way of 'healing wounds from craters. These biotopes are form green public park spaces, city gardens, parks, and squares for gatherings, recreation, and various cultural and sports events. The appearance of new green areas in the city 'naturally changes' the pre-war planning framework of the city of Borodyanka, many streets of which embrace this space and honor the memory of crippled happiness. In the inner space of the transformed quarter's street network, it is planned to place innovative eco-friendly residential buildings and multifunctional public complexes that will directly or indirectly solve multifaceted issues of sustainable development. This is illustrated by citing similar projects, including: Toyota Woven City; UN17 Village in Ørestad /Denmark/; the first vegetable tower /Romainville, France/; Europe's urban food production /Hague, Netherlands/; Administration building with roof greenhouse /Oberhausen, Germany/; residential group Woody Woodpecker /Nantes, France/ and others (Figure 2). The ECOPOLIS conceptual model can be effective in post-war reconstruction for other cities of Ukraine as well.

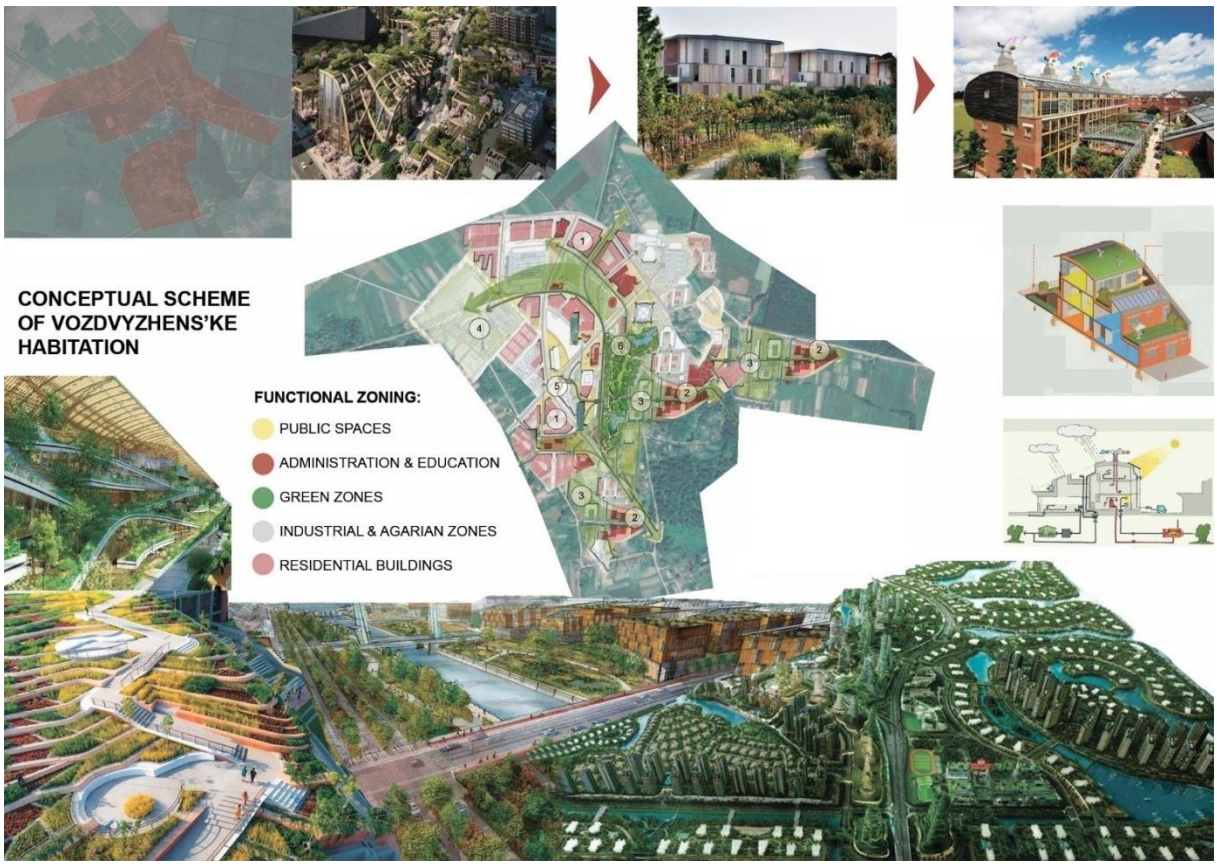

Figure 1. 'Phoenix Bird – Vozdvyzhenske'. ECOPOLIS (Master's degree students M. Selezeneva, O. Shvets, scientific supervisor Prof. I. Ustinova, 2021)

Figure 2. 'Urban Being Fabric – Borodyanka Metamorphoses' ECOPOLIS (Master's degree student A. Shevchenko, scientific supervisor Prof. I. Ustinova, 2022).

2.2. Features of Designing at the Building Level

Design at the building level covers various aspects of the multifaceted problem of sustainable development. This primarily concerns the search for rational architectural and urban planning solutions at all stages of design, providing the necessary balance between them and the natural environment. It is necessary to ensure the full use of the principles of flexible planning, allowing painless adaptation, transformation, and development of buildings to a variety of changing conditions for its operation.

The architectural and construction solutions used should include the use of efficient and lightweight structures, building products, and elements that ensure their modularity and transformability, optimization of assembly and disassembly, and taking into account the possibility of reuse. Concerning building materials and equipment in sustainable development, it is necessary to introduce high-quality and durable materials, taking into account their reuse and environmentally friendly and economical production. All kinds of local materials and resources should also be fully utilized to reduce transportation costs.

The next important aspect is to minimize the consumption of non-renewable energy and emissions with the maximum use of energy-water-saving technologies and solutions. At the same time, it is necessary to provide for the use of new alternative energy sources, saving raw materials, as well as the rational operation of buildings without the need for frequent repairs and reconstruction.

And finally, an important condition for the formation of sustainable architecture is the artistic, figurative, and aesthetic component, which ensures full respect and consideration of local historical and cultural traditions of the environment. To solve various problems of sustainable development, it is necessary to apply appropriate methods and models for studying an object of architecture with the definition of criteria for their assessment in terms of sustainability.

At the end of the 20th century, multi-criteria research methods dealing with issues of sustainable development were created. Among the most important are:

- Building Research Establishment Environmental Assessment Method (BREEAM), Great Britain;
- Building Environmental Performance Assessment Criteria (BEPAC), Canada;
- Leadership in Energy and Environmental Design (LEED), Green Building Challenge (GBC), European countries, Japan, Canada, USA;
- Haute Quality Environmental (HQE), France;
- Green Building, European Union;
- Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), Germany.

Based on the analysis of building assessment methods and certification programs, as well as personal experience in the field of sustainable development, the Professor of the Kielce University of Technology, L. Kamionka (our research partner), developed a model for assessing the object of sustainable architecture [27]. It is based on the assumptions of LEED and BREEAM methods tested in

many countries, taking into account the increase in the socialization of the building assessment process and accounting for the cost analysis of the building's full life cycle. Professor L. Kamionka suggests using the following criteria:

- Energy efficiency;
- Ecological use of the territory;
- Convenience use;
- The efficiency of materials and raw materials used;
- The efficiency of water supply and drainage;
- Local advantages and environmental friendliness of innovative solutions.

Professor L. Kamionka also formulated general recommendations for the design, construction, and use of a building based on a sustainable cultural and natural environment:

- Rebuild only when it is economically or practically impossible to use, to adapt the existing structure.
- Reduce the need for transportation during demolition, renovation, and construction, and carefully monitor all processes to reduce noise, dust, vibration, pollution, and debris.
- Exploit the area as efficiently as possible, for example by studying its history, purpose, microclimate, prevailing winds, weather cycles, solar orientation, public transportation accessibility, and the architectural shape of surrounding buildings.
- Design the building in such a way as to minimize its cost to the user and its impact on the environment throughout its lifetime, making it easy to maintain, energy and water efficient, and healthy, including due to the reduction of harmful substances emissions.
- Wherever you can, use construction techniques that are appropriate to the area, learning about local design traditions and the use of building materials.
- Put the function of the building and the convenience of its residents above any evidence of its owner or designer. This means: making it secure, flexible, and adaptable to future needs, and able to facilitate and encourage communication between users.
- Build with proper quality and durability. Durability largely depends on the shape, processing, and methods of materials assembly, as well as on their use.
- Avoid using materials from non-renewable or non-reusable sources [28].

Under the guidance of Prof. L. Kamionka, students of the Department of Theory and Architectural Urban Design of the Kielce University of Technology completed many educational projects. These projects took into account the principles and methods indicated in the models developed by the author. The projects aimed to create architectural objects that meet the requirements of sustainable design and to test the accepted assumptions in the design process. Solutions, that have been introduced, prioritize the rational management of water resources and the ecological relationship with the urban structure. In the process of environmental design, a highly qualified Building Management System (BMS) was used to optimize operating costs. In an ecological building project with the use of non-traditional building materials, student G. Krzemien created modular building elements from the mass of used paper. He developed cheap, environmentally friendly housing systems, presented in Figure 3.

Figure 3. Building module (design by student G. Krzemien, scientific supervisor Prof. L. Kamionka)

2.3. Features of Designing at the Level of Interiors

A modern interior is a complex dynamic system that is formed from a relatively static architectural space with the features of its structure, equipment, and works of monumental and decorative art. It also has dynamic content – a set of things, decor elements, furniture, and other forms that create conditions for the implementation of functional processes. The sustainable interior design of architectural buildings and structures is defined as interior design in which all systems and materials are developed with a focus on integration into the building's holistic life. It is also designed to create a cycle to minimize the negative impact on the environment and people and maximize the positive impact on the ecological, economic and social systems as a whole. Sustainable interior design is aimed at rationalizing the use of materials to preserve natural resources in a way that does not lead to environmental degradation. Compared to traditional design practices, where designers mainly are concentrated on the satisfaction of the aesthetic, physical and functional needs of clients, the sustainable interior design aims at harmonizing the human-environment ecosystem on a global scale, also focuses on the rational use of materials and their impact on the environment and human health.

Already at the design stage is a problem of rationality, when the designer must take into account the optimality of a ratio material consumption, the life span of the object, and the possibility of its further utilization. We must predict, consider and prevent:

- the possible environmental damage both in the manufacturing (raw materials, equipment,

technologies, energy consumption, waste, transportation);
- operation (energy consumption, harmful impact on nature, repair, durability);
- disposal processes (passive destruction, the harmfulness of released substances;
- destruction or processing, energy consumption, and harmful effects on nature;
- the possibility of a second life for the object) [29, 30].

So, we can highlight the following criteria for the evaluation of the interior in the context of the sustainable design paradigm:

1. Ecological efficiency related to energy and resource conservation, protection of the environment from pollution:
   - Reduction of the need for energy and water resources due to the use of energy-efficient interior solutions, including the introduction of intelligent control technologies for 'smart home' equipment. As well as rational functional zoning (for example, the zone of residential premises is placed on the south side of the building, the zone of auxiliary premises, such as bathrooms, toilet, pantry, wardrobe, auxiliary and technical premises – on the north side);
   - Use of special equipment and interior elements to save energy (window coverings, blinds, curtains, carpets, heat-insulating materials of equipment. Use of light colors and reflective surfaces in the interior to reduce the use of artificial lighting, etc.);
   - Use of materials that meet the principles of sustainable design when choosing equipment and forming the object-spatial environment (the assessment is based on a set of features: impact on the environment. Reduction of waste during production; durability and flexibility; the possibility of reuse; giving preference to materials of local origin, etc.) [31, 32];
   - Use of easily treated surfaces to reduce the number of harmful chemicals for their cleaning.
2. Ecological efficiency in terms of creating a comfortable living environment:
   - Support for physical parameters of space (temperature regime; air quality; optimization of lighting; acoustic comfort; use of anti-allergic materials; decisions that ensure the safety of the population).
   - Support for the functionality of space (functional zoning, ergonomics, design versatility and inclusiveness, adaptability of the interior to changes in the functional purpose of individual zones) [33, 34].
   - Visual Comfort (access to natural and artificial lighting; introduction of natural and artificial natural forms into the artificial environment; aesthetic perfection and compositional expediency of space).

Designing flexible spaces is one of the foundations of interior longevity. Thus, in the residential environment, innovative technologies make it possible to form various options for interior transformation:
- the walls that can be moved to redistribute the useful area, as a child gets older and begins to need their rooms;
- adjustable and mobile furniture that can be transformed by the changing needs of space organization;
- a modular floor that allows personalization and easy replacement the individual parts, etc.

Furniture is a key element in defining the type, function, and use of building premises. In a balanced (sustainable) interior design, designers try to reduce the amount of furniture, choosing smart furniture units that are versatile and able to serve more than one purpose. It envisages the possibility of re-using old furniture after updating it or making certain adjustments to its design. This type of reuse is not always considered to be aesthetic [35, 36]. It should be noted, that a mandatory condition for the implementation of the ideas of sustainable development, is the use of materials that meet the requirements of regulatory documents, and current quality standards, and is labeled properly [37, 38].

Landscaping has always been a regulator of the environmental ecological balance and an element of the decor and artistic decoration of premises. It is known that plants increase air ionization, disinfect it, and contribute to the creation of an acoustically favorable space. Currently, the following types of landscaping are distinguished: individual phytoelements, plant compositions, winter gardens, phytowalls, phytopaintings, and paludariums [39, 40].

Figure 4 – Figure 6 show the illustrations of the project proposals for interiors of various public purposes that meet the requirements of sustainable development, made by students of the Department of Interior and Furniture Design of the Kyiv National University of Technology and Design. Figure 4 shows the location plan of the furniture and visualization of the office premises based on the shopping and office complex 'Gulliver'. The author chose a natural bio prototype – the cellular structure of leaves with chloroplasts – as the basis of the functional planning solution. The open combined space is designed for departments that need teamwork, as well as individual offices for managers, executives, and accounts. The shape and location of interior elements correspond to the form and principle of the location of the chloroplasts in the cell [41-43].

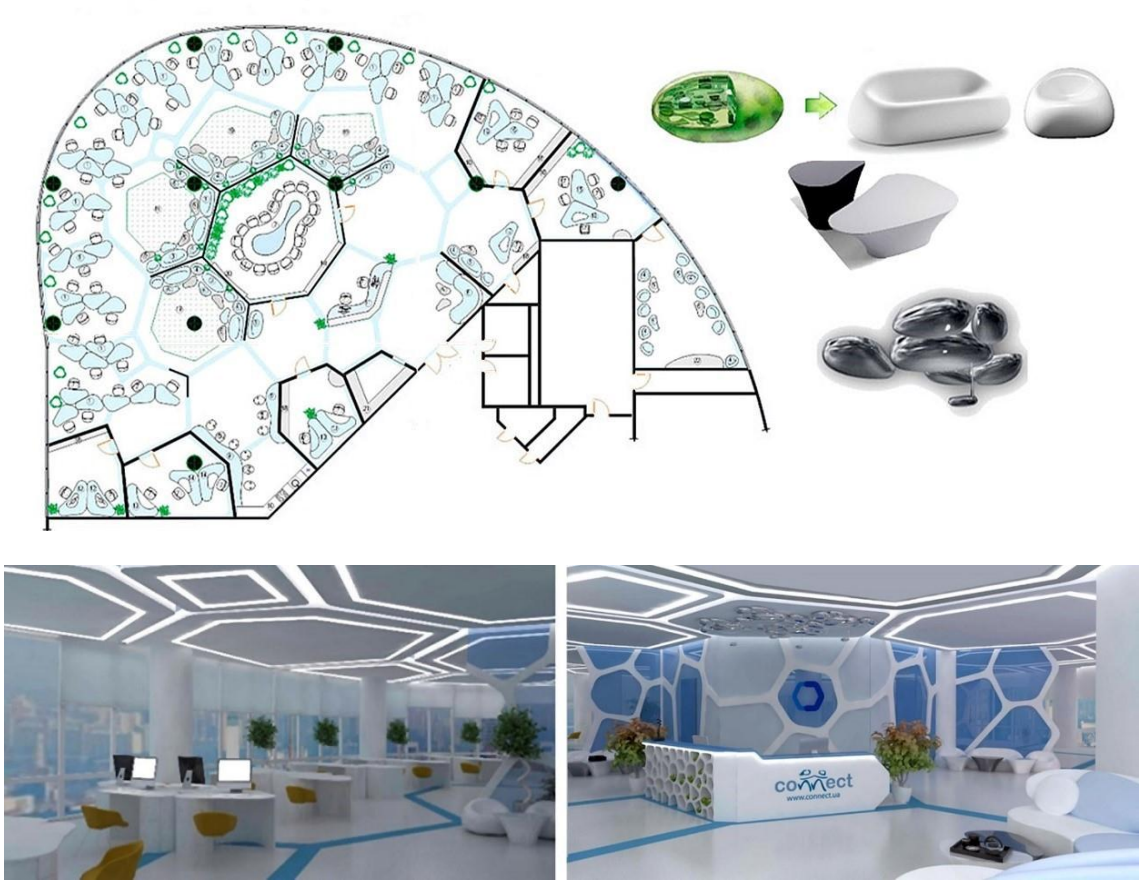

Figure 4. Office complex ‘Gulliver’ (Master's degree student Olga Bulgakova, supervisor Docent Olena Safronova)

Figure 5. Hotel interior design takes into account the combination of internal and external environments (Master's degree student I. Bevz, scientific supervisor Prof. V. Abyzov).

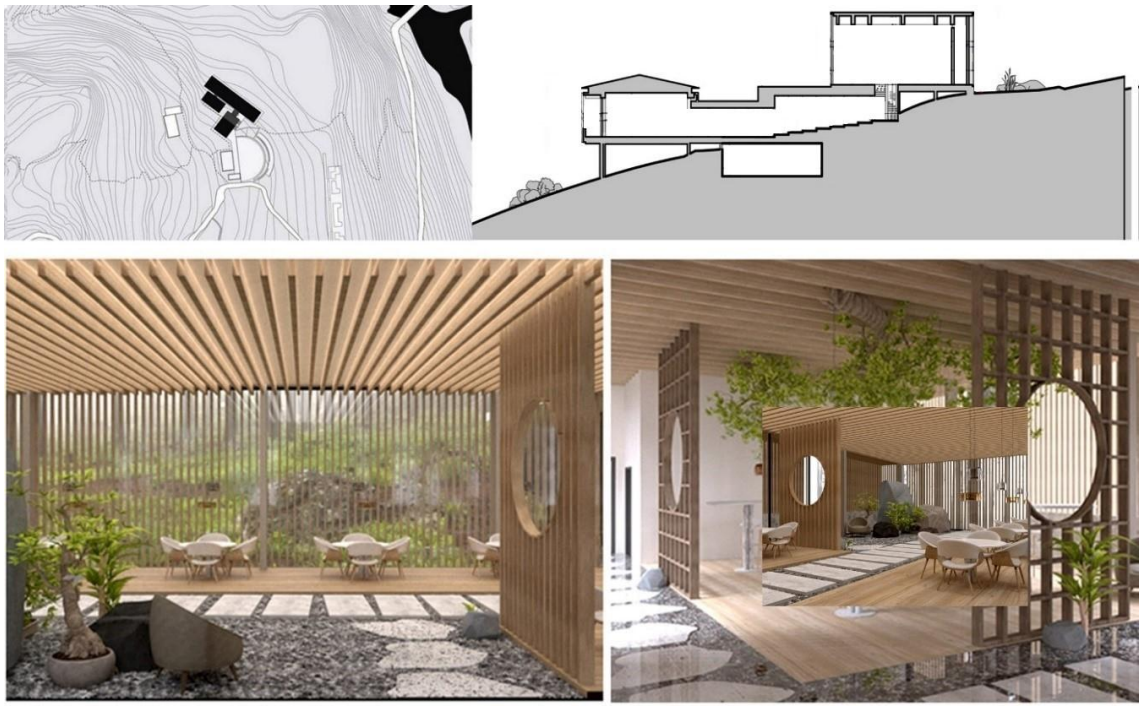

Figure 6. The interior of the cafe is located on a territory with complex topography in the Carpathians (Master's degree student Y. Melnyk, scientific supervisor Docent O. Safronova).

One of the main requirements for the design of interiors for various purposes in student works was the integration of the internal and natural environment, and the use of the principles of 'green design', the use of ecological building materials (Figure 5).

The main idea of the interior design of the cafe presented in Figure 6 is to introduce the principles and techniques of the Japanese landscape design (Zen philosophy), focused on contemplation of nature, peace, and self-discovery, unification of the interior with the surrounding natural space. Small architectural forms and characteristic elements of a Japanese garden (bonsai, stone garden, steam vases) are used in the decoration of the space, as well as appropriate talismans – wind music (copper bells), carp figurines made of white ceramics. Every element carries a special meaning. The project site lies against the forest and overlooks the valley and the mountains.

3. Conclusions

Of course, within the framework of one article, it is impossible to highlight all the acute problems that exist in creating a sustainable architectural environment. The authors of the article presented an attempt to unify and systematize the approach to understanding sustainable architecture, and also demonstrated how this knowledge is implemented in the educational process. From the point of view of sustainable development, it is necessary to note the importance of the spatial integrity of the architecture, which in this article was considered at three main levels: city, building, and interior. It is such a holistic perception that needs to be educated in students-architects, which in the future will allow them to realize the phenomenon of the architectural environment as a system built on sustainable development principles.

In the process of teaching, it is recommended to communicate openly with students and not be afraid to set tasks for which the answers are currently probably unknown. In this case, the implementation of the educational project becomes an interesting and new task that allows you to gain important and non-standard knowledge. Students develop a sense of commitment to something meaningful, to shaping the architecture of the future. Also, student projects can serve as a potential experimental platform for finding creative solutions for the formation of sustainable architecture. The implementation of the solutions obtained and their initial testing is possible within the framework of international workshops, which, of course, comprehensively enhances the educational process.

A comprehensive review and structural analysis of various conditions and trends in the development of the design of the architectural environment that determine sustainable development can be effectively used for further research when designing architectural objects. The authors of the article welcome further research of the proposed approaches and call for the improvement or creation of other models and concepts of sustainable architecture and their implementation in the educational process.

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