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Адреса редакції:

Національний університет «Львівська політехніка»
79013, вул. Степана Бандери, 12, м. Львів, Україна
E-mail: info@arch-studies.com.ua
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Editors office address:

Lviv Polytechnic National University
79013, 12 Stepan Bandera Str., Lviv, Ukraine
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Natalia Merzhievskay

PhD in Architecture, Associate Professor
Odesa State Academy of Civil Engineering and Architecture
65029, 4 Didrikhson Str., Odesa, Ukraine
<https://orcid.org/0000-0003-3100-4816>

Anzhelica Dunaievskaya*

Assistant
Odesa State Academy of Civil Engineering and Architecture
65029, 4 Didrikhson Str., Odesa, Ukraine
<https://orcid.org/0000-0002-7876-0558>

Integrated greenhouse module as one of the promising areas for the development of greenhouse structures

Abstract. The study addresses the issue of greenhouse structures in Ukraine, most of which, after an active period of construction (mid-20th century to the second half), have reached their limit in architectural-constructional and innovation-technological aspects, as contemporary scientific and practical papers in the field of architecture and greenhouse design are almost absent. The purpose of this study is to identify promising areas for the development of greenhouse structures, establish types of integrated greenhouse modules, and formulate basic recommendations for their organisation. The research methodology consists of three stages (preparatory, research and synthesis) using methods such as analysis of literary and scientific sources, terminological clarification of concepts, logical analysis, critical and comparative analysis, graph-analytical method, generalisation, induction, hypothesis and forecasting. As a result of examining examples of global experience, five types of integration of greenhouse modules into the structure of buildings and structures of various typologies were identified: “greenhouse module – open atrium”, the concept of which is to create a green module in the space of an open atrium to organise a cultural and aesthetic point of attraction; “greenhouse module – closed atrium”, which is formed in the space of a separate, closed atrium that separates different functional blocks and creates a buffer zone for employees of the institution; “greenhouse module – ‘green’ rooms”, which are implemented in those functional blocks that, to the extent of their specificity, require psychological and unloading rooms, rooms for emotional relaxation and meditation; “greenhouse module – floor”, which serves as a buffer floor between different functional blocks to create a comfortable environmental and social background for people in the working environment; “greenhouse module – entire building” is the rarest type, which increases the level of efficiency, motivation and creativity. An analysis of individual structures allowed identifying the following recommendations for integrating greenhouse modules: greenhouse modules should be incorporated in the design stage; medical, botanical and aesthetic aspects should be considered; carefully select the assortment of plants; proper care of plants will ensure the longevity of the module; the greenhouse module should address the set tasks. The practical value of this study

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*Corresponding author



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lies in the fact that the results can be used to create recommendations and methodological guidelines for designing greenhouse modules

Keywords: ecological design; modern public buildings; interior phytodecoration; integrated greenhouse; phytodesign; enclosed space

INTRODUCTION

The development and evolution of greenhouse structures are the result of complex changes in social-demographic, recreational-leisure and ecological needs of the population. A greenhouse structure combines botany, ecology, architecture and engineering in its concept, making interdisciplinary connections crucial in this field. There is a significant lack of research in the field of architecture concerning greenhouses in the Ukrainian scientific community, leading to a prolonged pause in the design and construction of new greenhouses, and unsuccessful attempts at the reconstruction and restoration of historical greenhouses.

M. Davydenko (2021) emphasised the significance of the activity of the academician of the NASU (National Academy of Sciences of Ukraine), Doctor of Biological Sciences, Professor A.M. Grodzinsky at the international level. Research conducted by A.M. Grodzinsky, allowed him to develop new approaches to solving problems of introduction and acclimatisation of plants, green construction, park science and allelopathy (chemical interaction of plants). These studies can be considered a foundation for the further active development of botanical gardens, including greenhouses and greenhouse complexes, focusing on the introduction and acclimatization of tropical plants in closed soil conditions. The author demonstrated that A.M. Grodzinsky's main achievements, serving as the basis for incorporating plants into the interior structure, include formulating a series of fundamental principles of phytodesign recognised by Ukrainian and global science: the aesthetic-psychological impact of plants on humans is achieved through the beauty of form and colour; improving the living environment, disinfecting and enhancing the environmental health are achieved through airborne phytoncides.

N. Hnilusha (2022) in his methodological recommendations for the discipline "Phytodesign" highlighted the specific contributions made by students and followers of A.M. Grodzynskyi in this field. For example, M. Schleiden & A. Regel described the influence of various plant groups on humans; V.V. Snizhko developed typical compositional-plant groupings for various interiors; I.P. Hornytska identified 30 forms of tropical and subtropical plants based on their biological and ecological characteristics, which proved to be very promising for interior phytodesign. The methodological recommendations reveal the features of typological application of phytodesign, provide a range of plants with prospects for use in phytocompositions, and provide guidelines for creating and regulating the necessary climate.

N. Merzhievskay & A. Sokolova (2021) addressed the terminology of cultivation structures, identified historical stages of development and evolution of closed ground types, and proposed a classification of greenhouse structures based on such criteria as the construction period, type of placement, role in shaping the urban environment, landscape structure, functional purpose, integration into other structures by typology, architectural-compositional solution, structural scheme, material of the load-bearing structure, material of the covering, ability to simulate climate and heating source.

V. Novosad *et al.* (2021) investigated the question of recreational plant resistance in an urbanised environment. They examined terms such as "resistance", "adaptation", "recreational resistance" and others. Based on biomorphological analysis, the authors proposed an algorithm for differentiating recreational resistance, through which marker signs of changes at different levels of plant formation and development can be identified. These studies were conducted concerning plants in natural environments, but such an algorithm can also be applied to plants in closed soil conditions, such as in greenhouses or hothouses.

O. Strashok & A. Morozko (2021) established that interior phytodecoration is an essential component of creating a comfortable environment for employees in various institutions. They investigated the phytodecoration of the interior of the Cabinet of Ministers of Ukraine, the history of which began around 2003. After the reconstruction of the Cabinet of Ministers' halls, specialists in landscaping and phytodecoration formed the first phytocompositions for decorating recreation rooms, entrance and transit zones, meeting rooms, press and journalism rooms, and the small hall of the building. Researchers proposed seven new compositions using an expanded range of tropical and subtropical plants, created with specialised software Real Time Landscaping Architect.

A. Dzyba & K. Saveliev (2023) identified the importance and necessity of cultural ecosystem services of parks during the war in Ukraine due to the emotional-psychological vulnerability of people. The conducted survey helped establish that a large number of respondents seek greater interaction with elements of park improvement and more areas for socio-cultural enrichment. D. Saadi *et al.* (2021) found that green environments have a strong restorative impact on human psychological and physiological parameters, depending on the function, aesthetics and quality of park plantings.



The purpose of the study was to identify prospective areas for the development of designing, constructing, and restoring greenhouses and greenhouse structures. The analysis of contemporary global architectural experience helped identify the specificity of modern public objects, incorporating “green” modules with different functional contents into their structure. The diversity of such modules prompted the derivation of types of integrated modules and the formulation of recommendations for their implementation.

MATERIALS AND METHODS

This study consisted of three stages: preparatory, research, and synthesis. In the first stage, the preparatory stage, the multi-level nature of the problem and the relevance of the study were determined. During the search for examples of greenhouses and greenhouse structures, mostly in the USA, European countries and Asia, using the method of logical analysis, it was disclosed that new greenhouses appear less frequently with a new philosophy of functioning, proposing more interaction with society and active participation in the ecological aspect. It was also found that increasingly, “green” modules are incorporated in new modern public structures. The analysis of literary and scientific sources, combined with the method of terminological clarification of concepts, helped clarify terms such as “winter garden”, “phytodesign”, “phytmodule” and combining them to formulate the term “integrated greenhouse module”.

In the second stage of the study, the exploratory stage, it was necessary to identify the relevance of introducing plants into the interior spaces of public buildings and structures. This involved applying the methods of critical and comparative analysis. Considering the multifaceted nature of the issues, an interdisciplinary research method was applied to determine the positive components of this integration on architectural-aesthetic, botanical, psychological and medical levels concerning humans. The research of A. Grodzinsky *et al.* (1989) was utilised for botanical and psychological aspects; N. Merzhievskaya & A. Sokolova (2021) – for architectural-aesthetic aspects; and the report from the U.S. Environmental Protection Agency (1989) – for ecological and medical perspectives. After clarifying the prerequisites and scientific foundation using critical and comparative analysis methods and the method of generalisation, a sample of objects was created based on criteria such as geographical diversity of locations, public purpose of the structure, a pronounced “green module”, variability of the module’s functional range, diversity in the structural scheme of the module and modern architectural-aesthetic solutions.

In the third stage, the synthesis stage, using the method of generalisation and a combination of induction and deduction methods, five types of integration of greenhouse modules into the structure of public buildings were derived, and five general recommendations for

their organisation were proposed. A graphic analysis was conducted on ten selected objects (two for each type of integration) using Archicad 24 and Adobe Photoshop 18, outlining the building’s contour, greenhouse module contour, main entrances/exits, and functional content of adjacent blocks. Graphic materials from almost all projects were sourced from a large electronic gallery of modern architectural objects – Achdaily. Applying the method of intuitive forecasting revealed prospective areas for the development of greenhouse structures, emphasising integrated greenhouse modules, particularly as the percentage of construction increases each year.

RESULTS AND DISCUSSION

The history of the development and evolution of greenhouses traces back to Ancient Egypt, and modern greenhouses have fundamentally changed compared to their early typological representatives. The shift in social needs has altered not only architectural planning decisions but also the philosophical significance of greenhouses in the city structure. In the contemporary world, greenhouse objects have a multifunctional, adaptive and innovative character (Merzhievskaya & Sokolova, 2021). The experience of designing greenhouse structures in Ukraine has also flourished, mainly driven by active development in the botanical-breeding field. This precondition has shaped the main feature of Ukrainian greenhouses – their location on the territory of botanical gardens, which are specialised higher educational institutions. In Ukraine, there are approximately 33 botanical gardens, with around twenty of them having individual greenhouses or greenhouse complexes. These structures serve multiple functions but are primarily oriented towards scientific, educational, recreational-leisure and ecological activities (Nature Reserve..., 2021).

Analysing the global experience of designing greenhouses and greenhouse structures, one can note a significant variability manifested in the restoration of the original appearance of historical greenhouses, the restoration of greenhouses with a change or adjustment of function, the construction of new ecological clusters, the construction of mobile greenhouse modules to enhance the aesthetics of the urban landscape, and the integration of greenhouse modules into the structure of various buildings. Considering the characteristics of Ukrainian and global architectural experience, greenhouse structures, both modern and preserved from previous eras, can be divided into four conditional groups in terms of their aesthetic-cultural significance in the city’s life.

The first group includes architectural and historical monument greenhouses. They reflect the best examples of architectural, structural, technological and landscape-floristic professionalism of the time. In terms of their socio-economic significance, such greenhouse objects currently bear the burden of museum facilities, characterised by a more demonstrative nature with minimal interaction with visitors.



The second group comprises contemporary greenhouses that reflect the incredible industrial development of the city and the country. Typically, these are large multifunctional complexes utilising state-of-the-art construction and climatic technologies. Greenhouse complexes, such as ecological clusters, where recreational activities are organised for all age groups, cease to be museum-like; they stand out for maximum interaction with visitors.

The third group includes integrated greenhouses harmoniously incorporated into the structure of public, specialised and residential buildings, creating a more comfortable, psychologically friendly, ecologically healthy and inspiring environment. This type of greenhouse is highly interactive with people, designed to improve their conditions for temporary or permanent stays.

The fourth group consists of greenhouse installations representing stationary or temporary compact-sized greenhouses of any configuration and construction scheme. Greenhouse installations serve as elements of public space in the urban environment, on streets, squares, recreational areas, or courtyard spaces. Among the main tasks faced by elements of landscape improvement, including greenhouse installations, are functional (ensuring the optimal nature of the territory's function realisation), aesthetic (possessing individuality and imagery) and ecological (establishing a possible balance between natural and anthropogenic components of the environment) (Tiurikova *et al.*, 2021). As of 2023, this type is not widespread but is actively applied in cities with poor air quality as a station for air purification and recreation.

The issue of actively integrating plants into the interior space of public buildings addresses a range of issues related to improving working conditions at ecological and medical levels, beyond the artistic and aesthetic aspect. In the era of the global environmental crisis, the problem of environmental pollution with xenobiotics becomes increasingly urgent. There is a pressing need to improve the state of atmospheric air in cities, as pollutant levels in indoor air are ten times higher compared to open urban areas (Vazquez & Adams, 2014). Interior greening goes beyond aesthetics; it involves the use of plants to disinfect indoor air from pathogenic microflora, purify the air from industrial dust and gases, and address issues such as air ionization, humidity, sound absorption, and, most importantly, oxygen enrichment. Therefore, the tasks of phytodesign are diverse and extend beyond simple greening (Snizhko & Kharitonova, 2006). Given that people spend 80-90% of their time indoors, the issue of improving indoor environments, particularly from medical and ecological perspectives, remains relevant (U.S. Environmental..., 1989).

Interior greening is one way to enhance public spaces and improve working conditions for people. Modern requirements for phytodesign include careful selection of predominantly decorative tropical and subtropical plants

and an understanding of their ability to thrive in the extreme conditions of interiors (Grodzinsky *et al.*, 1989). Preserving the decorative qualities of tropical and subtropical plants in the interior structure is only possible by creating conditions such as proper orientation of the building to light, adequate illumination, balance of humidity and dryness in the air, creating a favourable microclimate inside. As of 2023, the practice of introducing green modules after constructing buildings and placing equipment is still prevalent, especially in Ukraine. This practice makes the spaces less suitable for plants, hindering correct, long-term maintenance and increasing care costs. Therefore, the key to the longevity of active greening is to plan the specifics of their placement during the design stage.

After analysing global experience, the following types of greenhouse module integration into the structure of buildings of various typologies were identified:

1. Greenhouse module – open atrium;
2. Greenhouse module – closed atrium;
3. Greenhouse module – “green” room;
4. Greenhouse module – floor;
5. Greenhouse module – entire building

The variability of global design and reconstruction experience for greenhouses and greenhouse structures allows for a more detailed analysis of each of the above types of integrated greenhouse modules, using specific projects as examples.

The first type of integration – “greenhouse module – open atrium” – represents a space under an atrium with active greening. It can include individual plants in movable or stationary containers, the creation of floor compositions, rock gardens, vertical greening on pergola structures and additional greening of the corridor on each floor of the atrium space. Any public or residential buildings with an atrium are suitable for implementation. Simulating a climate for plants in an atrium module is not envisaged; only intermittent spraying is possible. Therefore, a judicious selection of plants capable of enduring extreme conditions is necessary. V. Monarch (2020) noted that it is important to consider the fact that plants grown indoors are brought from different countries and each type has its characteristic temperature regime based on its natural origin. Therefore, it follows that in one greenhouse module, plants from the same climatic zones should be arranged.

The researchers suggest that this is the most common type, as it can be arranged even after the construction of the building. As an example, the Jakarta hotel project on Java Island, Amsterdam, Netherlands, in 2018, was chosen. The hotel's green atrium is an undeniable focal point of the structure both architecturally and functionally. On the first floor, this module has quiet relaxation areas, a waiting area near the vestibule and adjoins the open restaurant area, creating a unique tropical atmosphere. The hotel rooms on the upper floors open into local “jungles”, providing temperature and humidity regulation (Fig. 1).



TYPES OF ORANGERY MODULES INTEGRATED INTO THE STRUCTURE OF PUBLIC BUILDINGS



Figure 1. The first type of integration – “Greenhouse module – open atrium”

Source: developed by the authors based on ArchDaily (2018; 2021c)

The expansion project of Helsinki Airport, Vantaa, Finland, in 2021, by the architectural bureau ALA Architects (lead architects – Juho Grönholm, Antti Nousjoki and Samuli Woolston), also includes a greenhouse module in the structure of an open atrium. This is an example of a minimalist-aesthetic phytomodule that reveals the flora and stylistics of the country, serving cultural-traditional and aesthetic-national aspects. The authors describe it as follows: “On the lower level, the first thing arriving passengers see after passing through customs is the natural diorama ‘Luoto’ – an installation of arbitrary shape with trees, bushes and stones in large pots. ‘Luoto’ combines characteristics of Finnish nature with Japanese garden art. It is also visible from the upper departure level through an opening in the middle of the registration area” (Fig. 1).

The second type of integration – “Greenhouse module – closed atrium” – represents an atrium enclosed by glass around the perimeter, with plants placed in floor-integrated, “sunken” reservoirs with appropriate soil mixtures. Unlike the “open atrium” module, which serves as a unifying element in functional zoning and architectural-compositional solutions of the building, the “closed atrium” module, on the contrary, serves to separate blocks with different functional contents and combines them with architectural-compositional solutions. However, this affects the functional range of using such modules. Buildings with a block volume-planning structure requiring clear functional distribution are suitable for implementation.

In such modules, people mostly stay for a short time, allowing partial simulation of the climate for plants. Since it is a closed-type module, temperature and humidity can be controlled, allowing for a wider range of plants, including those with lower adaptability.

This type is less common, as atriums are usually left open. An example of applying such a volume-planning structure is the Lufthansa Aviation Center, Frankfurt-am-Main, Germany, in 2002-2006. The object is located between the Federal Highway A3 and the Frankfurt Airport. To address issues with the noise threshold and high emissions through such transport hubs, it was decided to alternate office blocks with large greenhouse modules. Each module created typical landscapes of all five continents. Thematic gardens’ vegetation ranges from the “California Beach” to the traditional “Japanese Temple Garden”. Such diversity of landscape themes symbolises Lufthansa’s worldwide connections. An analysis of the vegetation of each region was conducted, and only a few species of trees, shrubs and ground cover plants were selected for each block. This approach helped choose plants with the highest level of inductivity, requiring a more or less similar climate, although they are from completely different climatic zones, resulting in significant cost reduction for creating an identical climate. Each block’s function varies, serving as a different recreation area; for example, one module has a beach volleyball court, while another has a quiet relaxation and meditation zone (Fig. 2).

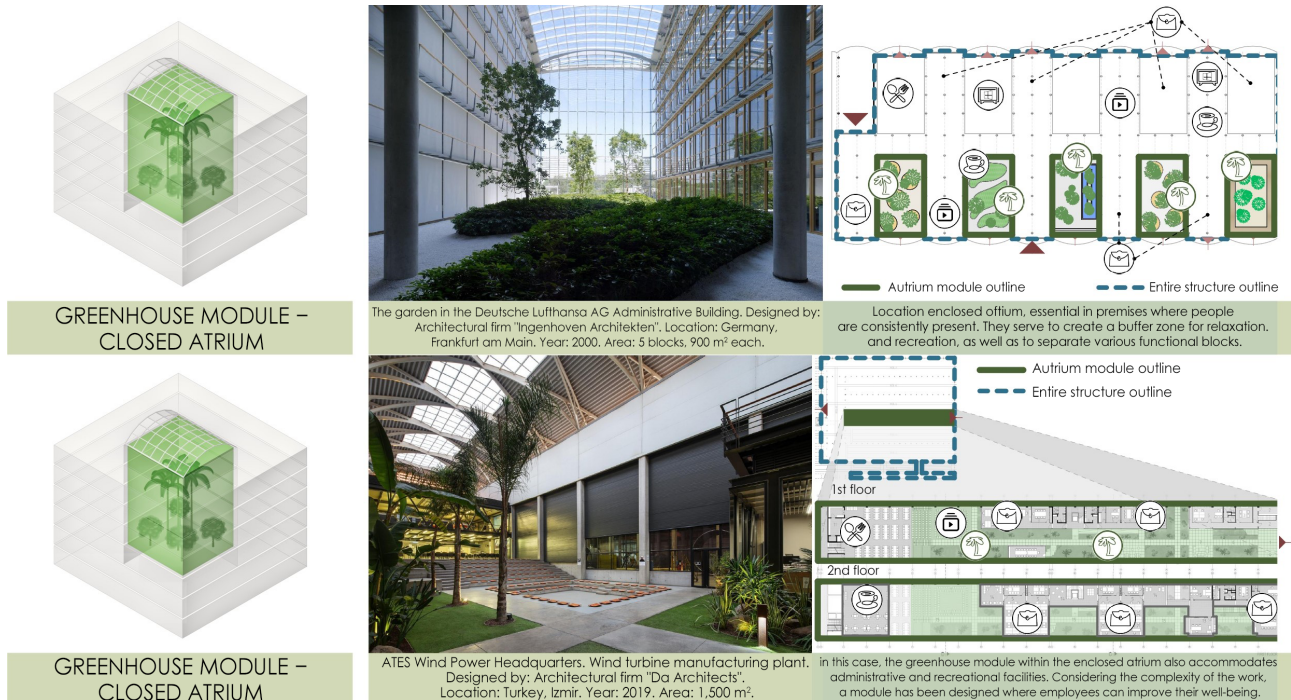


Figure 2. The second type of integration – “Greenhouse module – closed atrium”

Source: developed by the authors based on World Landscape Architecture (2013), ArchDaily (2021a)

The project of the ATES Wind Power headquarters within an industrial facility for wind turbine production, Izmir, Turkey, in 2019, by the architectural firm d.a.architects (chief architect – Durmus Ali Kasap). The object is located along the Gallipoli-Izmir expressway, not far from the Candarli port. The main task facing the architects was to place management offices in the centre of the production workshop with the possibility of direct contact. The solution to this task was the creation of a closed atrium module with an internal garden amidst the production workshops. The module incorporates all necessary zones and rooms (entrance zone, office rooms, small and large conference halls, negotiation rooms, large dining area, amphitheater for meetings and conferences). In their project description, the developers share recommendations they formulated during work: “Effective and efficient organisation of workspaces that meet the company’s actual needs, as well as flexibility to adapt to changing space requirements in the future. Creating diverse covered recreational relaxation areas to enhance social interaction among employees. Using passive design principles such as natural ventilation and lighting” (Fig. 2).

The third type of integration – “Greenhouse module – ‘green’ room” – is a closed glass space with an unlimited number and functional components, and several such integrated modules can be on one floor if needed. These modules are usually small in size and demographically focused on small groups of people; they can be meeting

rooms, conference rooms for a small number of people, rooms for psychological relief, offices for emotional relaxation, meditation rooms, etc. This type of integrated greenhouse is most suitable for buildings where people spend the entire working day, whether it’s office blocks, industrial production blocks, or schools, higher education institutions and others. The “green” room module should be introduced into the structure not just for aesthetic decoration but to improve the ecological-social background of the working environment, so the selection of plants is crucial in such modules to ensure maximum efficient air purification. For practical phytodesign implementation, it was suggested to purposefully introduce medicinal and essential oil tropical and subtropical plants with known healing properties into office interiors, lobbies, waiting rooms, etc. Soon, the creation of phyto-recreations from a professionally selected assortment of plant species for the prevention and treatment of various, including infectious, diseases was highlighted as a separate area – medical phytodesign (Kosenko *et al.*, 2020).

This type is also quite common, for example, in the Shenyang Public Center, China, in 2021, by the architectural firm Urbanus, led by chief architect Hui Wang. This public centre is rich in various green zones, including such an integrated “green” room, which functionally serves as a small meeting room or a room for separate meetings. The room is illuminated by panoramic windows and a skylight, and the vegetation maximally reflects the cultural and traditional features of the local flora and fauna (Fig. 3).



Figure 3. The third type of integration – "Greenhouse module – 'green' room"

Source: developed by the authors based on ArchDaily (2021d; 2022)

In another project of a public centre by Urbanus, led by chief architect Hui Wang, in Shenyang, on the site of old warehouse buildings, a rich variety of green zones has also been implemented. The greenhouse module of the "green" room, in this case, serves as a space for children's games and leisure. The effect of having a garden "will be a real gift for guests from the cold northern region", note the project developers (Fig. 3).

The fourth type of integration – "Greenhouse module – floor" – involves placing an entire greenhouse floor in the structure of a public facility as a buffer between different zones that need to be separated. It is most often located on the first or last floor but can also be implemented in the middle of a high-rise complex (regularly through every few floors). The floor module allows creating more climatic conditions for the quality existence of plants. Moreover, they

have enough space to install air purification and circulation systems throughout the complex. Such experimental mobile greenhouse pavilions were installed in Thailand, developed by the architectural firm Shma Company Limited (2020), where there were significant air pollution problems. The concept of operation of such installations involves obtaining air from the surrounding environment, purifying it from solid particles, achieving the required temperature; passing through the greenhouse module, where saturation with beneficial elements produced by plants occurs and then supplying it to the ventilation system for distribution across all floors (Fig. 4). Such developments for public spaces can complement C. Landry's (2020) creative place-making strategy, representing a new method of strategic planning that allows transforming the city into a more viable, comfortable and developed place.



Figure 4. Air purification system using a greenhouse module, Thailand, 2021

Source: ArchDaily (2021e)



The project of an integrated “greenhouse module – floor” is arranged on the first floor of the Olivia business centre in Gdansk, Poland, in 2021, designed by the architectural firm Malinowski Design Urban & Landscape. The large business centre (with an area of over 200,000 m²) organised a greenhouse on the first floor, as explained by the architects: “The Nature Connect concept assumes that the properly arranged space can completely reflect the

atmosphere of a natural ecosystem and thereby positively influence people who are there. The garden is decorated with plants from Indonesia, Australia, New Guinea, Madagascar, Venezuela and the tropical forests of the Amazon. For users, we have created four zones: ‘Dialogue,’ ‘Recreation,’ ‘Co-working’ and ‘Food and Drinks’. The implemented climate control system allows creating comfortable conditions for both plants and people” (Fig. 5).



Figure 5. The fourth type of integration – “Greenhouse module – floor”

Source: developed by the authors based on ArchDaily (2020; 2021b)

Gardens within the structure of office establishments that can be used for employee dining are gaining popularity. An example of such coexistence is the project of an administrative building with a rooftop greenhouse in Oberhausen, Germany, 2019, by architect Kuehn Malvezzi. The authors of the project note: “Part of the greenhouse on the roof, which was planned in collaboration with Haas Architekten, is a research area used by the Fraunhofer Institute for Environmental, Safety and Energy Technology in Oberhausen to implement its concepts in the field of integrated agriculture”. The area of such a floor is approximately 1000 m² and includes a lunch and relaxation area and the greenhouse core itself. This project is unique and differs from others considered in that it serves a utilitarian function – growing agricultural crops consumed by employees or for research (Fig. 5). The fifth type of integration – “Greenhouse module – entire

building” – represents a structure with a fully glass envelope, inside of which necessary floors with rooms are located. This is the rarest type of integration, where the impression is created that integration is happening into the structure of the greenhouse facility, not vice versa. Any types of plants can be located in such a greenhouse module, creating the necessary climatic background comfortable for everyone.

Among numerous examples, a unique project is the “Spheres of Amazon” headquarters of Amazon, Seattle, Washington, USA, 2018, by the architectural firm NBBJ. The building consists of three intersecting spheres, reaching a height of about 30 metres and accommodates more than 40,000 plants, samples of which were collected from high-altitude forests on five continents. Inside the spheres, there are four floors of conference rooms, offices, meeting rooms, cafeterias and relaxation areas (Fig. 6).



Figure 6. Types of greenhouse modules integrated into the structure of public buildings

Source: developed by the authors based on ArchDaily (2019)

Another example of a greenhouse module building is an experimental two-story wooden house located inside a greenhouse developed by students from the University of Rotterdam in the Netherlands (Fig. 6). The house consists of two residential floors, each with terraces and areas for planting on the roof of the top floor. The project was created for the study of passive solar heat use in a house surrounded by a greenhouse module to create a comfortable microclimate for both people and plants. A family already lives in the house, which will help students test the energy efficiency and functionality of such an eco-house (Foster, 2016).

Global experience shows that in market economy countries, greenhouse complexes are located in botanical gardens, representing nature conservation institutions, research and educational centres for all layers of the population, from which tourist and recreational complexes, parks of environmental technologies, museums, etc., are created. Since one of the main activities of modern botanical gardens is the protection and restoration of natural territories, botanical gardens are divided into territories that were previously subjected to anthropogenic influence or are unique landscape objects, as confirmed by H. Morchun & O. Martsenyuk (2019).

Long-term stay in artificial environments has provoked the development of ideas for the healthy existence of humans in them. A.M. Grodzinsky considered the main functions of phytodesign to create a pleasant (aesthetically) and comfortable environment that would correspond to the functional purpose of the room. Therewith, the premises would be disinfected from pathogenic bacteria,

viruses, fungi present in the air and on surfaces, purified from foreign gases, dust, volatile emissions of the human body and, conversely, the air would be enriched with substances that affect the well-being of a person working or resting (tonic or soothing effect) (Davydenko, 2013).

Each component of the urbanised urban planning system, whether it be a microdistrict, city, quarter, or individual building, carries a certain anthropogenic load on ecosystems. Therefore, an architectural-ecological approach is necessary for creating environmentally safe, energy-efficient and ecologically comfortable buildings, and structures (Kirnos, 2011). Integrated greenhouse modules implemented in the structures of public buildings are a manifestation of an architectural-ecological approach, specifically aimed at improving the ecological and social background of the working environment. This area of greenhouse structure development is quite popular in modern projects in the United States, European countries and Asia, and has all the prerequisites for successful implementation in buildings and structures in Ukraine (Dunaievskaya, 2023).

The process of integrating a greenhouse module into the structure of a building has also been described by V. Snizhko & I. Kharitonova (2006). They emphasised that for successful integration, rational space planning is necessary not only during construction but also during design. A well-thought-out and properly developed interior space design allows for the most efficient placement of plants to fulfil human life functions. The issue of incorporating "green" modules into the projects of restored industrial objects is relevant for almost every city in Ukraine. Neglected





industrial objects have been preserved in large numbers and their relevance has only increased over the years 2022–2023 due to the war, which has destroyed a significant number of buildings and structures. Some principles and approaches in modern research focus on revealing the recreational potential of the object or adjacent landscape, which should include integrated greenhouse modules and greenhouse structures. The principles of “alternative recreational use of industrial territories” and “optimisation of landscape territory parameters” are of particular importance for coastal cities with significant recreational tourism flows, needs for short-term leisure and “weekend” recreation for the local population, as well as long-term recreation for various groups of vacationers (Storozhuk, 2018). In the list of industrial enterprises that have undergone renovation in Odesa, as of 2021, N. Dmytryk (2021) noted new functions obtained, including student dormitories, trade and entertainment centres, hotels, medical institutions, higher educational institutions and administrative-legal institutions. Greenhouse modules must be integrated into the structure of these objects in the future.

As seen, many issues have been thoroughly and meaningfully discussed, but there is a lack of studies specifically addressing the architectural aspect of greenhouse structures, including integrated greenhouse modules. A greater number of practical developments and theoretical foundations can potentially incorporate such greenhouse modules on a state level into the structure of already built buildings and make them a mandatory parameter in the process of restoring buildings and structures. The functions performed by these modules could also be a crucial aspect for the rehabilitation and restoration of the overall psychosomatic state of the population of Ukraine after the end of military actions in the country.

CONCLUSIONS

As a result of exploring the prospects for the development of modern greenhouses and greenhouse complexes, three major areas can be distinguished. The first area involves the restoration of historical greenhouses while preserving their authentic appearance. In Ukraine, there are many greenhouses requiring immediate reconstruction and restoration. The second is the design of new modern greenhouses. This area will become more relevant when the potential, versatility, and necessity of structures of this typology become clear, using restored historical greenhouses as examples. Factors hindering the development of greenhouse structures include financial constraints, as there are few examples of successful financially active use of greenhouses in Ukrainian practice. The third development area involves the integration of greenhouse modules into the structure of public buildings and facilities, which can be

considered the most promising. Public spaces play a crucial role in city development, and the creation of such “green” modules leads to more favourable working conditions and enhances the comfort level of the population. Greenhouse modules can be arranged in already constructed buildings, especially suitable for the first (open atrium) and third (“green” room) types of greenhouse module integration. During the investigation of the third development area of greenhouse structures, which is considered the most promising for Ukraine, five types of greenhouse module integration into the structure of public buildings and facilities were identified: “module – open atrium”, “module – closed atrium”, “module – ‘green’ room”, “module – floor”, “module – entire building”. Using the graph-analytical method, the functional characteristics of each type were identified and recommendations for suitable structures for placement were provided.

Based on the examined objects, five main recommendations for integrating greenhouse structures into the structure of public facilities were formulated: for greater efficiency of the greenhouse module, it should be designed during the planning stage; when implementing the greenhouse module, the main three aspects – medical, botanical and aesthetic – must be taken into account, with professional input; proper selection of plant assortment will ensure the successful functioning of the module; longevity and decorative appearance of plants can be ensured by following the correct care instructions; creating a greenhouse module in a building should address important issues such as aesthetic appeal, improvement of emotional and psychological well-being, enhancement of indoor air quality and adjustment of temperature and humidity regimes. Considering the previous theoretical findings, the necessary area for further research in this field should involve more specific practical models of integrating greenhouse modules into new designs and models for implementing them into the structure of already built facilities. These models should combine recommendations regarding functional-planning aspects (layout of furniture, pathway systems, pavements and functional content), medical and eco-botanical aspects (plant selection considering climatic features of the project location and the level of necessary improvement of the working environment).

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CONFLICT OF INTEREST

None.

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**Наталія Юріївна Мержієвська**

Кандидат архітектури, доцент
Одеська державна академія будівництва та архітектури
65029, вул. Дідріхсона, 4, м. Одеса, Україна
<https://orcid.org/0000-0003-3100-4816>

Анжеліка Валеріївна Дунаєвська

Асистент
Одеська державна академія будівництва та архітектури
65029, вул. Дідріхсона, 4, м. Одеса, Україна
<https://orcid.org/0000-0002-7876-0558>

Інтегрований оранжерейний модуль як один із перспективних напрямків розвитку оранжерейних споруд

Анотація. В статті актуалізується питання оранжерейних споруд України, більшість яких, після активного періоду розбудови (середина – друга половина ХХ ст.), досягла своєї межі в архітектурно-конструктивних та інноваційно-технологічних аспектах, оскільки сучасні науково-практичні праці в галузі архітектури та проектування оранжерейних споруд майже відсутні. Метою даного дослідження є виявлення перспективних напрямків розвитку оранжерейних споруд, встановлення типів інтегрованих оранжерейних модулів та формування основних рекомендацій по їх організації. Методологічний апарат дослідження складається з трьох етапів (підготовчий, дослідницький та синтезуючий) з використанням таких методів: аналіз літературних та наукових джерел, метод термінологічного уточнення понять, метод логічного аналізу, метод критичного та порівняльного аналізу, графоаналітичний метод, узагальнення, метод індукції, метод гіпотези та прогнозування. В результаті дослідження прикладів світового досвіду було виділено п'ять типів інтеграції оранжерейних модулів у структуру будівель та споруд різної типології: «оранжерейний модуль – відкритий атріум», концепція якого полягає у створенні зеленого модулю в просторі відкритого атріуму, для організації культурно-естетичної точки тяжіння; «оранжерейний модуль – закритий атріум», що формується в просторі відокремленого, закритого атріуму, яким розділяють різні функціональні блоки, та створюють буферну зону для працівників заклад; «оранжерейний модуль – «зелені» кімнати», що впроваджуються в ті функціональні блоки, які, в міру своєї специфіки, потребують психологічно-розвантажувальних кабінетів, кімнат емоційної релаксації та медитації; «оранжерейний модуль – поверх», який слугує буферним поверхом між різними функціональними блоками, аби створити для людей комфортний екологічно-соціальний фон робочого середовища; «оранжерейний модуль – вся будівлі» є найбільш рідкісним типом, який підвищує рівень працездатності, мотивації та креативності. Аналіз окремих споруд дозволив виявити наступні рекомендації по інтеграції оранжерейних модулів: оранжерейні модулі треба закладати на етапі проектування; необхідно враховувати медичний, ботанічний та естетичний аспекти; ретельно добирати асортимент рослин; вірний догляд за рослинами забезпечить довголіття модуля; оранжерейний модуль має розв'язувати поставлені задачі. Практичне значення даного дослідження полягає в тому, що результати можна використовувати для створення рекомендацій і методологічних рекомендацій з проектування оранжерейних модулів

Ключові слова: екологічний дизайн; сучасні громадські споруди; фітодекорування інтер'єру; впроваджена оранжерея; фітодизайн; закритий простір



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Galyna Shevtsova*

Doctor of Architecture, Professor
Kyiv National University of Construction and Architecture
03037, 31 Povitroflotskyi Ave., Kyiv, Ukraine
<https://orcid.org/0000-0002-2401-8104>

The historic Lake Biwa Canal as a permanent catalyst for the development of Kyoto's landscape architecture

Abstract. The historic Lake Biwa Canal, an artificial waterway that supplies water from Lake Biwa to Kyoto, was built to revitalise Kyoto after the capital was moved to Tokyo in 1868. Apart from its main function, the canal plays a significant role in organising the cultural landscape of the surrounding areas. This study raised topical issues of sustainable development, preservation, and revitalisation of historic engineering structures. The artificial waterway was considered in terms of its pulling effects on the surrounding environment, both urban and landscape. The purpose of this study was to find the characteristics of the landscape-organising role of the Biwa Canal and its transformation over time, specifically with adaptation to the relevant problems of modern time. The study was conducted mainly using in situ field research methods. As a result, the key role of the canal as a constant catalyst for the development of Kyoto's landscape architecture was outlined, which has changed substantially over time, but has not weakened and has always been innovative, organically combining modern industrial achievements with local traditions. In the first period of its existence (until 1951), the focus of landscape organising activities in the areas adjacent to the canal was on the creation of private and temple gardens, but from the second period of its existence (1951-early 1990s), the focus of landscape activities around the canal shifted to public recreational and park aspects. During the third period (since the early 1990s), when the canal was recognised as a National Historic Site, trends in the development of industrial and landscape tourism were also observed. The experience of preserving, revitalising, promoting, and adapting the landscape role of the Biwa Canal to the new needs of the present can be used as an example of the direction of similar activities for historic waterways in the world

Keywords: cultural landscape; historical waterways; Kyoto landscape gardens; industrial tourism

INTRODUCTION

Japan has a variety of preserved historic canals on its territory, many of which require the development of a conscious strategy for protection and revitalisation. Since 2006, thanks to the efforts of local municipalities and volunteers, a considerable number of them have been included in a specially created national protection system Important Cultural Landscape property, which unites mostly historical cultural landscapes associated with various types

of water resources (Agency for Cultural Affairs, n.d.). Several new (as of 2023) scientific studies were devoted to the investigation of individual examples of the Important Cultural Landscape of Japan, which touch on the historical, functional, and socio-cultural aspects of the development of these protected areas in view of the modern problems of revitalization, the preservation of the cultural and ecological environment, the development of the local volunteer

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*Corresponding author



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movement, etc. (Watanabe *et al.*, 2019; Koike *et al.*, 2021; Ochiai, 2022). At the same time, it is worth noting the emergence of comparative studies related to the water cultural and historical landscapes of Japan and England (Hutcheson, 2021), as well as the historical water supply systems of Japan and Algeria (Rezig & Shevtsova, 2022). In general, according to the list of Important Cultural Landscapes of Japan (2015), this protection system mostly unites landscapes of rural areas and small towns.

The example of the industrial waterway Lake Biwa Canal (or Biwa-ko Canal in other sources) in metropolitan Kyoto, which was inscribed on the list in 2015 as part of the Okazaki Historic Urban Area (Important Cultural Landscapes, 2015), is unique in this regard. The Biwa Canal is the most iconic landmark of its kind in Japan, and its industrial and cultural role in the development of the city during the Meiji period cannot be overstated. The historical periodisation, functional diversification, and processes of the modern revitalisation of the Biwa Canal are discussed in G. Shevtsova & M. Parkhomchuk (2022). The study by A. Hosler (2023) contains a description of private villas with landscaped gardens available for viewing in the canal's influence area (Nanzenji Temple area, Keage district).

In general, this practically exhausts the list of relevant research studies as of 2023 on this or closely related scientific topics. The landscape role of the Biwa Canal is still understudied, with little coverage in the scientific literature, while the issue of proper preservation and conservation of historical monuments of engineering and landscape architecture is important, but impossible to resolve without substantial renovation, revitalisation, and rethinking of their functions within the architectural and social structure of settlements. That is why the purpose of this study was to identify the role of the Biwa Canal as a catalyst for the development of landscape architecture and landscape design in Kyoto from the end of the 19th century (the time of the Canal's construction) to the present day.

MATERIALS AND METHODS

This paper is based on the study by G. Shevtsova & M. Parkhomchuk (2022). The historical periods of development of the Biwa Canal and the analysis of the historical diversification of its functions were used to build a chronological scheme and identify the main areas of research. The study also drew on a wide range of Japanese and English-language scholarly literature on the industrial and economic development of the Biwa Canal (Tanaka, 2002; Ono *et al.* 2012; 2014). Information on the landscape component of the surrounding areas, specifically, the work of the garden designer Ueji (Ogawa Jihei VII), who in the late 19th and early 20th centuries, using water from the Biwa Canal, laid the foundations for a new type of Japanese park design, is mostly in the plane of popular literature (Amasaki, 1990; Shirahata, 2008a). In other cases, the author of this study had to use empirical sources of information. First of all, it is the archival and media base of the Lake Biwa Canal Museum in Kyoto (Lake Biwa Canal Museum, 2009; 2012).

The Biwa Canal Museum holds an extensive collection of visual archival materials: photographs of the construction and early periods of the canal, design maps and models of its engineering systems, and unique video footage, including a video of the Keage incline trolleys transporting boats across the Keage watershed, made in the late 1940s, almost before the railroad closed. Information from official Internet resources (Lake Biwa Canal Museum, 2018; The Lake Biwa Canal cruise Kyoto-Otsu, n.d.), promotional booklets of exhibitions and events related to the canal, etc. were also used as auxiliary materials. The study also draws heavily on the author's own experience in the in-situ study of the Biwa Canal, conducted within the framework of a research grant from the HAKUHO Foundation at the University of Kyoto.

The main methods of field research were field surveys and photography. The structure, surrounding landscape, and current state of the First (oldest) branch of the Biwa Canal, from its outlet from Lake Biwa (Otsu, Shiga Prefecture) to the distribution pond in the Keage district of Kyoto, as well as the structure of the Keage rail incline and the Nanzenji Suikoku aqueduct, Philosophers' Path, Higashiyama Ryokuchi Park, and the Lake Biwa Canal Museum were examined using the field research method. An internal visual survey of the First Canal Branch tunnels was also carried out (using a motorboat), as well as the cultural landscape and revitalisation practices of the Keage Filtration Plant. A separate block of time was devoted to the field study and photographic recording of the landscape gardens by the master Ueji: Maruyama-koen public park, the gardens of Heian-jingu, Nanzenji, Eikando and Honen-in temples, the Westin Miyako Kyoto hotel, the Namikawa Cloisonne Museum (former estate of the Namikawa family), as well as villas Murin-an, Hekiun-so and Kaiu-so. The author also examined modern manifestations of landscape design on the Biwa Canal (both permanent and temporary) and took part in new tourist and excursion events to promote the waterway and the historical engineering infrastructure of the Biwa Canal. The results of the field research were classified and structured, and comparative, chronological, causal, and graphical analyses were conducted on their basis.

RESULTS

The structure and history of the Biwa Canal in Kyoto. The Meiji era in Japan (1868-1912) was characterised by substantial changes in all spheres of life. At this time, Japan, which had been isolated from the outside world for several centuries due to the isolationist policy of the Tokugawa shogunate, and thus lagged far behind the world's progress, opened its external borders. Literally, the name of the Meiji era translates as the Age of Enlightenment, which fully reflects the general spirit of those times. With the beginning of the Meiji period, Japan's artificially preserved feudal structure gave way to a new capitalist system, which was introduced in 1868 based on a symbolic restoration of imperial rule. The Meiji Restoration marks the boundary between "traditional" and "new" Japan, when new European knowledge and traditions began to penetrate the country that



had been closed for about three centuries. A multi-year programme of economic and military modernisation was adopted, which allowed Japan to avoid colonisation by the West and subsequently gain weight in the world. Young Japanese people were sent to study in Western European countries and America in large numbers to learn the secrets of banking, medicine, railway, and road construction, heavy engineering, and other engineering (and other) specialities. Foreign specialists were also invited to work in Japan. The country was rapidly industrialising, with new plants and factories appearing and the rural population flocking to the cities. Western culture has spread widely in Japan. However, soon enough, the local traditional aesthetics regained its position, and Japan, having absorbed the new experience, entered the next stage of development of the national culture (Young & Young, 2004).

The construction of the industrial and transport water supply canal from Lake Biwa to Kyoto is directly related to the events described above. The Canal was conceived and implemented to support the economy and revitalise the city of Kyoto, which had begun to decline due to a sharp decline in population caused by the relocation of the capital and the move of the imperial court to Tokyo in conjunction with the Meiji Restoration. The idea of building a canal to deliver water from Lake Biwa to Kyoto has been popular in Japan for a long time and was discussed even in the Middle Ages, although at that time it was more of a dream that did not have the technical capacity to come true (Shevtsova & Parkhomchuk, 2022). But at the beginning of the Meiji period, almost immediately after the imperial family moved to Tokyo, Kitagaki Kunimichi, the 3rd governor of Kyoto Prefecture, mentioned this ancient idea (Lake Biwa Canal Museum, 2012). As a result, an extremely original and innovative industrial water supply project was implemented for Japan at that time. The canal was designed to transfer significant volumes of water from Lake Biwa to Kyoto, which, due to its geographical location in a mountainous basin, has historically experienced a shortage of water for agriculture. With the advent of the industrial era, this problem has become extremely acute, as the development

of enterprises dramatically increases the consumption of water needed to generate electricity. Thus, according to Kitagaki Kunimichi, who planned to build new factories in Kyoto, the Biwa Canal was to contribute significantly to the development of Kyoto's industry by meeting the city's growing needs for industrial, agricultural, and drinking water, as well as serving to transport goods and passenger boats between Lake Biwa and Kyoto. The construction costs were partly covered by the emperor and partly by the city of Kyoto (Lake Biwa Canal Museum, 2018).

The construction of the Canal was Japan's first major industrial project carried out by local engineers alone, without the help of foreign specialists. The Biwa Lake Canal has been in use for over 130 years and as of 2023 is still playing its direct role of water supply. In the second half of the 20th century, there was a period of certain decline in the canal, when its transport role was lost. But since the end of the 20th century, the Biwa Canal has been actively revitalised, gradually becoming a tourist and cultural attraction in the city. An extremely significant feature of the canal is its landscape function, which has been formed since the beginning of the canal's creation and, at the time of 2023, is still of no less importance (Shevtsova & Parkhomchuk, 2022).

The Biwa Lake Canal system consists of two main water supply branches. Construction of the first of them began in 1885 and was completed in 1890. It starts at Lake Biwa in Otsu and extends to the main water distribution point in the Keage district of Kyoto, with a length of approximately 11 km (Fig. 1). Then the canal goes on for about 9 km through the city to the Fushimi district. The first branch of the canal consists of a system of open water areas interspersed with four tunnels. The first and longest of these, the Nagarayama tunnel, is 2,440 m long, while the shortest, the second tunnel, is only about 124 m long. The second branch of the canal was completed 20 years after the first to increase the volume of water supply to Kyoto. It is more advanced in technical terms and is only 7.4 km long, but it is deeper and runs entirely in a tunnel, close to the bed of the first branch of the canal between Biwa and Keage (Tanaka, 2002).

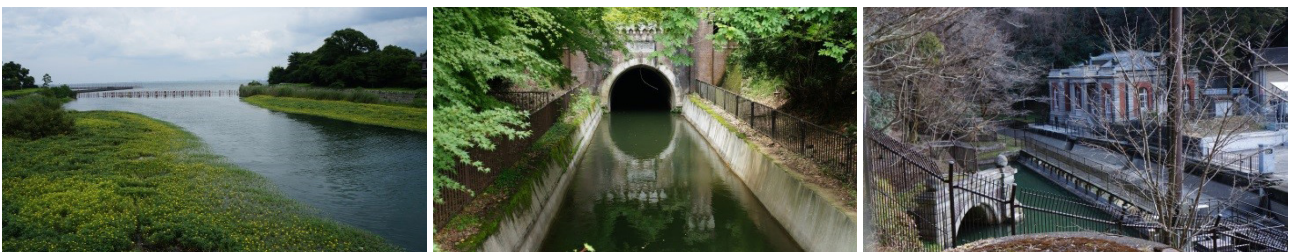


Figure 1. The start of the canal from Lake Biwa, one of the tunnels of the first canal branch and the Keage distribution pond
Source: photos taken by the author, 2019; 2022

The project was developed by Tanabe Sakuro, a young engineer who graduated from the Imperial College of Engineering in Tokyo. Tanabe Sakuro studied at college with Henry Dyer, a famous Scottish engineer who did much to develop Western-style technical education in Japan. After

graduating from college, Tanabe developed his thesis, which was an imaginary project for the construction of a water transport canal from Lake Biwa to Kyoto. With this in mind, Kyoto's leaders decided to immediately invite Tanabe to carry out a real project on site. In the end, this



somewhat risky invitation to such a responsible role for a young specialist with little or no real construction experience paid off. Many new methods were used during the construction works, such as the construction of the tunnel using vertical shafts that were driven into the future tunnel, serving as added excavation points (Tanaka, 2002). This made it possible to correlate the still insufficiently exact geodetic methods at that time and levelled the difficulties of ascending parts of the tunnel dug from different sides. Two structural shafts, 47 and 20 metres deep, which helped to construct Nagarayama's longest tunnel, are still in place as of 2023 and are used for ventilation and as emergency exits and are visible from both inside the tunnel and from the outside, in the mountain forest above the tunnel.

With the completion of the first branch of the canal, Japan's first commercial hydroelectric power plant was built in the Keage area (Kansai Electric Power, n.d.). The power from this plant was used for factories and night lighting in the city. At the same time, the canal became a powerful waterway for the movement of cargo boats transporting coal, wood, rice, and much more. There was also a passenger connection by canal, and many people even used this route for tourist purposes – to see the sights of the

city. After a few years, the water in the first canal became insufficient, as Kyoto's electricity needs increased significantly. Therefore, the then mayor of Kyoto, Saigo Kikudjiro, initiated the construction of the second canal from Lake Biwa, which took place from 1908 to 1912 (Tanaka, 2002). At the same time, the Keage filtration plant, which is still in use today, and several new hydroelectric power plants were built (Kansai Electric Power, n.d.).

A distinctive feature of the Biwa Canal project was the way boats were transported from the upper distribution pond in Keage to the lower jetty of Nanzenji Temple, where it was impossible to build a continuous waterway due to the 36-metre difference in the height of the watersheds of Lake Biwa and Kyoto. Therefore, boats were transported from Keage Pond to Kyoto via the so-called "Keage Incline", a 582-metre-long inclined rail track (Tanaka, 2002). On the shore of the upper Keage Pond, boats were loaded onto small open rail platforms that moved downhill on balancing cables, similar to a funicular, to the lower Nanzenji Pond, where the canal continued to the Kyoto area, gradually branching off in different directions (Fig. 2). In the Lake Biwa Canal Museum, one can watch a unique video of the rail transport of boats along the Keage Incline, which stayed in operation until the late 1940s.



Figure 2. Keage Incline and rail platforms between the upper and lower distribution ponds

Source: photos taken by the author, 2022

The study by G. Shevtsova & M. Parkhomchuk (2022) identified three main historical periods of the formation and development of the Biwa Canal. The first period of the canal's initial prosperity took place from 1890 to 1951. During this period, the canal acquired and strengthened its core functions. The second period, from 1951 to the early 1990s, was characterised by the loss of the transport function and a certain decline of the canal. The third period began in the early 1990s, when the canal was listed as a National and Kyoto City Historic Site and the Lake Biwa Canal Museum was built, which began the active revitalisation of the canal and the acquisition of new modern functions. This periodisation can be considered quite reasonable, and it is therefore considered appropriate to use it as a basis for further research into the landscape-organising role of the Biwa Canal.

The landscape component of the Biwa Canal in the first period of its existence, 1890-1951. From the very beginning of the Biwa Canal's existence, its water has been actively used to develop the surrounding landscape. The network of canal branches in Kyoto has created fire protection belts for the Imperial Palace and the surrounding major temples and

shrines, such as Heian-jingu, Nanzenji, Eikando, etc. Most importantly, however, the emergence of new waterways has led to the formation of a unique cluster of landscaped gardens in the Keage area, such as the Heian-jingu Shrine Garden Complex, Maruyama Public Park, the chamber garden at the Namikawa cloisonné enamel master's house, the gardens of the Murin-an, Hekiun-so, Kaio-so aristocratic villas, and the garden of the Westin Miyako Kyoto Hotel. All of them were created by Ueji (1860-1933), the outstanding garden master of his time, also known as Ogawa Jihei VII (Shirahata, 2008a; 2008b).

This Japanese gardener was born in the Kyoto suburb of Nagaoka-kyo, his name was Yamamoto Gennosuke. In 1877, he married Mitsu, the youngest daughter of the famous Ogawa family of landscape artists in Kyoto, and was adopted by the family, receiving the surname Ogawa (Ono, 2008). The tradition of adopting a daughter's husband has been widespread in Japan since ancient times and was done in cases where the family had no male descendants to legally pass on the family name and family business to the daughter and her husband. In 1879, after the sudden



death of his wife's father, Ogawa Gennosuke became the head of the family at the age of 19, inheriting the Ogawa manor in Kyoto along with the business and the name Ueji VII, which was the name of the eldest master in the Ogawa family. Since his daughter's father, Ogawa Ueji VI, died too young, Ueji VII did not have time to learn anything from him, and generally studied the art of Japanese landscape gardening on his own. His first significant works in this field date back to the early 1890s, meaning that Ueji VII began to work seriously in the field of landscape design after the age of 30. The growth of his skill is directly related to the water of the Biwa Canal, completed in 1890, which served as a fruitful basis for the development of Ueji's distinctive creative style. Thanks to the many connections of the Ogawa family, Ueji was able to meet prominent businessmen and politicians of his time, and eventually start working for them (Ono, 2008).

During the 1890s, the influential Nanzenji Temple, located in Keage right next to the main structural elements of the Biwa Canal, sold off some of its peripheral land, which was bought by wealthy citizens to build their own villas, which specifically gave Ueji's work such a powerful impetus (Ono, 2008). Ueji first used the water of the canal in 1894 to create a garden at the estate of his neighbour, the cloisonné enamel master Namikawa Yasuyuki, who was a leading expert in his field and repeatedly received prestigious Japanese and international awards for his works. Namikawa's estate was also home to his workshop, and he already had industrial water diverted from the canal, which

he used to polish finished products. Ueji made clever use of this opportunity by diverting the same water to create a pond (Ono, 2008). In his very first work using the water of the Biwa Canal (and it is possible that this was Ueji's first independent project), the master introduced some of his signature innovative techniques, which at the same time seemed to be within the framework of traditional Japanese garden construction, but stood out with extremely original accents (Fig. 3). Ueji uses stone basins for washing hands (the so-called *tsukubai*) of an unusual shape, which will later be developed in his other works. The composition of the garden is also characterised by the use of artificially processed stones from the Lake Biwa basin, which were transported to the construction site by the same canal. In this case, elongated stone blocks from the ruins of a castle in the town of Zeze were used for the threshold of the house. Almost the entire surface of the garden is covered by a pond with stones and a large island in the middle. The water flows in and out under the piles of the two-storey wooden house and workshop, filling everything around with murmur, as if subordinating the lives of the inhabitants to its own special rhythm. At that time, the use of a virtually continuous pond for a small plot of land of an urban residence was a revolutionary phenomenon, and later the theme of water became a leading one in Ueji's works. The presence of a pond creates the illusion of a wide space in a confined area, and a series of flat stones in the water, forming a kind of bridge for crossing (the so-called "steppingstones"), creates the illusion of water depth.

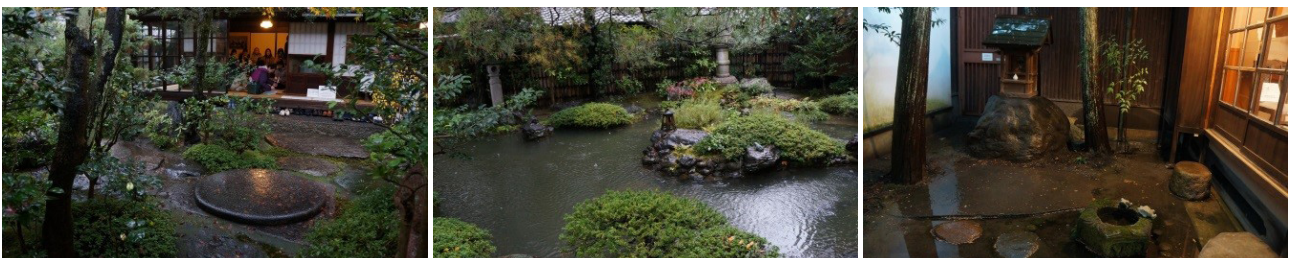


Figure 3. Garden of the Namikawa Museum

Source: photos taken by the author, 2019

Work on the garden of Murin-an Villa began in 1894 and became an example of the incorporation of the progressive landscape ideas of the villa's owner, an influential member of the Japanese government, General Yamagata Aritomo, and the skill of traditional Ueji garden construction (Yagasaki, 2012; Kato *et al.*, 2017). Water from the Biwa Canal was also used to create the Murin-an garden, for which an auxiliary water branch was diverted towards Murin-an. This was made possible by the local authorities' policy of turning this area of the city into a recreational destination. Aritomo Yamagata had a good education and a talent for design. He personally outlined the main priorities for future construction. Yamagata wanted the natural slopes of Mount Higashiyama to become the main element of the garden's composition. He also insisted that the garden should be formed based on an open grass lawn, rather than moss surfaces, as

was traditional for Japanese gardens. The lawn and mountain landscape were to be combined with large fir trees and fern-surrounded stones that seemed to have come down from the mountains (Kato *et al.*, 2017). The water from the Biwa Canal had to be incorporated into the landscape, it had to look like it was flowing straight from Mount Higashiyama. This innovative approach immediately reveals Yamagata's rejection of the traditional religious symbolism of the Japanese garden and the artificiality of the "garden-painting" as a three-dimensional interpretation of painting, which was borrowed by Japan from China and practiced for centuries as a central component of local gardening (Itoh, 1984). Yamagata proposed a naturalistic approach to garden design that would appear to be an improved extension of the natural landscape. Ueji did not accept Yamagata's ideas at first, trying to refer to the traditional foundations of stone



garden design (Ono, 2008), but eventually appreciated the boldness and breadth of the client's idea and brought it to life even more artistically than the author of the ideas had

imagined. The impression of naturalism in the Murin-an garden, however, is the result of precise calculations and detailed preliminary planning (Fig. 4).



Figure 4. Garden of Villa Murin-an

Source: photos taken by the author, 2019

The plot for the villa was allocated an elongated shape, the main living space is located at its end, from where the garden also begins, divided into two zones: smooth, calm and light low hills of the lawn are cut by two streams, along the banks of which tall fir trees enter the composition, hiding the tea room. Behind the fir trees, there is a pond with flat round “steppingstones” that create point transitions over the water. The pond is fed by an artificial waterfall flowing down dark rocks. By incorporating the surrounding landscapes of Mount Higashiyama into the composition, the garden looks much larger than it actually is. Against the background of this new coordinate system, some of the techniques and details of traditional Japanese gardening are accentuated, such as the shoals covered with large pebbles along the banks of the pond, which are clearly a reminiscence of aristocratic Japanese gardens of the Heian period. Thus, the effect of symbiosis of Yamagata's innovative ideas with Ueji's traditional artisanry emerges, which laid the foundation for a new generation of Japanese gardens. In the future, Ueji adapts, hones, develops, and improves this principle in his works. The gardens of two more great villas, Kaiu-so and Hekiun-so, also based on the principles developed during the creation of Murin-an, were created by Ueji shortly afterwards in the same area of Keage. The fundamental principle of the landscape gardens in both included the use of water from the Biwa Canal and the surrounding landscape of Mount Higashiyama (Shirahata, 2008b).

The plot for the construction of Villa Kaiu-so was purchased from the Nazenji temple by Inabata Katsutarō, a successful businessman and pioneer of Japanese cinema. The fact that this area was once a temple territory is evidenced by the wooden bell tower that is still preserved there. Ueji worked on the Kaiu-so Garden from 1905 onwards, redesigning and completing it several times until 1928 (Amasaki, 2008). The site is located on a slope directly below one of the outlet branches of the Biwa Canal, from where Ueji directed three streams down to the garden, one of which feeds the main pond, entering it in the form of a smooth waterfall flowing over artificial rocks and intruding slightly to the side into the field of view from the main veranda of the villa. The second stream flows into a small pond near the Rugin-an tearoom,

past which a path leads to the top of the hill, where the second tea room, called Sodo, is located. Along the way, the trail passes through an artificial tunnel with a stone tsukubai, a tea basin for washing hands. There are also small additional waterfalls in the garden, hand-washing basin in the form of hollowed-out stone gutters and stream crossings on flat steppingstones, typical of Ueji's work. The owner of the villa, who had studied in France, used the garden not only for traditional Japanese tea ceremonies, but also for Western style “garden parties” (Shirahata, 2008b).

The owner of the villa Hekiun-so, a major businessperson and art collector Nomura Tokushichi II, used his garden by Ueji in a similar way. Work on the Hekiun-so garden was started in 1917 by Ueji's eldest son, also an exceptionally talented young landscape designer, Hakuyo, who died unexpectedly in 1928, so Ueji had to take over the project (Shirahata, 2008b). The pond of the Hakiun-so villa was adapted for boating and is by far the largest pond of all Ueji's projects. The garden has 7 tea rooms, a stage for Noh theatre performances and another adapted for traditional Japanese dances. It is also a multifunctional garden, and it is important because it has not changed hands or been rebuilt throughout its history, fully preserving its authentic form (Amasaki, 2008). Ueji achieved a magical and innovative effect on the perception of the garden by placing a small round stone tsukubai washbasin in the pond water near the shore, almost flush with the edge of the water surface, so that water can flow over its edges, and those who lean into the basin can see the panorama of the Higashiyama Mountains over the far edge of the pond. Owner Nomura Tokushichi, who was a collector of Japanese antiquities, obtained large natural stones with ancient Buddhist carvings for the garden, which gave the landscape a special mysterious appeal. Another tsukubai washbasin, in the typical Ueji stone gutter shape, also creates a rather remarkable accent in the garden.

The project to build the Heian-jingu Shrine was started in 1894 by architect Ito Chuta to mark the 1100th anniversary of the founding of the city of Hei'an-kyo (the ancient name of Kyoto). The main pavilion of the sanctuary was a slightly reduced copy of the ancient audience hall of the Heian-kyo Palace (Niglio & Inoue, 2015). In the same year,





Ueji, who was just working on the Murin-an garden, received an invitation from the city authorities to create a large complex of gardens behind the shrine, where it was planned to bring water from the Biwa Canal as a fire protection measure. Heian-jingu's gardens were the first such large-scale project of the master, which finally established his image as a leading creator of Japanese gardens of a new generation. Ueji worked at Heian-jingu in several stages. In 1895, he created the Central and Western Gardens with ponds, while in 1897, he connected them with a stream. And in 1916, the work was completed with the creation of the largest Eastern Garden with a pond, which resulted in a semicircle of gardens behind the sanctuary (Niglio & Inoue, 2015).

Drawing on his experience at Murin-an, Ueji incorporated the naturalistic atmosphere of ponds and streams into the composition of the Heian-jingu gardens, which in the East Garden is complemented by the natural backdrop of the Higashiyama Mountains. Water enters the ponds of the sanctuary from the Biwa Canal. In this regard, recent studies by experts from the University of Kyoto have revealed that many species of lake fish once migrated from Lake Biwa through the canal and settled in the Heian-jingu ponds, and they still do very well there, while in Lake Biwa itself, due to changes in the ecosystem, some of them began to die out (Shirahata, 2008b). Therefore, the Heian-jingu

ponds have naturally formed a kind of recreation for the endangered fauna of Lake Biwa.

The most attractive elements of the Heian-jingu gardens are the two original bridges (Fig. 5). The first one, Garyu-kyo, is located in the Central Garden Pond and consists of vertically mounted stone pillars from the dismantled Sanjo and Gojo bridges of Kyoto, built in the time of Toyotomi Hideyoshi (16th century). The individual supports extend only slightly above the water surface, forming steppingstones in the form of round flat platforms above the pond surface. The second wooden bridge-pavilion, Taihei-kaku, located in the East Garden, was moved here in 1916 from the Imperial Palace. The stones for the construction of Heian-jingu gardens were brought by water through a canal from the Moriyama area on Lake Biwa, as well as from the ruins of Fushimi Castle on the northern outskirts of Kyoto (Amasaki, 2008).

The entire garden complex is marked by large open areas and water features, which display a variety of plants and landscape details (islands, stones, bridges) against the backdrop of the majestic slopes of Higashiyama. The Heian-jingu Gardens are also known for the seasonal flowering of many plant species, the most representative of which are the purebred irises in the West Garden (June-July) and the weeping sakura blossoms along the banks of the East Garden Pond in early April.



Figure 5. Gardens of the Heian-jingu sanctuary: West, Central and East

Source: photos taken by the author, 2023

Another project based on the use of water from the Biwa Canal was implemented by Ueji in Maruyama-koen, the first public park in Kyoto, founded in 1886 on the site of several temples that had been damaged by fire (Amasaki, 2008). The idea of public parks came to Japan from Europe, however, despite the successful creation of a wide public space in Maruyama-koen, the basic principles of the park's landscape design are traditionally Japanese. Ueji worked on the grounds

of Maruyama-koen in 1913-1914, adding a wide stream to the fountain pond created in 1893, which begins with a three-metre artificial waterfall and flows windingly down a gentle hill into the pond (Fig. 6). On the way to the pond, the stream flows over the steps of small rock-like natural stones that are laid in the water mixed with geometrically processed stones. In several places, the stream is crossed by bridges of several types, including flat steppingstones.



Figure 6. Maruyama-koen Park

Source: photos taken by the author, 2022



Ueji's last project was the design of the Aoiden garden at the Westin Miyako Kyoto Hotel, built in 1900 next to the Biwa Canal, which also used water from Lake Biwa. Ueji worked on the hotel's garden in 1915, creating a pond on a stepped steep relief opposite the banqueting hall, to which two streams flow from the Karaku-an tea room, one with a long-stepped waterfall and a grooved tsukubai washbasin, and the other with a small waterfall over a yellow striped

decorative boulder (Fig. 7). Another garden of the same hotel, Kasui-en, which also uses water from the Biwa Canal, is located up the slope and was previously a separate villa. It was created by Ueji's son, Hakuyo, in the form of a rocky wall-like composition with water flowing down it. Later, the famous Japanese architect Togo Murano complemented this landscape design with white pebble platforms in front of the pavilion (Amasaki, 2008).



Figure 7. Gardens of the Westin Miyako Kyoto Hotel: Aoiden and Kasui-en

Source: photos taken by the author, 2022

The landscape component of the Biwa Canal in the second and third periods of its existence (from 1951 to the present). After the Second World War, the Biwa Canal gradually lost its importance as a major transport artery when the railway took over the leading role in the region's freight and passenger traffic, leading to a gradual decline in boat traffic on the canal. In 1948, the Keage Incline was closed, and in 1951, boat traffic on the Biwa Canal was finally stopped, and the waterway began to decline (Lake Biwa Canal Museum, 2018). However, in the late 1960s and early 1970s, the canal again attracted the attention of local authorities in terms of prospects for landscape

development of the territory. A small branch of the canal, which runs from Keage to the north of Kyoto towards Ginkakuji Temple, has been transformed into a city promenade, the so-called Philosopher's Path, and lined with cherry trees on both sides. At the same time, the former Keage Incline with preserved rails was also transformed into a pedestrian walkway with sakura trees, and the Higashiyama Ryokuchi Public Park was established on the land of the canal between Lake Biwa and Kyoto, in the Yamashina suburb near the Tenshi Emperor's mound, which is now rich in rare species of local flora and fauna (Fig. 8) (Shiroshita, 2006).



Figure 8. Landscape design of the canal surroundings in the mid-20th century: the Philosophical Path, the sakura blossom park on the Keage Incline and Higashiyama Ryokuchi Park

Source: photos taken by the author, 2019; 2023

Another walking area is a three-kilometre-long branch of the canal from the Keage distribution pond to the Nanzenji Temple area, which accordingly to Tanabe Sakuro design crosses the ravine near the temple on the so-called Nanzenji Suirokaku, a special bridge structure similar to an ancient Roman aqueduct (Fig. 9). In 1983, the Nanzenji Suirokaku aqueduct and Keage Incline were designated as Kyoto City Historic Sites (Shiroshita, 2006). In 1996, the Lake Biwa Canal was designated a National Historic Site

(Lake Biwa Canal Museum, 2018). In connection with this event, the Lake Biwa Canal Museum was built in the Keage area, near the lower distribution pond, which collects artefacts, archival and scientific materials of the canal's history. The surrounding area, including the Keage Incline, was designed as an original landscape park (Fig. 10). This moment can be considered the beginning of the third, modern period of the Biwa Canal existence (Shevtsova & Parkhomchuk, 2022).



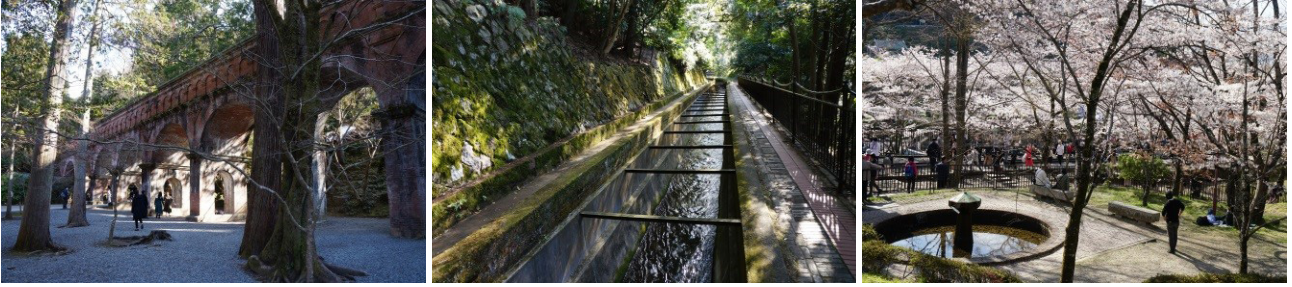


Figure 9. Nanzenji Suirokaku aqueduct, the walking path on its top and a small park at the walking path beginning near Keage Pond

Source: photos taken by the author, 2023



Figure 10. A pond near the Biwa Canal Museum, extension of the canal to the Heian-jingu area

Source: photos taken by the author, 2019

In 2015, an agreement between the mayors of Kyoto and Otsu launched the “Biwa Canal Boat Traffic Restoration Pilot Project”, which later grew into the “Biwa Canal Boat Traffic Project”. Thus, in 2018, after a 67-year hiatus, shipping on the Biwa Canal was resumed, this time for purely

tourist purposes (The Lake Biwa Canal cruise Kyoto-Otsu, n.d.). Currently, navigation is active only in spring and autumn, during the sakura and red maple blossom seasons along the canal, which allows for a full appreciation of its landscape attractiveness (Fig. 11).



Figure 11. Modern tourist navigation on the canal

Source: photos taken by the author, 2019

The Keage Filtration Plant is also part of the Biwa Canal landscape and park ensemble, with azalea bushes blooming in May on its terraced slopes. It is during the

azalea bloom that the Keage Filtration Plant organises a kind of “Open House” with tours, quests and tasting of filtered water (Yamazaki, 2021) (Fig. 12).

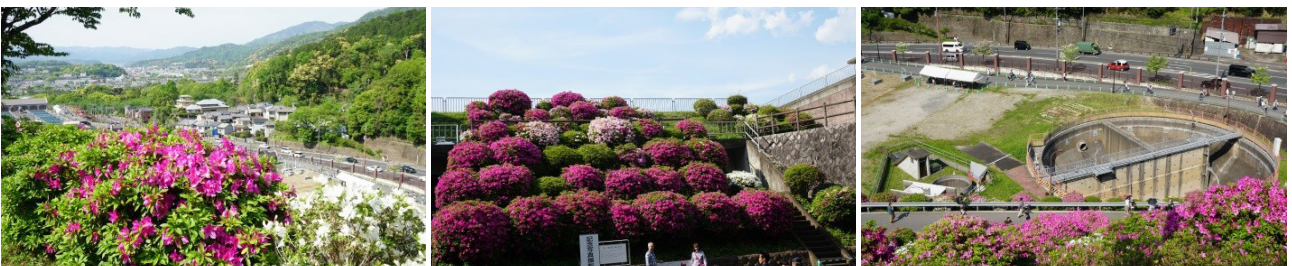


Figure 12. Landscapes and engineering infrastructure at the Keage Filtration Plant

Source: photos taken by the author, 2019



Another feature of the canal's recent history is the development of landscape lighting effects, namely seasonal design illuminations held in the gardens of Heian-jingu, Nanzenji, Eikando temples and Maruyama-koen public park during the cherry blossom season. In Heian-jingu, the weeping

sakura trees around the East Garden Pond are illuminated and light shows are held. Every year, Maruyama-koen hosts an elegant aesthetic composition of candle lanterns installed in groups directly in the stream flow of Ueji's work, which emphasises and deepens the master's composition (Fig. 13).



Figure 13. April lighting of Nanzenji, Eikando temples and Maruyama-koen park

Source: photos taken by the author, 2012; 2019

Landscape function of the Biwa Canal: innovative character and changes over time. The present study attempted to specify the landscape component of the development and historical existence of the Biwa Canal based on the periodisation adopted by G. Shevtsova & M. Parkhomchuk (2022) periodisation. During the first period of the canal's existence (1890-1951), the most powerful landscape design component of the territory was formed, which emerged on the surrounding lands solely due to the canal, and initially consisted mainly in the Keage area of a cluster of manor gardens (Murin-an, etc.) and temple gardens (Hei'an-jingu, etc.), and to some extent included an aspect of public space organisation (Maruyama-koen Park, gardens of the Western Miyako Kyoto Hotel). Notably, Keage was historically home to several large temples that included traditional gardens by prominent landscape designers of the 16th and 17th centuries, such as Kobori Enshu and others (Young & Young, 2005). The most famous of these is the Hojo Garden of Nanzenji Temple. Some of the traditional gardens of Nanzenji, as well as the garden of Eikando Temple, and others, have been reorganised and enriched thanks to the water from the Biwa Canal.

Master Ueji (Ogawa Jihei VII) played a leading role in the organisation of the latest landscape and park design. Ueji completely departed from the Chinese allegorical tradition of the "garden-picture", or garden as an imitation of a literary, poetic or pictorial ideal image. Ueji also departs from the idea of a symbolic-religious garden, inspired by the Chinese tradition, which was typical for medieval Japan (the Kamakura and Muromachi periods). He turns to the integration of the garden with the natural environment, which was an influence of the Western tradition. At the same time, Ueji gardens are a direct development of the purely Japanese gardening tradition, primarily the large promenade gardens of the Heian (Byodoin Temple garden, etc.) and Edo (Kenrokuen Garden in Kanazawa, etc.)

eras. The borrowing of traditional methods is felt in Ueji's works both in terms of aesthetics and technical means of execution. He also creatively reworked and expanded the idea of Shakkei, the so-called borrowed scenery, which implies the involvement of the surrounding large landscape (distant mountains or other large-scale natural scenes) in the chamber composition of a garden (Shirahata, 2008a). However, in contrast to the Japanese Shakkei of the 16th-17th centuries, where the outer landscape was only a distant background for the garden composition and did not combine with it in any way, in Ueji's works the surrounding landscape of the Higashiyama Mountains is compositional with the garden landscape through the use of visual transitional links: stepped artificial rocks, powerful water streams that seem to flow down from the mountains (but in fact come from the water of the Biwa Canal), large trees characteristic of mountain vegetation (fir, cypress), thus creating a kind of unifying 3D effect between the garden composition and the surrounding landscape. This is in harmony with the open and bright spaces of the gardens themselves, filled with air, sunlight and the pulsating sound of the murmuring water of streams and waterfalls. Instead of the moss traditional for a Japanese medieval garden, Ueji uses large open lawns, and the wide, calm water surfaces of the ponds create additional compositional effects due to reflections.

One of the characteristic features of Ueji's style is the idea of integrating elements of the artificial and natural, which manifests itself in quite different ways, and can be, e.g., the visual inclusion of architectural objects of the surrounding landscape, such as pagodas or gates of temples on Mount Higashiyama, in the composition of the garden. Another way of expressing the same idea is to combine artificially processed stones, often taken from dismantled ancient buildings such as bridges or castle ruins, with naturally shaped stones in the design of Ueji's gardens. The





viewer's impression is also reinforced by the immersion of tsukubai washbasin of unusual, semi-natural and semi-geometric shapes into the pond water, and a series of flat, processed "steppingstones" that serve as water crossings.

The second period of the canal's existence began in 1951, along with the closure of shipping, and lasted almost until the end of the 20th century. During this period, the Biwa Canal was in some decline. However, this does not apply to the development of its landscape component, which at this stage was quite intensive and, moreover, received a new direction. At that time, the canal served as the basis for the establishment of many public parks, pedestrian and recreational areas, often combining aspects of industrial and landscape (turning the Keage Incline into a sakura garden, creating walking trails near the Nanzenji Suirokaku aqueduct and the Philosophical Path) or ecological and landscape (Higashiyama Ryokuchi Park) influence on the development of the surrounding areas.

The third period of the canal's existence began in the late 1990s with the inclusion of the canal in the list of National Historic Sites and the creation of the Lake

Biwa Canal Museum. At that time, local authorities and residents of the city reassessed the attractiveness and potential of this unique monument of industrial and landscape construction and began to consciously develop this resource as a place of ecological and industrial tourism by restoring seasonal tourist navigation along the canal. This period also introduced the latest trends in the design landscape of the industrial parts of the canal in the traditional Japanese spirit (Fig. 10). Special attention should be paid to the development of an original modern phenomenon of temporary technological landscape design in the canal area – seasonal illumination and light shows (gardens of the Heian-jingu, Nanzenji and Eikando temples, Maruyama-koen park (Fig. 13)).

All of the above made it possible to build a visual diagram of the historical development and changes in the role of the Biwa Canal in the organisation of the landscape design of the surrounding area, which shows that, following different historical periods of the canal's existence, the functional nature of its landscape-organising component has changed substantially (Fig. 14).

Main landscaping functions of Biwa Canal at Kyoto

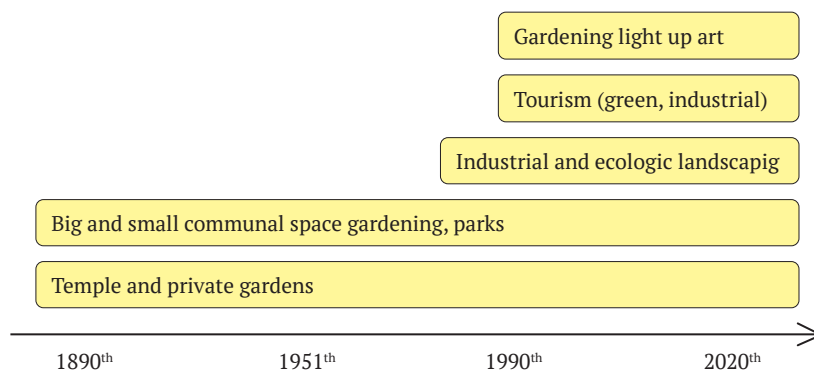


Figure 14. The landscape-organisational function of the Biwa Canal and its changes over time

Source: developed by the author

Thus, it can be summarised that in the first period of the canal's existence, its landscape and organisational impact on the surrounding areas mostly resulted in the local creation of private and temple gardens. In the second period, the tendency to create public landscape spaces, including recreational and environmental ones, intensified. The third period adds aspects of green and industrial tourism and technological landscape art design.

DISCUSSION

Analysing the study results, it should be noted that it has taken its place among the recent scholarly works on the cultural landscapes of Japan. These studies examine the synthetic elements of the Japanese cultural landscape in their sustainable development and interaction with the natural environment and the socio-cultural environment of the settlements. The study by N. Koike *et al.* (2021) explores

the cultural landscape and modern ways of revitalising the ancient reed plantations near Omi-hachiman in Shiga Prefecture, Japan, which exist on canals diverted from Lake Biwa and provide material for the production of Japanese sudare curtains. In the mid-20th century, this traditional local trade began to decline, and since the end of the 20th century, local authorities together with the community have been taking measures to revitalise it. As a result, the authors state that the preservation of the Omi-hachiman cultural landscape is more effective when communal rather than individual management of reed plantations is applied. The development of local tourism is now providing as much impetus for the preservation of this cultural landscape as the production of curtains.

The subject matter of Ye.-Ch. Chiang *et al.* (2013), which deals with the revitalisation and sustainable development of the cultural landscape of traditional terraced rice fields



in the Warabino area in Saga Prefecture (Japan). The study examines how Warabino fields affect the local environment, economy, and social fabric. At the time of writing, the cultural landscape of Warabino was being actively revived by local activists and NGOs. This has led to the creation of a local eco-friendly rice brand, tourism development, the return of young people and the revitalisation of local life. The conclusions of the study emphasise the importance of the cultural landscape's influence on the development and preservation of the local identity of society.

The study by C. Ochiai (2022) examines the protective wind walls of the mountain village of Tsuchigoya in Tanabe, Wakayama Prefecture (Japan) in relation to the layout of the village and its individual estates. The findings highlight the processes of shaping local building practices and cultural traditions as a response to the specifics of geography and climate and emphasise the major influence of the cultural landscape on the nature of the social structure of a settlement.

N. Rezig & G. Shevtsova (2022) compare the cultural specificity of traditional medieval water supply systems of the settlements of the M'zab Valley in Algeria and the Miyakojima Islands in Japan. The focus is on comparing these two cases in terms of history and engineering structure, functional diversification, and cultural role as factors in the formation of local identity. The study analyses the current problems of preservation, revitalisation, and sustainable development of historical water supply systems in their relationship with the local culture and natural environment.

All studies of this kind rightly focus on the relevant problems of sustainable development of cultural landscapes in their interaction with the surrounding natural, architectural, and socio-cultural environment. Considerable attention is paid to environmental issues, revitalisation and preservation of local identity, and the development of the tourism component. However, in contrast to the rural cultural landscapes considered in the studies of previous researchers, whose industrial component is traditional and technically simple, the object of the present study is of a somewhat different nature and represents a complex and rather innovative engineering structure. The Biwa Canal was created in the fully formed historical urban environment of the large metropolitan city of Kyoto thanks to the conscious efforts of the local authorities, and therefore has many specific aspects in its development. At the time of its emergence, it was itself a factor in the revitalisation of the decaying capital (Shevtsova & Parkhomchuk, 2022), and later played an increasingly vital role, provoking rapid development and qualitative changes in the surrounding area.

As for the direct study of the canal, previous studies on this topic mainly concerned its structure, planning, and industrial development (Tanaka & Kawasaki, 2001; Tanaka, 2002). The studies by Yo. Ono *et al.* (2012; 2014) cover the legal aspects of canal construction and the legal issues of water diversion from the canal to the surrounding gardens in the Keage area. S. Shiroshita (2006) investigated the emergence of industrial and landscape tourism on the

Biwa Canal in the second half of the 20th century. Only a small period of the canal's existence is considered, covering the last third of the 20th century.

Another group of related studies was devoted to the landscape development of the surrounding areas. H. Amasaki (2008), Yo. Shirahata (2008b) and K. Ono (2008) do not pay special attention to the role of the canal in the development of the surrounding landscape, although they do point out that the canal water was used to create park ponds. O. Niglio & N. Inoue (2015) consider the historical development of the urban landscape of the Okazaki area in Kyoto, and therefore, a small and purely informative section is devoted to its part – the Keage district and the Biwa Canal. G. Shevtsova & M. Parkhomchuk (2022) covered the general issues of the historical development and modern revitalisation of the canal. The authors develop a historical periodisation and describes the time changes in the functions of the Biwa Canal. However, even here, the canal's landscape-organising role is considered briefly and in passing, only as one component of its functional diversification.

The present study, in turn, provides a general chronological picture of the coexistence of the canal and the surrounding area in its cultural, urban and social aspects. This study is the first to highlight and chronologically detail the catalytic role of the Biwa Canal in the development of the architectural and cultural landscape and garden design of Kyoto, revealing the specifics of development of an outstanding artistic personality against the backdrop of the modern industrial era. Ueji's talent would not have been able to fully develop without the canal, as the possibility of using this water for his parks and gardens directly contributed to the master's creative growth. Thus, the canal provoked a qualitative leap in the approach to the organisation of the cultural landscape and led to the emergence of Ueji's innovative breakthrough in garden design, coordinating and mutually harmonizing tradition and innovation, influences of the East and West in the mind of the master. This phenomenon can be considered as an example of the involvement of an industrial facility in the main path of development of culture and great art in Japan, which was conditioned by the unique historical conditions, place and time of the Biwa Canal formation.

CONCLUSIONS

The great historical project of building the Biwa Canal in Kyoto defined the character of the city's urban development at the end of the 19th century, gaining extraordinary industrial, economic, and cultural significance. At the same time, the Biwa Canal has taken on the role of a powerful lever for revitalising and aesthetising its neighbourhood and the city as a whole. This also applies to the landscape development of the surrounding areas, especially the Keage district, which, thanks to the water from the Biwa Canal, received a developed cluster of private and public garden and park areas in the late 19th and early 20th centuries (the first period of the canal existence).





The gardens and parks of the Keage district, thanks to the talent of their creator, Master Ueji (Ogawa Jihei VII), have become an outstanding milestone in the development of the national idea and practice of landscape design in Japan. In general, Ueji's work met the needs of his era – enlightenment and industrialisation, equally aware of both Japanese tradition and Western trends. This led to the creation of a fundamentally new type of garden that incorporated both, in harmony with the spirit of the new society. This is an example of a qualitative leap forward in the development of the national gardening tradition, made possible by the personal talent of Master Ueji and by the involvement of and integration with new Western technologies and industrial capabilities of the modern era, primarily water from the Biwa Canal.

Since the mid-20th century (the second and third periods of the Biwa Canal existence), the landscape-organising role of the Biwa Canal has not diminished, but has changed its nature since the second period, it has increased the diversification of functions and acquired important public recreational, environmental, and tourist significance. This direction of landscape development of the canal's surrounding areas, considering current trends and changes, continues as of 2023. Modern design of master

Ueji's manner easily adapts to new and changing developments, but nevertheless is still in the creative mainstream of the national tradition. The Biwa Canal has been supplying Kyoto with drinking and industrial water for more than 130 years and is constantly adding new nuances of meaning to the historical heritage and development of Kyoto's urban landscape. The adaptation of the landscape-organising function of the Biwa Canal to the needs of the present, as well as the experience of its preservation, revitalisation, and popularisation, is a fruitful topic, and its further development over time encourages further research in the future. It is also promising to look at other extraordinary examples of the revitalisation and preservation of historic waterways in the world, and specifically in Japan.

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CONFLICT OF INTEREST

None.

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Галина Вікторівна Шевцова

Доктор архітектури, професор

Київський національний університет будівництва і архітектури

03037, просп. Повітрофлотський, 31, м. Київ, Україна

<https://orcid.org/0000-0002-2401-8104>

Історичний канал озера Біва як постійний каталізатор розвитку ландшафтної архітектури Кіото

Анотація. Історичний канал озера Біва, штучний водний шлях, що постачає воду з озера Біва до Кіото, було споруджено з метою пожвавлення Кіото після перенесення столиці до Токіо у 1868. Окрім основної функції, канал відіграє значну роль у організації культурного ландшафту навколишніх територій. Дослідження піднімає актуальні питання сталого розвитку, збереження та ревіталізації історичних інженерних споруд. Штучний водний шлях розглядається в аспекті його тяглових впливів на навколишнє оточення, як урбаністичне, так і ландшафтне. Метою роботи є виявлення характеристик ландшафтно-організуючої ролі каналу Біва та її трансформації у часі, зокрема, з пристосуванням до актуальних проблем сучасності. Робота велася переважно методами польових досліджень *in situ*. В результаті була окреслена вагома роль каналу як постійного каталізатора розвитку ландшафтної архітектури Кіото, що істотно видозмінювалася в часі, але не послаблювалася і завжди носила новаторський характер, органічно поєднуючи сучасні індустріальні досягнення з місцевими традиціями. Зокрема, у першому періоді існування (до 1951) фокус ландшафтно організуючої діяльності на прилеглих до каналу територіях припадав на створення приватних та храмових садів, але з другого періоду існування (1951-початок 1990х), фокус ландшафтної діяльності навколо каналу змістився на громадсько-рекреаційний та парковий аспекти. У часи третього періоду (з початку 1990х), коли канал було визнано Національним історичним надбаням, спостерігаються також і тенденції розвитку індустріально-ландшафтного туризму. Досвід збереження, ревіталізації, популяризації та пристосування ландшафтної ролі каналу Біва до нових потреб сучасності може бути використаний як приклад напрямку проведення аналогічних заходів для історичних водних шляхів у світі

Ключові слова: культурний ландшафт; історичні водні шляхи; ландшафтні сади Кіото; промисловий туризм

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Mukhlis Hajiyev

Doctor of Technical Sciences, Professor
Azerbaijan University of Architecture and Construction
AZ1073, 11 Ayna Sultanova Str., Baku, Azerbaijan
<https://orcid.org/0000-0001-6782-0941>

Masil Damirov*

Postgraduate Student, Senior Lecturer
Azerbaijan University of Architecture and Construction
AZ1073, 11 Ayna Sultanova Str., Baku, Azerbaijan
<https://orcid.org/0000-0002-3779-4305>

Stress-strain state and bearing capacity of compressed reinforced concrete elements of annular section

Abstract. The study of the stress-strain state and bearing capacity of compressed reinforced concrete elements of the annular section is of urgent importance, considering the ever-growing need to improve and optimise infrastructure facilities, such as bridges and supports, to ensure their reliability and safety. The purpose of this study is to investigate and analyse the stress-strain state of compressed reinforced concrete elements of annular section in order to determine their bearing capacity and improve the efficiency of design and construction of infrastructure facilities. The analytical method, classification, functional, statistical, synthesis, and other methods used in the paper should be highlighted. Compressed reinforced concrete elements of annular cross-section are widely used in various fields of engineering and construction. However, since the 90s of the 20th century, there has been a noticeable development of nonlinear deformation theory for the calculation of reinforced concrete structures, which complicates the analysis due to the specific features of round and annular sections and leads to the absence of simple analytical methods. This study presents an effective numerical technique for investigating the stress-strain state and bearing capacity of non-centrally compressed elements, using a linear fractional dependence for concrete under compression, approved in the Eurocode, and a symmetrical two-line diagram of reinforcement deformation. It is important to emphasise that this methodology avoids the need to classify elements as short or long, and to separately account for small and large eccentricities, as these aspects are automatically considered in the calculations. Confirmation of the effectiveness of this technique was obtained through the results of numerical experiments. The practical significance of this research lies in the development of more accurate and reliable methods for calculating and designing compressed reinforced concrete elements of annular section, which contributes to increasing the safety and durability of infrastructure facilities and reducing the risk of destruction

Keywords: reinforcement; eccentricity; load-deflection diagram; infrastructure facilities; numerical technique

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*Corresponding author



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INTRODUCTION

The research topic is defined as becoming important in light of the ever-growing need for modernization and optimization of infrastructure facilities, such as bridges and supports. These elements are an integral part of many engineering structures, and their reliability, safety, and efficiency are key aspects to ensure the sustainability of the infrastructure. Given the complex geometry of annular sections and current trends in nonlinear deformation theory, the development of accurate and reliable calculation methods becomes an urgent task, since it minimises the risks of destruction and reduces construction and maintenance costs. Thus, the study of this topic has a direct practical impact on the safety and efficiency of infrastructure facilities and buildings, which makes it relevant and important for the scientific and engineering community.

The problem of the study is that the compressed reinforced concrete elements of the annular section are complex structures with an inhomogeneous distribution of stresses and deformations, and as of 2023, there are no generally accepted analytical methods capable of providing an accurate calculation of their bearing capacity. The features of circular and annular sections make analysis more difficult, and existing traditional calculation methods often cannot be applied without additional simplifications, which can lead to inaccurate results and underestimation of the safety of the structure. Therefore, it is necessary to develop more efficient and accurate numerical methods that can consider all the features of such elements and provide a reliable analysis of their stress-strain state, which is of key importance for ensuring the safety and reliability of infrastructure facilities.

Researchers A. Janahmadov *et al.* (2021) noted that with the increasing complexity of engineering structures, such as bridges and supports, there is a need for more accurate and reliable calculation methods not only to ensure safety, but also to reduce construction and maintenance costs. Effective engineering solutions based on accurate calculations can contribute to the long-term reliability of structures and reduce operating costs, which is important for the sustainability of infrastructure, buildings and the economic efficiency of projects.

In a study conducted by N. Baghirzade (2022), it is noted that the calculation of wooden elements based on the model of nonlinear deformation is an important engineering tool for determining the behaviour of wooden structures under load. This technique allows considering nonlinear deformations, which significantly increases the accuracy of calculations and the safety of construction objects made of wood.

Kh. Seyfullaev & A. Garaev (2018) suggest using linear fractional dependence for concrete under compression, which may be an important element in the development of more efficient numerical methods for reinforced concrete elements. This dependence can become a key component in the development of more efficient numerical methods that can more accurately assess the stress-strain state and load-bearing capacity of such structures. It allows a more

accurate account of the concrete's behaviour in compression, which helps to improve the accuracy of the calculations.

T. Azizov (2021) emphasises the complexity of classifying elements as short or long, and the need to consider small and large eccentricities in the analysis of compressed elements, which requires more universal methods. The analysis of compressed elements of the annular section becomes more complicated due to the classification of elements as short or long and taking into account various eccentricities. This requires the development of universal analysis methods that consider a variety of parameters and conditions for more accurate design and calculations.

The study by B. Jian *et al.* (2023) confirms that the calculation of a compressed reinforced concrete element of circular cross-section according to a three-line concrete compression scheme is an important stage in the design of reinforced concrete structures. This technique considers the nonlinear behaviour of concrete during compression, which allows more accurately determining the bearing capacity of the element and ensuring its safety under various loads.

The study aimed to analyse the stress-strain condition of compressed reinforced concrete elements with an annular section, including assessing bearing capacity, identifying stress-strain parameters under various loads, and enhancing engineering structure design and construction procedures.

MATERIALS AND METHODS

The analytical method helped in the formalisation of the basic principles and patterns underlying the behaviour of compressed reinforced concrete elements of the annular section. This method established a connection between the geometric, material and load parameters of structures, which became the basis for the development of more complex and effective methods of calculation and design. The analytical method also allowed conducting theoretical studies and determining the influence of various factors on the stress-strain state of the elements, which made it possible to develop more accurate and reliable methods for predicting the bearing capacity and behaviour of structures under various operating conditions.

Using the functional method, models were created focused on describing the behaviour of compressed reinforced concrete elements of the annular section depending on various functional influences and conditions. This method allowed developing functional dependencies and equations describing the relationship between impacts and responses of structures. The application of the functional method provided a tool for a more detailed study and optimisation of projects, allowing the authors to consider various scenarios and impacts on compressed elements. This contributed to a more flexible approach to design and helped to better understand the variability of conditions, which ultimately increased the reliability and efficiency of engineering structures of the annular section.

The structural and functional method helped in a deeper understanding of the internal organisation of the



compressed reinforced concrete elements of the annular section and their functional characteristics. This method revealed the relationship between the structure of facilities and their function in the context of various loads and operating conditions. The application of the structural and functional method has enriched the knowledge of how changes in geometry, material and reinforcement affect the mechanical characteristics of elements. This allowed developing more optimal structures adapted to the conditions of the task, contributing to an increase in their bearing capacity and reliability.

The deduction method helped in the study of the initial principles and logical patterns underlying the behaviour of compressed reinforced concrete elements of the annular section. The application of this method allowed the researchers to identify the basic principles on which the constructions are based, and logically deduce patterns and dependencies between different parameters. This provided a deeper understanding of the processes occurring inside the elements, and allowed developing more accurate theoretical models to describe their behaviour. The deduction method became the basis for the development of more accurate and predictable methods of calculation and design, which, in turn, contributed to improving the reliability and safety of compressed reinforced concrete elements.

ABC Algorithmic Language was used in this research to perform mathematical calculations. This approach allowed to manipulate variables, observe outcomes, and draw conclusions about the language's effectiveness in handling specific formulas. In combination with quantitative analysis, it allowed to work with numerical data generated through the implementation of mathematical formulas in the ABC Algorithmic Language.

RESULTS

The investigation of load-bearing capacity is an essential component of the study aimed at determining the

maximum load that compressed reinforced concrete elements of the annular section can withstand until possible destruction or violation of rigidity conditions (Sadeghian *et al.*, 2021). This stage of research is of critical importance in the design and construction process, as it provides an opportunity for engineers to guarantee the safety and reliability of the structure in real operational conditions. The study of the stress-strain state and bearing capacity of compressed reinforced concrete elements of the annular section includes the analysis of the mechanical properties of materials, analytical and numerical calculations, physical experiments, and the creation of mathematical models (Zhang *et al.*, 2022). These efforts are aimed at a deeper understanding and improvement of the design and construction of such elements. In fact, this research plays a key role in ensuring the safety and efficiency of engineering structures where compressed reinforced concrete elements of the annular section are used. Diagram of concrete deformation under compression in the form proposed by Eurocode (1) (Spirande *et al.*, 2023):

$$\sigma_b = R_b \cdot \frac{k \cdot \frac{\varepsilon_b}{\varepsilon_R} - \left(\frac{\varepsilon_b}{\varepsilon_R}\right)^2}{1 + (k - 2) \cdot \frac{\varepsilon_b}{\varepsilon_R}}, \quad (1)$$

where ε_R – deformation corresponding to the maximum of the stress-strain diagram; ε_b – initial modulus of concrete deformation.

When developing the calculation methodology, it is assumed that concrete does not work for tension, stresses in the cross-section are completely accepted by reinforcement, for a complex cross-section up to the exhaustion of the bearing capacity, the hypothesis of flat sections is valid (Ruiz *et al.*, 2023). Depending on the flexibility and eccentricity of the compressive force, four options for the location of the neutral axis and the distribution of compressive stresses in concrete along the cross section are possible, as shown in Figure 1.

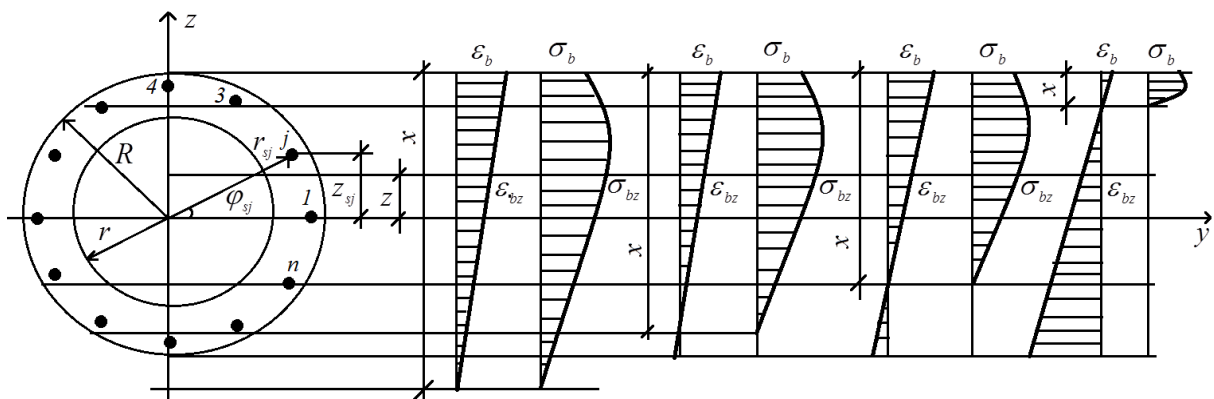


Figure 1. Design scheme of the annular section

Source: compiled by the authors based on G. Ruiz *et al.* (2023)

Based on the assumption of flat sections, with respect to the distribution of deformations across the section, the following statement can be formulated:

$\varepsilon_{bz} = \frac{\varepsilon_b}{x} \cdot (x - R + z)$. After substituting this expression in (1) and introducing the notation $\beta = \frac{\varepsilon_b}{\varepsilon_R}$ – level of deformations of the compressed section face, $\xi = \frac{x}{R}$ –





dimensionless parameter of the neutral axis, $\bar{z} = \frac{z}{R}$ – dimensionless coordinate, for the distribution of compressive stresses in concrete, it is possible to obtain (2):

$$\sigma_{bz} = R_b \cdot \frac{k \cdot \frac{\beta}{\xi} (\xi - 1 + \bar{z}) - \left(\frac{\beta}{\xi}\right)^2 (\xi - 1 + \bar{z})^2}{1 + (k - 2) \frac{\beta}{\xi} (\xi - 1 + \bar{z})}. \quad (2)$$

$$N_{bR} = 2 \cdot R^2 \cdot R_b \cdot N_{bR}^*(\beta, \xi); M_{bR} = 2 \cdot R^3 \cdot R_b \cdot M_{bR}^*(\beta, \xi), \quad (3)$$

$$N_{bR}^*(\beta, \xi) = \int_{-1}^1 \frac{k \cdot \frac{\beta}{\xi} (\xi - 1 + \bar{z}) - \left(\frac{\beta}{\xi}\right)^2 (\xi - 1 + \bar{z})^2}{1 + (k - 2) \frac{\beta}{\xi} (\xi - 1 + \bar{z})} \cdot \sqrt{1 - \bar{z}^2} \cdot d\bar{z}, \quad (4)$$

$$M_{bR}^*(\beta, \xi) = \int_{-1}^1 \frac{k \cdot \frac{\beta}{\xi} (\xi - 1 + \bar{z}) - \left(\frac{\beta}{\xi}\right)^2 (\xi - 1 + \bar{z})^2}{1 + (k - 2) \frac{\beta}{\xi} (\xi - 1 + \bar{z})} \cdot \bar{z} \cdot \sqrt{1 - \bar{z}^2} \cdot d\bar{z}. \quad (5)$$

Similarly, when the neutral axis passes outside the section of the inner circle and inside the outer circle, i.e., at $\xi \geq 1 + \gamma$, where $\gamma = r/R$ is the ratio of the radii of the inner

Using equation (2) to determine the normal force and bending moment caused by compressive stresses in concrete, provided that the neutral axis is outside the section (that is, at specific parameter values), the following can be derived (3-5):

and outer circles, to determine the normal force and bending moment caused by compressive stresses in concrete, the following results can be obtained (6-8):

$$N_{br} = 2 \cdot R^2 \cdot R_b \cdot N_{br}^*(\beta, \xi); M_{br} = 2 \cdot R^3 \cdot R_b \cdot M_{br}^*(\beta, \xi), \quad (6)$$

$$N_{br}^*(\beta, \xi) = \int_{-\gamma}^{\gamma} \frac{k \cdot \frac{\beta}{\xi} (\xi - 1 + \bar{z}) - \left(\frac{\beta}{\xi}\right)^2 (\xi - 1 + \bar{z})^2}{1 + (k - 2) \frac{\beta}{\xi} (\xi - 1 + \bar{z})} \cdot \sqrt{\gamma^2 - \bar{z}^2} \cdot d\bar{z}, \quad (7)$$

$$M_{br}^*(\beta, \xi) = \int_{-\gamma}^{\gamma} \frac{k \cdot \frac{\beta}{\xi} (\xi - 1 + \bar{z}) - \left(\frac{\beta}{\xi}\right)^2 (\xi - 1 + \bar{z})^2}{1 + (k - 2) \frac{\beta}{\xi} (\xi - 1 + \bar{z})} \cdot \bar{z} \cdot \sqrt{\gamma^2 - \bar{z}^2} \cdot d\bar{z}. \quad (8)$$

Based on the expressions obtained for this case, when the neutral axis passes outside the section of the inner

circles, it is possible to find (9, 10):

$$N_b = N_{bR} - N_{br} = 2 \cdot R^2 \cdot R_b \cdot (N_{bR}^*(\beta, \xi) - N_{br}^*(\beta, \xi)), \quad (9)$$

$$M_b = M_{bR} - M_{br} = 2 \cdot R^3 \cdot R_b \cdot (M_{bR}^*(\beta, \xi) - M_{br}^*(\beta, \xi)). \quad (10)$$

The following two functions are introduced (11, 12):

$$Y_{Nb}(\beta, \xi, a) = \int_a^b f(\beta, \xi, \bar{z}) \cdot \sqrt{a^2 - \bar{z}^2} \cdot d\bar{z}, \quad (11)$$

$$Y_{Mb}(\beta, \xi, a, b) = \int_a^b f(\beta, \xi, \bar{z}) \cdot \bar{z} \cdot \sqrt{a^2 - \bar{z}^2} \cdot d\bar{z}. \quad (12)$$

The designation (13) is introduced here:

$$f(\beta, \xi, \bar{z}) = \frac{k \cdot \frac{\beta}{\xi} (\xi - 1 + \bar{z}) - \left(\frac{\beta}{\xi}\right)^2 (\xi - 1 + \bar{z})^2}{1 + (k - 2) \frac{\beta}{\xi} (\xi - 1 + \bar{z})}. \quad (13)$$

Hence, depending on the location of the neutral axis, the following results (14-16) can be finally obtained for the normal force and bending moment due to compressive stresses in concrete:

$$N_b = 2 \cdot R^2 \cdot R_b \cdot N_b^*(\beta, \xi); M_b = 2 \cdot R^3 \cdot R_b \cdot M_b^*(\beta, \xi), \quad (14)$$

$$N_b^*(\beta, \xi) = \begin{cases} Y_{Nb}(\beta, \xi, -1, \bar{\leftarrow} 1) - Y_{Nb}(\beta, \xi, -\gamma, \bar{\leftarrow} \gamma); & \text{if } \xi \geq 2 \\ Y_{Nb}(\beta, \xi, 1 - \xi, \bar{\leftarrow} 1) - Y_{Nb}(\beta, \xi, -\gamma, \bar{\leftarrow} \gamma); & \text{if } 1 + \gamma \leq \xi < 2 \\ Y_{Nb}(\beta, \xi, 1 - \xi, \bar{\leftarrow} 1) - Y_{Nb}(\beta, \xi, 1 - \xi, \bar{\leftarrow} \gamma); & \text{if } 1 - \gamma \leq \xi < 1 + \gamma \\ Y_{Nb}(\beta, \xi, 1 - \xi, \bar{\leftarrow} 1); & \text{if } \bar{\leftarrow} 0 < \xi < 1 - \gamma \end{cases} \quad (15)$$

$$M_b^*(\beta, \xi) = \begin{cases} M_{Nb}(\beta, \xi, -1, \bar{\leftarrow} 1) - M_{Nb}(\beta, \xi, -\gamma, \bar{\leftarrow} \gamma); & \text{if } \xi \geq 2 \\ M_{Nb}(\beta, \xi, 1 - \xi, \bar{\leftarrow} 1) - M_{Nb}(\beta, \xi, -\gamma, \bar{\leftarrow} \gamma); & \text{if } 1 + \gamma \leq \xi < 2 \\ M_{Nb}(\beta, \xi, 1 - \xi, \bar{\leftarrow} 1) - M_{Nb}(\beta, \xi, 1 - \xi, \bar{\leftarrow} \gamma); & \text{if } 1 - \gamma \leq \xi < 1 + \gamma \\ M_{Nb}(\beta, \xi, 1 - \xi, \bar{\leftarrow} 1); & \text{if } \bar{\leftarrow} 0 < \xi < 1 - \gamma \end{cases} \quad (16)$$

The representation of the internal moment and the normal force in this form allows calculating these parameters using a single method. A software module has been compiled by the ABC Algorithmic Language for calculating these parameters. Based on the hypothesis of flat sections for deformation of arbitrary reinforcement (17):

$$\varepsilon_{sj} = \frac{\beta \cdot \varepsilon_R}{\xi} \cdot \left(\xi - 1 + \frac{r_{sj}}{R} \cdot \sin \phi_{sj} \right). \quad (17)$$

Then, according to the accepted reinforcement deformation diagram, the following expression (18) can be obtained for the normal stress of an arbitrary reinforcement:



$$\sigma_{sj} = \begin{cases} E_{sj} \cdot \frac{\beta \cdot \varepsilon_R}{\xi} \cdot \left(\xi - 1 + \frac{r_{sj}}{R} \cdot \sin \phi_{sj} \right) ; & \text{if } \left| \frac{\beta \cdot \varepsilon_R}{\xi} \cdot \left(\xi - 1 + \frac{r_{sj}}{R} \cdot \sin \phi_{sj} \right) \right| \leq \varepsilon_{sj, ax} \\ R_{sj} ; & \text{if } \frac{\beta \cdot \varepsilon_R}{\xi} \cdot \left(\xi - 1 + \frac{r_{sj}}{R} \cdot \sin \phi_{sj} \right) > \varepsilon_{sj, ax} \\ -R_{sj} ; & \text{if } \frac{\beta \cdot \varepsilon_R}{\xi} \cdot \left(\xi - 1 + \frac{r_{sj}}{R} \cdot \sin \phi_{sj} \right) < -\varepsilon_{sj, ax} \end{cases} \quad (18)$$

In these expressions E_{sj} , R_{sj} , r_{sj} , ϕ_{sj} , $\varepsilon_{sj,ax}$ respectively, the modulus of elasticity, the tensile-compressive strength, the distance from the centre of the cross-section of the rod to the centre of the section of the reinforcement, the central angle, the deformation of the yield of the

reinforcement (Fig. 2). According to the stresses found in the reinforcing bars, according to the following dependencies, it is possible to calculate the normal force and bending moment coming to the share of the reinforcing bars (19):

$$N_s(\beta, \xi) = \sum_{j=1}^{k_s} \sigma_{sj} \cdot A_{sj}; M_s(\beta, \xi) = \sum_{j=1}^{k_s} \sigma_{sj} \cdot A_{sj} \cdot r_{sj} \cdot \sin \phi_{sj}, \quad (19)$$

where k_s – the number of reinforcing bars.

$$2 \cdot R^3 \cdot R_b \cdot M_b^*(\beta, \zeta) + M_s(\beta, \zeta) = P \cdot (e + f). \quad (21)$$

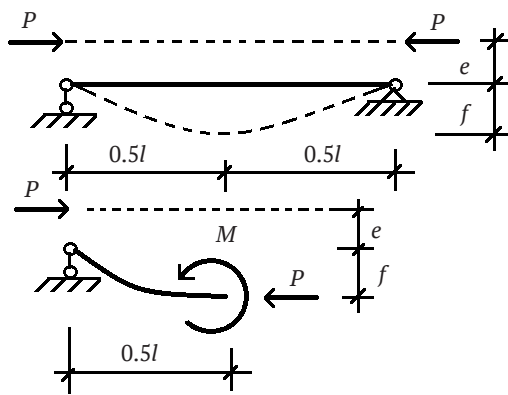


Figure 2. Design scheme of the compressed rod

Source: compiled by the authors

Composing the equilibrium equations for half of the rod can be written as (20, 21):

$$2 \cdot R^2 \cdot R_b \cdot N_b^*(\beta, \zeta) + N_s(\beta, \zeta) = P, \quad (20)$$

$$\Phi(\beta, \zeta) = 2 \cdot R^3 \cdot R_b \cdot M_b^*(\beta, \zeta) + M_s^*(\beta, \zeta) - \left(e + \rho_* \cdot \frac{P}{\xi} \right) \cdot [2 \cdot R^2 \cdot R_b \cdot N_b^*(\beta, \zeta) + N_s^*(\beta, \zeta)] = 0. \quad (24)$$

From this equation, for a given value of one of the parameters, the second parameter is found as a solution to a nonlinear equation with one unknown. Since the limits of parameter change β are known in advance, its value is set and the corresponding value of parameter ξ is found. After that, by (23) it is possible to calculate the parameter f and by (21) it is possible to calculate the compressive force corresponding to the assumed value β . The remaining parameters at known values β and ξ are calculated easily. Thus, passing over the whole range of variation of parameter β , a connection is obtained between P and f , which allows building a load-deflection diagram. The maximum of this curve determines the bearing capacity of a compressed rod of annular section (Huang *et al.*, 2021). The described numerical calculation algorithm is easily programmed and the corresponding software module is compiled by the ABC Algorithmic Language. When constructing the computational model, no restrictions are made regarding the

This nonlinear system of equations includes three unknown parameters β , ξ and f , but the maximum deflection of the rod can be expressed in terms of β and ξ . Approximating the deformed axis of the rod with a suitable curve, for example, for a pivotally supported rod: (22) (Kraus & Rimoli, 2023):

$$y(x) = f \cdot \sin \frac{\pi \cdot x}{l_0}, \quad (22)$$

where l_0 – estimated length of the compressed rod.

Then for the curvature of the most stressed middle section $-\chi = y''\left(\frac{l_0}{2}\right) = f \cdot \frac{\pi^2}{l_0^2}$, on the other hand $-\chi = \frac{\varepsilon_b}{x} = \frac{\beta \cdot \varepsilon_R}{\xi \cdot R}$. Equating these two expressions (23):

$$f = \rho_0 \cdot \frac{\beta}{\xi}; \quad \rho_0 = \frac{l_0^2 \cdot \varepsilon_R}{\pi^2 \cdot R}. \quad (23)$$

Thus, considering (23), the main resolving system of equations (20) and (21) are a nonlinear system with respect to the parameters β and ξ . Given (20) in (21), the following nonlinear equation can be obtained that relates the parameters β and ξ to each other:

flexibility of the rod and the eccentricity of the compressive force application. The presence of such a software module allows for various numerical experiments. The results of some numerical experiments are given.

Example 1. The annular cross-section of the compressed element with the radius of the outer circle $R = 0.2$ m, the inner circle $r_{sj} = 0.1575$ m uniformly reinforced with $k_s = 12$ reinforcement of a periodic profile of a class A 400 with a diameter $\varnothing 25$ of the cross-sectional area of each $A_{sj} = 4.9087 \cdot 10^{-4}$ m², $E_{sj} = 2 \cdot 10^5$ MPa, $R_{sj} = 350$ MPa, concrete B 25 with a compressive strength limit $R_b = 14.5$ MPa. To investigate the effect of the flexibility of the compressed element on the bearing capacity of a pivotally supported rod with conditionally central compression with eccentricity, $e = 1$ cm calculations were performed at the following lengths $l_0 = 3$ m, $l_0 = 4$ m, $l_0 = 6$ m, $l_0 = 9$ m, $l_0 = 12$ m and $l_0 = 15$ m. Based on the results of the performed calculation, Figure 3 shows the “load-deflection” graphs.



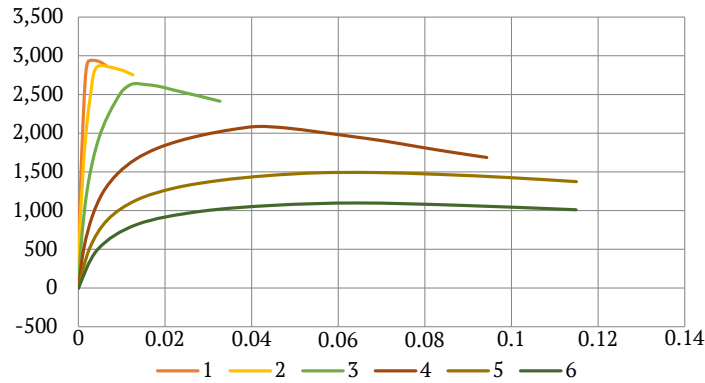


Figure 3. Load-deflection graphs for a conventionally centrally compressed rod at various lengths

Source: compiled by the authors

As can be seen in all graphs, descending branches are implemented, with an increase in the length of the rod, the bearing

capacity decreases. The parameters of the stress-strain state at the moment of loss of bearing capacity are given in Table 1.

Table 1. Parameters of the stress-strain state at the moment of loss of bearing capacity

l_0 ; m	β	ξ	f ; m	P ; kN	$\frac{P_{cr}}{P}$
3	1.2	3.1708	0.0035	2,940.44	16.72
4	1.1	3.2621	0.0055	2,873.17	9.63
6	1.0	2.8936	0.0126	2,637.08	4.66
9	1.0	1.9892	0.0413	2,086.34	2.62
12	0.8	1.7052	0.0684	1,491.75	2.06
15	0.5	1.7658	0.0646	1,098.55	1.79

Source: compiled by the authors

Additionally, for small values of flexibility, the bearing capacity is mainly determined from the condition of strength or rigidity, and in flexible elements from the condition of stability (Fan *et al.*, 2023). For example, for the considered rods with a length of $l_0 = 3$ m, $l_0 = 4$ m and $l_0 = 6$ m at the moment of exhaustion of the bearing capacity, the reinforcing rods with numbers 3, 4 and 5 reach the yield strength, and the remaining rods work within the limits of elasticity. For a rod with a length $l_0 = 9$ m – only

the reinforcement with the number 4 reaches the yield strength. And in rods with a length $l_0 = 12$ m and $l_0 = 15$ m at the moment of exhaustion of the bearing capacity, all reinforcing rods work within the limits of elasticity.

Example 2. To clarify the effect of the eccentricity of the compressive force on the bearing capacity, the rods considered in the first example were calculated for different values of eccentricity. Table 2 provides the parameters that correspond to the exhaustion of the bearing capacity.

Table 2. Parameters corresponding to the exhaustion of the bearing capacity

$l_0 = 3$ m					
e , m	β	ξ	f , m	P , kN	
0.01	1.2	3.1708	0.0035	2,940.44	
0.02	1.3	2.3902	0.005	2,691.49	
0.05	1.5	1.7929	0.0076	2,186.31	
0.1	1.6	1.4557	0.01	1,632.69	
0.15	1.7	1.2996	0.0119	1,295.91	
$l_0 = 4$ m					
e , m	β	ξ	f , m	P , kN	
0.01	1.1	3.2621	0.0055	2,873.17	
0.02	1.2	2.3786	0.0082	2,612.37	
0.05	1.4	1.7654	0.0129	2,108.77	
0.1	1.6	1.4224	0.0182	1,567.4	
0.15	1.7	1.2796	0.0215	1,247.39	



Table 2. Continued

$l_0 = 6 \text{ m}$				
$e, \text{ m}$	β	ξ	$f, \text{ m}$	$P, \text{ kN}$
0.01	1.0	2.8936	0.0126	2,637.08
0.02	1.2	2.0727	0.0211	2,372.39
0.05	1.4	1.622	0.0315	1,889.16
0.1	1.6	1.3389	0.0436	1,394.06
0.15	1.7	1.2304	0.0504	1,118.29
$l_0 = 9 \text{ m}$				
$e, \text{ m}$	β	ξ	$f, \text{ m}$	$P, \text{ kN}$
0.01	1.0	1.9892	0.0413	2,086.34
0.02	1.0	1.8243	0.045	1,898.13
0.05	1.1	1.4592	0.0619	1,479.93
0.1	1.2	1.2317	0.08	1,099.59
0.15	1.3	1.1433	0.0933	893.31
$l_0 = 12 \text{ m}$				
$e, \text{ m}$	β	ξ	$f, \text{ m}$	$P, \text{ kN}$
0.01	0.8	1.7052	0.0684	1,491.75
0.02	0.8	1.5775	0.074	1,345.14
0.05	1.0	1.2525	0.1165	1,051.42
0.1	1.2	1.1188	0.1565	832.1
0.15	1.2	1.0714	0.1634	702.88
$l_0 = 15 \text{ m}$				
$e, \text{ m}$	β	ξ	$f, \text{ m}$	$P, \text{ kN}$
0.01	0.5	1.7658	0.0646	1,098.55
0.02	0.5	1.6174	0.0705	984.34
0.05	0.7	1.1952	0.1335	752.1
0.1	1.1	1.046	0.2397	623.47
0.15	1.2	1.0151	0.2695	543.32

Source: compiled by the authors

Similarly, for a rod with a length $l_0 = 4 \text{ m}$ in Figure 4 shows the “load-deflection” graphs. From these graphs, it is seen that for small eccentricities, the bearing capacity is determined from the stability condition, and for

large values of eccentricity from the strength or stiffness condition. With large values of eccentricity, descending branches are not implemented in load-deflection diagrams.

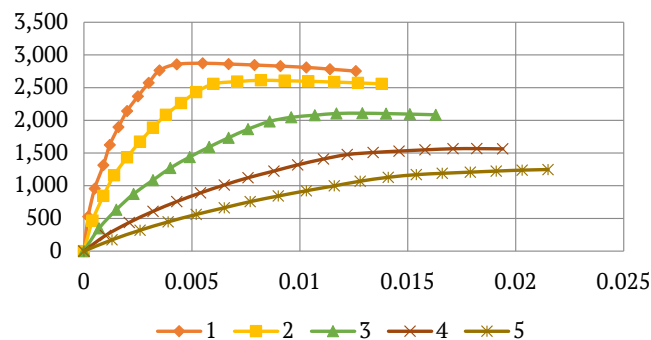


Figure 4. Load-deflection diagrams for an element with a length $l_0 = 4 \text{ m}$ at different values of eccentricity

Source: compiled by the authors

Example 3. The influence of the percentage of reinforcement on the bearing capacity of compressed reinforced concrete elements of the annular section is studied here. For this purpose, an element with a length $l_0 = 4 \text{ m}$ with a conditionally central compression with

an eccentricity $e = 1 \text{ cm}$ was additionally calculated with the following reinforcements 12 $\emptyset 22$, 12 $\emptyset 20$, 12 $\emptyset 18$, and 12 $\emptyset 16$.

The values corresponding to the point of bearing capacity exhaustion can be found in Table 3.





Table 3. Values of the parameters corresponding to the moment of exhaustion of the bearing capacity

Reinforced	β	ξ	f, m	P, kN
12 \emptyset 25	1	2.4845	0.0205	2,459.24
12 \emptyset 22	1.1	3.2621	0.0055	2,873.17
12 \emptyset 20	1.1	3.1678	0.0056	2,464.73
12 \emptyset 18	1.1	3.0914	0.0058	2,221.28
12 \emptyset 16	1.1	3.004	0.0059	2,000.49

Source: compiled by the authors

The percentage of reinforcement also strongly affects the bearing capacity.

“Load-deflection” plots for the considered reinforcement options are plotted in Figure 5.

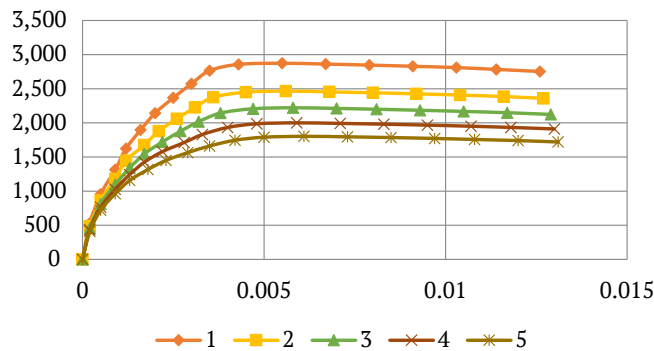


Figure 5. Load-deflection graphs for an element with a length $l_0 = 4$ m with conditionally central compression with eccentricity $e = 1$ cm for various reinforcement options

Source: compiled by the authors

These graphs show the significant influence of the percentage of reinforcement on the behaviour of compressed reinforced concrete elements of the annular section. Changing the reinforcement level significantly affects the bearing capacity. A higher percentage of reinforcement can significantly increase the load-bearing capacity, making the structure more reliable and able to withstand higher loads. These results are of great importance in the development of engineering solutions and optimisation of structures with annular elements. By controlling and regulating the percentage of reinforcement, engineers can achieve the desired characteristics in the behaviour of the structure, which contributes to the safety and efficiency of engineering projects.

Thus, the analysis of the influence of the percentage of reinforcement on the behaviour of compressed reinforced concrete elements of the annular section emphasises the importance of optimal design and control during construction to achieve optimal results in constructive work.

DISCUSSION

Annular cross-section elements are widely used in infrastructure projects such as bridges, stadiums, towers, and even ordinary buildings. They provide not only a supporting function, but can also be important elements of design and architectural value. Insufficient understanding and incorrect design of such elements can lead to accidents and serious consequences.

The stress-strain state of compressed reinforced concrete elements of the annular section is influenced by several factors, including the geometry of the element, the class of concrete and reinforcement used, and the loads acting on the element. Engineers can use knowledge of the stress-strain state to design the elements of the annular section accurately. This involves optimizing the element’s geometry, selecting materials, and placing the reinforcement correctly to ensure maximum load-bearing capacity and safety. Failure to accurately estimate the stress-strain state can result in excessive material consumption or even the destruction of the element.

Reinforcement plays a key role in increasing the load-bearing capacity of compressed reinforced concrete elements. The correct placement and number of fittings help to control the stress-strain state and prevent the destruction of the element during compression. Various methods are used to analyse the stress-strain state and assess the bearing capacity of annular elements. This includes numerical modelling, laboratory mock-up tests and analytical calculations. Modern engineering programmes and computer simulations help to more accurately assess the behaviour of such elements.

The application of this research is seen in the design and construction of many structures, including bridges, water towers, and in industrial structures. For example, when designing high towers with annular elements, it is necessary to consider the stress-strain state to ensure their



stability and safety. Modern research in this field is aimed at developing new materials, methods of analysis and design, and at finding sustainable and innovative solutions to improve the bearing capacity and durability of compressed reinforced concrete elements. Problems may include insufficient reinforcement, incorrect design of the geometry of elements, changes in operating conditions over time, and many other factors. Solutions often require engineering analysis and design modification. Discussion of all these aspects will help to better understand the importance and relevance of this topic in engineering practice and emphasise the need for continuous development in this area to ensure the safety and sustainability of infrastructure facilities.

According to the results of research by X. Wang *et al.* (2015), the behaviour of short round tubular reinforced concrete columns subjected to off-centre compression is an important research topic in the field of structural mechanics and engineering design. This type of structure is commonly found in a variety of engineering applications, such as bridge supports, poles, wind turbine supports, and many others. Off-centre compression means that the load axis does not coincide with the geometric centre of the column. This can occur due to various factors, including the eccentricity of the load application or heterogeneity within the structure. Due to this uneven load distribution, additional stresses and deformations occur in the column, which can significantly affect its bearing capacity and stability. Results obtained by the researchers are consistent with the findings of this study. Research in this field is focused on the development of numerical models and analytical methods for the analysis of such columns. These scientific studies allow engineers to more accurately predict the behaviour of columns and optimise their design considering the impact of eccentric loads. The essential aspects of the analysis are the assessment of normal and transverse stresses, stability testing and the development of safety measures to prevent possible emergencies. Understanding the characteristics of short round tubular reinforced concrete columns under eccentric compression is critical to ensuring the reliability and safety of engineering structures.

S. Indriūnas *et al.* (2023) have found that the behavioural analysis of a mast with a combined system, including pre-stressed columns and a core of centrifuged concrete of circular cross-section, is an interesting area of research in engineering construction. This approach combines two key elements to ensure high load-bearing capacity and stability of the mast. Pre-stressed columns are an effective way to strengthen the structure and increase its load-bearing capacity. They create compression stresses that compensate for part of the load and increase resistance to bending moments. The core of centrifuged concrete of circular cross-section, in turn, provides additional structural strength and stability. Behavioural analysis of such a mast includes the study of many aspects, including stress distribution in pre-stressed columns, deformations and dynamic behaviour under various loads and operating conditions (Chovnyuk *et al.*, 2022). In addition, it is important

to consider the interaction between the various elements of the system, such as columns and core, to ensure their coordinated operation. These data correspond to the statements set out in the previous section and in earlier researches in this field. For example, Q.-L. Wang *et al.* (2008) analysed load-deformation curves of the concentrically compressed concrete and got similar conclusions. From which it can be inferred that research in this field can contribute to optimising the design of such masts, providing high load-bearing capacity and durability with minimal use of materials and economical design. This is especially relevant in the context of the construction of tall buildings and towers, where security and stability play a crucial role.

R. Kliukas *et al.* (2020) determined that the mechanical properties of centrifuged concrete play an important role in reinforced concrete structures. Centrifuged concrete is a specific type of concrete that is subjected to high centrifugal forces during production. This allows achieving a higher density and strength of the material compared to conventional concrete, which makes it an attractive choice for various engineering applications. One of the key mechanical properties of centrifuged concrete is its compressive strength. This parameter determines the ability of the material to withstand the load directed along its axis. The high compressive strength makes centrifuged concrete ideal for use in compressible elements such as pillars, columns and foundations. The paper confirms the results of this study. The mechanical characteristics of centrifuged concrete cover parameters such as tensile strength, modulus of elasticity, and resistance to fracture during bending, among other factors. The understanding of these properties is an important aspect in the process of designing and analysing reinforced concrete structures. This contributes to ensuring the safety and reliability of structures, and also allows optimising their design based on the requirements for loads and durability.

P. Feng *et al.* (2015) determined that the study of the mechanical behaviour of a square steel pipe with a concrete core subjected to axial compression is an interesting area in the engineering and scientific community. Such composite structures combine the advantages of various materials and can be used in various engineering applications, such as the construction of bridges, towers, and other structures where a combination of high strength and stability is required. The results of the author's research can reveal possible problems and limitations in the use of this type of composite materials in various engineering projects, which contributes to more efficient and safe design and construction. Thus, the analysis of the mechanical behaviour of such structures under axial compression is an important stage in the research of engineers and scientists.

Researchers M. Kosior-Kazberuk *et al.* (2022) have shown that the approximation model of the method of calculated resistance of reinforced concrete to bent elements is an important engineering tool that allows engineers to evaluate the bearing capacity of reinforced concrete structures under the influence of bending moments. This





method uses various simplifications and approximations to predict the behaviour of reinforced concrete elements during bending and can be useful in the design and analysis of building structures. The approximation model includes parameters such as concrete strength, reinforcement strength, and geometric characteristics of the element. It can be used to determine critical parameters, such as the maximum bending moment that the structure can withstand without breaking. These results confirm the above study, as this method allows engineers to carry out preliminary calculations and analysis of structures more quickly and efficiently, which reduces risks and ensures safety in construction. However, it is important to remember that the results obtained using approximation models should always be supplemented with more accurate and detailed studies and experiments to ensure the reliability and accuracy of calculations.

A. Pavlikov *et al.* (2020) examined the strength characteristics of compressed reinforced concrete elements with a circular cross-section and uniform reinforcement under the influence of axial load and bending moment. They proposed a simple method of analysis for engineering practice that reduces the basic formulas of nonlinear analysis to the formulas of the resistance of materials. The results of their study are consistent with the data obtained, and the use of nonlinear diagrams of deformation of materials allows for a more accurate description of the real behaviour of reinforced concrete elements. Developing simplified engineering techniques based on nonlinear analysis is an important direction for improving the design efficiency of such structures. However, it is important to keep in mind the limitations of such simplified models and the need to verify the results using more detailed numerical and experimental studies.

Overall, the mentioned studies represent a valuable contribution to advancing the methods for analysing and designing non-centrally compressed reinforced concrete elements with a circular cross-section.

CONCLUSIONS

Elements, such as pillars, columns, or supports, are frequently subjected to compression loads, and understanding

their behaviour during deformation is crucial for guaranteeing the safety and durability of building structures. A robust numerical method has been developed in this study to explore the stress-strain state and load-bearing capacity of compressed reinforced concrete elements with an annular cross-section. This technique enables the examination of the behaviour of reinforced concrete elements with an annular section using a unified approach, without imposing limitations on flexibility, force application eccentricity, or the percentage of reinforcement. The results of numerical experiments affirm the necessity of employing a nonlinear deformation model based on real material deformation diagrams for a reliable analysis of the stress-strain state and bearing capacity of compressed reinforced concrete elements. This makes the method appealing for use in constructing bridges, buildings, and other infrastructure facilities. However, it is essential to consider various factors during the design process, such as the element's geometry, the quality of the concrete and reinforcement, and environmental conditions like exposure to aggressive media and temperature changes, as neglecting these parameters may result in the element's destruction or loss of bearing capacity.

It is worth noting that ongoing research and development in the field of building materials and technologies are continuously enhancing the bearing capacity of compressed reinforced concrete annular section elements and improving safety in construction. In conclusion, understanding the stress-strain state and bearing capacity of such elements remains a pivotal aspect in the field of engineering practice and construction, necessitating further research and development. For further exploration of this topic, a more comprehensive investigation into the impact of long-term operation, dynamic loads, and alternative building materials on the bearing capacity of compressed concrete elements with an annular cross-section is essential.

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CONFLICT OF INTEREST

None.

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Мухліс Ахмед огли Гаджиєв

Доктор технічних наук, професор
Азербайджанський архітектурно-будівельний університет
AZ1073, вул. Айни Султанової, 11, м. Баку, Азербайджан
<https://orcid.org/0000-0001-6782-0941>

Масіл Махір огли Даміров

Аспірант, старший викладач
Азербайджанський архітектурно-будівельний університет
AZ1073, вул. Айни Султанової, 11, м. Баку, Азербайджан
<https://orcid.org/0000-0002-3779-4305>

Напружено-деформований стан і несуча здатність стиснутих залізобетонних елементів кільцевого перерізу

Анотація. Дослідження напружено-деформованого стану та несучої здатності стиснутих залізобетонних елементів кільцевого перерізу є актуальним з огляду на постійно зростаючу потребу в удосконаленні та оптимізації об'єктів інфраструктури, таких як мости та опори, для забезпечення їх надійності та безпеки. Метою даної роботи є дослідження та аналіз напружено-деформованого стану стиснутих залізобетонних елементів кільцевого перерізу для визначення їх несучої здатності та підвищення ефективності проектування і будівництва об'єктів інфраструктури. Слід виділити аналітичний метод, класифікацію, функціональний, статистичний, синтез та інші методи, що були використані в роботі. Стиснуті залізобетонні елементи кільцевого перерізу широко застосовуються в різних галузях машинобудування та будівництва. Однак з 90-х років 20 ст. спостерігається помітний розвиток нелінійної теорії деформування для розрахунку залізобетонних конструкцій, що ускладнює аналіз через специфічні особливості круглих і кільцевих перерізів і призводить до відсутності простих аналітичних методів. У цій роботі представлено ефективну чисельну методику дослідження напружено-деформованого стану та несучої здатності нецентрально стиснутих елементів, яка використовує лінійну дробову залежність для бетону при стисненні, затверджену в Єврокодi, та симетричну дволінійну діаграму деформування арматури. Важливо підкреслити, що ця методика дозволяє уникнути необхідності класифікувати елементи на короткі та довгі, а також окремо враховувати малі та великі ексцентриситети, оскільки ці аспекти автоматично враховуються в розрахунках. Підтвердження ефективності цієї методики отримано за допомогою результатів чисельних експериментів. Практичне значення роботи полягає в розробці більш точних і надійних методів розрахунку та проектування стиснутих залізобетонних елементів кільцевого перерізу, що сприяє підвищенню безпеки і довговічності об'єктів інфраструктури та зменшенню ризику їх руйнування

Ключові слова: арматура; ексцентриситет; діаграма «навантаження-прогин»; інфраструктурні об'єкти; чисельна методика

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Bohdan Cherkes

Doctor of Architecture, Professor
Lviv Polytechnic National University
79000, 12 Stepan Bandera Str., Lviv, Ukraine
<https://orcid.org/0000-0001-6809-956X>

Yuliya Idak*

Doctor of Architecture, Professor
Lviv Polytechnic National University
79000, 12 Stepan Bandera Str., Lviv, Ukraine
<https://orcid.org/0000-0002-1123-5759>

Roman Frankiv

PhD in Architecture, Associate Professor
Lviv Polytechnic National University
79000, 12 Stepan Bandera Str., Lviv, Ukraine
<https://orcid.org/0000-0003-1100-0930>

The concept of “gated community” and its explication in the theory and practice of urban planning: A literature review

Abstract. The research relevance is determined by expanding the meaningful boundaries of the concepts that are actively used in modern urban planning theory and practice. The study aims to reveal and understand the essence of the concept of “gated community”, identify its interrelationships with urban concepts and establish its role in the context of urban planning theory and practice. A comprehensive methodological approach based on a logical and philosophical approach and combining terminological and spatial analyses was used. The study identified the essential features of the concepts of “community” and “gated community”, as well as their relationship with other concepts related to the organisation of the living environment at the territorial level. The definition of the concept of “gated community” is expanded to include the urban planning component. The results of the study indicate that the formation of gated communities can have both a positive and negative impact on urban development. A gated community is proposed to be regarded as a group of objects characterised by a pronounced focus on internal interaction and mutual assistance between its members. Such a definition was preceded by the results of revealing the place and role of “gated communities” in the city structure, identifying the essential features of the initial concepts of “community” and “gated community”, establishing the relationship with the concepts that take place when describing the peculiarities of the organisation of the living environment at the territorial level, as well as the correspondence of the definition of a gated community to its specifics of functioning at the territorial level. It is determined that in urban planning its characteristic features are physical isolation and controlled access. It is clarified that this type of community can lead to the fragmentation of the city into smaller, separate territorial units. The practical value of this work is the possibility of considering its results in the process of developing a city development

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*Corresponding author



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strategy for the rational organisation of the living environment. In addition, the results can help governing institutions identify the best ways to cooperate with gated communities, ensuring a balance between their needs and the requirements for preserving urban identity and sustainability

Keywords: closed residential complexes; essential features; concepts; planning of cities

INTRODUCTION

The modern urban landscape of Ukraine is characterised by a variety of approaches to shaping the urban living environment. There is a growing importance of gated communities that contradict the strategy of sustainable urban development. This aspect is causing active discussions among urban planners.

In the context of intensive implementation of the strategy of sustainable urban development in Ukraine (Decree of the President of Ukraine..., 2015), gated communities have become a prominent phenomenon and have been accepted as an understandable and natural fact. At the same time, urbanists and city planners promoting the European way of life, based on various acts and regulations (for example, the Leipzig Charter “European Cities on the Path to Sustainable Development” (Weigel, 2021), deny the need to form such associations. This is because, at the territorial level, they are seen as limiting physical accessibility and limiting the functional diversity of the living environment. A diametrically different approach is observed in the real estate market. In the face of intense competition, it tries to please the buyer in various ways and promotes what it considers to be the necessary methods of organising the living environment. As a result, gated communities continue to spread, especially in developed and stable parts of the world (Blandy & Atkinson, 2022), with distinct formal characteristics at the level of urban planning. Because of this, a gated community is a way of organising a living environment where the feeling of security, comfort and privacy prevail over thoughts of the global needs of humanity and the protection of the interests of future generations.

Ukrainian discourse is shaped by popular media, which, in most cases, aim to focus on the issue of population segregation, fragmentation of the territory or containing hidden interests. As for the existing scientific works that in one way or another address the problem of communities, they are situationally tangential. Many studies consider the community as an abstract phenomenon, while its analysis aims to identify external factors that influence the processes of development, organisation, and formation of the living environment. For instance, O. Deineko (2021) studied the peculiarities of social cohesion formation at the level of amalgamated territorial communities through the prism of community. Yu. Idak & R. Frankiv (2022) identified the peculiarities of organising gated communities in the context of mass housing construction in the city of Lviv. However, the context of this phenomenon, its essential characteristics, and the appropriateness of calling the phenomena that occur in society at the level of the territorial organisation of the city by this term remain unexplored and debatable.

As of 2023, the socio-legal framework has become a central feature of gated communities (Tanulku, 2023). In addition, studies aimed at identifying the specifics of gated communities in different countries of the world have become widespread (Wanie, 2018), particularly in those where the phenomenon of gated communities has a historical background (Hamama & Liu, 2020). Under similar circumstances, comparative studies have been conducted to identify the peculiarities of gated communities in a changing urban environment (Hamama *et al.*, 2019). At the same time, their theoretical and methodological basis remains the early works that define gated communities as residential formations with physically limited access to them (Blakely & Snyder, 1997). This interpretation remains relevant in the context of active development and changes in the real estate market (Brown, 2022). Thus, due to unresolved theoretical issues, there is no consensus on the concept of urban enclaves in English-language sources and there is no single designation and definition that they are referred to.

This problem has become particularly pressing in urban planning, where social and economic issues do not fully reflect the specifics of this phenomenon and the problem that arises when implementing the concept of sustainable urban development (Alagamy, 2023). There is also a contradiction between the personal interests of citizens and the interests of the state-level society. Under such conditions, the theory of urban planning needs to expand the conceptual and categorical apparatus and deepen the content of the concept of “gated community” through the selection of characteristic features.

The methodological basis of the study includes the logical and epistemological approach, general scientific and special methods based on the theoretical foundations of studying the form of organisation of the social and material-spatial organisation of the living environment within a certain territory, which is denoted by the concept of “gated community”. Their application is conditioned by the understanding of the phenomenon of “closeness” and “community” in urban planning and the identification of those features that can describe them. The method of theoretical analysis proved to be effective. It provided the choice of the research topic, the definition of the etymology and essence of the key concept of “gated community”, the systematisation and generalisation of facts about the specifics of functioning and the peculiarities of the formation of gated communities in urban areas. In the process of deepening knowledge about the concepts and categories relevant to the study, a terminological analysis was carried out. The results were reinforced by the method of spatial analysis, which was



used to study the geometric and geospatial characteristics of the territories of gated communities in Lviv.

The theoretical basis of the study includes scientific information and references about the community as a lexiconographic product and works on the definition of “gated community”, the nature of functioning of gated communities within the city and the specifics and features of its organisation at the territorial level. In the process of applying the logical and epistemological approach, in addition to reference books, the researchers considered works that deepen the essential features of the concepts of “community” and “gated community”, focusing on its practical aspects: territorial (geoprospective data, natural conditions, space limitations, organisation of plots) and communicative (internal communication, information exchange) characteristics.

The source base, which included graphic images and annotations about Lviv’s gated communities and the definition of key concepts for the study, helped to obtain information about the specifics of the functioning of gated communities at the territorial level. The materials made by the author (Yulia Idak) during her research fellowship (Vienna, 2022) and data obtained from official websites helped to identify the specifics of the functioning of gated communities.

This study largely addresses the theoretical gap that exists in the theory of urban planning and is provoked by the development of a special form of social and material-spatial organisation of the living environment within a certain territory. The study firstly addresses the problem of conceptual and terminological issues in architecture and urban planning and identifies the essential features of a “gated community” as a way of organising the living environment in a certain territory. The main part of the study is devoted to the search for such features in urban development objects and their expression through specific concepts and categories. The study aimed to provide an in-depth analysis of the concept of a “gated community” aimed at revealing its key aspects that are relevant for both theoretical development and practical application in urban planning and are relevant for 2023.

EVOLUTION AND LOCAL PECULIARITIES OF THE CONCEPT OF “GATED COMMUNITY”

Compared to the earlier studies of this phenomenon, some peculiarities can be observed. They are that at the initial stages, the subject of special attention was the actualisation of the problem of enclavism and the development of ghetto-like formations (Atkinson & Blandy, 2005). Due to the emphasis on social and economic aspects (Grant & Mittelsteadt, 2004), the topic of gated communities has had limited theoretical development. However, the genesis of the concept of “community” continues to be the subject of coverage by a significant number of information sources and is part of the discourse that studies various aspects of this phenomenon. It is worth noting that it is the English-language works that are distinguished by their diversity. They can be divided into two groups. The first group consists of early works that appeared at the beginning of

the growing interest in the topic of gated communities. Attention was primarily paid to theoretical aspects, with a special emphasis on social and economic challenges. Among them, studies on the actualisation of the problem of gated communities (Webster *et al.*, 2002), classification (Grant & Mittelsteadt, 2004) and conceptual apparatus (Roitman, 2010) can be highlighted. S. Roitman (2010) questioned the acceptability of this name and noted that the existing name does not fully reflect the essence and features of this concept. Some similarities in understanding the community through the prism of urban planning issues were found in the work of T. Caldeira (2000). Based on some comparative data from the cities of São Paulo and Los Angeles, the author identified new models of segregation in 2000. A “gated community” as one of these forms was seen as a socially homogeneous area, fenced, and built up with several residential buildings (mostly high-rise), with a controlled entrance and all kinds of amenities for collective use. Subsequently, this topic is considered at the level of urban planning, and it is noted that gated communities are a form that physically separates a certain territory from its context and creates zones that limit the development of the functional and planning structure of the urban area.

The second group of works was formed later based on the first one and is more regional in nature, as it is tied to the study of gated communities in specific places. Some studies focus on the processes of functioning of different types of communities marked by cultural and ethnic diversity and the assessment of their impact on the development of society and the material and spatial environment in general (Balčaitė & Krupickaitė, 2018). For example, K. Barrantes Chaves (2021) notes that gated communities, which are actively spreading in Latin America, have a negative impact. They exacerbate feelings of fear and provoke social isolation. At the same time, the mechanisms of their functioning and development are not clearly explained in most of them. The reason for this is the interdisciplinary nature of the community as a unique phenomenon of social organisation within a specific place as of 2023.

The identification of specific features in the development of gated communities at the regional level gives impetus to expanding the concepts that characterise these communities and deepening the understanding of their functioning. P. İşcan & M. Akbulut (2019) noted that in Turkey, the phenomenon of transformation of gated communities has become noticeable. This is due to the inclusion of additional functions in such a structure to improve the quality of life of their residents. Therefore, they also emphasised the expansion of terminology and the introduction of new clarifying concepts, such as “urban container”.

A comparative analysis of current research on gated communities (Aulia & Suryani, 2020) has shown that the theoretical basis for most of them remains early works (Grant & Mittelsteadt, 2004; Atkinson & Blandy, 2005) on the nature and ways of functioning of gated communities as a social phenomenon. The definition of “gated community” proposed by E.J. Blakely & M.G. Snyder (1997) is the





most popular. It is believed that the authors were the first to give a reasonable assessment of closed enclaves in urban areas. It is possible to assume that this work contributed to the further development of discussions and research on this phenomenon.

Given the state of study of the problem related to the peculiarities of organising gated communities at the territorial level, it is necessary to direct research to expand the understanding of this phenomenon in the context of urban planning and to propose a more precise definition, considering gated communities as integral clusters of the modern urban environment.

TERMINOLOGICAL ANALYSIS OF THE CONCEPTS OF “COMMUNITY” AND “GATED COMMUNITY”

The conceptual and categorical apparatus is an indicator of the development of a particular field of scientific knowledge. For this reason, its development has become one of the priority areas of modern research and occupies a key position in the development of all branches of science. In architecture and urban planning, solving this kind of problem is particularly relevant. Here, concepts as a way of understanding and abstract representation of the results of cognition (Margolis & Laurence, 2007), including architectural and territorial objects, through understanding their defining characteristics, practically do not change but are actively expanding and deepening. There is a tendency for architectural and urban planning research to include a task that is limited to deepening and clarifying concepts and terms. This approach is driven by the constant development and changes in the modern urban environment, which require a more accurate and up-to-date terminological apparatus (Schliephake, 2014). First of all, it has become common for urban planning studies to deepen the existing conceptual and categorical apparatus based on a modern understanding of the specifics of the functioning of the material and spatial environment of the city (Pleshkanovska, 2021). Thus, as of 2023, the range of special concepts and terms in architecture and urban planning has become extremely wide. Due to the huge amount of such data, they should be divided into groups, each of which, in a certain context, can answer questions related to ethnic, cultural, substantive, territorial, functional, morphological, aesthetic, and temporal features of the city’s organisation and development.

In clarifying and deepening certain concepts and categories, of particular research interest are those that relate to the territorial, substantive, and cultural characteristics of the material and spatial environment of human activity and are interdisciplinary in nature. In this case, interdisciplinarity destroys the traditional boundaries of the scope of a certain concept, and its content, as European principles and standards are adapted, is expanded to include those properties that denote sustainable urban development. This situation emphasises the importance and increases the relevance of studying several categories and concepts that describe the concepts of implementing

European living standards in the urban environment and highlight such aspects of urban lifestyle as safety and comfort. Given the state of development of residential areas in Ukrainian cities, the implementation of the principles of safety and comfort is a priority. According to urbanists, to ensure their successful implementation, it is necessary to introduce European standards of urban living environment (Noltinh, 2020). On the other hand, in the context of new construction, it has become possible to shape it in a somewhat unusual way (Idak & Frankiv, 2022). In this situation, the real estate market is also important, as it tries to please the buyer in various ways in a competitive environment and promotes what they consider to be “modern” approaches to the development of residential complexes. Even though they proclaim the principles of comfort and safety as priorities, the real situation contradicts other principles of European city development. This contradictory connotation is reflected in the new urban form (Aulia & Suryani, 2020), which is called a “gated community”.

In 2020, the organisation of gated communities was recognised as a global trend (Hamama & Liu 2020). As gated communities are now more than just a simple set of certain physical and socio-legal characteristics (Atkinson & Blandy, 2005), interdisciplinary research has become widespread, as well as research focused on defining concepts and searching for categories that would provide a clear understanding of what gated communities are in the face of uncertainties and contradictions (Roitman, 2010). Therefore, when it comes to new forms of organisation of the material and spatial environment of human activity, as well as in the context of active implementation of the ideas of balanced urban development, the issue of explication of the concept of “gated community” is relevant.

The initial concept of the study is the term “community”. The terminological analysis, which is based on the studies of I. Bilodid (1978) and R. Boldyriev *et al.* (2006), confirms that its history dates back to the 14th century. At that time, the term was used to refer to a group of “several people connected by the fact of living in the same area”. Variants of the definition also included “ordinary people”, excluding rulers or clergy. The etymological roots of the term “community” from Latin, Old French, and Old English (Online Etymology Dictionary, n.d.) and Ukrainian (Boldyriev *et al.*, 2006) indicate the general idea of a group of people who share certain ties or common interests. At the socio-cultural level, community can refer to both abstract phenomena and concrete things that are described by physical dimensions. It also refers to things related to place and interests, feelings (and not always positive ones), identity and belonging (Lowe, 2021), as well as groups united by social media (Gruzd *et al.*, 2016). Finally, in the context of studying the current state of communities in urban society, L. Lyon & R. Driskell (2011) emphasise the differences in the definition of “community”. They note that when a word has multiple meanings, it is better suited to the subtleties of philosophy than to the strict precision required for scientific terms.



INTERDISCIPLINARY CHALLENGES OF THE CONCEPTS OF “COMMUNITY” AND “GATED COMMUNITY”

In the context of architecture and urban planning, the term “community” refers to the territory and resources shared by a group of people who share common interests, values, and behavioural habits. Communities can be of many different sizes and different types. Their size and character depend on whether they are located in the city centre, on the outskirts or in the suburbs, and on the ethnic or social group to which they belong. Ethnographic groups can be organic territorial “cells”. They are formed given the special structure-forming role of the territory and are distinguished by the way of economic activity and cultural peculiarities (Dnistryanskyi, 2006). Until the beginning of the 20th century, the structure of Ukrainian cities was characterised by specific clusters formed based on nationality. Compact living, a high level of self-organisation, established traditions and limited access to the territory allowed different ethnic groups to preserve their identity and coexist in interaction (Pasitska, 2012).

Given the development of cities following the principles of sustainable development, the task of considering

the social component has been updated. They are solved at the stage of forming different types of housing, organising specialised neighbourhoods, creating recreation centres, etc. Studies of the community as a social unit have become widespread (Chaskin, 1997; 2008). In a broad sense, one group of communities may include several others. For example, several ethnic groups may be located in a single territory (Tropman *et al.*, 2000). One of the varieties of the concept of “community” is “gated community”. It is characterised by restricted access for outsiders within a defined territory. In addition to the rules that apply here, they may have their own unique cultural, religious, or social identity, which distinguishes them from open communities. An example of the functioning of a boarding house as a social unit in the city structure is the territory of House Hohe Warte in Vienna (Austria) (Fig. 1). The territory consists of two parts: residential and recreational areas. While the former is closed, the latter, where the Setagayapark Japanese garden operates, is open to the public from April to October. The garden allows the residents to integrate and communicate with the “outside world”.

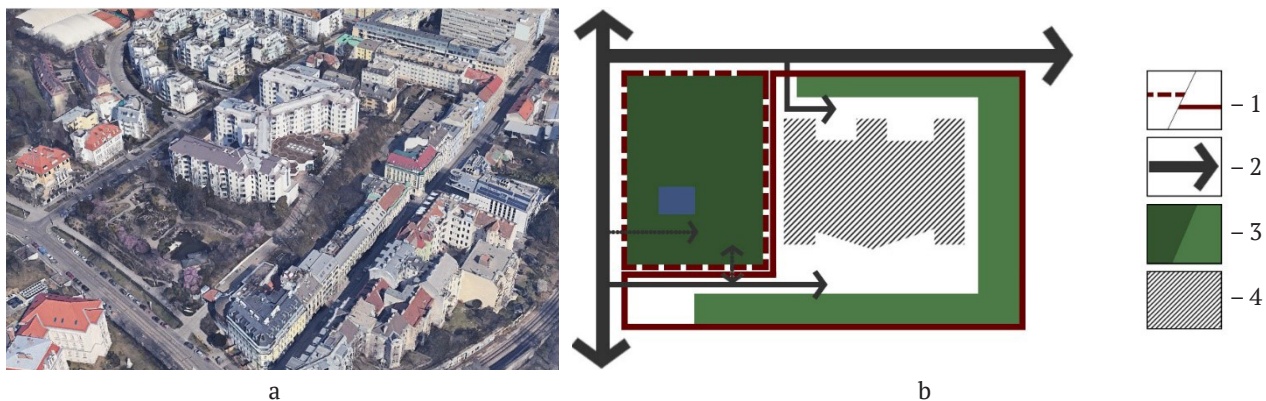


Figure 1. Features of the functional and planning organisation of the territory of the House Hohe Warte complex, Vienna (Austria): a – general view of the territory; b – scheme of functional and planning organisation of the territory

Notes: 1 – territory boundaries; 2 – transport/pedestrian connections; 3 – green areas; 4 – built-up area

Source: modelled by the authors based on Google Earth (2023)

Despite the considerable scientific heritage present in English-language publications, the concept of a “gated community” is still controversial in the Ukrainian language environment. The controversy is related to the interpretation and application of this term in the context of Ukrainian culture. There are several key reasons for this. Firstly, it is worth noting the socio-cultural and political changes that took place in the country during 1990-2007 (Polishchuk, 2018). Secondly, the impact of democratisation at the turn of the 20th and 21st centuries, which reformed the organisation of modern society, should be considered (Lozovytskyi, 2018). The third aspect is globalisation, which has influenced various spheres of life and has become one of the most common topics (Yuskiv, 2009). Finally, the fourth reason includes the expansion of cultural

exchange with other countries, which should also be considered in the context of this topic (Recommendation of the United Nations..., 1976).

In the Ukrainian context, the concept of a “gated community” can be defined in different ways, depending on which criteria and parameters are considered. On the one hand, it can refer to traditional rural communities, where for many centuries there were special rules, customs and norms that distinguished them from other social groups (Manuilova, 2019). On the other hand, it relies on the modern understanding of the concept of a “gated community”. It refers to social groups that voluntarily restrict other people’s access to their connections, information, or resources (Atkinson & Blandy, 2005; Le Goix & Webster, 2008). Most of these definitions focus on physical elements. Characteristics





such as the type of housing, location, and socioeconomic status of residents are not common or are subject to disagreement (Roitman, 2010).

In addition, the concept of a “gated community” can also have a controversial connotation associated with the possible negative consequences of “closeness”. For example, some closed communities function as a community with a real expression of social change in the context of transformation and the emergence of elite private groups that contradict the system of wealth distribution (Aulia & Suryani, 2020). Finally, K. Christiaanse (2007) is convinced that the openness of the modern city has peaked and closed enclaves are becoming the norm. Within the framework of the Urban Transformation forum, the author of the thesis notes that “Someday our grandchildren may tell their grandchildren that between 1820 and 2080, there was a period when cities were open ... Circulation within the city increasingly means traveling along a main transportation axis and turning off only for the purpose of entering closed or enclosed sectors”.

The topic of gated communities has been described as a physical expression of post-industrial social change (Le Goix & Webster, 2008) and has become particularly relevant in the context of sustainable development (Chaskin, 2008; Lyon & Driskell, 2011). On the one hand, gated communities are associated with physical security (Grant & Mittelsteadt, 2004; Le Goix & Webster, 2008; Aulia & Suryani, 2020). However, in this circumstance, they have relative characteristics due to their association with a sense of physical limitations that is opposed to human capabilities: that is, if any limits are set, a person feels a lack of development (Idak & Frankiv, 2022). On the other hand, the imposition of physical restrictions contradicts the current concept of social cohesion, which is popularised within the framework of sustainable urban development (Weigel, 2021) and is a consequence of post-revolutionary transformations in society (Rochovska & Miláčková, 2012). Such characteristics correspond to the ancient concept of the European city walls and gates, which were installed to limit and control the entrance to the settlement (Belk, 2017). Thus, the concept of a “gated community” in modern urban development can be viewed in two different ways. One is based on the need for physical security and control, and the other points to obstacles to social inclusion and the development of the city as a coherent community. Thus, depending on the specific conditions, the concept takes on different meanings, including contradictory ones.

THE CONCEPT OF “GATED COMMUNITY” AS AN URBAN PLANNING CATEGORY

If something controversial is to be comprehended, a logical and philosophical approach can be applied. Its experimental basis was the results of the spatial and typological analysis conducted in a previous study (Idak & Frankiv, 2022), as well as the collection of data on gated communities operating in new buildings in Lviv (Ukraine) as of 2023 (Catalogue of New Buildings in Ukraine, 2023). In this approach, the “gated community” is considered a

unique unit that takes place within the city and functions as a new form of its structural organisation. The experience of Lviv shows that at the territorial level, it is described by a fixed boundary, a typical functional organisation and planning structure, as well as a necessary set of infrastructure components (Idak & Frankiv, 2022).

In urban planning, a “gated community” should be considered as a unique form of organisation of a residential area, which is a separate structural element of the city with limited access to external influences and active social interaction. Considering the peculiarities of urban planning theory and practice, as well as the results of terminological analysis and semantic characteristics of the concepts of “community” and “gated community”, there is a need for an in-depth analysis of various aspects. Among these aspects, an important place belongs to the awareness of the situation when a “gated community” functions as a kind of enclave for the city, and for its residents it is not only a space with limited access, but also an area where the absence of danger and the solution of many social needs are ensured. Therefore, the meaningful boundaries of the concept of “gated community” can be revealed with the help of philosophical categories and other concepts that denote different aspects and meaningful boundaries of this definition. Such categories are fragmentation, which denotes the separation of a gated community, group identity, which emphasises the interaction of gated community residents, which is expressed at the level of material and spatial organisation of the living environment, and security, which indicates limited access.

Fragmentation is one of the consequences of the formation of gated communities in urban development (Barrantes Chaves, 2021). The Cambridge Dictionary (n.d.) defines fragmentation as the action or process of breaking something into smaller parts. In urban planning, this property is particularly important, as it can affect the development of urban areas (Angel *et al.*, 2012). The most common use of the concept of fragmentation is in information technology, ecology, and economics. In the natural and social sciences, this concept has a negative connotation, as it is associated with transformation and isolation. In the ecological context, fragmentation indicates a change in the shape and properties of the habitat (Aulia & Suryani, 2020). Fragmentation as a problem that indicates the irrational distribution of territory, and its inefficient use is written about in a cross-section of economic research aimed at the development of agriculture and agricultural business (Schultz, 1953). In general, territorial fragmentation is seen as a serious challenge. Given the growing division, diversity, and disparity between different types of territories, it is proposed to distinguish between different concepts (Böhme & Martin, 2019): a) geographical, caused by the diversity of natural zones, landscapes, and ecosystems; b) demographic, caused by differences in population density; c) political, defined at the legislative level for the organisation, management, and development of the territory; d) economic, which occurs in the context of uneven distribution of resources and their consumption.



Opinions differ on the assessment of this phenomenon in urban planning. Some point to the negative effects of such formations (Atkinson & Blandy, 2005), while others believe that fragmentation is not necessarily seen as something that should be prevented at all costs in urban planning and urban studies (Hidding & Teunissen, 2002). For example, the authors of the key work for this study (Le Goix & Webster, 2008) note that a gated community is an ephemera that hides the way a city is managed. It indicates a tendency to make certain urban planning decisions that fragment the territory into smaller parts that can be managed or analysed separately. As of 2006, in the United States, they accounted for a significant portion of the new housing market and symbolised the fragmentation of the metropolis (Le Goix, 2005). Fragmentation as a key attribute of urban spatial development is mentioned by S. Angel *et al.* (2012). Analysing satellite images of 120 cities for 1990 and 2000, the authors found that cities usually contain or disturb a huge amount of open space, which on average is equal to the area of their built-up areas, while it is noted that it is decreasing. The authors also reached certain conclusions: 1) large cities are less fragmented; 2) cities with higher income levels are more fragmented; 3) cities with higher car ownership are less fragmented; 4) cities that hinder urban development are less fragmented.

In the context of multiculturalism and diversity, when different cultures, nationalities, ethnic groups, and other diverse components coexist in a limited territory, the issue of forming and manifesting social identity is relevant and complex. Social identity has become a central object in the psychological sciences and is associated with a person's awareness of affiliation with certain social groups (Leaper, 2011). At the level of urban planning, the social identity aspect exists in the form of group identity, which involves both the categorisation of the "in-group" concerning the "out-group" and the tendency to perceive personal group with a positive bias towards other groups (Nientied *et al.*, 2022). The physical space of this type of formation is expressed by the specifics of lifestyle and can be either closed (Farid & Ahmed, 2018) or open. An example of the open type is the Domagk neighbourhood in Munich. Here, in 2012, a residential environment was created on the site of one of the largest art colonies in Europe. The cross-cutting idea in the organisation of such a formation was to preserve the artistic component and create opportunities for the realisation of the author's ideas at the level of organising the subject-spatial environment. The consequence of this decision was to ensure maximum cohesion of the inhabitants of the residential formation in a limited area (Idak & Frankiv, 2022). It should be noted that the three-dimensional composition of the Domagk development manifests itself as an independent and integral element, while the territory is not physically isolated, and the created space interacts with the surrounding environment. Finally, R.J. Chaskin (1997) notes that communities are open systems in which membership and obligations are partial and relative and that the definition of

neighbourhood boundaries is a negotiated and imperfect process, often driven by political considerations.

One of the defining characteristics that justifies the functioning of gated communities is safety. In a general sense, security includes taking measures to protect against potential threats from the outside and ensuring conditions for safe stay, in particular for children, in a certain territory. Lviv's experience has shown that the most common security measures in a gated community are the installation of security systems and access control. On the other hand, there is an opinion (Roitman, 2010) that gated communities are formed precisely because of the need to create a safe environment. An analysis of scientific sources (Sankov *et al.*, 2021) has shown the relevance of this category in the organisation of the urban environment. It is noted that the concept of safety includes a variety of aspects that reflect both the physical (Le Goix & Webster, 2008) and psychological safety of city residents. Much attention is also paid to social (Mitáš *et al.*, 2018) and environmental safety (Maas *et al.*, 2009).

Thus, the proposed categories reveal the semantic boundaries of the concept of "gated community", which considers its essential characteristics and various aspects of the organisation of the living environment as a unique form in the structure of the city. This expands the understanding of this concept and indicates the importance of further research for the development of urban planning theory and practice, as well as improving the quality of urban lifestyle.

CONCLUSIONS

At the current stage of development of urban planning theory, explication of the concept is a key tool for achieving clarity and depth of understanding, especially when it comes to interdisciplinary concepts. It is noted that both at the level of general scientific discourse and within a specific scientific concept, the concepts of "community" and "gated community" are controversial. Their meaning varies from the understanding of a concrete thing that denotes a fenced built-up area to an abstract phenomenon that represents a complex network of interactions and socio-cultural aspects, affecting the lives and identity of its inhabitants. It has changed significantly from the way it was used in the early stages of its formation. The term "community" as a group of "several people connected by the fact of living in the same area" does not correspond to the realities of today. It has acquired a much broader meaning compared to previous centuries, changing the way it is organised and the nature of its functioning. Now it is limited by social, territorial, economic and legal factors. Therefore, its specification requires a logical and philosophical approach. It is clarified that a "gated community" in urban planning is a unique form of organisation of a residential area, which is a separate structural element of the city with limited access to external influences and active social interaction. In this paper, the logical-philosophical approach is considered as a tool that helped to deepen the understanding of the concepts of "community" and "gated community" at the





territorial level by combining generally accepted categories that affect the quality of life in the city. These are those related to the spatial development of urban territory – fragmentation, formation of social interaction zones where people can exchange experiences, ideas, and resources – group identity and comfortable stay in a certain territory – security. It is noted that these categories do not have clear positive or negative characteristics, and their assessment depends on the conditions under which the gated community functions. This study creates a theoretical basis for

further research on the impact of gated communities on the territorial development of the city, as well as for studying strategies to improve urban life by finding optimal ways to integrate them into the urban planning structure.

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CONFLICT OF INTEREST

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**Богдан Степанович Черкес**

Доктор архітектури, професор
Національний університет «Львівська політехніка»
79000, вул. Степана Бандери, 12, м. Львів, Україна
<https://orcid.org/0000-0001-6809-956X>

Юлія Володимирівна Ідак

Доктор архітектури, професор
Національний університет «Львівська політехніка»
79000, вул. Степана Бандери, 12, м. Львів, Україна
<https://orcid.org/0000-0002-1123-5759>

Роман Богданович Франків

Кандидат архітектури, доцент
Національний університет «Львівська політехніка»
79000, вул. Степана Бандери, 12, м. Львів, Україна
<https://orcid.org/0000-0003-1100-0930>

Поняття «закрита спільнота» та його експлікація у теорії і практиці містобудування: огляд літератури

Анотація. Актуальність дослідження полягає у розширенні змістовних меж понять, що активно використовуються в сучасній містобудівній теорії та практиці. Таким є поняття «закрита спільнота», яке через свій міждисциплінарний характер в сучасній теорії і практиці містобудування не є чітко означене і змістовно окреслене. Мета дослідження спрямована у розкритті та розумінні сутності поняття «закрита спільнота», виявлення його взаємозв'язків із урбаністичними концептами та встановлення його ролі в контексті теорії і практики містобудування. У дослідженні використано комплексний методологічний підхід, що базується на логіко-філософському підході і поєднує термінологічний та просторовий аналізи. У ході дослідження було визначено сутнісні ознаки понять «спільнота» та «закрита спільнота», а також їх взаємозв'язок з іншими поняттями, що стосуються організації житлового середовища на територіальному рівні. Розширено визначення поняття «закрита спільнота» з урахуванням містобудівної компоненти. Результати дослідження вказують на те, що формування закритих спільнот можуть мати як позитивний, так і негативний вплив на розвиток міста. Запропоновано розглядати закриті спільноти як групу об'єктів, що характеризуються вираженою орієнтацією на внутрішню взаємодію та взаємодопомогу між її членами. Такому визначенню передували результати щодо розкриття місця та ролі «закритих спільнот» у структурі міста, виявлення сутнісних ознак вихідних для дослідження понять «спільнота» та «закрита спільнота», встановлення взаємозв'язку із тими поняттями, що мають місце при описі особливостей організації житлового середовища на територіальному рівні, а також відповідності визначення закритої спільноти до її специфіки функціонування на територіальному рівні. Визначено, що у містобудуванні її характерними ознаками є фізична ізоляція та контрольований доступ. Уточнено, що такий тип спільноти може призводити до роздробленості міста на менші відокремлені територіальні одиниці. Практичною цінністю даної роботи є можливість врахування її результатів у процесі розробки стратегії розвитку міста з метою раціональної організації житлового середовища. Крім того, результати можуть допомогти керуючим інституціям визначити оптимальні шляхи співпраці з закритими спільнотами, забезпечуючи баланс між їх потребами і вимогами до збереження міської ідентичності та сталості

Ключові слова: закриті житлові комплекси; сутнісні ознаки; концепти; містопланування



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Roman Liubytskyi*
PhD in Architecture
Lviv Polytechnic National University
79013, 12 Stepan Bandera Str., Lviv, Ukraine
<https://orcid.org/0000-0001-8666-7743>

Development of the transport network considering the specifics of Lviv's planning structure (compared to Leipzig and Krakow)

Abstract. The relevance of this study is determined by the need to adapt the transport network of Lviv to the requirements of modern urban traffic. The planning structure of Lviv was formed based on radial roads, later developing ring connections, which is typical for most European cities, but eventually acquired its own characteristics. The purpose of this study was to analyse the specific features of the current planning structure of Lviv, which affect the development of urban transport infrastructure and mobility of each mode of transport. The methodology of this study involves analysing the modern street and road network as the formative basis of the planning structure of the city of Lviv and assessing transport mobility based on geospatial data from open sources. Comparison with similar European cities, such as Leipzig and Krakow, helps to highlight the specific features and rational ways of developing Lviv's transport network. The results of the study point to the main feature of Lviv's planning structure, which is its compactness and high population density – twice as high as in comparable cities. This makes it impossible to adapt the transport infrastructure for car travel and highlights the need to improve public transport networks and cycling infrastructure as more efficient and environmentally friendly ways of urban transport. However, the study of urban transport mobility found that the means of limiting the use of private cars in Lviv are inferior to those implemented in comparable cities, and the public transport network and bicycle infrastructure are underdeveloped and do not provide a quality alternative to car travel as of 2023. The practical value of the study lies in highlighting the most problematic aspects of Lviv's transport infrastructure that require urgent decisions to function in the context of the specific planning structure of the city

Keywords: urban mobility; sustainable urban transport; development of urban transport; transport system of European cities; historically formed cities

INTRODUCTION

The planning structure of Lviv was historically formed based on radial roads that were not designed for the intensity of modern traffic (Petryshyn & Liubytskyi, 2018). The same path was followed by most European cities, which were formed from the early Middle Ages based on a radial-ring planning structure. With the growth of cities and the emergence of new ways of moving around them, the planning structure, which is based on the street and road network,

has undergone appropriate transformations to meet the requirements of modern traffic.

The specific feature of Lviv, compared to Western European cities, is that the development of modern transport infrastructure in post-Soviet cities began only in 1990, along with the rapid growth of motorisation as a result of the transition to a market economy (Cavoli, 2021). At the same time, processes of rapid urban densification began

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*Corresponding author



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and are still ongoing due to the rapid construction that became possible in market conditions (Habrel *et al.*, 2020). For example, in the Ukrainian SSR in 1981, the level of motorisation was 31 cars per 1,000 residents (for comparison, in Germany it was about 300 cars per 1,000 residents). The small number of cars in the Soviet period led to stagnation in the development of transport infrastructure, the state of which still affects traffic today. On the other hand, it minimised radical interventions in the historical planning structure of Lviv. For comparison, as early as the 1950s, the scientific literature of developed countries considered the idea of introducing fees for private cars entering the central zones of cities (Lehe, 2019).

To limit the presence of vehicles in the city, especially in narrow historic streets with limited capacity, it is advisable to apply a strategy of intercepting cars at the entrances to the city, including the median zone and the city centre itself. These measures are aimed at excluding transit vehicles through the urban space, as well as at intercepting vehicles travelling from nearby settlements to the agglomeration centre and for movement within the city itself. Measures to restrict the use of private cars are aimed at improving the functioning of other means of transport in the city. It has been proven that in more developed countries with higher incomes, citizens prefer sustainable modes of transport to car travel, and that cars have a negative impact on stress levels (Avila-Palencia *et al.*, 2018).

In cities that have inherited historically dense development, it is important to give preference to public transport as the main means of urban mobility, given its ability to carry many passengers compared to cars, while taking up less space on the road. In historic European cities, trams and light rail are the main public transport modes, achieving high passenger and speed performance (De Las Heras-Rosas & Herrera, 2019). Providing priority to public transport on roads and designating dedicated lanes are strategically important measures to avoid traffic congestion. The comfort of public transport, which includes coverage of all urban areas by a network, precise timetables, maintenance of vehicles, etc., makes it more attractive for citizens to use it, which at the same time helps to reduce the frequency of private car use.

A well-developed network of bicycle paths and a well-developed public transport system have a positive impact on reducing the use of private cars in the urban environment. Historic cities with dense, compact development have significant potential for the development of cycling and walking infrastructure. Recent studies indicate that the old neighbourhoods of historic cities are much more attractive for these modes of travel than new urban areas (Telega *et al.*, 2021). By avoiding busy main streets, walking, or cycling is often faster and more comfortable than using public transport or a private car, and a typical cycle lane has 5 times the capacity (per person) and one parking space can be replaced by a parking space for 10 bicycles (Gehl, 2018).

The purpose of this study was to identify the specifics of the current planning structure of Lviv, which has an impact on the development of urban transport infrastructure

and mobility of each mode of transport. A common modern trend in the development of a sustainable transport system in the planning structure of a historic city is the simultaneous implementation of two sets of measures – restrictions on private cars and the development of alternative urban transport – public, cycling, and walking. This article sets the following objectives:

- Analysis of the planning structure of the city, the formative basis of which is the historically formed street and road network;
- Assessment of urban transport mobility – private cars, public transport, cycling;
- Identification of rational approaches to the development of Lviv's transport network and individual modes of transport, considering the unique features of the planning structure, which is a scientific originality of this study.

MATERIALS AND METHODS

The study was conducted in two stages: firstly, an analysis of the city's planning structure was used, and then, based on this, urban mobility was assessed for each mode of transport. For the comparative study, the cities of Leipzig and Krakow were chosen, which are similar to Lviv in terms of their historically formed radial-ring planning structure, historical development, and population (Lviv – 758,500, Leipzig – 575,000, Krakow – 744,230). The comparison with similar cities helped to identify approaches to the development of the transport network that are appropriate for Lviv, as well as to identify those that are irrational due to the differences in the city's planning structure.

By analysing the planning structure of the city, the key elements of the planning structure of cities were identified, such as different categories of motorways (international, national, regional, etc.) that pass through the city and the intra-city street network. The presence and level of development of the system of ring streets and roads of various categories used for transit and intra-city movement to bypass the historic core was assessed. It was also planned to determine the length of the street and road network to assess the potential of urban mobility.

The assessment of urban transport mobility included an analysis of the mobility (efficiency of use) of private cars, urban public transport, and cycling. The analysis of private car mobility was carried out in the context of restrictions on movement within the city. The research phase included the identification of the main ring streets and roads, the location of transfer hubs ("Park&Ride" car parks), and the identification of areas where the presence of cars is restricted. The stage of public transport mobility analysis involved identifying the areas of the city covered by different types of public transport services and conducting calculations to determine the extent of coverage of the city (line lengths) by each of these types of transport. Furthermore, the study considered the convenience of use – compliance with timetables, the condition of the rolling stock fleet, etc. At the stage of analysing cycling mobility, the study identified the areas covered by the bicycle route network and

calculated the extent of this coverage. Moreover, the quality of the cycling infrastructure was analysed, including the logic of cycling connections, routing (via motorways or quiet streets), characteristics of cycle tracks and their location (on carriageways or dedicated lanes), and the availability and number of cycle parking spaces.

The main source of source data used for the study was the OpenStreetMap geospatial platform (n.d.), data from which was obtained using the QGIS geographic information system through the “QuickOSM” plug-in. The study of geospatial data of urban transport network elements using a geographic information system allows for the analysis and further processing of a large array of data, which as a result objectively reflects the quantitative and qualitative indicators of the elements under study. Some of the thematic layers of OpenStreetMap geospatial data may contain minor inaccuracies and be incomplete, but for the scale of the entire city and the formulation of fundamental patterns, the use of this data is of great value.

The original geospatial data, which was extracted from the list of OpenStreetMap layers (n.d.) and used in the study:

- planning structure of cities – a layer of the street and road network (“key=highway”), which contains data on streets and roads of all hierarchical levels (“key=highway, value=primary”; (“key=highway, value=secondary”, etc.);
- private car mobility – a layer of the road network (“key=highway”) with further selection of ring roads; layers of car parks (“key=amenity, value=parking” etc.) with selection of interceptors (“Park and Ride”); a layer of boundaries (“key=boundary”), which may contain data on restricted parking zones;
- public transport mobility – a layer of routes (“key=route”), which contains data on public transport routes of all types (“key=route, value=tram”; (“key=route, value=bus” etc.); taxi stands (“key=amenity, value=taxi”);
- bicycle mobility – a layer of bicycle paths (“key=cycleway”; “key=highway, value=cycleway”); a layer of routes with dedicated bicycle routes (“key=route, value=bicycle”) of different hierarchical levels – international, national, regional, local (“network=icn/ncn/rcn/lcn”); location of bicycle rental points (“key=amenity, value=bicycle_rental”); bicycle parking (“key=amenity, value=bicycle_parking”).

Furthermore, to the OpenStreetMap geospatial platform, the study used additional sources for each city under study, which complement the OpenStreetMap data and contain specific information, including data on ring roads; location of interceptor car parks (“Park&Ride”); parking restriction zones, etc. In the end, the quantitative and qualitative results of the study were formulated based on the generalisation of data, the density of the city’s street and road network, the length of the public transport network, the presence of bypass rings, etc. Based on the data obtained, thematic diagrams were developed and the results were compared, followed by the formulation of conclusions: establishing the interdependence of mobility of different modes of urban transport on the existing planning structure of cities; comparing the characteristics of the planning structure and

transport mobility of Lviv, Leipzig, and Krakow; substantiating the feasibility of future development of each mode of transport in the planning structure of Lviv.

RESULTS AND DISCUSSION

The planning structure of the cities of Leipzig, Krakow, and Lviv. The cities under study – Lviv, Leipzig, and Krakow – used a system of radial paths in their historical planning of their structure, which were directed to the central part of the city. After the dismantling of the medieval walls (in Lviv in 1777 (Krypiakevych, 1991); Leipzig in 1777 (Franz, 2004); Krakow in 1806 (Swiszczowski, 1955)) that ran around the historic core, circular “streets around the city” were formed, which at the present stage perform both transport and walking functions. Subsequently, the development of the planning structures of these cities continued based on radial paths, while creating connecting ring links between them.

Leipzig. Leipzig’s main motorway network covers various road categories, including motorways of European importance, autobahns, federal motorways, and state motorways. Other types of roads in Germany, such as district and local roads (kreisstraße, gemeindefraße), are designed to provide local communications. Transit motorways of European significance and motorways bypass the city of Leipzig, unlike federal and state roads, which run through the inner-city planning structure. This is conditioned by the fact that even within the historic centre of the city, these roads are wide. For example, the federal road “87”, which runs right up to the city centre on the north side, has 6 lanes for car traffic and 2 separate lanes exclusively for tram traffic (Fig. 1).

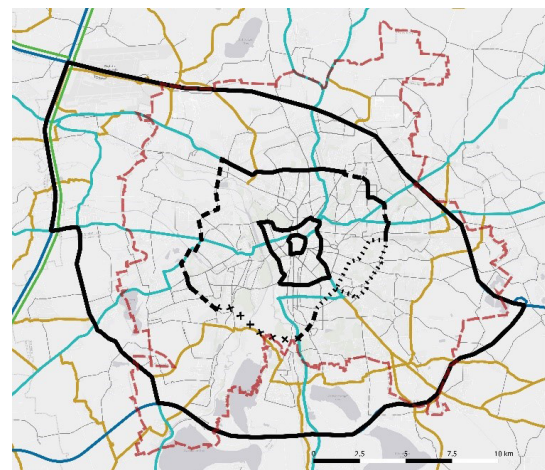


Figure 1. Street and road network as the basis of the planning framework of Leipzig

Notes: city limits are marked with a red dashed line; existing bypasses are shown with black lines, projected bypasses with a long-dashed line, suspended bypasses with a short-dashed line, and blocked bypasses with crosses; European motorways (“E”) are shown in green, Autobahns in dark blue, federal roads (“B”) in light blue, state roads (“L”) in yellow, streets and local roads in thin grey lines

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)



The wide width of the streets in Leipzig ensures a high capacity for traffic moving within the city. This situation can be explained by the consequences of the post-war reconstruction of Leipzig, which led to the expansion of historically established neighbourhoods and the construction of new streets through the city centre. Nevertheless, Leipzig is marked by a distinctive historical radial-ring planning structure, in which four bypass rings stand out. The first ring (“Innenstadtring”) runs through the former medieval walls (Franz, 2004). The second ring is called the “Tangentenviereck” (Department of Urban Development and Construction, 2004) and runs between 0.50 and 1.5 km from the first ring, roughly bypassing the boundaries of the area built up until the end of the 19th century (Busch, 1891). As of 2023, the third bypass ring (“Mittlerer Ring”) is not completed and bypasses the core of the historic city at 3 to 6 km, roughly on the border of the interwar period (City of Leipzig, n.d.-b). Due to insufficiently substantiated transport feasibility and crossing of city parks, the development of incomplete southern and eastern segments of the third ring caused protests among residents, which in turn stopped the design process. Implementation of measures to build the northern and western sections of the third transport ring is envisaged in the medium and long term (Department of Urban Development and Construction, 2011). The fourth transport ring does not have clearly defined official boundaries, but

its contours are clearly recognisable in the planning structure. This network coincides with the motorways and federal roads that bypass the city, functioning for transit traffic at 7-15 km from the centre of Leipzig (Fig. 1).

Based on the analysis of geospatial data from OpenStreetMap (n.d.), the total length of the street and road network was calculated to be 2,314.47 km. It is estimated that there are 4.02 m of street length per resident (population 575,000). With an area of 297.36 km², Leipzig has a street and road network density of 7.78 km/km².

Krakow. In the transport system of Krakow, road categories are represented by motorways of European importance, motorways, and expressways, national roads and voivodeship roads. These categories, except for voivodeship roads, provide interconnection between the largest cities in Poland or are intended for international transit. Voivodeship roads serve to connect the main cities of the voivodeships. The remaining categories of roads in Poland – county and municipal roads (droga powiatowa, droga gminna) – are used to provide local communication (Announcement of the Sejm of the Republic of Poland..., 2017). The network of major roads in Krakow, except for the voivodeship roads, goes around the city along the administrative boundary. The voivodeship roads that run radially from the second bypass ring are key routes to national and international transit roads (Fig. 2).

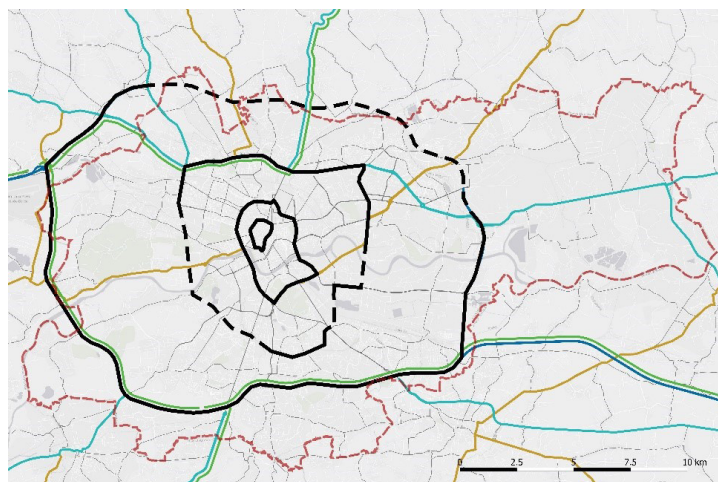


Figure 2. Street and road network as the basis of the planning framework of Krakow

Notes: The city limits are indicated by a red dashed line; existing bypasses are shown as black lines, and projected bypasses are shown as dashed lines; motorways of European importance (“E”) are marked in green, motorways (“A”) and expressways (“S”) in dark blue, national roads (drogi krajowe) in light blue, voivodeship roads (drogi wojewodzkie) in yellow, streets and roads of local importance in thin grey lines

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

There are four bypass rings in Krakow, the development plan of which is prescribed in the City Development Strategy until 2030 (Resolution of the Krakow City Council No. XCIV/2449/18, 2018). The first bypass ring runs through the areas where the medieval city walls were located. The second ring, which bypasses the historic core outside its boundaries, is located at a distance of 0.5 to

2 km from the first ring, roughly along the contour of the territory built up until the end of the 19th century. The third ring is in implementation and covers the territory that was built up during the interwar period (except for the part adjacent to the east) (Zaremba, 1930). As of 2023, the western and eastern segments are still unfinished. Once completed, the third bypass ring will bypass the historic city centre at

3 to 5 kilometres. The fourth bypass ring in the southern and western parts of the city coincides with the A4 international motorway, and the northern segment of this ring is being implemented. Upon completion, the fourth ring will run close to the administrative city boundary of Krakow, at 6 to 10 kilometres from the historic centre (Fig. 2). The implementation of a network of bypass ring roads is of great strategic importance for Krakow, specifically because most of the streets in the historic part of the city have one-way traffic due to the small width of the streets, which causes considerable difficulties for transit travel.

Based on the analysis of geospatial data from OpenStreetMap (n.d.), the total length of the street and road network of Krakow was found to be 2,666.51 km. It is estimated that there are 3.58 m of street length per resident (population 744,230). With an area of 326.85 km², Krakow has a street and road network density of 8.16 km/km².

Lviv. The network of key roads in Lviv consists of roads of European importance, international roads of state importance, national roads of state importance and regional roads of state importance. Roads of European significance and international roads are used for transit traffic across the country's borders, national roads play the role of connecting administrative centres of oblasts, and regional roads provide connections between cities of oblast and rayon levels (Law of Ukraine No. 2862-IV, 2001). The main motorways, including international and European ones, are integrated into the internal transport system of Lviv and pass through the central part of the city, which contributes to the congestion of the central part with transit vehicles (Fig. 3).

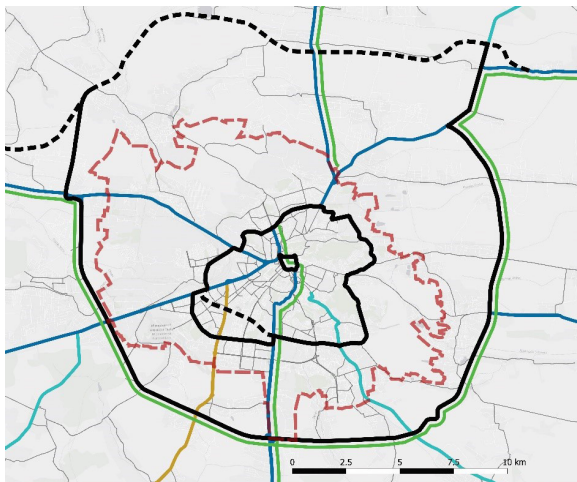


Figure 3. Street and road network as the basis of the planning framework of Lviv

Notes: the city limits are marked with a red dashed line; existing bypasses are shown with black lines, projected bypasses with a dashed line; European motorways (“E”) are shown in green, international motorways (“M”) in dark blue, national motorways (“N”) in light blue, territorial motorways (“T”) in yellow, streets and roads of local importance are shown with thin grey lines

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

Lviv's bypass roads include three traffic rings. The first ring runs along the territory where the medieval city defensive walls used to be located, which were completely dismantled in 1825. The second bypass ring was formed roughly along the contour of the city territory built up during the interwar period and as of 2023 is located at a distance of 1.5 to 4.5 kilometres from the first bypass ring. The current alignment of the ring is different from the plans for its development that were laid down in the Soviet period but never came to fruition. In the post-Soviet period, the city experienced and continues to experience rapid construction, the location of which is determined by commercial interests rather than urban development requirements (Habrel *et al.*, 2020). The number of traffic lanes on the second bypass ring varies, affecting the change in capacity on different segments. The third ring is a city bypass road laid at 8 to 10 km from the outline of the historic centre of Lviv. The lack of the northern ring segment causes transit traffic to pass through the historic part of the city, and the large distance of the second bypass ring from the central core of Lviv excludes the possibility of intra-city traffic bypassing the historic part of the city. Furthermore, the historic core of the city still performs its original functions today, with 4 administrative offices, 45 service establishments, and 8 cultural institutions located on Rynok Square itself, adding to the traffic load on the historic centre (Cherkes & Linda, 2019). The planning structure of Lviv does not have a bypass ring that would bypass the central part of the city, which is typical for other similar historic cities (the second Leipzig and Krakow bypass ring) (Fig. 3).

Based on the analysis of OpenStreetMap geospatial data, the total length of Lviv's street and road network was found to be 1,360.85 km. It is estimated that there is 1.79 m of street length per resident (population 758,500). With a city area of 150.09 km², the density of the street and road network is 9.07 km/km².

Mobility of private cars in Leipzig, Krakow, and Lviv. *Leipzig.* Roads that provide international and domestic transit are represented by motorways that bypass the city. Federal (Bundesstraße) and state (Landesstraße) roads are woven into the city's structure and even adjoin its historic centre. This is explained by the extensive network of German high-speed motorways, which began to develop in 1920 (Schiller *et al.*, 2010). Most transit traffic passes through motorways, while other roads have a lower priority and play a secondary role in providing intra-agglomeration and intra-city connections. The main transit flow through the city is intercepted by two bypass rings: the “Tangentenviereck” (second) and the “Mittlerer Ring” (third), the latter of which has unfinished sections that are being completed in stages to reduce the importance of the federal motorways within the second bypass ring (Department of Urban Development and Construction, 2011).

To intercept private cars that are regularly used by residents to commute to the city centre, Leipzig has a well-developed network of interceptor “Park&Ride” facilities, which includes 14 sites with a total capacity of 3,208 parking



spaces (City of Leipzig, n.d.-b). The “Park&Ride” network is built on the existing infrastructure of the “S-Bahn” urban high-speed railway and is often also adjacent to tram services. Parking in these interceptor car parks is free of charge and the operating hours are around the clock.

Since 2011, Leipzig has had an “Ecological Zone” (“Umweltzone”), which covers 62% of the city (City of Leipzig, n.d.-a). Private cars are only allowed within the “Ecological Zone” if they are compliant with the established emission standards and have a green sticker. This restriction applies to all types of vehicles, including those owned by foreign drivers. Furthermore, to improving the environmental situation in the city, the “Ecological Zone” also regulates the access and transit of cars through the city.

To reduce the parking pressure on the historic centre of Leipzig, 12 multi-level or underground car parks with a total of 7,124 spaces are located around the historic core. These car parks are owned by different companies and set different prices for their services and opening hours (City of Leipzig, n.d.-b). The operation of a paid parking zone covering an area of 8.97 km² in the central part of the city helps to reduce the attractiveness of using private cars for trips to the city centre (City of Leipzig, 2020) (Fig. 4).

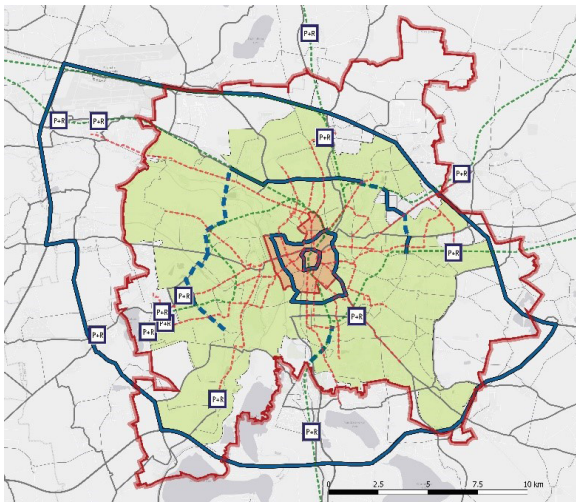


Figure 4. Means of intercepting private vehicles in Leipzig

Notes: city limits are indicated by a red line; existing bypasses are shown by blue lines, planned bypasses are shown by a dash; intercepting “Park&Ride” facilities are shown by the “P+R” icons; paid parking zones in the city centre are shown with a red fill, the “Ecological Zone” (“Umweltzone”) with a green fill; the “S-Bahn” network is shown with green dashed lines, the tram network with red dashed lines

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

Krakow. Unlike Leipzig, Krakow does not have any international motorways in its internal planning structure. International and domestic transit trips are carried out via the outer ring road (the fourth ring), but the northern section of this ring is still unfinished as of 2023. This leads to the fact that traffic from the northern direction of the city passes

through the northern fragment of the third ring, which is included in the inner-city structure. In turn, intra-agglomeration and intra-city transit traffic mainly passes through the second ring, as fragments of the third ring are currently missing. The city authorities of Krakow note that the second bypass ring does not meet the required capacity, so the completion of the third ring, which is envisaged in the development strategy, is essential to avoid local transit traffic through the central area of the city (Resolution of Krakow City Council No. XCIV/2449/18, 2018).

To control the entry of cars regularly travelling to the city from the Krakow agglomeration (daily labour migration), interceptor “Park&Ride” car parks located at the tram terminals are used. Currently, there are five such car parks in the city with a capacity of 843 cars, and two more are under construction (Road Administration of the city of Krakow, n.d.). Interceptor car parks are available from 4.30 am to 2.30 am, with a daily parking fee of PLN 10. During the day, the use of public transport is free for parking users. If one buys a public transport pass, the use of interceptor parking is free of charge (Resolution of Krakow City Council No. LIII/723/12, 2012). By the year 2030, according to the city’s parking programme, it is planned to implement 17 interceptor car parks in the city, which will provide parking for 3570 cars (Public Information Bulletin of the City of Krakow, 2012).

To limit the excessive number of cars in the historic part of Krakow and reduce the so-called “cruising for parking” phenomenon (Barter, 2016), Krakow has a paid parking zone covering 12.78 km² of the historic part of the city (Resolution of Krakow City Council No. LXXXIX/2177/17, 2017) (Fig. 5). Furthermore, 30 parking garages are planned to be built on the territories within the second ring, four of which have already been constructed.

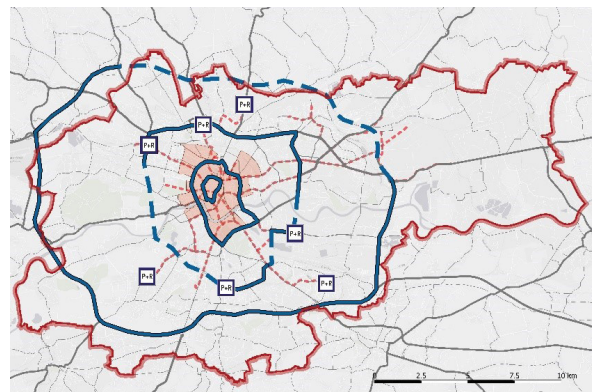


Figure 5. Means of interception of private vehicles in Krakow

Notes: city limits are shown as red lines; existing bypasses are shown as blue lines, projected bypasses are shown as dashed lines; “Park&Ride” intercepts are shown as “P+R” icons; paid parking zones in the city centre are shown as red fills; tram network is shown as red dashed lines

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

Lviv. The restriction of private cars in the central part of Lviv is partially implemented by traffic rings that redirect





transit trips. Although the second ring is formally present on the city plan, its imperfections are explained by its brokenness, partial overlap with radial roads, and variable width of the cross-sectional profile and, accordingly, the number of lanes. The missing segment of the bypass road (the third ring) causes international and intercity transit trips through the historic centre of Lviv. The long distance from the first to the second bypass ring causes excessive traffic on the I ring for intra-city travel. The situation is further complicated by the fact that Lviv is the centre of a monocentric agglomeration that “attracts” a significant amount of traffic from the surrounding settlements (Rusanova, 2015). A study was conducted on the impact of traffic congestion (5 km/h) on the environment (on the example of the Bandera Street), which indicates an 8-fold increase in emissions compared to a 50 km/h traffic flow (Kachmar & Lanets, 2020).

The restriction of the presence of cars in the historic part of Lviv is implemented through a pedestrian zone in the historic core of the city, which today runs roughly along the border of the medieval city walls, as well as five paid parking zones. Parking zones I-III with a total area of 7.2 km² have clearly defined boundaries (Fig. 6), while zone IV formally covers the rest of the city. V zone – special paid parking areas near the airport and railway station. Paid parking zones apply only to designated on-street parking spaces within their boundaries, so even in the central part of the city there is still a significant number of “free” parking spaces – especially in the third parking zone. The progress and problems of on-street parking in the central part of Lviv are discussed separately in the publication C. Zhou *et al.* (2022).

There are no transport hubs with intercepting car parks (“Park&Ride”) on the boundary of the historic area in Lviv. Also, no garages have been built in the central part of the city, which would be aimed at short-term “daytime” visitors (“Park&Walk”). Such garages should replace on-street parking spaces to expand pedestrian areas and improve the conditions for other modes of public transport.

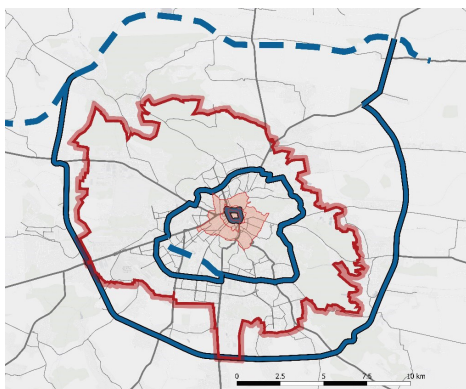


Figure 6. Means of interception of private vehicles in Lviv
Notes: the city boundary is marked by a red line; existing bypass rings are shown by blue lines, projected ones – by a stroke; I-III paid parking zones in the central part of the city are marked with a red fill
Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

Mobility of public transport in Leipzig, Krakow, and Lviv. *Leipzig.* The geospatial data analysis revealed that Leipzig’s urban public transport system consists of a network of tram, bus, and rail routes with a total length of 514 km (with a city area of 297.36 km² and a density of 1.73 km/km²). Tram lines are 146 km long, bus lines are 302 km long, and rail lines are 66 km long. There is a well-developed network of interceptor “Park&Ride” facilities at tram and rail (“S-Bahn”) terminals, as well as on the city’s outskirts outside the third ring, which are free of charge (Leipzig transport company, 2023). The tram lines run close to the city limits and the IV bypass ring. In 2013, the construction of a 3.6-kilometre long (5.3 km including portals and ramps) “S-Bahn” tunnel under the city centre was completed, with 4 railway stations. Tickets for public transport are unified, which makes it possible to transfer between diverse types of transport. There are one-day, three-day, weekly, and monthly passes that enable travel within the city or agglomeration, as well as tickets for groups (Leipzig transport company, n.d.). The density of the public transport network in Leipzig, including the passenger-capacity and highly mobile tram and rail networks, is 0.71 km/km² (Fig. 7).

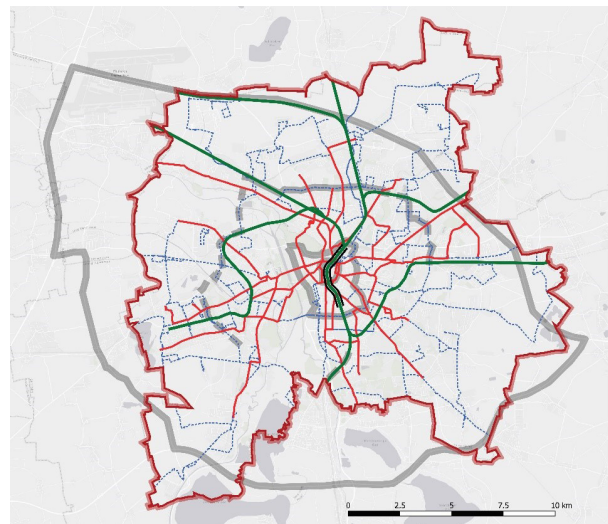


Figure 7. Public transport network in Leipzig
Notes: city limits are shown as red lines; the “S-Bahn” network is shown as green lines, the tram network as red lines, and the bus network as blue dashed lines; existing bypasses are shown as light grey lines, and the projected bypasses are shown as dashed lines
Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

Krakow. The city’s public transport is represented by tram and light rail systems, a bus system, and a railway network with a total length of 498 km. Given the city’s area of 326.85 km², the density of public transport lines is 1.52 km/km². Analysis of geospatial data showed that the tram network has a length of 97 km, including a high-speed tram with a network length of 32 km. The specific feature of Krakow’s tram network is the presence of an underground



tunnel that runs under the city centre. Its construction was completed in 2008. The tunnel is 1,538 metres long and has 2 underground stations. Most of the tram lines are directed to the peripheral districts of Krakow outside the third ring. There is also an extensive network of free "Park&Ride" car parks at the tram terminals (Road Administration of the city of Krakow, n.d.). The tram network is complemented by bus routes that cover areas of the city not covered by the tram network. The total length of the bus lines is 327 km. Furthermore, the 74 km long railway network in Krakow is used for both intra-city and agglomeration passenger transport (TOR Economic Advisory Team, 2011). The density of the network of highly mobile and passenger-capacious public transport modes in Krakow, such as tram, light rail, and rail, is 0.52 km/km² (Fig. 8). The public transport network in Krakow is divided into two zones: inner-city and agglomeration, with ticket prices depending on the zone chosen. Tickets (hourly, daily, monthly, and group tickets) are standardised for travel by any type of public transport, including rail, and allow transfers between diverse types of transport (Municipal Communication Company in Krakow, 2021).

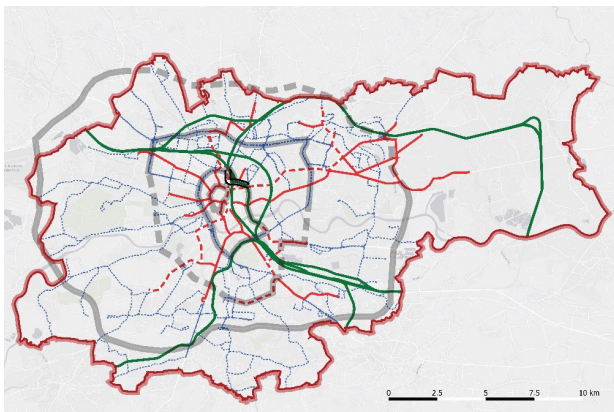


Figure 8. Public transport network in Krakow

Notes: city limits are marked with a red line; railway network is shown with green lines, tram network with red lines, BRT routes with red dashed lines, bus network with blue dashed lines; existing bypasses are shown with light grey lines, projected bypasses are shown with a dash

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

Lviv. Lviv's public transport system consists of a network of tram, trolleybus, and bus routes. According to OpenStreetMap (n.d.), the total length of the lines is 257 km, and the total density of the network of all public transport modes is 1.71 km/km² with a city area of 150.09 km². The tram network is 34 km long. Lviv's tram lines were laid in the city's interwar period (Kotlobulatov, 1931) and run only up to the boundaries of the modern second bypass ring. The exception is the newly built line to the Sykhiv district. Transport links in the new areas of typical Soviet-era housing construction were provided by a trolleybus network, which today has a total length of 52 km. The rest of the city is served by a 170 km long bus network.

The network of highly mobile and passenger-intensive urban transport (including only tram lines) has a density of 0.23 km/km² (Fig. 9).

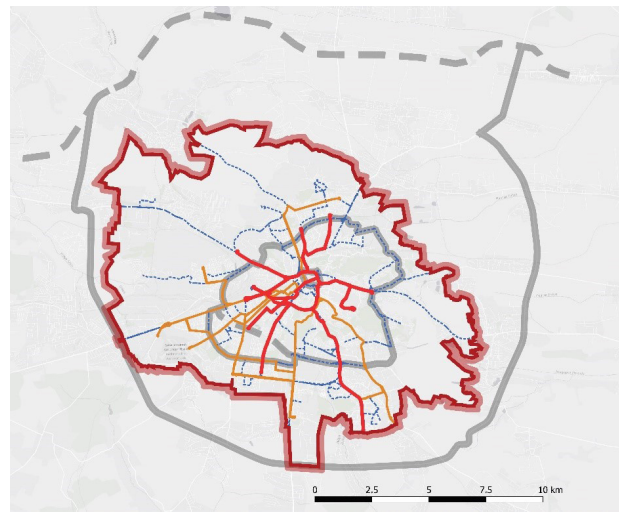


Figure 9. Public transport network in Lviv

Notes: city limits are marked with a red line; tram network is shown with red lines, trolleybus network with orange lines, bus network with a blue dashed line; existing bypass rings are shown with light grey lines, projected ones with a dash

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

The planning and development of the Lviv light rail network, which began in Soviet times, has not received a boost in the modern period either. As of 2023, only designated tram lanes on Horodotska, Chernivetska, Vakhnyanyna, Sakharova, Lychakivska, Knyahyni Olhy Streets and a new line on Chervonoi Kalyny Avenue, which was also planned to be implemented in the Soviet period, are operational (Novakovskij *et al.*, 1983). Due to the fact that tram traffic mostly runs on shared carriageways with cars, strict adherence to timetables is not possible. The concept of a high-speed tram with underground tunnels, which was developed in the Soviet period, was not implemented due to difficult geological conditions.

As the tram network is underdeveloped, the peripheral areas are served only by buses and partially by trolleybuses. The bus network is mainly provided with small-sized rolling stock with low passenger capacity, and modern large-sized buses mostly serve radial routes with the highest demand (EasyWay, n.d.). Most existing trolleybuses have already suffered wear and tear and obsolescence – as of 2017, 59 out of 78 trolleybuses are models or modifications of developments of the 1970s and 1980s (Škoda 14TR, 15TR, LAZ-52522) (Ukrelectrotrans, n.d.). One of the most significant problems that hinders the smooth operation of bus and trolleybus routes is the movement of these vehicles along with private vehicles on common carriageways.

Despite the presence of railway lines and stops in the central part of Lviv, the existing railway infrastructure is



not used for regular city and intra-agglomeration passenger transport. An unsuccessful six-month experiment in 2009 to introduce a “rail bus” from the Sykhiv district to the central part of Lviv was stopped due to unprofitability, which was caused by a bad schedule and long travel times (From Sykhiv to Pidzamche..., 2021).

As of 2023, there is no single ticket in Lviv public transport that would allow transfers between different modes of transport and routes. The use of the electronic fare collection system is limited and available only for tram and trolleybus routes. Even though most buses have already been equipped with validators for cashless payment, only privileged passengers can use them, while others pay for travel only in cash.

Cycling mobility in Leipzig, Krakow, and Lviv.

Leipzig. The total length of bicycle routes in Leipzig is 904 kilometres, including 193 kilometres of nationally important bicycle roads and 711 kilometres of city bicycle routes. The number of bicycles for every thousand Leipzig residents is 905 (City of Leipzig Transport and Civil Engineering Department, 2018). The network covers areas of Leipzig that do not have adequate tram connections and connects the main recreational facilities that form the city’s waterfront. The total density of bicycle routes in Leipzig is 3.04 kilometres per square kilometre (Fig. 10). The network of bicycle infrastructure is formed by “Nextbike” bicycle rental stations, which serve 32 stations, as well as 927 bicycle parking spaces (OpenStreetMap, n.d.).

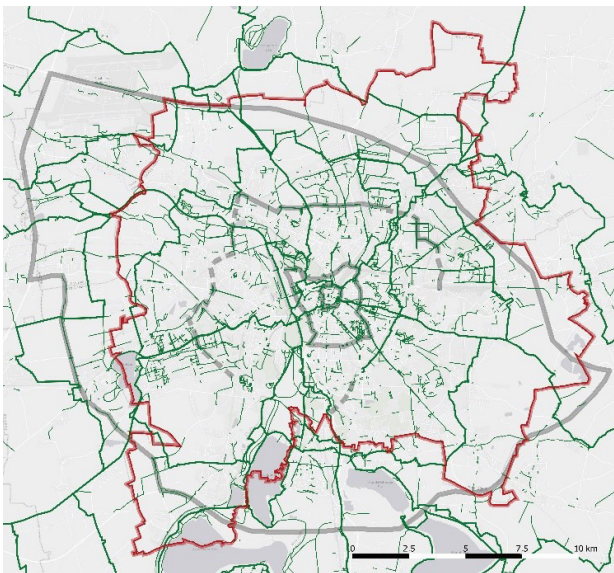


Figure 10. Leipzig cycle network

Notes: the city limits are marked with a red line; the network of main bicycle routes is shown with thick green lines, secondary bicycle routes with thin green lines; existing bypass rings are shown with light grey lines, projected ones with a dash

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

Krakow. Krakow’s cycling network is 658 km long, of which 169 km are national cycle routes and 489 km are city cycle paths. A denser system of bicycle routes is developed in the west-east direction, which compensates for the lack of tram lines in these areas. Krakow has a well-developed infrastructure for cyclists, which is mainly concentrated in the historic city centre (within the third bypass ring). It is estimated that the density of Krakow’s cycling network is 2.02 km/km² (Fig. 11). Within the third bypass ring, rental stations are located at a distance of 500 to 1,000 m. According to OpenStreetMap (n.d.), there are 1,406 bicycle parking spaces in the city.

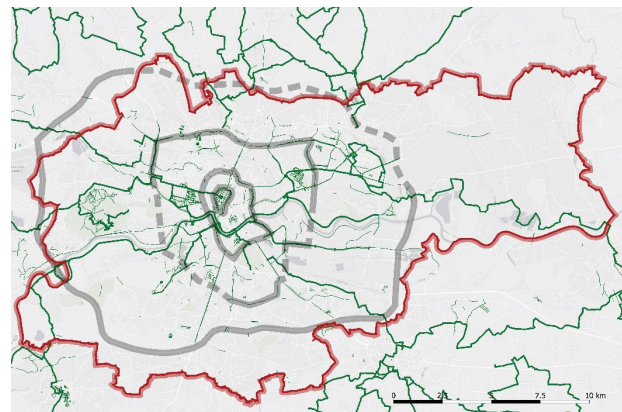


Figure 11. The network of bicycle paths in Krakow

Notes: the city limits are marked with a red line; the network of main bicycle routes is shown with thick green lines, secondary bicycle routes with thin green lines; existing bypass rings are shown with light grey lines, projected ones with a dash

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

Lviv. The total length of urban bicycle routes in Lviv is 304 km, mostly concentrated within the second bypass ring. The main challenge for cycling infrastructure is the lack of systemic connections, which in many areas are interrupted and suddenly end. The total density of bicycle paths in Lviv is 2.03 km/km², although this figure also includes paths in parks, which are formally also suitable for cycling (Fig. 12). Lviv does not have a network of bicycle routes of national importance (as in Leipzig or Krakow), which would serve to connect the main urban areas, towns and villages of the agglomeration and tourist and recreational routes. The cycling infrastructure, according to OpenStreetMap (n.d.), consists of 24 “Nextbike” bicycle rental stations and 150 bicycle parking spaces. In recent years, there has been a growing interest in cycling, with the city launching the “Bolt” and “E-wings” electric scooter rental services and considering the creation of mobile applications for cyclists (Teslyuk *et al.*, 2019).

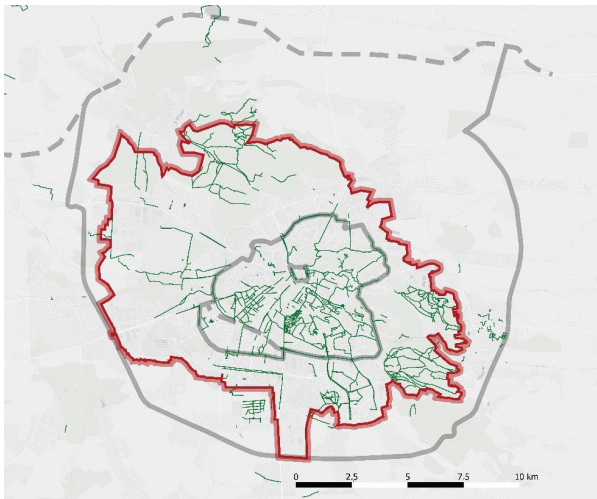


Figure 12. The network of bicycle routes in Lviv

Notes: city limits are marked with a red line; the bicycle network is shown with green lines; existing bypass rings are shown with light grey lines, projected ones are shown with a dash

Source: developed by the author of this study based on geospatial data from OpenStreetMap (n.d.)

The layout of bicycle lanes within the cross-sectional profiles of streets is imperfect, creating dangerous situations for pedestrians and cyclists. In the central part of the city, one can find bicycle lanes that are laid on sidewalks and marked only with a distinct colour paving type (e.g., on Kulisha, Sichovykh Striltsiv, Horodotska Streets) or on the roadways (Voronoho Street).

Specifics of the development of Lviv's transport network. The analysis of the parameters of the street and road network as the main formative element of the planning structure of the cities under study helps to highlight the specific features of Lviv. With the same population, Lviv has twice the population density, which is due to the city's twice smaller area. The length of Lviv's street and road network per capita is also half as long (Table 1). The above facts, as well as the fact that Lviv has not undergone major street reconstruction and widening in the past, prove that the city is unsuitable for intensive traffic development. Nevertheless, unlike Leipzig and Krakow, transit roads of international and European importance run through the historic part of Lviv, and the incomplete system of bypass traffic rings (especially the lack of a ring that would bypass the historic centre) provokes transit traffic through the historic core of the city.

Table 1. Generalised indicators of planning structure and urban transport mobility in Leipzig, Krakow, and Lviv

No.	Indicator	Leipzig (575,000 residents)	Krakow (744,230 residents)	Lviv (758,500 residents)
Characteristics of the planning structure				
1	City area	297.36 km ²	326.85 km ²	150.09 km ²
2	Length of the street and road network	2,314.47 km	2,666.51 km	1,360.85 km
3	Per 1 resident	4.02 m	3.58 m	1.79 m
4	Density of the street and road network	7.78 km/km ²	8.16 km/km ²	9.07 km/km ²
5	Main roads through the historic city centre	no	no	yes
6	Bypass transport rings	4	4	3
Urban transport mobility				
<i>Private motor transport</i>				
7	Number of cars	253,575	292,492	153,217
8	Cars/1,000 residents	441	393	202
9	Cars/km ² of the city	853	895	1021
10	Cars/km of street	110	110	113
11	Interceptor car parks ("Park&Ride")	14 (3,208 parking spaces)	5 (843 parking spaces) + 2 (under construction)	-
12	Controlled parking area	8.97 km ² of paid parking area in the city centre (dedicated parking spaces) 62% of the city's area ("Umweltzone")	12.78 km ² of paid parking zone in the city centre	7.2 km ² of paid parking zones in the city centre (zones I-III, dedicated parking spaces)
<i>Public transport</i>				
13	Length of public transport network	514 km	498 km	257 km
14	City railway	66 km	74 km	-
15	Tram	146 km	97 km	34 km
16	Bus	302 km	327 km	170 km



Table 1. Continued

No.	Indicator	Leipzig (575,000 residents)	Krakow (744,230 residents)	Lviv (758,500 residents)
17	Trolleybus	-	-	52 km
18	Network density (total)	1.73 km/km ²	1.52 km/km ²	1.71 km/km ²
19	Network density (urban rail and tram)	0.71 km/km ²	0.52 km/km ²	0.23 km/km ²
<i>Bicycle transport</i>				
20	Length of the cycle network	904 km	658 km	304 km
21	Network density	3.04 km/km ²	2.02 km/km ²	2.03 km/km ²
22	Bicycle parking	927	1,406	150

Notes: numerical indicators were calculated by the author using QGIS based on geospatial data from OpenStreetMap (n.d.), except for those specifically referenced in the text

Source: developed by the author of this study

The number of private cars in Lviv is half that of Leipzig and Krakow, despite the same population, but their pressure on the road network is more noticeable as of 2023. This is explained by the fact that the number of cars in Lviv per km² of city area is already 20% higher than in Leipzig, and 14% higher than in Krakow. Given the prospects for growth in car ownership to reach the European average of 560 cars/1,000 residents in 2020 (European Automobile Manufacturers' Association, 2022), and in the absence of new restrictive measures on the use of private cars, Lviv will face a transport collapse. G. Zantke (2015) substantiated the need to introduce restrictions on entry to the central part of Lviv. The feasibility of such restrictions for cars is substantiated by many studies on sustainable urban transport, namely, P. Schiller *et al.* (2010), V. Vuchic (2017) and L. Lehe (2019).

Despite the need for restrictions on cars, Lviv has not yet implemented any transport hubs with intercepting "Park&Ride" car parks that would restrict the entry of private vehicles into the city centre. For comparison, there are 14 such hubs in Leipzig, 7 in Krakow, and there is a consensus to increase their number. A positive trend is the expansion of the paid parking zone in Lviv, which since 2018 has increased from 0.95 to 7.2 km² (parking zones I-III, which have clearly defined street boundaries), but within the third zone there are still many streets with free parking spaces (Zhou *et al.*, 2022). The experience of Krakow, where the paid parking zone provides for payment for parking on all streets within its boundaries, and not only on separately defined streets, as in Lviv, seems appropriate.

Although the density of the public transport network in Lviv and comparable cities is identical, it is misleading. This is because, according to the study, 86% of the network in Lviv is bus and trolleybus transport, with most of it being small buses. This type of transport is inefficient in historic districts, as it is not possible to organise dedicated lanes on most of Lviv's narrow streets. The remaining 14% is covered by the tram network, which in historically established European cities is usually the basis of public transport due to its high passenger capacity and high mobility, as well as the priority of trams on the roadways. The railway will not be used for urban transport in 2023. In contrast, in Leipzig

and Krakow, the total share of trams and urban rail in the public transport structure is 41 and 34%, respectively. According to modern works in the field of public transport development, specifically P. Daniels *et al.* (2013), J. Walker (2014) and E. Sclar *et al.* (2016), it should be the basis of urban transport, especially in dense historic cities, and its operation should be unhindered by dedicated traffic lanes.

According to OpenStreetMap (n.d.), the density of bicycle paths in Lviv is comparable to Krakow (Leipzig has half as many), which indicates the gradual development of this type of urban transport. Given the much smaller number of bicycle parking spaces in Lviv, it can be concluded that the popularity of using a bicycle for urban transport is low today. Nevertheless, the city's compactness (the distance from the centre to the bypass road is only 8-10 km) substantiates the relevance of developing and promoting cycling, which is also confirmed by the studies of E.J. Adams *et al.* (2016) and A. Telega *et al.* (2021), which emphasise that historic city districts are more attractive for cycling than new ones. A widely used measure in European cities is the conversion of individual on-street parking spaces into bicycle parking (Pucher & Buehler, 2012; Gehl, 2018), which is also rational for Lviv.

The generally accepted approaches to sustainable transport development mentioned in the above works are also necessary for implementation in Lviv. However, the results of this study highlight the city's distinctive characteristic – high population density combined with the compact historical planning structure of Lviv, which exacerbates the problem of transport infrastructure more than in similar cities.

CONCLUSIONS

The study covered the specific features of Lviv's planning structure, which include a high population density and a preserved compact network of narrow historic streets, which makes intensive car traffic impossible and requires solutions to improve highly mobile and passenger-capacious modes of urban transport. First and foremost, solutions are needed to optimise the planning structure – organising bypass routes for the central part and removing transit roads from it. The construction of new large-scale architectural and urban planning complexes should be



carried out outside the historic area, which will reduce the additional traffic load on the historic centre of Lviv. Furthermore, it is advisable to reconsider the removal of city and regional administrative functions from the historic core.

The creation of missing interceptor “Park&Ride” lots and the improvement of strict paid parking zones in Lviv can motivate residents not to use cars without a justified need, without introducing a “ban”, but by regulating the demand for parking spaces with high prices. These solutions are politically unpopular and will not gain the support of residents at first, but this is the path taken by all European cities that have experienced excessive traffic pressure on the road network. Reducing car traffic on the streets of Lviv will create the preconditions for the development of alternative modes of urban transport. For mass and fast movement, the most efficient way is the tram network, which is underdeveloped as of 2023. It should be expanded to densely populated areas outside the city’s historical area. Small bus routes, which currently account for the largest share of urban transport, should only complement the network of highly mobile

and passenger-capacious public transport in remote and sparsely populated areas of the city.

The generally accepted trends of “sustainable transport development in historic cities”, such as limiting car use and developing public transport and cycling, are ideal for Lviv, but given the specific features of the planning structure identified in this study, measures should be more decisive, rigorous, and urgent. Given the specific features of Lviv mentioned in the article, further research on the decentralisation of the city centre and the formation of new sub-centres is relevant, which will reduce the traffic pressure on the historic part of the city. In addition, given the compactness of Lviv, special attention should be paid to the development of the cycling and pedestrian infrastructure network, which also deserves future research.

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None.

CONFLICT OF INTEREST

None.

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Роман Ігорович Любицький

Кандидат архітектури

Національний університет «Львівська політехніка»

79013, вул. Степана Бандери, 12, м. Львів, Україна

<https://orcid.org/0000-0001-8666-7743>

Розвиток транспортної мережі із врахуванням специфіки планувальної структури Львова (у порівнянні з Лейпцигом та Краковом)

Анотація. Актуальність статті зумовлена необхідністю адаптації транспортної мережі Львова вимогам сучасного міського руху. Планувальна структура Львова формувалася на базі радіальних доріг, згодом розвиваючи кільцеві зв'язки, що притаманно більшості європейських міст, проте із часом набула власних особливостей. Метою статті постає аналіз особливостей сучасної планувальної структури Львова, які впливають на розвиток міської транспортної інфраструктури та мобільності кожного виду транспорту. Методика даного дослідження передбачає аналіз сучасної вулично-дорожньої мережі, як формотворної основи планувальної структури міста Львова та оцінку мобільності транспорту, спираючись на геопросторові дані із відкритих джерел. Порівняння із схожими європейськими містами – Лейпцигом та Краковом, дозволяє виокремити особливості та раціональні шляхи розвитку транспортної мережі Львова. Результати дослідження вказують на основну особливість планувальної структури Львова, яка полягає у його компактності та високій щільності населення – вдвічі більший за порівнювані міста. Це унеможливує адаптацію транспортної інфраструктури для автомобільних поїздок та підкреслює необхідність вдосконалення мереж громадського транспорту і велоінфраструктури, як більш ефективних та екологічних способів міського пересування. Проте дослідження міської транспортної мобільності виявило, що засоби обмеження використання приватних автомобілів у Львові поступаються тим, які реалізовано в порівнюваних містах, а мережа громадського транспорту та велоінфраструктури розвинена недостатньо і станом на 2023 р. не складає якісної альтернативи автомобільним поїздам. Практична цінність дослідження полягає у виокремленні найбільш проблемних аспектів транспортної інфраструктури Львова, які вимагають прийняття невідкладних рішень задля функціонування в умовах специфіки планувальної структури міста

Ключові слова: міська мобільність; сталий міський транспорт; розвиток міського транспорту; транспортна система європейських міст; історично сформовані міста



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Dzhumamedel Imankulov

Doctor of Architecture, Professor
Kyrgyz State Technical University named after I. Razzakov
720044, 66 Ch. Aitmatov Ave., Bishkek, Kyrgyz Republic
<https://orcid.org/0009-0007-9256-0134>

Tian Jing

Doctoral Student
Kyrgyz State Technical University named after I. Razzakov
720044, 66 Ch. Aitmatov Ave., Bishkek, Kyrgyz Republic
<https://orcid.org/0009-0003-4139-0957>

Wu Fei

Doctoral Student
Kyrgyz State Technical University named after I. Razzakov
720044, 66 Ch. Aitmatov Ave., Bishkek, Kyrgyz Republic
<https://orcid.org/0009-0003-9597-3218>

Tatyana Filatova

PhD in Architecture, Associate Professor
Kyrgyz State Technical University named after I. Razzakov
720044, 66 Ch. Aitmatov Ave., Bishkek, Kyrgyz Republic
<https://orcid.org/0009-0001-1333-2560>

Azyk Orozonova*

PhD in Economics, Associate Professor
Kyrgyz National University named after Jusup Balasagyn
720033, 547 Frunze Str., Bishkek, Kyrgyz Republic
<https://orcid.org/0000-0001-6877-7674>

The architectural complex of Shah Fazil in legends and writings about the period of the Arab conquest of Ferghana

Abstract. The historical and architectural complex of Shah Fazil is one of the holiest places for Muslims and a historical monument, and the relevance of its study is related to its religious, historical and cultural importance. The purpose of the study is to investigate the establishment of the Shah Fazil architectural complex and determine the connection between the legends about the foundation of the Shah Fazil mausoleum during the Arab conquest of Ferghana and real historical facts. The study used general scientific methods of analysis and synthesis, comparison, as well as historical-critical, comparative and dialectical methods. As a result, it was established that the Shah Fazil architectural complex is a unique object of cultural heritage. It includes several architectural monuments, the most significant of which is the 11th

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*Corresponding author



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century mausoleum. Of particular value is the interior of the mausoleum, decorated with carved carvings and religious inscriptions. According to legend, the founder of the complex, the great-grandson of the prophet Muhammed, Shah Fazil, who conquered the Ferghana Valley in the 7th century, is buried in the mausoleum. Here, according to legend, is the burial place of 2,700 Arab soldiers, companions of Shah Jarir, father of Shah Fazil, who died at the hands of local pagans. The soldiers were buried by the maid Safid-Bulan, after whom the village where the complex is located is named. The figures appearing in the legend of the individual are the fruit of folklore, but the story itself has a historical basis and serves as an echo of real events that took place at the beginning of the conquest of the Ferghana Valley by the Arabs. The practical value of the study is determined by the fact that its materials can be used in further research of the historical and architectural complex of Shah Fazil, and is also a source for the use of elements of ancient architecture in the design of modern buildings

Keywords: Islamic architecture; mausoleum; mazar; mashhad; ornament; hankov carving

INTRODUCTION

One of the historical sites on the territory of Kyrgyzstan, which has important cultural and religious significance, is the Shah Fazil complex in the village of Safid-Bulan, Jalal-Abad region. This object is of interest as a monument of Islamic architecture, and as one of the most ancient architectural monuments associated with Islam preserved on the territory of modern Kyrgyzstan. Shah Fazil, in addition, has an important religious significance as a place of pilgrimage for Muslims. The village of Safid-Bulan is one of the mazars, that is, holy places where the burials of Muslim saints are located. The sacred significance of this place is connected with a legend that traces the foundation of the Shah Fazil complex to the time of the Arab conquest of Ferghana. According to legend, 2,700 Arab warriors, martyrs of Islam killed by local pagans, are buried here. The complex itself, according to legend, was built by the great-grandson of the Prophet Muhammad, Shah Fazil, who finally conquered the Ferghana Valley. By the name of the founder, who, according to the legendary version, was also buried in this mausoleum, the complex got its name (Exnerová, 2023).

The Shah Fazil complex is a unique ancient monument of Islamic architecture on the territory of Kyrgyzstan, so its study is still relevant in many scientific articles. D. Imankulov *et al.* (2020), for example, in their paper emphasised the architectural features of the Shah Fazil complex in the context of the architecture of the Karakhanid era. The legends about the foundation of the Shah Fazil complex and their possible connection with real historical events were investigated by S. Kamoliddin (2022). The researcher analysed different versions of legends and came to the conclusion that the personalities of Shah Fazil and other persons associated with the foundation of the complex according to legend are purely legendary. The author attributes the foundation of the complex to the 11th century and believes that Muhammad ibn Nasr of the Karakhanid dynasty was buried in the mausoleum.

V. Exnerová (2023) also discusses The Shah Fazil complex in the context of other monuments of Islamic architecture of Central Asia. The researcher explored the sacred sites for Muslims located in the Ferghana Valley and architectural monuments that were built here in the Middle

Ages. The author notes that Central Asia is characterised by the presence of mazars, among which, in addition to Shah Fazil, she mentions the Buston Buva mazar in the Ferghana Valley. Such objects, according to the author, served as places of memory for local Muslims. The history of Islamic architecture and medieval architecture of Central Asia, in particular, was studied by R. Mukimov & S. Mamaljonova (2020). The researchers give a general description of the traditions of construction in Central Asia in the Medieval era, analyse the process of development of temple architecture, and also point to a significant number of mazars as one of the features of the Central Asian region.

Collective study by E. Boronbaev *et al.* (2023) is devoted to the preservation of the Shah Fazil complex in the 21st century. The problem for the preservation of the complex, especially its valuable interior decoration, is high humidity, especially in the winter season. The researchers specify that as of 2023 the Shah Fazil mausoleum has unacceptable microclimate conditions, since too low temperature and high humidity are observed on the inner surfaces of the walls and in the lower zones of the dome. In most of the papers devoted to the study of this topic, the historical and architectural complex of Shah Fazil is considered in the context of the general development of Islamic architecture in Central Asia. On the other hand, the research pays insufficient attention to the architectural features of the complex itself, its key differences from other similar structures in Central Asia, and the process of forming the object as an integral architectural ensemble.

The purpose of the study was to trace the establishment of the Shah Fazil architectural complex, determining the connection of oral legends about its foundation with the data of historical sources. In accordance with the goal, the following tasks are set: to investigate the architectural features of the Shah Fazil complex; to determine the historical and cultural significance of the Shah Fazil complex for Kyrgyzstan and Central Asia.

MATERIALS AND METHODS

In the process of studying the designated topic, various methods were used. Using the method of analysis, it was possible to investigate the architectural features of the Shah

Fazil complex, and, in addition, to trace the process of establishment of the complex, starting from pre-Islamic times and ending with the modern era. The method of analysis also helped to give a certain assessment to the legends and works that provide information about the foundation of the Shah Fazil complex. In addition, using this method, it was possible to collect data on the architectural, historical and cultural characteristics of the Shah Fazil complex, and to conduct a primary analysis of the specific data obtained. The above method provided a clear and specific characterisation of the architecture of the Shah Fazil complex.

The synthesis provided an opportunity to understand the commonalities in various historical and architectural complexes of the mazar type located in Central Asia. Moreover, the synthesis allowed presenting a general picture of the creation of monuments of Islamic architecture in Central Asia. At the same time, the comparison helped to bring together the information of legends about the connection of the Shah Fazil complex with the Arab conquest of Ferghana. Based on this method, it was possible to determine the key points of the legendary narrative and to find the historical basis of the legends under study.

The historical and critical method allowed investigating this issue from the standpoint of the evaluation of historical sources for their reliability. Using this method helped to look at the texts telling about the foundation of the Shah Fazil complex not literally, but considering the historical context, and also to determine the degree of their historical authenticity. It was with the help of the historical and critical method that it was possible to isolate the historical grain from the legendary information about the foundation of the Shah Fazil complex during the Arab conquest of Central Asia, and to determine how much this information corresponds to the information of historical sources about the process of the Arab conquest of the Ferghana Valley and the further Islamisation of its population.

The comparative method helped to investigate the common and different in architectural complexes of the mazar type located in various regions of Central Asia. It was possible to determine how similar these objects are to the Shah Fazil complex, and what their fundamental difference is. The comparative method helped to investigate the legends and data from historical sources about the foundation of the Shah Fazil complex, the Arab conquest of Ferghana, and the death of Arab soldiers-martyrs, identifying key differences and determining what is common in these legends and historical sources.

Finally, the dialectical method allowed investigating the legends about the foundation of the Shah Fazil architectural complex during the Arab conquest of Ferghana in the context of historical events that took place at that time in Central Asia and the struggle that took place between the leaders of the Central Asian Sogdian principalities and the Arab conquerors. The juxtaposition of data determined the main stages in the Islamisation of the region and the emergence of Islamic architecture objects here. In addition, this method allowed designating the Shah Fazil complex

as a place that demonstrates the connection between the pre-Islamic era in the history of Central Asia and the time when this region became part of the Islamic world.

RESULTS

The oldest monument of Islamic architecture on the territory of modern Kyrgyzstan is the Shah Fazil complex, located in the Ferghana Valley, on the land where the famous Great Silk Road once passed. Shah Fazil is a place of pilgrimage for pious Muslims, since, according to a popular legend, 2,700 martyrs of Islam – Arab soldiers who died at the hands of pagans at the beginning of the Arab conquest – are buried here. Thus, Shah Fazil is one of the mazars, that is, the resting place of an Islamic saint, which is a place of pilgrimage for Muslims. The presence of mazars is a characteristic feature of the Central Asian region. Some places here are designated as the resting place of one or another iconic person in the history of Islam, and the veneration of Central Asian mazars is based mainly on local folk legends, and not reliable historical sources (Mukimov & Mamaljonova, 2020). Often such holy places are revered not only as tombs, but also as Mashhad, that is, the place of martyrdom of Muslims for their faith. In Central Asia, mazars are usually associated with the martyrdom of the Askhabs, companions of the Prophet Muhammad (Kamoliddin, 2022). It is worth noting that Islam prohibits direct worship of a saint or an object associated with him, as this contradicts the principle of monotheism. However, Islam allows the veneration of the memory of the holy righteous in his resting place, which determines the spread of Muslim pilgrimage to the mazars (Kuiper, 2009).

The Shah Fazil complex itself has a longer history than the era of Islamisation of Central Asia. The veneration of this place was characteristic of pre-Islamic times. According to archaeological research, there was a sanctuary on the territory of the village of Safid-Bulan, within which Shah Fazil is located, back in the Bronze Age. In the pre-Islamic era, this place was a sanctuary of the phallic cult, which is now recalled by a vertically standing stone in the form of a phallus, preserved since that time and being an integral part of the Shah Fazil complex (Soucek, 2000; Boronbaev, 2020).

Despite the unambiguous antiquity of the complex, local legends associate its foundation with the time of the Arab conquest of Ferghana. The key figures in this story are three legendary personalities: the grandson of the Prophet Muhammad Shah Jarir, his son, and, accordingly, the great-grandson of the Prophet Muhammad, Shah Fazil, as well as the Shah Jarir's servant Safid-Bulan, after whom the village where the Shah Fazil complex is located was named. According to legend, Shah Jarir set out to conquer the Ferghana Valley, and Shah Jarir was successful at first: he managed to defeat the local rulers Akhshid and Karvan-bas. However, taking advantage of the moment when Shah Jarir and his soldiers were performing Friday prayers, Karvan-bas and his fighters attacked the unarmed Muslims. As a result



of the massacre, 2,700 Arab soldiers laid down their heads, but Shah Jarir himself managed to escape. Next to the fallen soldiers was a black servant of Shah Jarir named Bulan. She washed the heads of the martyrs cut off by the enemies and buried them. Because of the incessant work, Bulan's hands were worn to the bone, and her skin suddenly turned white. Therefore, it began to be called Safid-Bulan, that is, White Bulan. Forty years after the events that took place, Shah Jarir's son Shah Fazil arrived in the Ferghana Valley with an army of Muslim Arabs. He managed to finally conquer this region and spread Islam here. In addition, by order of Shah Fazil, a complex was built at the place of the death of his father's companions, where Shah Fazil himself was later buried (Kamoliddin, 2022; Exnerová, 2023).

According to legendary data, the Arab conquest of Ferghana took place in the 7th century, but according to historical sources, this event took place in the 8th century and is associated not with the legendary personalities of Shah Jarir and Shah Fazil, but with the Arab commander Kuteiba ibn Muslim (Kennedy, 2007; Tor, 2009). No reliable historical sources confirm the existence of such personalities as Shah Jarir, Shah Fazil, and Safid-Bulan. Regarding the opponents of the Muslims of the local rulers Akhshid and Karvan-bas, then, most likely, there are not proper names here, but the titles of rulers adopted at that time. It can be clearly understood that the name Akhshid means the title of ikhshid, which was worn by the Sogdian rulers before the Arab conquest (Kennedy, 2007). The image of the girl Safid-Bulan, most likely, refers to pre-Islamic religious archetypes. The name Bulan is not Arabic, but Turkic in origin, meaning "deer" or "moose".

Thus, the name Safid-Bulan literally means "white deer". Most likely, the image of Safid-Bulan has its roots in pre-Islamic ideas about the deer girl as a totemic deity or guardian (Kamoliddin, 2022). Despite the dubious historicity of the legend of Shah Fazil, it is likely that it has some factual basis. It is possible that during the first caliphs, Arab conquerors raided the territory of Central Asia and the Ferghana Valley. Then for the first time the Arabs came face to face with the local rulers of the Ikhshids and with the unwillingness of the local population to undergo violent Islamisation. The echoes of these first clashes between the population of the Ferghana Valley and the Arabs are folk legends, which, after the final establishment of Islam in this region, acquired the character of a story about the martyrdom of the Islamic conquerors (Ettinghausen *et al.*, 2001; Kuiper, 2009).

The earliest capital buildings of the complex do not belong to the 7th or 8th centuries, but to the 11th century. Based on this, the Shah Fazil complex belongs to the monuments of the epoch when most of Central Asia was under the rule of the first Turkic dynasty of the region, the Karakhanids. The most likely ruler who laid the mausoleum and was buried in it is a representative of the Karakhanid dynasty, Muhammad ibn Nasr, who ruled in part of the Karakhanid state between 1020 and 1056. The identity of Muhammad ibn Nasr is known, first of all, according to numismatics, very little is known about him (Soucek, 2000) (Fig. 1). The construction of the Shah Fazil complex, which began under Muhammad ibn Nasr, was completed during the reign of his son Malik, the former ruler of Ferghana (Biran, 2015; Kamoliddin, 2022).



Figure 1. Coins of Muhammad ibn Nasr

Source: modelled by the authors based on a real coin

In addition to the mausoleum of the Karakhanid era, the Shah Fazil complex includes burials of different eras. These graves are revered by Muslims, the burial places of the righteous of Islam. Inside the Shah Fazil complex, there are 14 kayraks – stone tombstones with inscriptions. Most of the kayraks date back to the 12th-13th centuries, there are also burials of the 14th and 15th centuries. Various persons are buried here, mainly notable persons and spiritual figures: muftis, imams, sheikhs, fakihs (Jing & Imankulov, 2022). But among the people buried on the

territory of the Shah Fazil complex, there are also merchants of non-local origin and pilgrims (Kamoliddin, 2022).

The mausoleum building itself is a square structure in the form of a simple single-chamber structure with an ordinary entrance door. The base of the building has the form of a truncated pyramid, on top of which there is a stepped drum and a high dome (Fig. 2). The height of the structure is 15.5 m, of which the height of the wall is 5.2 m, and the height of the dome is 10.3 m. The area of the mausoleum's interior is 7.84 square metres. The thickness of the walls





of the building is 163-167 cm. The entrance dome room in the northern part of the complex is a later construction. On each opening on both sides of the mausoleum door, there is a panel with stucco moulding and slots of simple geometric patterns. The panel on the left at the entrance to the building is located rectangular. In the centre of the panel, there is a six-pointed star with a pattern created with the continuation of all the constituent lines. This leads to the differentiation of diamond-shaped, hexagonal and arrow-shaped sections. The only addition is two embedded lines in the centre of the main elements of the strap. The opposite panel has basically a curved pattern centred in a circle (McClary, 2020).



Figure 2. Shah Fazil mausoleum

Source: R.P. McClary (2020)

The exterior of the mausoleum is devoid of any decorative elements. The most valuable from the standpoint of uniqueness is the interior of the mausoleum, which is covered from floor to ceiling with gancha carvings. This is a magnificent epigraphic ornament, which is engraved on the inner surface covered with plaster. The carving belts are bounded horizontally by three massive belts of inscriptions in Arabic and Persian, which represent religious texts. According to the technique of execution, a flat carving with a background selection with a kufic font differs on the sockets only in the size of the letters. Two belts of horizontal inscriptions differ both in large sizes and in the technique of execution of letters. If the horizontal belt above the trumpet arcs has dimensions of 25 cm, then the second one below the trumpet arc is distinguished by a large size of 60 cm in width of the belt and large convex letters (Kia, 2015; McClary, 2020). The total length of the inscriptions is 130 m. The inscriptions are continuous horizontal stripes without diacritical dots and spaces in words. The upper frieze is 26 metres long. It is decorated with simple ornamental outlines, and has been preserved without significant damage (Fig. 3). The middle frieze is 31.5 m long, but only a third of its length has been preserved (Moghbeli, 2017).

It is decorated with larger relief letters, which are divided into several parts. The worst preserved lower frieze, 72.5 m long, of which only a quarter has been preserved. The lower frieze is painted with smaller and simpler letters (Fig. 4). All inscriptions were probably created by a single craftsman, a carver-calligrapher specialised in architectural calligraphy (Kamoliddin, 2022).

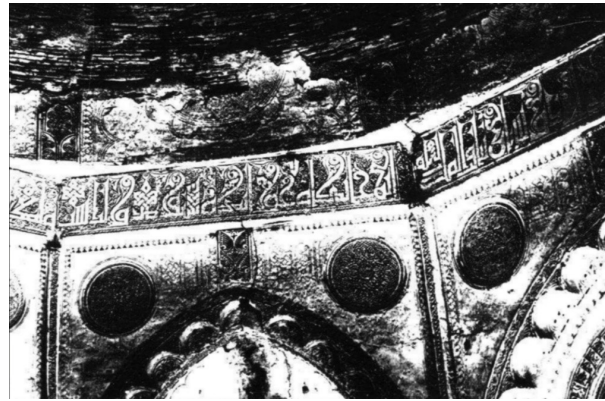


Figure 3. Fragment of the inscription of the upper frieze
Source: founded and studies by authors based on Pinterest (n.d.)

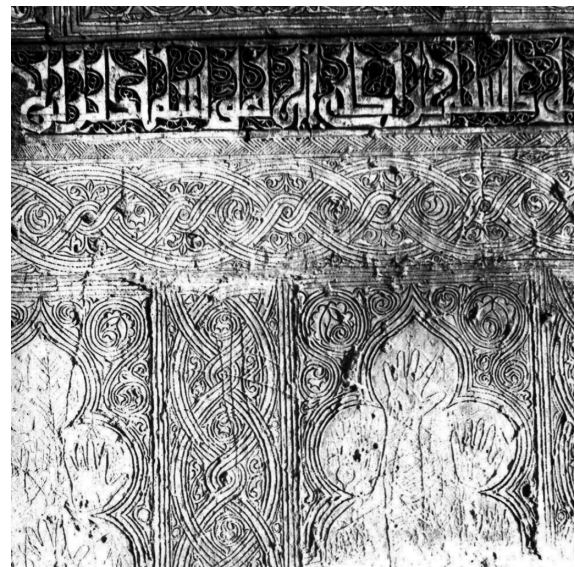


Figure 4. A fragment of the inscription on the lower frieze with graffiti in the form of a hand on the stucco at the bottom

Source: founded and studies by authors based on Pinterest (n.d.)

By themselves, the inscriptions in the interior of the Shah Fazil mausoleum also represent a historical source. It follows from them that Muhammad ibn Nasr from the Karakhanid dynasty is buried in the mausoleum. Moreover, in relation to Muhammad ibn Nasr, the term *shahid* is used, which may indicate the violent death of the buried. It is believed that Muhammad ibn Nasr fell in battle as a result of an internecine struggle that took place in the Karakhanid



State in the middle of the 11th century (van der Straeten & Obertreis, 2022).

In addition to medieval buildings, the complex also includes buildings whose construction dates back to the 19th century. This is, in particular, the mausoleum of the standard-bearer Khoja Alamdar, located on the slope of the Archa-Mazar mountain 250 m east of the central ensemble. A mosque was built on the site of the massacre of Arab troops (Kyrgyz), which was lost in the middle of the 20th century. Now there is a new mosque with the same name Kyrgyn-Mosque on this place. Not far from the mosque, there is a burial place for the bodies of 2,700 soldiers, while their heads are buried in the mausoleum of the central ensemble of the complex (Kamoliddin, 2022). Thus, the architectural complex consists of a central ensemble established at the most ancient mausoleum of Shah Fazil. The entrance dome room in the northern wall of the ensemble is one of the later buildings. A brick fence with an openwork brick lattice – panjara in the upper part connects the mausoleums of Shah Fazil, 2,700 heads of soldiers of Islam (callahan), Safid-Bulan and ziyaratkhana in the form of an aivan terrace into a single ensemble. In the courtyard of the ensemble, there are several tombstones – sagan over the graves of the holy sheikhs (Uzdurum *et al.*, 2023). The complex itself underwent restoration work in 1980-1985 and in 1988-1989. Some conservation work was carried out in 2014-2016. In 2015-2016, work was also carried out to survey the temperature and humidity regime. A plan of measures for the conservation of the facility in winter has now been developed, which provides for limiting its visits at this time of the year (Urmanbetova & Joniak-Lüthi, 2022; Boronbaev *et al.*, 2023).

Thus, the historical and architectural complex Shah Fazil is a unique example of the architecture of the Karakhanid era, located on the territory of Kyrgyzstan. The object is notable as a place of pilgrimage for Muslims, which is associated with legends about the death of Arab soldiers in this place, and an example of ancient architecture and carved calligraphy. The question of the origin of the complex and its real founders, and who is really buried in this mausoleum, despite the research of recent years, continues to be open.

DISCUSSION

The historical and architectural complex of Shah Fazil has been the subject of study by various scholars who have investigated its various aspects from its architectural features and significance as a monument of medieval architecture of Central Asia to folklore monuments associated with this iconic site. Most researchers have studied the Shah Fazil complex in the general context of medieval Islamic architecture in Central Asia, at the same time noting that certain features make the Shah Fazil complex unique.

The history of Islamic culture is considered, in particular, by K. Kuiper (2009). The researcher explores the development of Islamic culture and art, in particular, architecture. National and regional differences in Islamic

architecture are indicated in the work and the mutual influence of different cultures is shown by illustrative examples. In addition, the researcher considers such a special form of Islamic architecture as the mazar, that is, the tomb of the saint. The study by K. Kuiper is valuable for investigating the Shah Fazil complex as it allows understanding the context in which this architectural structure was created. It also gives an idea of the development of decorative components in the architectural structures of the Islamic world. With the help of his analysis, it becomes clear that the interior decorative components of the Shah Fazil mausoleum are inherently unique.

Among the researchers who have studied the Islamic architecture of Central Asia, it is worth mentioning R.P. McClary (2020). This researcher has studied the complex of architectural monuments of the Karakhanid era, built in the 11th-12th centuries. The author also paid attention to the Shah Fazil mausoleum, noting its characteristic features. The researcher gives a detailed description of the monument, focusing on its shape and interior. Following the researcher, Shah Fazil is one of the earliest architectural monuments of the Karakhanid era. Other objects that arose in that era later followed the principles of construction that were used in the construction of Shah Fazil. In addition, the researcher noted that other monuments of that era do not have such an abundant number of inscriptions as on Shah Fazil, which in many ways makes this object unique. The author has identified the main characteristics and features of the Shah Fazil Mausoleum, and in this regard, his research is quite valuable. The researcher did not consider the problem of the connection of the construction of the complex with the folk legend about the death of 2,700 Arab soldiers and its possible historical basis. According to the researcher, the Shah Fazil complex was built during the time of the Karakhanids. Agreeing with the author's opinion regarding the connection of this object with the Karakhanid epoch, it is hardly possible to fully agree with the thesis that this object carries characteristics mainly of this period. Anyway, the Shah Fazil complex includes objects from previous historical eras.

The book by R.D. McChesney (2021) revealed the theme of Islamic architecture in Central Asia. The author examined the most significant architectural monuments of the region using concrete examples. The researcher came to the conclusion about the high development of architectural art in medieval Central Asia, and also notes that this region developed its own special approach to the construction and decoration of religious buildings. The author concludes that mazar has become one of the most widespread religious buildings in Central Asia. Central Asian mazars, as a rule, were associated with legends about the death of Muslim saints in these places, but most of these legends are not historically confirmed. Moreover, several places at once claimed to be considered tombs of one or another person. In general, the researcher correctly identified the key features of monumental religious buildings in Central Asia. Based on to the estimates and characteristics of the





CONCLUSIONS

buildings given by the researcher, one can understand how the Shah Fazil complex is unique in its kind, and how its design corresponds to other similar structures in Central Asia. The researcher's conclusions are quite trustworthy and expand knowledge in the field of medieval Islamic architecture of Central Asia.

Other researchers who have studied the remarkable objects of the Ferghana Valley are Y. Lintz & R. Rante (2022). The paper by these authors gives a detailed description of the architectural monuments of the Ferghana Valley and their characteristic features. Since the active Islamisation of the region, individual objects have been considered as places of pilgrimage for Muslims, although their veneration begins in an older era. The researchers speak about the importance of the valley itself as a fertile oasis in the Central Asian region, through which the Great Silk Road passed. The researchers' opinion on the importance of the holy places of the Ferghana Valley in the religious and cultural life of residents of various Central Asian countries should be fully agreed, because the veneration of such places as Shah Fazil demonstrates a kind of symbiosis of pre-Islamic traditions and Muslim faith, and also helps to preserve the historical memory of the people. Thus, the paper by the researchers is very valuable for studying the holy places and monuments of the Ferghana Valley.

Researchers who have studied the Shah Fazil complex agree on the uniqueness of this architectural and historical object, both for the world cultural heritage and for the heritage of Central Asia. In this regard, scientists especially note the carved decorative elements in the interior of the Shah Fazil mausoleum, the volume of which is unique for such an object. Most scholars, based on the inscriptions in the interior of the complex, claim that Shah Fazil was built during the reign of Muhammad ibn Nasr of the Karakhanid dynasty in the 11th century, while the identity of the legendary founder of the complex Shah Fazil, his father Shah Jarir, and the maid Safid-Bulan are considered fictional. Although most researchers agree on the legendary nature of the narrative about the foundation of the complex in the 7th century, the question of the exact ownership of the burial in the mausoleum, and the possible historical basis of the legend, about the campaign of the grandson of the Prophet Muhammad to Ferghana, remains open, and therefore, it is hardly worth rejecting the historicity of the narrative.

In the course of the study, conclusions were reached that the Shah Fazil architectural complex is an important cultural and religious object, including a mausoleum of the 11th century, burial sites of the 11th-15th century, and individual monuments of the pre-Islamic era and later. The most valuable object in architectural terms is the mausoleum, which is an example of the early architecture of the Karakhanid State. The cultural and historical value of the mausoleum is largely determined by its interior, which is decorated with gancha carvings with religious inscriptions, the total length of which is 130 m. Inscriptions in the interior of the mausoleum give a certain understanding of the time of its construction. They mention the identity of the ruler Muhammad ibn Nasr from the Karakhanid dynasty, so the construction of the mausoleum dates back to the 11th century, when this monarch ruled.

The Shah Fazil Mausoleum is a unique object on the territory of Kyrgyzstan, representing an early example of a mazar-type dome structure in Central Asia. In addition, Shah Fazil is the earliest architectural monument of the Karakhanid era, which has survived to our times. The building itself has the appearance of a truncated pyramid topped with a dome, while the height of the dome is about twice the height of the mausoleum wall. The entrance to the mausoleum is a single door decorated with patterns. The external walls of the mausoleum are devoid of decorative elements, and its interior is decorated with three tiers of carvings with inscriptions, of which the upper tier is best preserved, and the lower one is the least preserved.

To expand knowledge about this object, further research should pay attention to the engineering details of the complex: consider the structures, the use of materials and construction techniques, and study the dome (its height, shape, and construction). This will also help to establish how Shah Fazil's architectural solutions influenced modern architecture, expand the understanding of the history of the complex, and provide an additional contribution to the study of the cultural heritage and architectural traditions of the Central Asian region.

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CONFLICT OF INTEREST

None.

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Джумамедель Джумабаєвич Іманкулов

Доктор архітектури, професор

Киргизький державний технічний університет ім. І. Раззакова
720044, просп. Ч. Айтматова, 66, м. Бішкек, Киргизька Республіка
<https://orcid.org/0009-0007-9256-0134>

Тянь Цзинь

Докторант

Киргизький державний технічний університет ім. І. Раззакова
720044, просп. Ч. Айтматова, 66, м. Бішкек, Киргизька Республіка
<https://orcid.org/0009-0003-4139-0957>

Ву Фей

Докторант

Киргизький державний технічний університет ім. І. Раззакова
720044, просп. Ч. Айтматова, 66, м. Бішкек, Киргизька Республіка
<https://orcid.org/0009-0003-9597-3218>

Тетяна Аркадіївна Філатова

Кандидат архітектури, доцент

Киргизький державний технічний університет ім. І. Раззакова
720044, просп. Ч. Айтматова, 66, м. Бішкек, Киргизька Республіка
<https://orcid.org/0009-0001-1333-2560>

Азик Абдикасимівна Орозонова

Кандидат економічних наук, доцент

Киргизький національний університет ім. Жусупа Баласагіна
720033, вул. Фрунзе, 547, м. Бішкек, Киргизька Республіка
<https://orcid.org/0000-0001-6877-7674>

Архітектурний комплекс Шах-Фазіль у легендах та працях про період арабського завоювання Фергани

Анотація. Історико-архітектурний комплекс Шах-Фазіль є одним зі святих місць для мусульман та історичною пам'яткою, а актуальність його вивчення пов'язана з релігійною, історичною та культурною важливістю. Метою статті є вивчити формування архітектурного комплексу Шах-Фазіль та визначити зв'язок легенд про заснування мавзолею Шах-Фазіль під час арабського завоювання Фергани з реальними історичними фактами. Під час дослідження використовувалися загальнонаукові методи аналізу та синтезу, зіставлення, а також історико-критичний, порівняльний та діалектичний методи. В результаті було встановлено, що архітектурний комплекс Шах-Фазіль є унікальним об'єктом культурної спадщини. Він включає кілька архітектурних пам'яток, найзначнішим у тому числі є мавзолей XI ст. Особливу цінність представляє інтер'єр мавзолею, прикрашений ганчовим різьбленням та написами релігійного змісту. Згідно з легендою, у мавзолеї поховано засновника комплексу, правнука пророка Мухаммеда Шах-Фазіля, який завоював Ферганську долину в VII ст. Тут же, за легендою, знаходиться поховання 2700 воїнів-арабів, сподвижників Шах-Джаріра, отця Шах-Фазіля, які загинули від рук місцевих поганців. Воїни були поховані служницею Сафід-Булан, іменем якої названо село, де розташований комплекс. Постаті, що фігурують у легенді особистості, є плодом фольклору, проте сама історія має під собою історичну основу і служить відлунням реальних подій, що відбувалися на початку підкорення арабами Ферганської долини. Практичне значення статті визначається тим, що її матеріали можуть бути використані в подальших дослідженнях історико-архітектурного комплексу Шах-Фазіль, а також є джерелом для використання елементів стародавньої архітектури при проектуванні сучасних будівель

Ключові слова: ісламська архітектура; мавзолей; мазар; машхад; орнамент; ганчове різьблення

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Olena Kaidanovska*

Doctor of Pedagogy, Professor
Lviv Polytechnic National University
79000, 12 Stepan Bandera Str., Lviv, Ukraine
<https://orcid.org/0000-0002-7764-1696>

Petro Dumnych

Postgraduate Student
Lviv Polytechnic National University
79000, 12 Stepan Bandera Str., Lviv, Ukraine
<https://orcid.org/0009-0009-9189-2393>

Current problems of arranging shelters in educational institutions in Ukraine

Abstract. This study covered the issue of creating safe conditions for all participants of the educational process in educational institutions in conditions of potential danger. The topic has become particularly relevant since 2022 as a result of the armed aggression of the Russian Federation against Ukraine. The arrangement of simple shelters (fortifications) in existing school buildings is decided by state authorities, legislative structures, regional institutions, and school administrations. The purpose of this study was to comprehensively examine the problem of creating a safe learning environment, identify indicative research areas, establish legislative guidelines, and preventively assess the real needs of protective structures to ensure the educational process at school. The study used the initial analysis of legal provisions, general scientific methods, systematisation and generalisation of special information, empirical methods, the method of expert assessments, factor analysis (for consideration of architectural solutions), and an interdisciplinary review of the provisions of the educational process security. The stages of solving the problem of designing and building shelters in educational institutions of Ukraine were outlined. The main factors in the formation of architectural solutions for shelters and the safety of the educational process were identified as follows: legislative; organisational; architectural and planning; engineering and technical; pedagogical; and daily. The scientific and pedagogical principles were addressed, the study highlighted the modern trends and innovative models of school education that influence the architectural organisation of school buildings. Planning solutions should provide for variant ergonomic organisation of the educational process, open educational, communication, and recreational spaces. It was emphasised that the educational environment of a school should consider security requirements. The study examined the case of a newly built school with a shelter for pupils and teachers that has adequate conditions for learning. The practical value of the study lies in the possibility of applying certain aspects and conclusions in the real design of educational institutions based on a comprehensive consideration of security requirements

Keywords: civil security; school shelter; school architecture; educational space

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*Corresponding author



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INTRODUCTION

The main prerequisite for quality education is safety and compliance with all measures to preserve the lives of participants in the educational process. Law of Ukraine No. 2145-VIII (2023), state programmes for the development of the sector solve the strategic task of integration into the European Education Area, and a systemic transformation of Ukrainian education is underway to ensure its new quality from pre-school education to higher education and adult education. The education system faces global challenges in creating safe learning environments. The Ministry of Education and Science of Ukraine engages in organisational and informational activities, receiving significant support from various international organisations and institutions, such as the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the United Nations Children's Fund (UNICEF), the World Bank, public and private organisations from different countries, international foundations and communities.

Currently, scientific and practical positions have been established for ensuring a safe school environment. There have been significant developments in the educational sector of Ukraine aimed at optimising the activities of educational institutions in cooperation with the authorities, in line with European traditions of public administration (Danylenko & Larina, 2022). Additionally, pedagogical teaching technologies have been updated (Palamarchuk & Baranovska, 2018). The proposal of a holistic educational space as the foundation for constructing a strategy aimed at the advancement of contemporary Ukrainian education is presented by R. Pavelkiv & I. Petrenko (2021). This concept will offer pupils social, emotional, and behavioural assistance in critical situations. A comparable comprehensive view of a secure academic environment is supported in R. True's (2020) thesis at both the school and city district level. The key elements of a safe school environment were identified as follows: adherence to legislative norms, professional safety standards, adequate training for staff, sufficient financial resources for safety activities, heightened awareness among all participants in the educational process, appropriate school architecture and facility design, and regular maintenance of facilities.

The architectural design of schools ought to comprehensively shape the educational environment, considering safety measures, contemporary practices of innovative pedagogy and child-orientedness, as well as adapting appropriate space for the full development of children. The study conducted by N. Wright *et al.* (2021) focuses on the significance of establishing communication between architects and teachers when designing educational spaces. The study emphasizes the concept of "flexible learning", adequate free space, incorporation of areas for both group and individual activities, and the potential for functional transformation of premises. The design of school space is important for the organisation of the educational process and the health of pupils.

In Ukraine, conditions are being created to promote the experimental construction of new types of school buildings and alternative educational institutions that embody the latest pedagogical concepts of integrated child development. A condition for the functioning of a school under increased external threat, for conducting classes in a face-to-face format, is the provision of protective structures in educational institutions. An analysis of statistics (Ministry of Education and Science of Ukraine, 2022a) showed that the network of general education institutions numbered 13,834 (as of 22.08.22), as a result of Russia's military aggression in Ukraine, the number decreased by 157, and 929 institutions were damaged. At the end of the 2022/23 academic year, 74.7% of secondary schools were equipped with protective structures. All possible measures are being taken to organise the educational process under martial law; specifically, the security of school buildings and grounds has been strengthened, the existing fund of civil defence structures is being gradually brought into readiness, and new facilities are being designed and built.

The Civil Protection Code (2023) serves as the primary document governing the relationships aimed at safeguarding the populace, the natural environment, and buildings from emergencies. This Code outlines the proper functioning of the state's civil protection system, defines the duties and responsibilities of government and local authorities, and stipulates the rights and obligations of citizens, institutions, and organizations. In the field of architecture and construction, there exist regulatory documents such as the State Building Regulations of Ukraine (SBR), State Standards, and Rules for the implementation of engineering and technical methods of civil protection, which consider inclusiveness requirements, especially in the design of protective facilities for educational institutions.

Designing and modernizing schools to meet safety requirements is a significant area of development in the architecture of Ukrainian secondary schools. Significant practical experience has been gained in determining optimal functional parameters, flexible layout, and design of common spaces and classrooms. In studying the problem of safety of the educational process, it is necessary to consider scientific and pedagogical positions: patterns and content of school education; school science, education management. The newest areas of updating school education in Ukraine, in terms of integration into the European educational sphere, are important, namely, the concept of "Education 4.0: Ukrainian Dawn" in line with the level of technical development of society (Ministry of Education and Science of Ukraine, 2022d), the Concept of the New Ukrainian School (NUS) (Reform formula, 2017).

The purpose of this study was a comprehensive analysis of the factors that form a safe educational environment and influence the modern architecture of school buildings. It is necessary to determine the successive stages of investigating the problem of educational safety, establish a regulatory framework for school design, collect



and systematise empirical data, and analyse architectural, and scientific and pedagogical practices in organising a non-threatening school space.

MATERIALS AND METHODS

The study systematically applied certain steps: consideration of the current security situation in Ukraine; clarifying the urgency of the problem of arranging school shelters; identifying the components of subsystems; determining the structural elements of the research process; and considering possible ways and prototypes for designing shelters in educational institutions. The research methodology was determined by the legal provisions set out in the Laws of Ukraine and some state documents adopted during martial law. During the hostilities in Ukraine, state services and authorities have developed several recommendations for the safety of participants in the educational process (Ministry of Education of Ukraine, 2022b, 2022c; State Education Quality Service of Ukraine, 2022). The Educational Ombudsman of Ukraine (2022b) is responsible for school shelters.

The study of the problem of creating a safe space of an educational institution is based on general scientific methods. The study applied theoretical analysis and synthesis, systematisation and generalisation of facts about the specifics of the functioning of civil defence structures and their classification. The study required the identification of key concepts such as safety, safe educational environment, protective structures and facilities, and the educational process. An analytical review of the regulatory positions on the construction, arrangement, and operation of school shelters in Ukraine was carried out to determine the design principles and features of shelters in educational institutions.

The methodological basis included a factor analysis for the formation of architectural solutions for shelters and the safety of the educational process. The general issue of educational environment safety is divided into various factors: legislative, organizational, architectural and planning, engineering and technical, pedagogical, and daily. The legislative factor integrates the norms of the Laws of Ukraine in the security, educational, architectural and construction sectors. The organizational factor determines the administration's role in educational institutions, as well as the rules and norms of behaviour for participants during dangerous situations, including security methods and means. This is compared with Israeli security practices and Ukrainian experience. The architectural and planning aspect of designing the school's structure to meet safety requirements aims to optimize functional areas, consider contemporary forms of education, and provide comfortable learning and recreational spaces for pupils.

The general classification of shelters includes five main types of civil protection structures: shelter, radiation shelter, dual-purpose structures, rapidly constructed structures, and simple fortifications. To determine their compliance with the specific features of organising the educational process in schools under conditions of danger, the study uses the method of expert evaluation. Several independent

experts from the architectural and educational sectors were involved:

- V. Nikolaichuk, chief architect of BUD-KONTUR projects in Khmelnytskyi. (BUD-KONTUR, n.d.);
- T. Hazda, principal of Primary school No. 1 of Khmelnytskyi City Council (Primary school No. 1..., n.d.);
- R. Harasym, Director of Secondary Comprehensive School No. 48 in Lviv (Secondary comprehensive school..., n.d.).

All individuals gave permission to be interviewed and to disseminate the information provided during the interview. Empirical data was important for determining the real state of the school shelter at Primary School No. 1 of the Khmelnytskyi City Council: photographs collected by one of the authors, the results of interviews with teachers, pupils, and their parents in the 2022/23 school year. The experimental basis of the study is the project of a secondary school for 1,440 schoolchildren in Khmelnytskyi.

The suggested study constitutes the preliminary phase of examining the issue of constructing shelters in Ukrainian educational facilities. The study aims to comprehensively analyse the problem, identify potential research avenues, establish legislative recommendations, and evaluate the proactive requirements for protective structures to secure the academic process at school. The next stages of the research are planned as follows:

- detailed classification and assessment of the suitability of protective structures for educational institutions in terms of safety requirements, structural, planning, aesthetic, and other characteristics;
- comparative analysis of architectural prototypes of protective structures and measures to ensure the safety of the educational process;
- developing a conceptual model of the school repository, considering the impact of external and internal factors of influence, pedagogical and psychological aspects;
- substantiation of design models of shelters for educational institutions of different types and categories of protection.

Open sources and publications on social media confirmed the importance of the safety factor in the school's architecture, clarified the difficulties and practices of organising children's stay in the shelter, and revealed the specifics of conducting classes during air raids.

RESULTS

The safety of citizens is guaranteed by the Law of Ukraine No. 2469-VIII (2023), and civil defence structures are defined as engineering facilities for protecting the population from the impact of various hazards (emergencies, military operations or terrorist acts) (Civil Protection Code of Ukraine, 2023). Depending on the nature of the origin of events that can cause emergencies (anthropogenic; natural; social; military), the classification of protective structures is presented:

- A shelter is a sealed structure designed to protect the public from hazards for an extended period. It enables





the creation of conditions that safeguard against potential dangers;

- A radiation shelter is a non-hermetic protective structure that can guard against ionising radiation in the presence of radioactive contamination in the area, as well as against conventional weapons;
- Dual-purpose structures (above or below ground, comprising separate parts) are designed or adapted to provide temporary shelter for the population.
- Prefabricated defences that can be constructed quickly from specific structures in compliance with building regulations.
- Basic shelter (fortification) involves utilizing a cellar or underground location as a temporary refuge for individuals to decrease the potential for collateral harm.

In current practice, educational establishments usually have basic shelters located in basements and on the ground floor. Enclosed shelters are only found in exceptional cases, such as in newly-built premises or when refurbishing former industrial sites. Shelters located directly in the educational institution will provide effective protection for participants in the educational process. This is confirmed by the conclusions of scientists and practitioners, as well as the recommendations of experts (Shelter in an educational institution, 2022).

A well-designed and well-equipped shelter offers an opportunity to conduct in-person training according to organizational requirements. This includes conducting necessary briefings, training evacuations to the shelter,

and checking fire and engineering systems. If the shelter is located in another building or next to a school, there are risks to the life and health of children depending on the time it takes to evacuate. The evacuation process should be planned depending on the number of teachers, pupils, school staff, and the nature and conditions of the security situation.

The issues of equipment, conditions of functioning of civil protection structures are important, and they are regulated by the established norms (Shelter in an educational institution, 2022) and the passport of the protective structure. It should take 12-24 hours to make them ready for their intended use. In times of danger, the following can be used to shelter the population as dual-purpose structures and basic shelters: underpasses, subway stations, all types of tunnels; constructed underground facilities of the pit type; inactive defence facilities and bases; underground cavities for various purposes; basements, ground floors, and first floors of buildings; other facilities suitable for sheltering the population (Order of the Ministry of Internal Affairs of Ukraine No. z0879-18, 2022; Resolution of the Cabinet of Ministers of Ukraine No. 138, 2023).

The problem of architectural solutions for shelters and the safety of the educational process should be considered as a system of identifying current needs, considering the experience and best practices of various industries and institutions in the interaction of the following factors (Fig. 1): legislative; organisational; pedagogical; daily; architectural and planning; engineering and technical.

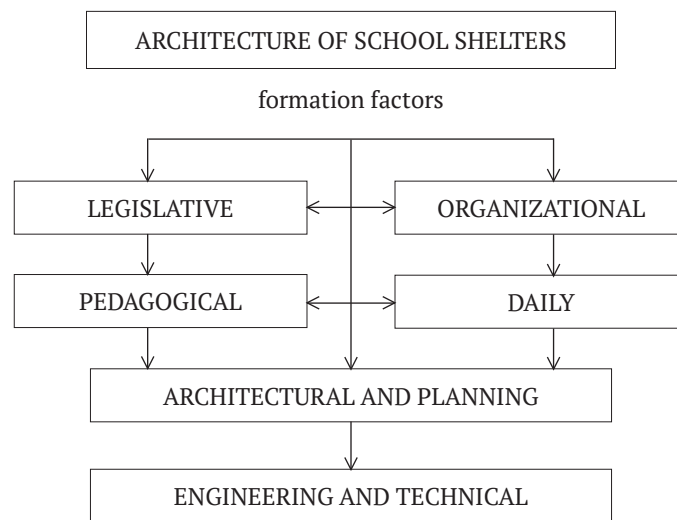


Figure 1. Structuring the problem of school shelter architecture

Source: compiled by the authors of this study

Legislative factor. It establishes norms and procedures for all participants in the educational process. The situation of a state of emergency and military operations is regulated by the Civil Protection Code of Ukraine (2023), Law of Ukraine No. 2145-VIII (2023) and regulatory documents that cover important tasks of ensuring the safety and health of the population (Decree of the President of

Ukraine No. 392/2020, 2020). The norms for regulating the educational process of the school are set out in Law of Ukraine No. 2145-VIII (2023), Law of Ukraine No. 463-IX (2023), specifically, the right of pupils to safety in education. The safe educational environment of an educational institution is defined as a set of conditions for excluding the possibility of physical, property and/or moral harm to



pupils, and the head of the institution is responsible for this (State Education Quality Service of Ukraine, 2022).

The financial issues of equipping shelters under the state decentralisation programme can be resolved at the expense of the budget of the communities that are the founders of educational institutions. An educational subvention of UAH 1.5 billion from the state budget was allocated to local budgets exclusively to provide safe conditions in general secondary education institutions (Resolution of the Cabinet of Ministers of Ukraine No. 419, 2023), and rules and procedures for obtaining funds for the repair or construction of school shelters were established (Creation of shelters..., 2023). At present, funding for upgrading the material and technical base, which does not include routine repairs and the construction of shelters, is a problem.

The design and construction of civil defence structures for educational institutions is subject to the provisions of urban planning legislation, State Building Regulations and legislative documents on safety and accessibility of facilities for people with limited mobility, high-quality engineering and technical civil defence measures, and compliance with fire safety requirements:

- State Building Regulations of Ukraine V.2.2-3:2018 (2018) regulate the design and reconstruction of buildings of all types of educational institutions and contain requirements for the development and functional zones of sites, requirements for space-planning solutions for all groups of premises, a set of engineering, technical and sanitary-hygienic standards;
- State Building Regulations of Ukraine V.2.2-5-97 (1998) substantiate the design and reconstruction of protective facilities as the main means of collective protection of the population, and specify the design standards for dual-purpose protective facilities;
- State Building Regulations of Ukraine V.1.2-4:2019 (2019) define the scope and content of measures for various defined categories of facilities according to the zoning of the territory by the level of potential danger (means of mass destruction, possible accidents and anthropogenic disasters);
- State Building Regulations of Ukraine V.2.5-56:2014 (2015) and State Building Regulations of Ukraine V.1.1.7-2016 (2017) establish general fire safety requirements for houses, buildings and structures of any purpose aimed at limiting the spread of fire between and within buildings, ensuring evacuation and rescue of people, extinguishing fire, and applying fire protection systems.

The norms for providing educational institutions with shelters were established by Ukrainian legislation only in 2018 (Order of the Ministry of Internal Affairs of Ukraine No. z0879-18, 2022), before that there were no direct instructions in the regulatory documents. The design of protective structures was envisaged in buildings in potentially hazardous areas, e.g., near nuclear power plants.

Organisational factor. Determines methods and ways to ensure the functioning and requirements for the arrangement of shelters, appropriate actions of the

administration of educational institutions, involvement of necessary services and technical services. It is important to create the safest possible conditions for all participants in the educational process, which is facilitated by joint efforts of the authorities and the administration of educational institutions. For this purpose, an algorithm of actions for preparing protection facilities and training the population in the event of emergencies was introduced (Resolution of the Cabinet of Ministers of Ukraine No. 444-2013-p, 2023).

The main tasks to be solved by the heads of educational institutions are identified (State Emergency Service of Ukraine, 2022): 1) to make the existing protective structures ready for use; 2) to calculate the full quantitative need for shelter for all participants in the educational process; 3) in the absence of protective structures on the balance sheet of the educational institution or when an additional need for them is established: to initiate a survey of existing structures and premises; to ensure the creation and arrangement of the simplest shelters on the territory of educational institutions; to determine the possibility of using the protective structures of other business entities for shelters.

To organise in-person training, the capacity of the shelter must be considered. Schools draft the appropriate timetable, adjusting the number of children, and some classes attend school on different days. Various forms of education are combined – full-time, distance (using IT technologies and online access in areas close to the combat zone), family and external; multi-times and mixed modes of attendance. The requirements for the organisation of training of educational institutions emphasise that participants in the educational process should receive full information about the location of protective structures and know the rules of conduct while in the shelter (Ministry of Education of Ukraine, 2022c). Each educational institution should develop an individual algorithm for dealing with the air raid alert. The security situation at a school depends on the territorial location, number of people, location of the shelter, age of pupils (primary/secondary school), etc. It is recommended to set up a universal communication channel and provide instructions. It is proposed to use preventive measures to identify possible risks, an individual approach to pupils (Hamilton-Ekeke, 2017), and strive to create a positive school climate with relationships of trust and respect between pupils and staff.

The Specialist in Security project was launched in Ukraine to improve the safety of the educational environment, including the prevention of possible negative phenomena and any dangerous incidents. A security specialist in the educational environment is an official of the executive body of a village, town, city, or regional council whose knowledge and skills correspond to current security challenges. When performing official duties in educational institutions, the specialist directly interacts with public authorities, police and rescuers, school administrators and staff; parental self-government bodies; public organisations, monitors the state and compliance with safety





standards at school. Requirements for a specialist – a citizen of Ukraine over 21 years of age, higher education, specialised training (Ministry of Internal Affairs of Ukraine, 2021). It is worthwhile to examine Israel's approach to school security where schools are well-protected against armed and terrorist attacks due to clear organizational guidelines amidst the country's conditions of war, weapon legalization and use. The administration's actions to ensure the security of educational institutions are guided by the 2012 Circular (Education Ombudsman of Ukraine, 2022a), specifically, to protect against possible explosive devices in the building or on the school grounds, shooting or seizure of the educational institution.

Schools with more than one hundred pupils are provided with a professional security guard, whose functions are much broader than those of similar school guards in Ukraine. Schools and other educational institutions in Ukraine can have two types of security guard positions. The first is to protect and prevent damage to school property, maintain order, and prevent the introduction of explosive devices and other suspicious objects. However, such guards (positions of security guard, janitor, duty officer, etc.) are not responsible for the complete safety of pupils and teachers, and in problematic situations they are obliged to call the police. The second type is an employee of a security company who works directly to protect children and school staff. The educational institution concludes a relevant agreement (Law of Ukraine No. 4616-VI, 2022).

In Israel, security guards are trained according to police standards, and their main responsibilities include: morning checks of the school grounds before classes to identify suspicious persons, objects, and vehicles; regular checks of the school during school hours; control of the area near the entrance gate and response to emergencies; and control of access routes to the school. No unauthorised access is allowed, and the entrance gate is locked. The security guard registers unauthorised persons and cars entering the territory (Education Ombudsman of Ukraine, 2022a).

The Israeli police establish three states of security in educational institutions and security enhancement (Education Ombudsman of Ukraine, 2022a):

- standby mode, in which daily security activities are performed;
- alert mode during the preparation for the holiday season, which requires additional instruction of the guards;
- lert status in a situation when the security system is preparing to prevent hostile subversive activities, additional measures are to be taken, and police patrols are to be increased.

During martial law in Ukraine, clear instructions and rules of conduct for participants in the educational process during air raid alerts in various situations have been developed and are being implemented. The shelter should be left in an organised manner after the air raid warning signal or in case of a sudden life-threatening emergency (Education Ombudsman of Ukraine, 2022b; Ministry of Education of Ukraine, 2022). If the air raid alarm catches parents and

children on their way to or from an educational institution, it is important to plan and follow a specific route in advance and identify shelters along the route that can be used in the event of a danger signal.

Schools in Ukraine often organise meetings between pupils and the military, military volunteers and doctors to discuss possible dangerous situations and answer children's questions. The soldiers (often graduates of this school) lecture on behaviour in dangerous situations, first aid rules in case of need, self-preservation practices; ways to overcome panic, maintain a stable emotional state in dangerous situations; and handling dangerous objects. Apart from telling stories, a military officer or veteran can also conduct classes on tactical medicine in middle and high schools (Lykhovyd, 2023).

A separate topic is explaining the rules of conduct in a shelter. Evacuation is carried out along an established safe route (with preliminary training) to a particular designated location, and the same rules apply to the return evacuation back to the classrooms. Teachers accompany pupils to the shelter, prevent panic, check the number of pupils, ensure that they are seated in the designated places, and offer various activities in the shelter. It is forbidden to: move around the room unnecessarily; enter technical rooms; unauthorisedly switch on or off special equipment units (State Education Quality Service of Ukraine, 2022; Presentation "Rules...", 2023).

The educational institution develops all possible trajectories for different age groups of children to move to the shelter from different parts of the territory, accompanied by teachers and responsible persons – from classrooms, the school yard, classes are suspended. The school health worker must be able to reach the designated location quickly and be prepared to provide all types of first aid and psychological support.

Pedagogical factor. The project is aimed at creating a comfortable educational space, integrated modern design according to current trends in school pedagogy. The benchmark is the NUS Concept, which envisages the introduction of a person-centred model of education based on the ideology of child-centredness, aimed at new quality results: the acquisition of competences, the ability to acquire and use knowledge in solving educational and life problems, and the unlocking of pupils' individual potential to form a successful, independent personality (Reform formula, 2017).

It is planned to change the spatial and subject environment, programmes, and teaching aids. The school space should be maximally adapted to the introduction of new approaches to teaching based on the pedagogy of partnership in organising dialogue communication, interaction and cooperation between teachers, pupils, and parents. There is a variant ergonomic organisation of the classroom space, open educational spaces (Scott, 2010; Dudek, 2012). The author outlines the introduction of innovative educational technologies for activating the pupil's cognitive independent activity, learning through research, preference is given to teaching methods based on cooperation and



joint activities (games, projects – social, research, experiments, group tasks, etc.), the possibility of studying in multi-age subject or interdisciplinary groups (Shchekatunova, 2013). The implementation of the school education reform is ensured by the New Educational Space social project based on the following principles: motivating space and creativity; technological efficiency; energy efficiency; and inclusiveness (New educational space, 2019).

In planning school shelters, it is important to combine flexibility and stability through appropriate zoning to allow for effective education in the shelter. The flexible organisation of the space will allow for rapid changes depending on educational situations and include various forms of work (Ernst, 2007). The principle of stability provides the basis for learning activities, and in space planning it means the presence of stable zones and elements. The mobile elements of the arrangement will provide the possibility of quick reorganisation, first of all, the arrangement of pupil workplaces in the shelter, not only as standard tables and chairs, but also a variety of group and individual work (sitting, standing, even lying down), communication and rest. Conventional forms of teaching should be supplemented by conversations and discussions in a circle, free arrangement of pupils, which can be on the floor; for group work, furniture can be grouped. This method will reduce stress levels and provide positive emotions during the children's forced stay in the shelter.

The newest concept Education 4.0: Ukrainian Dawn (2022/23) is designed to meet the contemporary challenges as a poly-model lifelong education based on personalised content that meets the human resource requirements of the Generation 4.0 industry (Ministry of Education and Science of Ukraine, 2022d). It envisages the transformation of educational institutions in the integration of technical achievements and experience of innovative pedagogy – independent, accessible and inclusive learning, problem-based and collaborative learning, and pupil-centred learning. The priority tasks are to provide schools with functional infrastructure and shelters, and to reconstruct educational institutions.

The development of Ukraine's education system in the post-war period envisages the transformation of the security sector of education according to the North Atlantic Treaty Organisation (NATO) doctrine, the development of educational infrastructure with the mandatory construction of shelters during the restoration of damaged and construction of new schools, the creation of modern educational institutions that will provide appropriate conditions for obtaining quality education at the level of world standards (Education of Ukraine..., 2022).

Daily factor. Determines the necessary equipment for the organisation of school shelters, equipment for their operation in times of danger, to ensure the possibility of continuous stay in them for at least 48 hours according to the estimated number of all employees, teachers, and pupils of the institution. Regulatory documents and recommendations provide a list of property needed to equip a protective

structure, a minimum list of medical supplies for primary care, etc. (Ministry of Education of Ukraine, 2022c). An additional requirement is the availability of special items for evacuation, sealed buckets for faeces and waste, and hygienic toilet bags. Each pupil has their own evacuation backpack, which will contain an information tab: surname, child's name, date of birth, address, parents' contacts, child's photo, family photo with signatures, blood type and Rh factor. Parents pack the necessary things according to the recommendations provided, as a rule, these are warm clothes, long-term storage products, and water.

Architectural and planning aspect. Updating the school's structure to comply with safety requirements involves improving functional areas while creating comfortable and healthy conditions for pupils to learn and relax. Modern trends in school architecture should be considered, including free space planning, mobile distribution of learning, communication, and recreation areas, modern interior design tools, and active interaction between the building and natural elements (Kovalska, 2010; Shmelova, 2021).

The functional organisation of the school space embodies the latest forms and methods of organising the educational process:

- multifunctional use of school premises, integration with other institutions – sports facilities, food outlets, leisure centres, etc;
- Individualisation of education requires the creation of specialised premises for various educational services in the school structure – a cluster spatial organisation consisting of separate premises united by a common communication space into a single object is advisable;
- group method of teaching in a constant change of the size of educational groups – micro groups (1-3 pupils), medium groups (class), large groups of pupils;
- Intensification of the educational process using modern technical teaching aids.

The school's educational functions are expanding and modifying alongside the increasing role of research and experimental learning, and the use of latest technical means. This reflects a new type of universal open space, consisting of open lecture halls, coworking spaces, laboratories, and media libraries. These spaces form the core of the school's planning structure and can be combined with the learning areas situated around it through transformation. The variable construction of the educational process requires maximum flexibility of the planning structure of the school building in the ability to quickly change the size and shape of classrooms, and mobility of functional links (Almeida *et al.*, 2015; Chuhai, 2021). The inclusion of shelter space in the educational process and the development of different ways of using it on a daily basis have significant potential in this regard. The prospect of using school shelters in peacetime can be based on various functions, such as sports activities, labour or artistic training, and creative activities. The standard procedure is to organise a shelter on the ground floor or basement, or alternatively, on the first floor of the building if there are surrounding





structures. This must consist of at least two emergency exits, one of which must be designated specifically for emergency use. Other requirements relate to engineering networks, bio-toilets in the absence of sewage, and the geometry of the premises with the calculation of the area, necessary things and items.

Fire safety regulations for educational institutions in Ukraine are crucial, particularly regarding adherence to maintenance requirements for the premises and determining the quickest evacuation routes and exits to the designated safe zones (Order of the Ministry of Education and Science of Ukraine, 2016). Primary fire extinguishing equipment, external and internal fire water supply systems, fire automation and alarm systems are required. The location of fire extinguishing equipment and the plan for evacuation from the shelter should be visible and accessible. Non-flammable, secure materials should be used in the furniture and equipment situated within the shelter. It sets out the rules for organising evacuation, preventing panic, and the priority actions to evacuate people.

Universal school design should establish equitable use of space by all user groups in the physical accessibility of school elements; attractive design of premises and surrounding area; ensuring safety in the school for all children, teachers, visitors (Ford, 2007; Dudek, 2012). Accordingly, greater attention should be paid to the entrances to the protective structure, which should provide free access, sufficient capacity, inclusive requirements, and door tightness. The school management should ensure that: prominent and clear fire safety instructions are posted, evacuation plans and signs are clearly visible; and that evacuation through windows is possible (free opening, no bars).

Engineering and technical factor. The safety architecture of schools combines the positions of regulatory documents of state structures and organisations of Ukraine on the design, maintenance of communications of protective structures, engineering networks, engineering and special equipment, life support systems, and flood protection. Recommendations for the maintenance and operation of storage facilities define the rules for the arrangement of ventilation systems, diesel power plants and electrical equipment, water supply, sewerage and heating systems, communication and warning systems (Order of the Ministry of Internal Affairs of Ukraine No. z0879-18, 2022).

The design of engineering and technical civil protection measures in case of emergencies is guided by the State Building Regulations of Ukraine according to the zoning of the territory by the nature and scale of possible anthropogenic accidents and disasters, as well as military situations (State Building Regulations of Ukraine V.1.2-4:2019, 2019). The project documentation includes a separate section on these measures for planning and development projects and individual architectural objects. To ensure normal living conditions for the population, it is necessary to maintain acceptable levels of air gas composition, ionising radiation and protection against hazardous chemical and biological substances in the storage facilities. To protect

against airborne shock waves during military events, shelters should be equipped with additional protective devices: shutters, protective partitions, overpressure valves, etc. The defence structure must be equipped with high-quality lighting, and there are certain requirements for electric lamps.

According to the information provided by experts during the interviews, the main area of reconstruction of basements and equipment of shelters in them is engineering networks – repair of water and sewage systems, ventilation systems, electrical networks, thermal modernisation, and waterproofing of foundations. Additionally, generators are installed, and the basement's power supply network is changed to switch to an additional source during power outages. A frequent problem is the lack of windows in the basement, which requires additional installation of ventilation equipment. The vast majority of basements did not have sanitary rooms – they were either completed or bio-systems were installed.

The practice of implementing school shelters in Ukraine. It is illustrated on the example of the general secondary education institution “Primary School No. 1 of the Khmelnytskyi City Council”, commissioned in 2021 on the eve of Russia's military invasion of Ukraine (the BUD-KONTUR project). The school is designed for 810-820 pupils in grades 1-4 and has a shelter for 960 people, which meets the requirements of the time (Primary school No. 1..., n.d.).

Architectural solutions are integrated with the system of educational activities of pupils, which develops skills and abilities in all educational areas, applies active teaching methods, introduces information technology, and combines learning and life skills. Safe and comfortable conditions for studying and working were created in the building and on the territory of the institution (Fig. 2). The school's layout is in keeping with the nature of the site and its surroundings, combining classrooms, a gym, a food block, a medical block and other regulatory areas and premises. For active developmental learning, the school has computer labs, language rooms, an assembly hall and a choreography room, a gym, club rooms, a library, and a media library. The classrooms are of a larger size (80 m²) and are equipped with modern multimedia facilities. The facility has three floors, two lifts. Inclusivity requirements were met, and as of 2023, 17 pupils with special needs are able to study freely.

The basement floor contains a specially equipped shelter that allows the educational process to continue in the face of danger. For first-graders, there are stationary classrooms, while other pupils are free to use the play and recreational areas. For longer stays, there are two-level bunk beds. The dining hall offers serving meals to pupils in rotation. The shelter has a first-aid post, bathrooms and a bathroom for people with limited mobility. All the engineering and technical requirements for power supply and ventilation, including offline, have been met. One of the disadvantages is the lack of a heating system for a comfortable stay of schoolchildren in winter, which is planned to be completed.

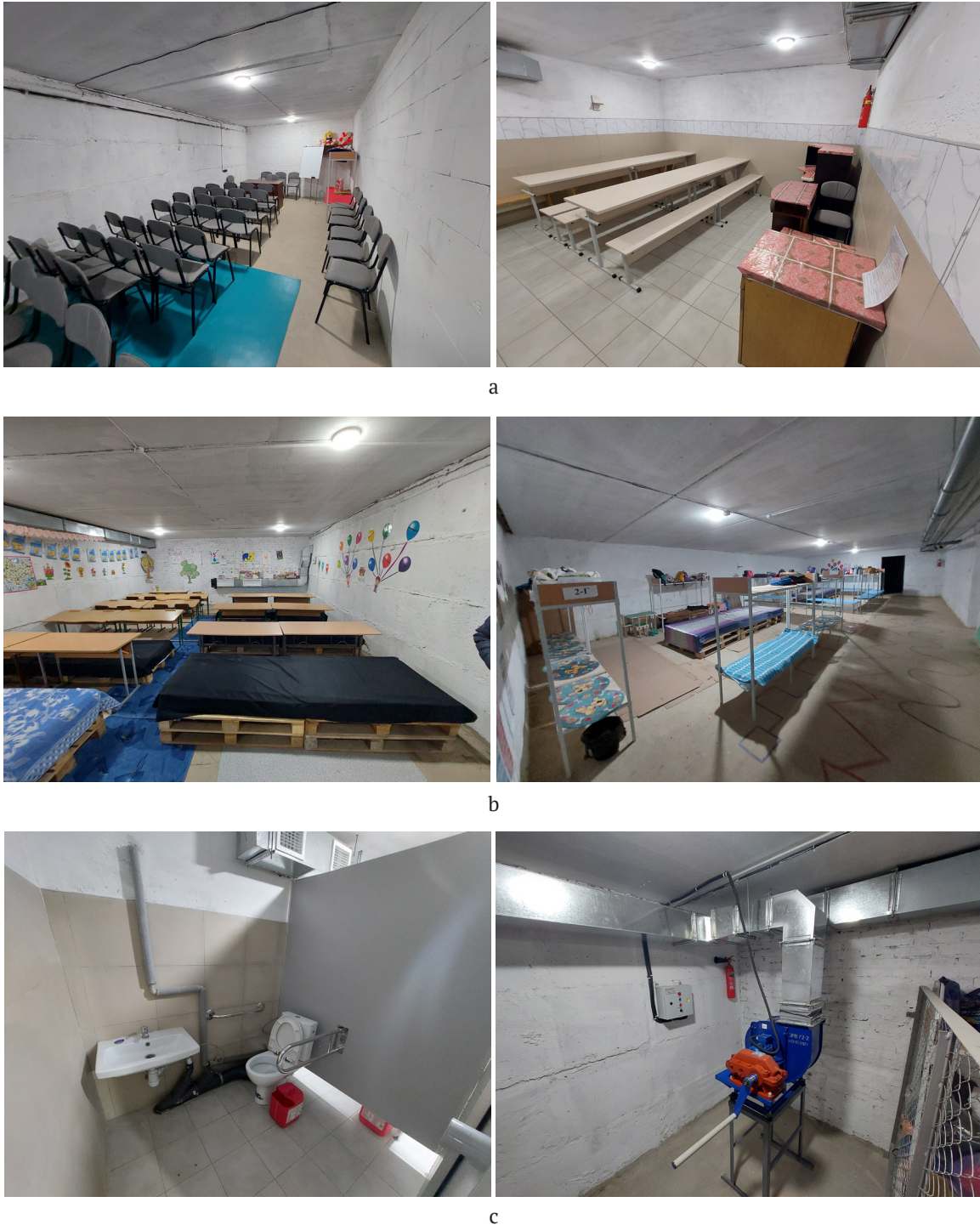


Figure 2. School in Khmelnytskyi

Notes: a – training areas; b – areas of long-term stay; c – sanitary, technical areas

Source: photo by P. Dumnych (2022)

An example of a school project with a shelter. The projected school in Khmelnytskyi (BUD-KONTUR project with the participation of one of the authors) has a capacity of 1,470 pupils and consists of a gymnasium (750 pupils) and a lyceum (720 pupils). According to the State Building Regulations, the following functional groups are provided for (Fig. 3): educational and educational-production

premises, a sports and fitness block with changing rooms, a library, a media library, club and entertainment facilities, a catering unit, medical care rooms, administrative and service premises, auxiliary and utility rooms (State Building Regulations of Ukraine V.2.2-3:2018, 2018). According to the project, the school has four floors, full inclusivity, four lifts, and a sufficient number of communications.



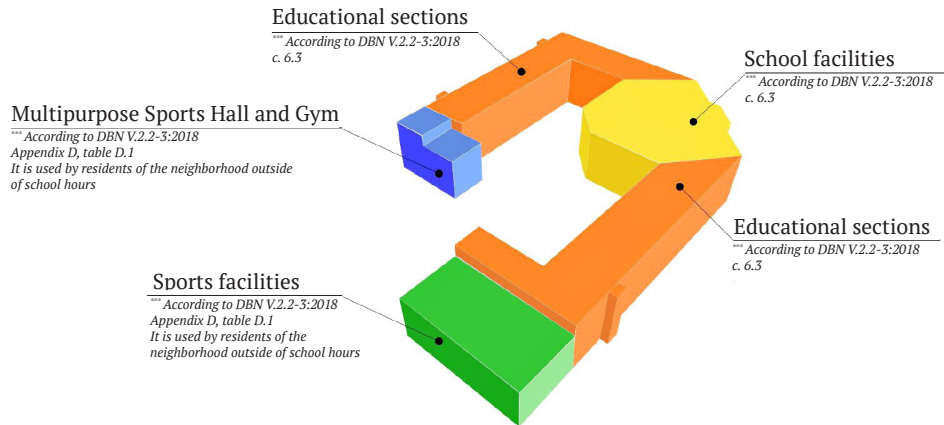


Figure 3. Functional diagram of the designed school

Source: materials from BUD-KONTUR (n.d.)

The basement floor houses a radiation shelter for 2,500 people for pupils and teachers, and additional areas for residents of the surrounding residential buildings. The entire basement space is divided into five separate fire compartments, and six external exits are equipped with special gateways with safety doors. The shelter's layout is based on a corridor scheme that combines common spaces, classrooms, food and cooking areas, storerooms, and storage for

contaminated outerwear. Six sanitary blocks with toilets, three medical posts and a separate medical centre with a treatment room were designed. In peacetime, the shelter can be used as a training range (Fig. 4). A separate technical unit for the diesel power plant, additionally isolated in case of an anthropogenic disaster, makes it possible to provide the school with electricity for 48 hours. All the necessary engineering solutions are provided.

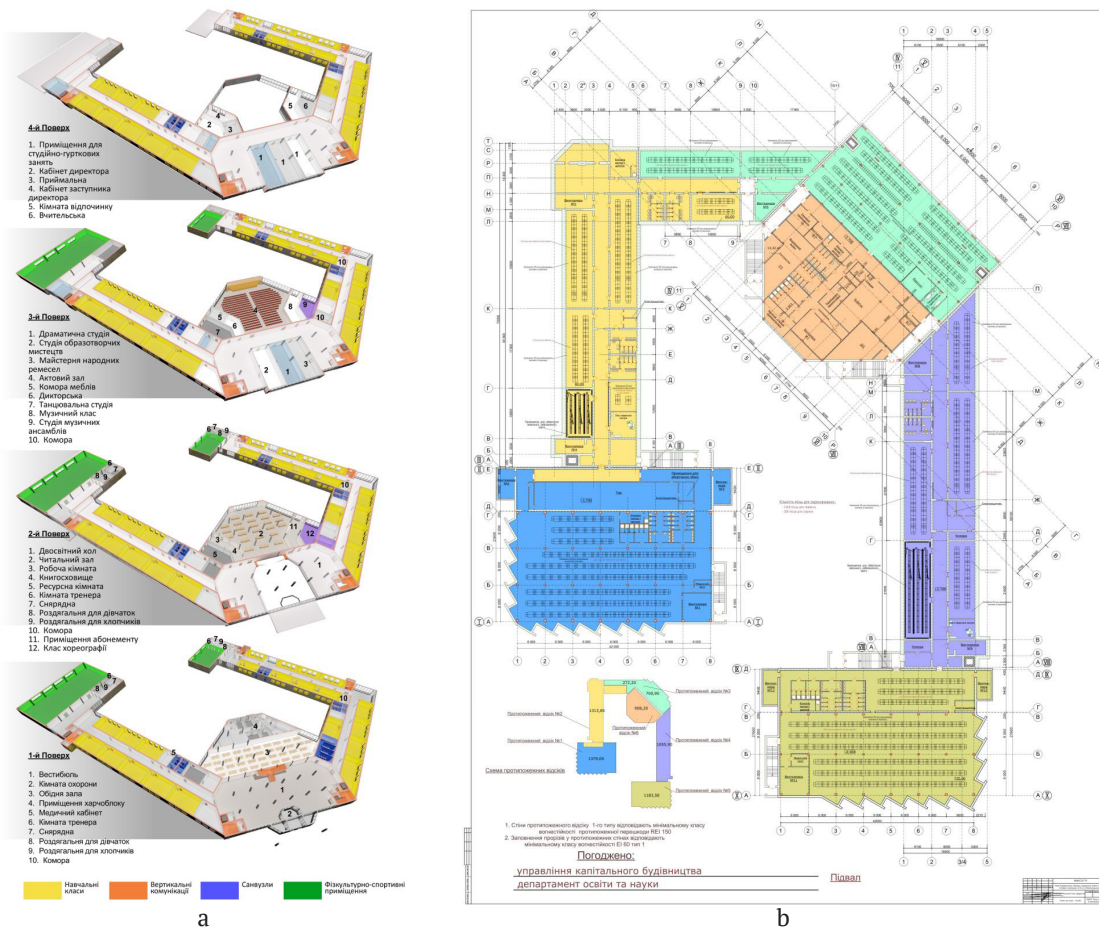


Figure 4. Planning of the projected school

Notes: a – floor plans; b – basement shelter plan

Source: materials from BUD-KONTUR (n.d.)



The structural design of the building ensures the strength, rigidity, and stability of the building. The shelter's reinforced strength is provided by pile foundations, monolithic reinforced concrete floor and column elements, and precast concrete walls of the underground part. In the world practice of shelter architecture for educational institutions, different approaches are used depending on the current security needs of the region: free-standing concrete ground shelters of various capacities (Israel, bombing protection); reinforcement of enclosing structures with metal (USA, tornado protection). In the event of natural disasters (floods, earthquakes, storms), schools often serve as temporary shelters for residents.

Schools in Europe and the United States built in the second half of the 20th century often had built-in bomb shelters. One example is the Abo Elementary School in Artesia (New Mexico, USA), built in 1962, most of the building is underground, as a shelter for pupils and citizens in case of nuclear war or other disaster for 2,160 people, with the possibility of holding classes (Abo School, 2013). The building's concrete walls and structures were reinforced, the reinforced concrete floor serves as the basis for an outdoor sports ground on the roof, and three external exits were equipped with steel security doors. Inside, there are classrooms, rest rooms, and storage rooms for food and water supplies, all the necessary things, air filtration systems, emergency power supply, disinfection, and fire protection. The school's layout is rectangular, with two corridors with access to classrooms and exits at the ends. There is a large multifunctional room, administrative offices, toilets, and a cafeteria. Today, the school is not functioning and is a tourist attraction.

On the territory of Ukraine, stationary bomb shelters of that time were built separately – on the territory of a university campus, often in residential areas, or integrated into industrial facilities. At present, it is possible to consider the need for their reconstruction depending on the condition of the facilities.

DISCUSSION

It was established that the creation of a safe learning environment is an important area of architectural science and practice. The architectural principles of school space organisation have been sufficiently researched in terms of functional parameters and groups of rooms, communication zones (Curtis, 2003; Kovalska, 2010). The development of a model of territorial educational complexes for basic and additional education of children with an expanded range of services (Kovalska *et al.*, 2019) contributes to a more economical use of the territory but imposes additional security requirements.

The study by D. Domalewska *et al.* (2021) compared the individual perception of safe educational space by pupils in Poland and Vietnam. The results showed that neither gender nor family context influenced pupils' sense of safety at school. However, the feeling of safety is largely related to nationality and personal role models in a potentially

dangerous environment. This issue requires further study in terms of designing shelters in school buildings to consider cultural and regional traditions and the individual characteristics of different age groups of children.

Studies of school safety as a complex and multidimensional phenomenon are constructive (Massey-Jones, 2013). Positive outcomes can be achieved by integrating the factors of the learning environment and the risk management process (Savolainen, 2023). Additionally, the significance of fire safety in schools, specifically using non-flammable materials in the construction, providing adequately wide passages and unobstructed spaces for evacuation, is highlighted in relation to creating a secure physical learning environment. The author has built a model of safe educational institutions of a cyclic type, which shows the process of risk management, analysis of safety information to build a safer school environment. The merging of the pedagogical, psychosocial, and physical environment has interesting implications for the design of new buildings in light of online learning and new pedagogical solutions.

Clarification of the concepts of safety and security, as well as their role in creating a comfortable environment for the physical, emotional and social well-being of pupils, considering environmental safety factors (Mubita, 2021) correlates with the findings of the study on the direct impact of the school's architectural design on children's development, and the issue of school safety and security is a priority. Pupils and teachers need to feel safe, which will allow them to focus their energy on learning and creativity, and to test the latest pedagogical methods.

The notion of learning safety is viewed as a responsibility of school management and educational authorities, which is based on exploring organisational and managerial practices to enhance individual and collective well-being in British schools. This study draws from the research of A.D. Vicario & J.G. Sallán (2017) and employs a comparable data collection methodology entailing structured interviews with school principals, occupational safety, and health specialists, along with teaching and non-teaching personnel, and consultation with family focus groups and experts. This study focuses on legislative norms and recommendations and their implementation in architectural practice.

The methodology of data collection is described in detail in D. Nwobodo & U.I. Maria (2017) – a checklist and questionnaire on security and security management in public secondary schools, the results were verified by three experts. The conclusion is the need for additional staff training, strengthening the material base of school protection, reconstruction of buildings with the installation of additional equipment, which coincides with the identified engineering aspect of the study.

In a study of ways to improve safety in US schools (Jagodzinski, 2019), the method of interviews with parents, teachers, and staff was also used to model safety strategies. The author offers 17 recommendations that are important for both school leaders and architects. The





recommendations include structural and technical aspects of individual building elements, specifically, ballistic resistant glazing of windows, arrangement of evacuation entrances, fencing of the territory, and other details. Special attention is paid to the organisational aspect – the development of a comprehensive emergency response plan for different types of emergencies, unique to each school. Mandatory training with simulated rescue from fire, destruction and other situations, involving professional consultants, and media information. A clear protocol for the actions of all participants in the educational process during an emergency should be developed and made available, which should be ensured by an appropriate and convenient layout of the school building and grounds.

The interdisciplinary analysis points to the importance of a comprehensive consideration of the problem of a safe educational environment at school, establishing a correlation between the planned actions of pupils in an emergency and the layout of the school building and territory, planning possible risks and methods of their elimination. To develop architectural principles for modelling an optimal school space, it is important to rely on practical experience and scientific positions from various fields – pedagogy and psychology, school administration, medicine, construction and engineering technologies.

CONCLUSIONS

In line with the strategic objective of integrating into the European Education Area, a systemic transformation of education is occurring to guarantee its enhanced quality from pre-school to higher and adult education. The Russian Federation's military aggression towards Ukraine since 2022 has brought up the issue of establishing safe conditions for all participants in the educational process. State authorities, legislative structures, regional institutions and educational institution administrations are addressing this matter. The prospects for the development of Ukraine's education system in the security and defence sector are to comply with NATO doctrine, build educational infrastructure with mandatory bomb shelters during school reconstruction, and create modern educational institutions that meet international standards.

The study identified the stages in the design and construction of shelters in educational institutions in Ukraine: 1) comprehensive examination of the issue of establishing a secure learning environment. It identifies key areas for research and sets forth legislative guidelines. Additionally, it assesses the prevention needs of protective structures to ensure the safety of educational institutions; 2) careful classification and evaluation of the suitability of different protective structures for educational institutions; 3) an

in-depth comparative analysis on architectural prototypes of protective structures, as well as measures to guarantee the safety of the educational process; 4) development of a conceptual model of a school shelter; 5) substantiation of design models of shelters for educational institutions of various types and categories of protection. At the first stage, the problem of forming architectural solutions for shelters and the safety of the educational process is structured in the allocation of factors: legislative; organisational; architectural and planning; engineering and technical; pedagogical; and daily.

Acceptable types of civil protection structures were documented; in Ukraine, the most relevant is the provision of simple shelters in basements and ground floors of school buildings. The future plans include the design of full-fledged shelters and radiation protection shelters. Taking into consideration scientific and pedagogical principles, contemporary trends, and innovative models of school education, state initiatives for the enhancement of school education dictate that schools' architectural organization must comprehensively create an educational milieu while adhering to safety regulations. The focus is on creating a comfortable educational space, modern design and content. Planning solutions should provide for variant ergonomic organisation of the educational process, open educational, communication, and recreational spaces.

When designing school shelters, it is crucial to adhere to all regulations and guidelines set by law and the relevant authorities. It is also important to determine the most suitable functional zoning of the area to ensure a safe and comfortable environment for children, including facilities for classes, leisure activities, meals, and any other potential requirements. The results of the empirical study of the completed facility and the school project showed the importance of an integrated approach to the architectural solution of the educational institution, considering innovative methods of educational activities and current safety requirements for all participants in the educational process.

The study considers only the main aspects of shelter construction in Ukrainian schools, given the lack of experience in designing full-fledged protective structures. However, a more detailed study of the experience of the actual operation of basement spaces in schools in Ukrainian cities in 2022/23 is planned in further research on the topic.

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CONFLICT OF INTEREST

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Олена Олександрівна Кайдановська

Доктор педагогічних наук, професор
Національний університет «Львівська політехніка»
79000, вул. Степана Бандери, 12, м. Львів, Україна
<https://orcid.org/0000-0002-7764-1696>

Петро Іванович Думнич

Аспірант
Національний університет «Львівська політехніка»
79000, вул. Степана Бандери, 12, м. Львів, Україна
<https://orcid.org/0009-0009-9189-2393>

Актуальні проблеми облаштування укриттів у закладах освіти України

Анотація. В статті розглянуто проблему створення безпечних умов для всіх учасників навчального процесу у закладах освіти в умовах потенційної небезпеки. Тема стала особливо актуальною від 2022 року внаслідок збройної агресії російської федерації проти України. Облаштування найпростіших укриттів (фортифікаційних споруд) в існуючих шкільних будівлях вирішується державними органами влади, законодавчими структурами, регіональними інституціями та адміністраціями навчальних закладів. Метою дослідження є комплексне вивчення проблеми створення безпечного навчального середовища, визначення орієнтовних дослідницьких напрямків, встановлення законодавчих орієнтирів, превентивна оцінка реальних потреб захисних споруд для забезпечення навчального процесу школи. Використано вихідний аналіз нормативно-правових положень, загальнонаукові методи, систематизація та узагальнення спеціальної інформації, емпіричні методи, метод експертних оцінок, факторний аналіз (для розгляду архітектурних рішень) та міждисциплінарний огляд положень безпеки освітнього процесу. Окреслено етапи вирішення проблеми проектування та будівництва укриттів у закладах освіти України. Визначено основні фактори формування архітектурних рішень укриттів та безпеки освітнього процесу: законодавчий; організаційний; архітектурно-планувальний; інженерно-технічний; педагогічний; побутовий. Увагу приділено науково-педагогічним принципам, сучасним тенденціям та інноваційним моделям шкільного навчання, які впливають на архітектурну організацію шкільних будівель. Планувальні рішення повинні передбачати варіантну ергономічну організацію навчального процесу, відкриті освітні, комунікаційні та рекреаційні простори. Підкреслено, що освітнє середовище школи повинно враховувати вимоги безпеки. У дослідженні розглянуто приклад новозбудованої школи з облаштованим укриттям для учнів і вчителів, яке має належні умови для навчання. Практична цінність проведеного дослідження полягає у можливості застосування визначених аспектів та висновків у реальному проектуванні освітніх закладів на основі комплексного врахування безпекових вимог

Ключові слова: цивільна безпека; шкільне укриття; архітектура шкіл; освітній простір

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Mykhailo Parkhomchuk*
Postgraduate Student
Kyiv National University of Construction and Architecture
03037, 31 Povitroflotskyi Ave., Kyiv, Ukraine
<https://orcid.org/0000-0003-3891-4716>

Transformation of tradition in Kenzo Tange's projects as a way of shaping contemporary Japanese architecture

Abstract. This study explored the transformation of tradition in contemporary Japanese architecture, with a focus on Kenzo Tange's works as a potential solution to the lack of national identity in modern urban spaces, particularly prevalent in post-socialist countries. Such homogenisation, as established by previous research, has negative implications for human psychology. The purpose of this study was to identify K. Tange's creative approach to the use of tradition in the context of modernity. Ukrainian, Japanese, English, American, and other sources on the history of traditional and modern architecture in Japan, including the theoretical achievements of K. Tange himself and several sources on the architect's works, were used in the study. A considerable amount of photographic material was also collected for the study. The paper described certain types of traditional religious architecture in Japan. The architecture of Shinto and Buddhism were considered as prototypes. Accordingly, the following objects of K. Tange were analysed: The Peace Memorial Museum in Hiroshima, in comparison with the Ise Shrine Complex; Kurashiki Town Hall in comparison with the main pavilion of the Buddhist temple complex; the Kagawa Prefecture Government Office Building in Takamatsu in comparison with the Buddhist wooden pagoda. As a result, it was found that the transformation of tradition in K. Tange's works can occur at four levels: the organisation of the master plan, the formation of the interior space of the building, the formation of its overall structure, and at the level of semantics. For each example of transformation, appropriate references were made to certain features of Japanese architecture or traditional Japanese worldview that were discovered during the study. In addition, an algorithm for introducing traditional features into modern architecture was presented, which, given the need to rebuild Ukrainian cities destroyed as of 2023, could help revive them while avoiding the architectural shortcomings of the past

Keywords: architectural tradition; Shinto architecture; Buddhist architecture; Hiroshima Peace Memorial Museum; Kurashiki Town Hall; Kagawa Prefecture Government Office Building in Takamatsu

INTRODUCTION

An individual vision of the world is an inherent feature of every nation, and the unique features of this vision distinguish people from each other. In this diversity of cultures, the beauty of this world is expressed in a certain way. Nowadays, as intercultural boundaries gradually disappear and globalisation becomes increasingly prominent, there is a growing interest in identifying and reviving individ-

ual local traditions in the context of modernity. This is particularly relevant in terms of achieving harmony between modern architecture and the historical memory of a particular place (Shevtsova & Linda, 2020). Research in the psychology of urban space perception confirms the negative impact of a unified architectural environment on the human psyche (Ricci, 2018). Thus, appealing to local

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*Corresponding author



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traditions is an important step towards identifying the modern urban environment as “friendly”, “familiar”, and ultimately habitual, safe, and associated with pleasant feelings (Shevtsova *et al.*, 2020). At first glance, the problem seems simple: incorporating national motifs into modern architecture. However, as M. Micale (2018) notes, the direct introduction or citation of traditional architectural forms in contemporary urban development may not always lead to positive outcomes. In many cases, it appears inappropriate. Thus, in addition to the cultural factor, the functional and aesthetic components of the borrowed form deserve consideration (Pieczara, 2019). Therefore, it is necessary to establish some new methods of transmitting the architectural tradition in modern construction, to refuse direct formal or ornamental quotations, and to pay attention to the global principles of local traditional architecture.

To answer this question objectively, one can look to the expertise found in Japanese architecture. The second half of the last century in Japan also began with post-war ruin, which contributed to the rapid spread of modernist architecture. However, the architecture of Japanese modernism is known for examples of a harmonious combination of architectural achievements of the present and the past. One of the inaugural proponents of Japanese modernism in this field was the globally renowned architect and architectural theorist Kenzo Tange, who could apply and validate his approach to integrating the traditional and the modern. This paper proposes to consider the main provisions of this approach on the example of some of the architect’s completed projects.

Given the problem, the purpose of this study was to identify and consistently interpret K. Tange’s creative approach to combining the national tradition with the architectural principles of modernism. Using the methods of comparative and retrospective analysis, the study examined information about Kenzo Tange’s work based on written sources and a field survey of the objects of his authorship (study of composition, general structure and imagery of buildings, their photographic documentation, etc.) This provided a more profound insight into Tange’s authorial ideas, identified during the study. The study also employed the method of description to depict the traditional sacred architecture of Japan; the most illustrative completed projects of K. Tange were compared, and the findings were summarised using the method of generalisation.

Accordingly, the basis for analysis included the works as follows:

- The Peace Memorial Museum in Hiroshima (compared to the Ise Shrine Complex).
- Kurashiki Town Hall (compared to the main pavilion of the Buddhist temple complex).
- The Kagawa Prefecture Government Office Building in Takamatsu (compared to a Buddhist wooden pagoda).

In all the projects selected for analysis, the study considered both the composition of the building or the complex (layout and volumetric and spatial structure) and their semantics (hidden or allegorical meaning). The concept of

object composition refers to three levels of perception of an architectural object: creation of a master plan, formation of the building structure, and organisation of the interior space. The relation of compositional and semantic components is proposed to be considered as a relation of form and content. By analysing the objects in terms of these three levels of composition and the aspect of semantics, an attempt was made to identify the methods of transformation of the Japanese tradition in Kenzo Tange’s architecture.

LITERATURE REVIEW

Modern and traditional architecture in Japan, despite its worldwide popularity, is still understudied and largely incomprehensible to people unfamiliar with the culture of this country. Therefore, apart from the sources on contemporary architecture, this paper offers an insight into some of the main provisions of traditional Japanese construction.

The book by G. Shevtsova (2011), for the first time in Ukrainian scientific practice, provides a detailed overview of the formation and development of Japanese construction since ancient times. In addition to this book, two publications by the same author on the importance of tradition in contemporary Japanese architecture were also considered (Shevtsova & Linda, 2020; Shevtsova *et al.*, 2020). In the books by Y. Watanabe (1964) and A. Isozaki (2006), the authors discuss the architecture of Japan in general, and the Ise Shrine in particular. S. Mizuno (1974) presented a detailed overview of one of the oldest Buddhist monastery complexes, Horyuji. In addition, the study considered a textbook on the history of Chinese architecture by S. Liang & W. Fairbank (1984).

The study examined the publications of Kenzo Tange himself (co-authored with other prominent architectural historians), which, in the context of a review of certain objects of historical Japanese architecture, outline his vision of architectural creativity in general. The article by K. Tange (1956) covers the issue of interaction between modern architecture and tradition, and K. Tange (1960) discusses the newly built Kurashiki Town Hall. The joint work of architects K. Tange & W. Gropius (1960), using the example of the Imperial Villa Katsura, describes the dichotomy of the principles of Yayoi and Jomon – the power of tradition and the energy of primitive creativity. It was also important to consider the history of architecture, namely a historical overview of the formation and ideological content of the Ise Shrine (Tange *et al.*, 1962). The research work was significantly aided by K. Kawaguchi & K. Hasegawa’s (2021) collection of rare material that sheds light on an architect’s formative years and creative pursuits.

In addition to the above, this study also examined relevant literature, such as U. Kultermann’s (1970) and M. Bettinotti’s (1997) books discussing the work of Kenzo Tange. Furthermore, it incorporates K. Kurokawa’s (1977) book, which explores the development of modern architecture based on the principles of metabolism in Japan during the 20th century, as well as K. Nute’s (1993) research on the influence of Japanese tradition on the architecture of F.L. Wright presents publications by researchers

R. Pernice (2006; 2007), describing the post-war development of Japanese urban planning, N. Ricci (2018), studying the influence of the architectural environment on the human psyche, M. Pieczara (2019), addressing the issue of adapting traditional architectural details in modern design and M.G. Micale (2018), justifying the inadmissibility of unprofessional use of traditional forms in architecture.

HISTORICAL DEVELOPMENT OF JAPANESE ARCHITECTURE

The architecture of Japan is exceptionally rich and diverse. Furthermore, due to certain historical and national specific features of this country, many examples of traditional architecture from different eras, starting from the time of the formation of Japanese statehood, are well preserved. This paper examines sacred architecture, which most clearly reflects national culture. Two religious teachings prevail in Japan, the first of which is Shinto. Shinto is an authentic religious and philosophical doctrine of Japan that has been formed over many centuries and is based on the animistic beliefs of the Indigenous inhabitants of the archipelago. The second doctrine is Buddhism, which was transferred to Japan from the continent in the middle of the first millennium BC (Shevtsova, 2011).

The prototype of a Shinto Shrine is considered to be a type of building called a *takayuka*, a granary built on piles and used to store crops (Watanabe, 1964). Such structures were common in the Neolithic and Bronze Age and occupied a central place in Japanese settlements. Over time, they acquired sacred significance. The most famous example of a Shinto shrine in the *takayuka* form is the Ise Shrine, which was equated by Western architects and researchers to the Greek Parthenon in terms of its importance for Japanese architecture (Tange *et al.*, 1962).

Buddhist architecture was brought to Japan by foreign masters and was largely borrowed from China; it was later modified and integrated into the Japanese architectural tradition. There are many examples of well-preserved ancient Buddhist temples, starting with the Horyūji monastery complex, built in its present form in the late 7th century (Mizuno, 1974; Shevtsova, 2011). However, they all share a certain structure of the complex, which consists of separate buildings and structures, or rather certain objects and zones, the role of which is defined by Buddhist religious doctrine. Traditionally, it is a pagoda, a central worship pavilion and a lecture hall.

With the advent of Buddhism, Japanese architecture continued to evolve. The periods of pronounced influence of Chinese architecture were interspersed with periods of relatively independent development, during which Chinese architectural traditions were substantially modified and acquired a Japanese national flavour. Since its self-isolation in 1641 (Shevtsova, 2011), Japanese architecture has almost completely lost influence from the continent. A new era of development in Japanese architecture began in the second half of the 19th century, when the country re-entered the world stage and began rapid modernisation in all

sectors, including architecture, actively adapting Western building traditions and styles.

Attempts to introduce traditional Japanese features into Western architecture took place in the first half of the 20th century. Thus, one of the first architects to recognise the integrity of the conventional aspects of Japanese architecture was Frank Lloyd Wright. Although he dismissed any external influences on his designs, present-day researchers suggest that the Japanese tradition had a significant impact on his work (Nute, 1993). Describing the stages of development of modern Japanese architecture, architect Kisho Kurokawa identifies a period of ultra-nationalist architecture (Kurokawa, 1977). During this time, architects based their designs on Western-style buildings and attempted to give them a national character by incorporating external elements, such as curved roofs, decorations of cornices, and the facade with national ornaments, according to the ideology of Japanese imperialist nationalism. But with the defeat in World War II, the history of modern Japan was divided into “before and after”, so this approach could no longer be used for ideological reasons. A new stage in the development of Japanese architecture began in the post-war period under the influence of Western architecture, which this time was represented mainly by architectural modernism. Kenzo Tange is one of the first and at the same time the most famous representatives of this period.

TRADITIONAL ARCHITECTURE IN KENZO TANGE'S PROJECTS

Inspired by the works of Le Corbusier (Kultermann, 1970), the artist sought to create buildings that would be in line with contemporary Western trends, noting that in many ways 20th-century architectural views coincided with the established traditions of Japanese architecture. Later, the tendency to preserve national features could often be traced in the architect's works. Kenzo Tange put his ideas into practice in urban planning, planning projects for the city of Tokyo in the mid-20th century (Pernice, 2006; 2007). He consistently embodied the same ideas in architectural objects. The first building of this kind was the Hiroshima Peace Memorial Museum complex built in the 1950s (Kultermann, 1970). Kenzo Tange has repeatedly returned to the theme of the transformation of tradition in his other projects, drawing on the cultural characteristics of the Japanese nation.

In his article “Creation of Modern Architecture and Japanese Architectural Tradition” (Tange, 1956), the architect notes that true architectural creativity is the search for a visible combination of a typified function with the ideal of beauty (thus, one can see that the author reinterprets the Vitruvian architectural qualities: strength, utility, and beauty). In this case, the author suggests that a standardised function is the best solution for a specific household problem in contemporary times. As for the concept of beauty, an analysis of K. Tange's creative career suggests that, at a particular point, traditional architecture was his ideal.

In another, more recent publication, *Tradition and Creation in Japanese Architecture* (Tange & Gropius, 1960),



the author discusses the issue of the architect's interaction with tradition more broadly. Tange revisits the theme of architectural creativity, but from a new perspective. He presents the concept of a dialectical synthesis between tradition and anti-tradition, which can be a constructive force for progress and a safeguard against tradition becoming a mere formality. Drawing parallels with the history of the country, the author identifies the first two historical periods of Japan as the quintessence of the embodiment of these two opposite concepts. During the Jomon period, an ancient culture of hunters and gatherers lived in harsh conditions, geographically separated and struggling against an aggressive environment. This is clearly reflected in the rough and dynamic form of the art examples of that time (Fig. 1). The second period is the Yayoi era, during which continental cultures and immigrants from Korea played an active role, resulting in agricultural growth and the formation of a hierarchical society. This era significantly altered the nature of art, as evidenced by the haniwa mound ceramics (Fig. 2), which exhibit an emphasis on smoothness and balance (Shevtsova, 2011).



Figure 1. Clay statue, late Jomon period (1000-400 BC), Tokyo National Museum

Source: author's photo

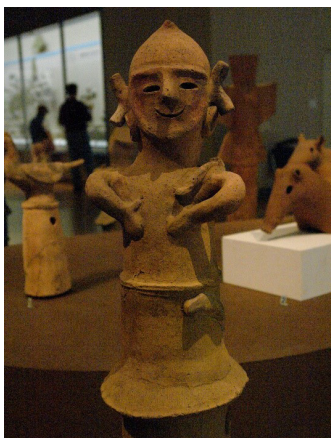


Figure 2. Clay statue of the Yayoi period, (300 BC-300 AD), Kashihara Archaeological Museum in Nara

Source: author's photo

Comparing these two periods, K. Tange considers the first to be the embodiment of the destructive energy of anti-tradition, which is formed spontaneously under the influence of aggressive external factors. The second period, on the contrary, is considered to be a force that restrains, orders, and shapes the first, i.e., the force of tradition. According to Tange, an architect's work is a combination of these two opposites. However, when defining the meaning of the traditional in the creative process itself, Tange believes that the approach of imitating traditional forms should be avoided as one that does not correspond to the ideas of modernity. In his work "Building and Project" (Tange, 1960), K. Tange asserts that tradition should serve as a catalyst, prompting the chemical process and guiding it in a certain direction, but ultimately absent in the final product. That is, as K. Tange contends, the architect's aim is to develop on the foundation of architectural tradition, while ensuring that the end result is still a product of contemporary architecture. For a more detailed analysis of the described principle, it is proposed to consider examples of several implemented projects by K. Tange.

HIROSHIMA PEACE MEMORIAL MUSEUM

The complex was built in the post-war period (in 1956) in the city of Hiroshima, which was destroyed by the atomic bomb at the end of World War II (Kultermann, 1970). The museum complex is a vivid example of a combination of the modern international style of 20th-century architecture and the embodiment of the ancient architectural tradition of Japan. The idea behind the Hiroshima Peace Memorial complex was conceived by the architect during his years of study at the University of Tokyo, when in July 1942 (Kawaguchi & Hasegawa, 2021) he took part in The Greater East Asia Memorial Competition. According to the architect, the complex was to become a place of communication with the ancestors, i.e., a place of unity between two worlds – the world of the living and the dead. The idea of the complex developed around the main axis – a high-speed motorway that would connect the holy mountain (Mount Fuji) with the holy place (the Imperial Palace). In the centre of the axis was to be placed a complex consisting of two parts located opposite each other on elevations along the highway and connected by a bridge (Fig. 3). On the right side (towards Mount Fuji), the main pavilion was to be located, the shape of which was borrowed from the main building of the Ise Shrine. The planned complex was never implemented, but the semantics of the memorial later formed the basis of the architect's next work, the memorial complex of the Hiroshima Peace Memorial Museum. Despite the significant difference between the target orientation and the ideological basis of the construction, both projects have the influence of the Japanese architectural tradition, namely Shinto architecture (Isozaki, 2006).



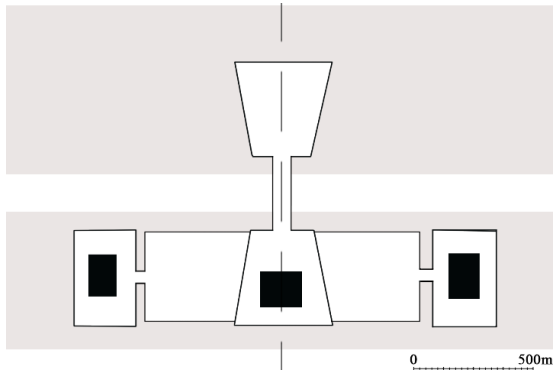


Figure 3. Schematic plan of the Great East Asia Memorial Complex

Source: developed by the author of this study

In this case, it is worth referring to the aforementioned example of ancient Japanese Shinto architecture – the Ise Shrine. According to one of the Japanese chronicles, the sacred complex in Ise was built around the 3rd century. Although architectural historians date the appearance of the sanctuary to the 5th-6th centuries (Shevtsova, 2011). The shrine consists of two parts located at a certain distance from each other: The Naiku Shrine and the Geku Shrine. The complex is unique in that, according to Shinto beliefs, it must be rebuilt every 20 years so that the deity living inside can constantly receive a new, “untainted” home. The reconstruction takes place on the adjacent territory near the sanctuary, and the architectural form and design of the new building stay unchanged. This ritual expresses the desire to get rid of the so-called “taint”, which in the context of Shinto is associated with blood and death (Shevtsova *et al.*, 2020). This tradition has survived to this day and is one of the features of ancient Shinto architecture. Due to constant reconstructions, the authentic appearance of the sanctuary stays unchanged and has no time distortions. Accordingly, it is still possible to observe the oldest traditional techniques of Japanese architecture in the Ise Shrine.

Analysing the sacred complex in Ise in his article “Ise – Origin of Japanese Architecture”, Kenzo Tange highlights several features inherent in Japanese architecture in general. Thus, one of the major features that clearly characterises the Japanese tradition is a smooth, flowing connection between the interior space of a building and its environment. On the contrary, the Western worldview has always sought to separate a certain space from its external space, completely isolating it using architecture (Tange *et al.*, 1962). Other specific features of the Ise Shrine are the horizontal development of the complex in the plan, as well as the division of buildings by functional purpose. Kenzo Tange believed that the reason for this approach was, on the one hand, the lack of technological experience of the builders of the time, and, on the other hand, the religious requirement that some buildings of the complex be separated. An example was given of an ancient Japanese settlement, where dwellings for unmarried men and women, pregnant women, etc. were to be separate buildings (Tange *et al.*, 1962).

The division of buildings by function was also typical for sacred complexes. Both the Naiku and Geku sacred complexes located on the territory of Ise consist of one main building and two secondary buildings symmetrically located along the main axis of the complex. One of the most prominent features of the Ise Shrine that distinguishes it from others is also the symmetrical structure of the general plan and the development of the complex along the main axis (Fig. 4; Fig. 5).

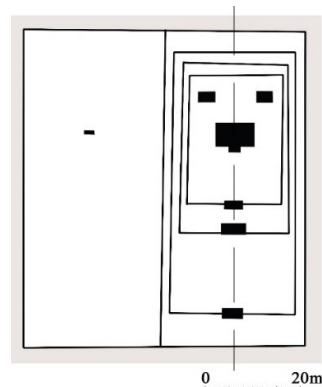


Figure 4. Plan diagram showing the main axis of the Naiku part of the Ise Shrine

Source: developed by the author of this study



Figure 5. General view of the Naiku of Ise Shrine

Source: author's photo

When analysing the architecture of the Peace Museum complex in Hiroshima, it becomes apparent that the traditional forms of the Ise Shrine are borrowed at the levels of the general plan of the complex and the structure of its buildings. The complex is located in the central city park and has no clear separation from the latter. Similarly, the complex is formed in a horizontal direction: it consists of three main buildings (one main and two secondary), which are symmetrically, but with some differences from the Ise Shrine, located along the main axis of the complex. Referring to the idea of constant renewal of the Ise Shrine, one can trace in the idea of the memorial complex a powerful message to future generations that even a city that has been burned to the ground can be reborn and continue its life.

The main axis of the museum complex is also similar to the axis of the Ise complex, but at the same time it is



interpreted as a reference to the traditional funerary culture of Japan: stretching from north to south, it symbolises the connection between two worlds: Higan (literal meaning “the other river bank”), the world of the dead, represented by the so-called Atomic Dome, the ruins of the Hiroshima Products Exhibition Hall located on the opposite side of the river, and Shigan (literal meaning “this river bank”), the world of the living, represented by the revived city on the other side of Hiroshima’s main street, Peace Avenue (Kawaguchi & Hasegawa, 2021) (Fig. 6; Fig. 7).

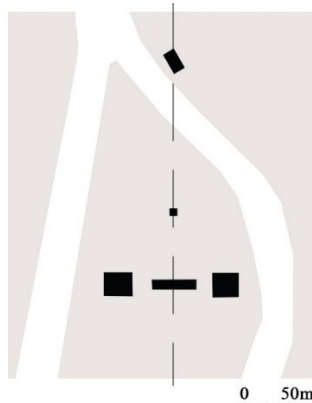


Figure 6. Plan diagram showing the main axis of the Peace Memorial Museum complex in Hiroshima

Source: developed by the author of this study



Figure 7. General view of the Peace Memorial Museum complex in Hiroshima

Source: author’s photo

Another important feature is that the central building of the museum is raised above ground level (Fig. 8; Fig. 9). This is conditioned upon the use of ancient granaries called takayuka, which later became the prototype of Shinto shrines, as an example of the construction of granaries. According to the Japanese perception, it is also a reference to the type of ancient imperial warehouses or temple storehouses (specifically, the Shosoin Treasure House in Todaiji Monastery in Nara (Watanabe, 1964; Shevtsova, 2011)). One of the main functions of this type of storage is to store temple relics or ancient family heirlooms. Drawing a parallel between the storage buildings and the museum, it should be noted that the latter probably plays the role of relics to

the various testimonies of the terrible catastrophe that occurred in the city during the atomic bombing.



Figure 8. Shosoin Treasure House at Todaiji Monastery in Nara

Source: author’s photo

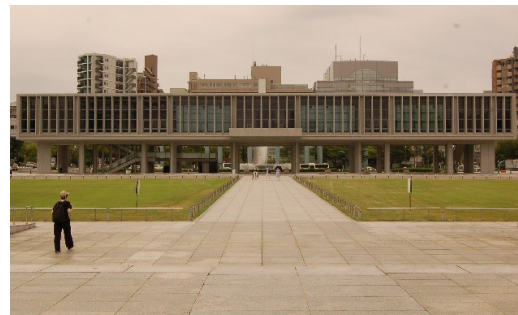


Figure 9. Central pavilion of the Peace Memorial Museum complex in Hiroshima

Source: author’s photo

According to Kenzo Tange, another important feature of the Japanese tradition is the presence of a symbol that reflects the essence of a particular space (Tange *et al.*, 1962). The role of the symbol of the memorial is assigned to the concrete crypt, which is located in the centre of the complex. It has the form of ceramic houses of the dead, the so-called haniwa, which refers to the ancient Japanese tradition of burial mounds (Fig. 10; Fig. 11). Thus, the symbol makes it clear that one of the main ideas of the complex is to create a place of remembrance for the dead.



Figure 10. Arch over the concrete crypt of the Peace Memorial Museum complex in Hiroshima

Source: author’s photo



Figure 11. The shape of the haniwa house

Source: author's photo

Given the target orientation of the complex, all borrowed details can be divided into three semantic groups. The first one includes borrowings from the sacred architecture of the Shinto religion, the second – images and forms of traditional funerary rites; the third – the idea of preserving monuments, expressed in the borrowing of the form of a treasury-reliquary. However, all of these traditional borrowings acquire a new meaning: the principle of rebuilding the architecture of Sinto is the future revival of the city, traditional funerary images are a memorial to the victims of the bombing, and the treasury is the preservation of the monuments of the disaster. It is also interesting that the architect later returned to similar ideas in his later, completed work dedicated to the victims of the Second World War – Memorial Plaza for Students Who Perished in the War. This project retains the idea of the main axis and the symbolism of space.

KURASHIKI TOWN HALL

The town hall (now the City Art Museum) was built in 1960 in the ancient city of Kurashiki. At the time of completion, the building became the dominant feature of the city space. According to the architect's plan, it was to determine the trajectory of further development of the city on a new scale (Kultermann, 1970). The building is an example of architectural brutalism, but at the same time its structure and composition embody the techniques of Buddhist architecture.

Buddhist teachings were brought to Japan in the 6th century (Shevtsova, 2011). Unlike the Shinto religion, whose shrines were closed and often not fully accessible to ordinary pilgrims, Buddhism professed the equality of all segments of the population, and thus had a slightly different structure of complexes from the very beginning. Therefore, Buddhist adherents needed to build new types of buildings and architectural complexes that would meet the needs of the new religious movement. The builders were invited from countries where Buddhism was already widespread. This is how Buddhist monastery complexes with a clearly structured architectural environment appeared in Japan. The main buildings of the Buddhist complex were a pagoda, a central pavilion and a lecture hall. The pagoda was intended to store sacred relics. The central pavilion housed Buddhist statues and was the main place of visit

for pilgrims. The lecture hall was intended for classes, as Buddhist monasteries in ancient times also served as educational institutions (Shevtsova, 2011).

The construction of the main pavilion of the Buddhist monastery was based on a post-and-beam system, the building usually had a rectangular plan. The gaps between the supporting structures were filled with clay or boards. The composition of the pavilion was symmetrical, the number of intercolumns was odd, so that the main entrance was always located in the centre. The top of the building was covered with a heavy tiled roof, the load from which was transferred to the pillars by means of complex multilayered cantilevered capitals – kumimono (Shevtsova, 2011). As a result of this roof structure, a rather wide cornice was formed, which later became one of the characteristic features of Japanese architecture in general (Fig. 12). In addition, an inherent feature of Japanese Buddhist architecture is the two-tiered building of the main pavilion (Fig. 13). It is believed that this feature was inherent in the Chinese architecture of the Tang Empire (VI-IX centuries) (Liang & Fairbank, 1984), and it was then that it came to Japan. This design has taken root in Japan to such an extent that over time it has been actively used even in Shinto architecture.

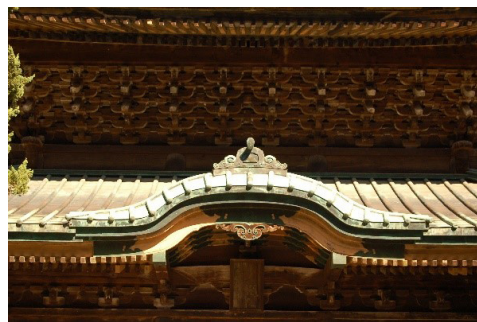


Figure 12. Cornice and structures of the second floor of the central pavilion of Kenjoji Monastery in Kamakura
Source: author's photo



Figure 13. General view of the central pavilion of Kenjoji Monastery in Kamakura
Source: author's photo

The structure of the interior space of the Buddhist pavilion directly depended on the structure of the building and consisted of two main volumes: the “moya” – the



central core of the building and the “hisashi” – the gallery that covered the central part on four sides. “Moya” was spatially separated from “hisashi” by an elevated ceiling level, which was formed by the superstructure of the upper tier. “Hisashi” had a slightly lower ceiling (Fig. 14; Fig. 15). A statue of Buddha was located in the central part of the pavilion, thus emphasising the role of the central part as the sacred core of the entire complex.

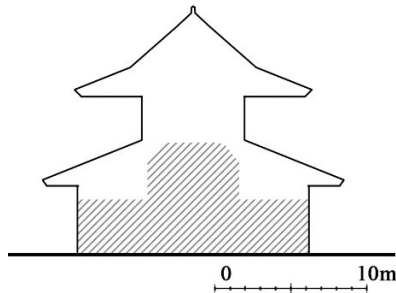


Figure 14. Spatial division of the building of the central pavilion of Kenjoji Monastery in Kamakura

Source: developed by the author of this study

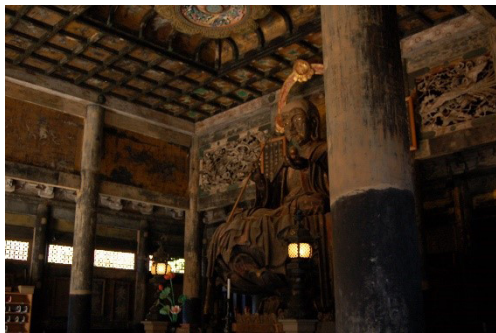


Figure 15. A general view of the “moya” part of the central pavilion of Kenjoji Monastery in Kamakura

Source: author’s photo

Analysing the building of Kurashiki Town Hall, one can notice the author’s use of the characteristic features of Buddhist architecture at the level of the structure and interior space of the building. The building is made of reinforced concrete and also has a post-and-beam system, but the architect used concrete panels and glass as a filler for the interframe spaces. It is also interesting that the building bears a certain resemblance to the ancient Japanese log temple storehouses built according to the takayuka principle (Fig. 8), but according to Tange himself, this idea was not his original creative intention but came to life spontaneously (Tange, 1960). The visual image of the storehouses arises from the combination of pylons protruding from the corners and the elongated rectangular shape of the façade itself. The texture of the façade, formed by longitudinal and end concrete rods, also emphasises this similarity. It resembles the walls of a storehouses made in a horizontal log construction technique with a characteristic angular joint (Fig. 16; Fig. 17). The analogy with Buddhist architecture can also be observed in the symmetry of the building’s

façade in general, which is emphasised by the central entrance in the middle and the division of the lower volume of the building into an odd number of spaces.



Figure 16. External corner connection on the facade of Kurashiki Town Hall

Source: author’s photo



Figure 17. Exterior of the Kurashiki Town Hall

Source: author’s photo

The interior space of the Kurashiki Town Hall, according to the spatial organisation of the Buddhist pavilion, is also divided into two main volumes. The central part of the building unites the space of two floors (Fig. 18; Fig. 19) and serves as a lobby for visitors, which is also similar to the central part of “moya” and, according to its function, acts as the semantic core of the building. Two galleries of the entrance groups on the north and south sides of the hall serve as “hisashi”. The main volume of the first floor is intended for visitors, while the second floor houses the main working premises of the city centre institutions.

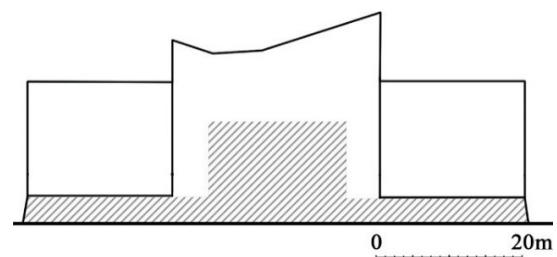


Figure 18. Spatial division of the interior of the Kurashiki Town Hall

Source: developed by the author of this study



Figure 19. General view of the central part of the interior of Kurashiki Town Hall

Source: author's photo

The building is encompassed by a series of external galleries formed in the gap between the main load-bearing structures brought outward and the entrance part recessed inward (Fig. 20; Fig. 21). This element can also be perceived as a continuation of the “Hisashi” part of the exterior.



Figure 20. External galleries of Kurashiki Town Hall

Source: author's photo

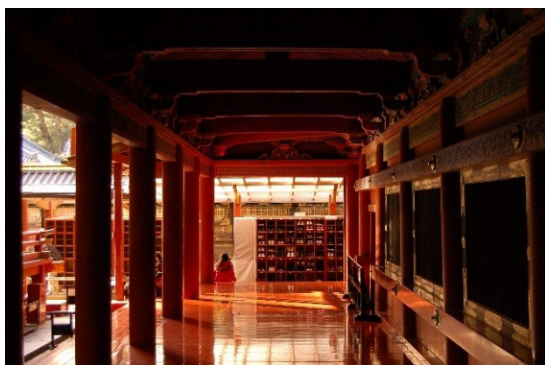


Figure 21. The galleries of the main pavilion of Toshogu temple in Niko

Source: author's photo

Thus, upon entering the city centre through the main entrance, visitors are greeted with an experience similar to that of visiting an ancient temple. They pass under a wide

eave and through an ordinary entrance, only to find themselves suddenly in a grand, central space with a balcony for speeches situated on the second floor. This balcony compositionally echoes the location of the main semantic centre of the temple – the face of the Buddha statue. Looking for an answer as to why the architect selected this solution for the town hall in Kurashiki, it is important to note that Buddhism, which in its doctrine did not differentiate between social classes, initially introduced the principles of equality to the land of Japan. Buddhism also had a profound influence on the tea culture of Japan, which, in times of internecine strife between individual rulers, became an expression of the idea of national unity (Tange & Gropius, 1960). Therefore, in this instance, the application of Buddhist architectural principles may be construed as a manifestation of Tange's aspiration to highlight the significance of the urban centre as a democratic institution that is all-inclusive, diverging from the pre-war Japanese state institutions that were inapproachable and exclusive.

THE KAGAWA PREFECTURE GOVERNMENT OFFICE BUILDING IN TAKAMATSU

In the project for the Kagawa Prefecture Government Office Building in Takamatsu, Kenzo Tange takes a slightly different approach. At the time, the project was criticised for its excessive stylisation and inconsistency with the architect's main idea (Kultermann, 1970). One of the main features of the building is the use of structural techniques of a wooden Buddhist pagoda on the facade. This feature refers too directly to the architectural tradition of Japan, which is probably the reason for the criticism.

In its original form, the idea of a pagoda originated in India. The oldest monuments date back to the 4th-3rd centuries BC, when they had the shape of a hemispherical stupa. When Buddhism came to China, the design of the pagoda absorbed local architectural traditions and took the form of a multi-tiered tower. Such towers were built of brick, wood, or both. The buildings possessed unoccupied indoor spaces on each floor, which, besides serving a religious purpose, were utilized as monastic libraries, storehouses and at times as watchtowers (Shevtsova, 2011). With the spread of Buddhism in Japan, the design of the pagoda is changing again. The main material is wood, and almost the entire interior space is occupied by structures and a central core pillar (the so-called “shin-basira”), with a small free space remaining only on the ground floor. Thus, in Japan, the pagoda again loses any practical significance and actually becomes a sculptural structure (Shevtsova, 2011). The structural basis of the pagoda is made up of four pillars placed on the ground floor, called “shiten-bashira” (Mizuno, 1974) (Fig. 22; Fig. 23). The name literally means Four Heavenly Kings: deities who guard the cardinal points. Another characteristic feature of Japanese pagodas is an odd number of tiers, the most common being three or five tiers, and in ancient times there were also multi-tiered pagodas with 7 and 9 tiers (Shevtsova, 2011).

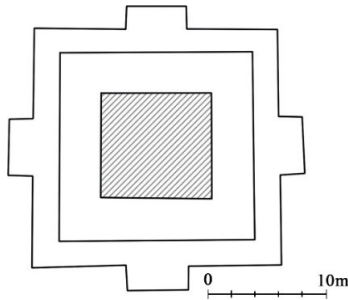


Figure 22. Schematic of the structural core of the five-tiered pagoda at Kofukuji Monastery in Nara

Source: developed by the author of this study



Figure 23. General view of the five-tiered pagoda of Kofukuji Monastery in Nara

Source: author's photo

Tange based the Kagawa Prefecture Government Office Building on his previous project of a similar purpose, the former Tokyo City Centre building (Kultermann, 1970; Kawaguchi & Hasegawa, 2021). Created according to the principles of post-war modernist architecture, the building once became a symbol of building a new open democratic society. But unlike its predecessor, the Kagawa Prefecture Government Office Building is also a vivid example of the use of the so-called “wooden technique” in concrete architecture (Kultermann, 1970).

The use of traditional principles in the architecture of the Kagawa Prefecture Government Office Building is mainly limited to the building structure. The building consists of nine floors surrounded by open galleries. The galleries are formed by extending the transverse beams and, accordingly, bringing the floor ceiling outwards, which creates a visual resemblance to the rhythmic repetition of the widely spaced eaves of a Buddhist pagoda. Similar features can be observed in the building's layout. In the centre is the structural core, which is the main support for the floors around it and is also the main functional communication of the building. Thus, the structural system of the administrative centre can be correlated with the structure of a pagoda (Fig. 24; Fig. 25), which also develops around a central core.

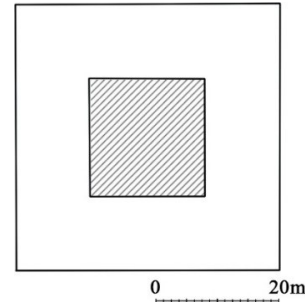


Figure 24. Schematic diagram of the structural arrangement of the Kagawa Prefecture Government Office Building in Takamatsu

Source: developed by the author of this study



Figure 25. General view of the Kagawa Prefecture Government Office in Takamatsu

Source: author's photo

In general, the metrical composition of the building's façade refers to the systematic and orderly design of Japanese pagodas, but also, due to its proportions, some researchers believe that it is inspired by traditional Shinto “mikoshi” – ritual festive stretchers made in the form of a small temple (Kawaguchi & Hasegawa, 2021). The architect actively uses traditional elements in the interior design of the building – imitation of traditional interior elements, monochrome paintings, etc.

In contrast to the previous two projects, where visitors were mainly presented with conventional spatial solutions, Kagawa's building architecture relies on the construction level. Tange employs existing traditional wooden techniques as a foundation, replicating them in reinforced concrete, which forms the frame structure of the building. Thus, by effectively using modern building materials, Tange manages to preserve the traditional image of a multi-storey building that is familiar to the Japanese.

K. TANGE'S METHOD OF TRANSFORMATION OF THE TRADITION

According to Kenzo Tange, tradition in the hands of an architect is a form that guides the creative process, it has no value in itself. Similarly, disordered, unrestrained creativity does not bring fruitful results. With this approach





to design, the architect achieves a visual combination of the building's function with the traditional ideal of beauty (Tange, 1956). In other words, he manages to combine modern construction requirements with a contemporary concept of beauty, which itself is derived from traditional art and architecture.

The methods of transformation of the Japanese tradition used by Kenzo Tange are the result of a profound analysis of the Japanese architectural tradition. In an attempt to systematise the identified methods, they can be

conditionally divided into four levels: master plan development; building structure development; organisation of internal space; and semantics (Table 1). Borrowings at the level of the master plan are clearly reflected in the design of the Peace Museum complex; at the level of the interior space – the Kurashiki Town Hall; at the level of the structure – the Kagawa Prefecture Government Office Building in Takamatsu and the central building of the Peace Museum complex. Each of the projects also embodies certain semantic images related to the function of the building.

Table 1. Features of traditional architecture according to the planning levels of the project

	Hiroshima Peace Memorial Museum complex	Kurashiki Town Hall	The Kagawa Prefecture Government Office Building in Takamatsu
Outdoor space	<ul style="list-style-type: none"> – shapes of burial mound artefacts – principles of forming the architecture of Shinto – principles of shaping temple storehouses 	<ul style="list-style-type: none"> – a formal imitation of a log cabin storehouses 	<ul style="list-style-type: none"> – distant associations with the form and planning structure of the Japanese tiered pagoda
Construction	<ul style="list-style-type: none"> – structural elements of an ancient temple storehouses (piles, etc.) 	<ul style="list-style-type: none"> – frame with infill, traditional for the construction of the central Buddhist pavilion 	<ul style="list-style-type: none"> – construction of a Japanese tiered pagoda with a central pillar and wooden frame construction technique (post-and-beam system, wide eaves overhang, tectonicity)
Interior space		<ul style="list-style-type: none"> – use of the increased interior space of the Buddhist pavilion 	<ul style="list-style-type: none"> – the central structural core around which the centre's layout develops
Semantics	<ul style="list-style-type: none"> – the image of the resting place of the dead, which was traditionally expressed in haniwa mound ceramics – a symbol of the city's revival, which is expressed in the idea of a permanent tradition of rebuilding the Ise Shrine – the idea of preserving memory, which was traditionally expressed in the form of a takayuka granary (later – temple storehouses) 	<ul style="list-style-type: none"> – the idea of social equality, traditionally expressed in the architecture of Buddhist temples and related tea architecture 	<ul style="list-style-type: none"> – the idea of transparency and social equality of a democratic society, which is expressed in traditional forms of Buddhism and in the overall transparency and rhythmicity of the structure

Source: developed by the author of this study

Thus, in the projects presented by K. Tange, one can clearly note the interconnectedness of traditional architectural forms and principles with the main ideological content of the building. The author also demonstrates the possibility of preserving even the constructive methods of the past by translating them into construction from modern materials. This shows that K. Tange's method of transformation is not limited to external resemblance to individual examples of traditional architecture or their interpretation but is mostly just a tool for expressing the author's creative ideas in the context of contemporary architecture.

CONCLUSIONS

Analysing Kenzo Tange's creative approach, his algorithm of borrowing traditional forms can be presented as follows: determining the general planning solution of the object in accordance with the requirements of society; searching for a traditional form that would embody a similar idea; adapting the traditional form to the modern needs of society.

The ideas behind the construction of the Museum of Peace complex, which are embodied in traditional forms,

are 1) creation of a place of honour for the dead; 2) formation of a symbolic space reflecting the idea of rebirth; 3) creation of a place to store documentary evidence. The first idea is embodied in traditional funerary images (the idea of the interconnection between our world and the world of the dead, Higan-Shigan; the clay burial house of Haniwa); the second – in the forms of sacred architecture of Shinto (the structure of the master plan of the Ise complex), the third – in the form of a traditional takayuki warehouse. Traditional images are adapted through abstract interpretation and modern reinterpretation of traditional forms.

The building of Kurashiki Town Hall embodies the need to create a place for a large number of people to gather in a traditional form, emphasising the idea of a democratic institution. It is reflected in the adaptation of the shape of the interior volume of the Buddhist pavilion. In implementing this idea, the author rejects almost all elements of the pavilion's exterior design, focusing solely on its interior volume.

The main requirement of the Kagawa Prefecture Government Office Building project was to create a modern city centre that would meet the requirements of the new



social order. Taking the planning structure of Tokyo's city centre, which was based on a typical post-and-beam system, Tange simultaneously refers to a similar traditional Buddhist pagoda structure. Tange borrows only the general design principle, adapting it to the conditions of modern construction.

Tange's approach to traditional forms is pragmatic; for him, tradition in architecture is a form that loses its functional content, loses its meaning. In his projects, K. Tange imbues the traditional form with a fresh and contemporary content. However, at the same time, his approach is not from form to content, not from tradition to function. Instead, the function manifests itself through a specific traditional form, retaining only what is pertinent and useful in modern conditions. Admittedly, the modernist architecture exemplified in the works of K. Tange discussed in this article may no longer be relevant, but the approach he pioneered stays universal and has been adopted by subsequent generations of Japanese architects, even those working today.

This paper considered one of the possible methods of interaction between a contemporary architect and the architectural tradition of the past. Notably, the transformation

method described in this paper is not exhaustive and that there are other methods that would also be interesting to explore. It is worth considering the possibility of the author's parallel use of different, even ideologically opposite approaches, which can be traced to some extent even in the projects presented in this paper. It would also be interesting to explore and compare the works of other Japanese architects, ranging from his contemporaries to well-known architects of the present, with K. Tange's projects.

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CONFLICT OF INTEREST

None.

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Михайло Сергійович Пархомчук

Аспірант

Київський національний університет будівництва і архітектури

03037, просп. Повітрофлотський, 31, м. Київ, Україна

<https://orcid.org/0000-0003-3891-4716>

Трансформація традиції в проектах Кендзо Танге як шлях формування сучасної японської архітектури

Анотація. Статтю присвячено розгляду питання трансформації традиції в сучасній архітектурі Японії на прикладі робіт Кендзо Танге, як можливої спроби гармонізації сучасного міського простору, характерною рисою котрого, особливо у постсоціалістичних країнах, є типовість і відсутність характерних національних ознак, що за результатами досліджень сучасних науковців має негативний вплив на психіку людини. Метою роботи було виявлення творчого підходу К. Танге до використання традиції в умовах сучасності. В роботі використовувалися українські, японські, англійські, американські, та інші джерела з історії традиційної і сучасної архітектури Японії, включаючи теоретичні напрацювання самого К. Танге та декілька джерел присвячених роботам архітектора. Для дослідження також було зібрано значну кількість фотоматеріалу. В статті було викладено опис окремих типів традиційної релігійної архітектури Японії. В якості прототипів розглядалися архітектура Синто та буддизму. Відповідно до цього було проаналізовано наступні об'єкти К. Танге: меморіальний центр миру в Хірошімі, у порівнянні з храмовим комплексом Ісе; будинок муніципалітету в Курашікі у порівнянні з головним павільйоном буддійського храмового комплексу; будівля префектури Кагава в Такамацу у порівнянні з буддійською дерев'яною пагодою. В результаті, було виявлено, що трансформація традиції в творах К. Танге може відбуватися на чотирьох рівнях: організація генплану, формування внутрішнього простору будівлі, формування її загальної конструкції та на рівні семантики. Для кожного прикладу трансформації було наведено відповідні відсилки до окремих виявлених в ході роботи рис японської архітектури або традиційного японського світосприйняття. Також, було представлено алгоритм впровадження традиційних рис у сучасну архітектуру, що в умовах необхідності відбудови зруйнованих станом на 2023 рік українських міст, могло б стати допомогою у можливості відродження їх з уникненням архітектурних недоліків минулого

Ключові слова: архітектурна традиція; архітектура Синто; архітектура буддизму; Меморіальний центр миру в Хірошімі; муніципалітет в Курашікі; Адміністрація префектури Кагава в Такамацу

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