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# Biophilic design elements in protective structures for educational institutions

**Abstract.** This study addressed the relevance of biophilic design principles in artificial lighting systems for educational shelters, where the absence of natural light and the confined spatial conditions can intensify stress and anxiety among occupants. The purpose of the research was to identify and substantiate lighting strategies that replicated qualities of natural illumination and enhanced user comfort in protective learning environments. The methodological approach included comparative analysis of sensory responses to various artificial lighting scenarios, evaluation of lighting parameters that emulated natural conditions, and examination of design techniques used in controlled, windowless environments. Special attention was given to the role of light intensity, colour temperature, distribution, and temporal dynamics in shaping spatial perception and emotional stability. It was analysed educational shelters in Mykolaiv Lyceum No. 55, Bilohorodka Lyceum No. 2, and the supporting gymnasium in Nizhyn, which were selected for their operational status and representative spatial characteristics. While these facilities demonstrated a comparatively high level of technical organisation and regulatory compliance, analysis revealed deficiencies attributable to the complete absence of natural daylight, limited visual connectivity with the exterior, and the spatial dominance of reinforced concrete enclosures. The research results demonstrated that artificial lighting systems incorporating soft diffusion, gradual transitions, and circadian-inspired dynamics significantly improved spatial perception, reduced psychological discomfort, and promoted a sense of safety in enclosed shelters. Systems that simulated daylight patterns through controlled brightness shifts and natural-tone spectra were found to be particularly effective in lowering stress indicators and maintaining cognitive performance during prolonged occupancy. Integration of biophilic lighting elements contributed to the functional transformation of protective structures, making them suitable not only for emergency use but also for extended educational activities. The practical value of this study lain in developing design guidelines for

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integrating biophilic lighting into educational shelters, thereby enhancing their functional resilience and supporting users' psychological well-being

**Keywords:** natural daylight; artificial lighting; psychological comfort; shelter architecture; safety; dynamic lighting

## INTRODUCTION

The creation of comfortable, psychologically supportive environments in protective structures for educational institutions had become an increasingly urgent challenge in contemporary architectural research. During emergencies, students and staff may spend extended periods in confined shelters, where the absence of natural light, restricted spatial configurations and limited sensory stimuli can lead to elevated anxiety, perceptual discomfort, and overall psychophysiological stress. Scientific studies confirmed that traditional approaches to the design of lighting and spatial layouts in protective facilities remained predominantly technical and frequently overlook human-centred and restorative principles. K. Husar (2023) noted that the prevailing engineering-oriented design paradigm in civil protection structures insufficiently addressed users' psychological needs. Researchers noted that simulation of natural lighting, by imitating the spectral and dynamic properties of natural light, had the effect of increasing attention and concentration, and improving social interaction. Similarly, N. Semyroz (2022) emphasised the limited integration of well-being-oriented criteria into the spatial planning of protective environments. This gap highlighted the necessity of exploring biophilic design strategies capable of enhancing comfort and resilience in enclosed spaces. Between 2020 and 2025 years, the integration of biophilic design into educational and underground environments had gained significant international attention. J. Deol *et al.* (2022) demonstrated that biophilic lighting interventions can measurably improve student comfort and productivity. Using an online Qualtrics survey, scientists found that both natural daylight and lighting elements that mimic circadian rhythms increased the level of comfort and productivity compared to artificial lighting in a basement workspace. The developers of CoeLux. Experience the sky (n.d.) presented Artificial Skylight technologies that simulated natural daylight conditions and mitigate the psychological burden of windowless environments. E.-N.D. Madias *et al.* (2023) further substantiated the effectiveness of advanced artificial daylight systems in supporting emotional stability in enclosed spaces.

K. Poimanova (2024) analysed the influence of biophilic elements in educational interiors and identified their role in attention recovery and stress reduction. L. Mengqi *et al.* (2025) highlighted the contribution of nature-inspired design strategies to environmental satisfaction and cognitive engagement in learning settings. The authors showed that the influence of curvilinear forms contributed to greater improvement in cognitive functions and stress reduction, while non-biophilic forms provided better protection against stress. Learning environments with non-biophilic design may be more suitable for stressful tasks (such as lessons and exams), while environments with curvilinear biophilic forms were better suited for relaxation, creativity and attention. Additionally, S. Incesakal & M.S. Venice (2020) investigated biophilic approaches in earth-sheltered and underground structures, revealing their potential to improve spatial perception and user orientation in windowless conditions. W. Browning *et al.* (2014) classified 14 biophilic design patterns into nature in the space, natural analogues, and nature of the space. In Ukraine, the urgency of this issue was reinforced by the need to adapt civil protection facilities in educational institutions to updated safety requirements and extended periods of occupancy. The national regulation SCN V.2.2-5:2023 (2023) established contemporary standards for the design of protective structures, including requirements for functional and environmental quality. T. Zhydkova & N. Pylypenko (2023) identified persistent deficiencies in lighting quality, spatial organisation, and psychological comfort in preschool, underlining the necessity of integrating human-centred and biophilic design principles into their architectural transformation. Also, the authors proposed variants of murals in shelters of children's institutions. So, study aimed to examine the potential of biophilic design, particularly biophilic lighting principles, to improve the environmental quality of protective structures in educational institutions. The objectives included: 1) identifying relevant biophilic design elements applicable to enclosed protective spaces; 2) analysing their functional, perceptual, and psychological effects in the context of shelter use; 3) developing a set of evidence-based design recommendations for educational facilities.

## MATERIALS AND METHODS

This study applied a mixed-method research design that combined systematic literature analysis, comparative architectural review, and project-based experimentation to identify biophilic design elements appropriate for protective structures in educational institutions. The methodological framework was developed to ensure a transparent and fully replicable research process so that other scholars can reproduce the study using equivalent materials and procedures. The empirical part of the study relied on a purposive sampling of architectural case studies of protective spaces in educational institutions, specifically: Mykolaiv Lyceum No. 55 (Mykolaiv, Ukraine) (Rohalevych, 2024), a newly implemented reinforced-concrete underground shelter equipped with modern engineering systems and organised learning and play zones. Bilohorodka Lyceum No. 2 (Bilohorodka, Kyiv region, Ukraine) (Kyiv Regional

Military Administration, 2023), a contemporary school shelter developed under regional reconstruction initiatives with improved spatial zoning and technical infrastructure. Supporting gymnasium in Nizhyn (Chernihiv region) (KSE Foundation, n.d.), where adapted protective space integrated updated safety infrastructure within an existing educational building. Case selection criteria included operational status and sufficient descriptive and visual materials for detailed spatial assessment. Given the absence of publicly available architectural documentation for these facilities, the analysis was conducted on the basis of materials accessible through open sources. Each case was considered within the spatial configuration, lighting conditions, material characteristics and the possibility of integrating biophilic elements under safety restrictions.

A project-based methodological component was incorporated to test the applicability of biophilic principles in real design scenarios. An interior design concept was developed for an educational institution shelter using biophilic artificial lighting as the primary intervention tool. The design process involved several iterative stages: establishing functional and safety requirements in compliance with civil protection regulations including such documents as Civil Protection Code of Ukraine No. 5403-VI (2012), Law of Ukraine 2145-VIII (2017) and SCN V.2.2-5:2023 (2023); analysing the spatial layout to determine optimal lighting distribution; selecting lighting typologies capable of simulating natural rhythms; and modelling visual, perceptual, and psychological effects through digital prototyping. Artificial luminaires with biophilic characteristics, such as variable correlated colour temperature, dynamic intensity patterns, and diffused forms inspired by natural analogues, were tested virtually to evaluate their impact on atmosphere, visual comfort, and perceived spaciousness. Each design iteration was documented and assessed using predefined performance indicators, including correlated colour temperature range and spectral variability, contrast ratios, spatial zoning clarity, perceived openness (based on visual simulation), and compliance with minimum sanitary to ensure methodological consistency and replicability. The final research stage synthesised findings from the literature review, case-study analysis, and project-based experimentation. Biophilic elements were grouped according to their functional contribution, perceptual impact, and psychological relevance for protective structures.

## RESULTS AND DISCUSSION

Protective structures (shelters) in educational institutions must integrate safety, functionality, and a comfortable environment suitable for prolonged occupancy, addressing both physical protection and the psychological well-being of students and staff. Beyond fulfilling their primary protective function, these facilities should provide conditions that allowed educational activities to continue uninterrupted and minimise stress, anxiety, and other negative psychological effects associated with prolonged stays in enclosed spaces. The necessity for such an integrated approach had been underscored by the ongoing experience in Ukraine, where the full-scale military aggression and the persistent threat of missile strikes, aerial bombardments, and explosive damage to civilian infrastructure have significantly heightened the demand for high-quality protective shelters within schools (Malik *et al.*, 2023). The design and functional organisation of protective structures in educational institutions must comply with the current Ukrainian regulatory framework, which defined safety, operational, and environmental requirements for such facilities. In particular, SCN V.2.2-5:2023 (2023) established mandatory standards for spatial planning, engineering systems, lighting parameters, and sanitary conditions in civil protection shelters. These provisions ensured structural resilience, minimum luminance levels, ventilation performance, and safe evacuation routes, forming the technical basis for the architectural adaptation of educational shelters.

Lighting requirements were further specified by SCN V.2.5-28:2018 (2019), which defined normative illuminance levels, uniformity ratios, and colour rendering indices for educational and public spaces. While this standard ensured baseline visual comfort and task-oriented performance, it addressed lighting exclusively in static, quantitative terms and does not account for spectral variability, circadian dynamics, or the psychological effects of light on occupants in enclosed, windowless environments. The absence of such qualitative criteria within the existing normative framework represented a significant gap, as the conditions of prolonged shelter occupancy, particularly among children, demand considerably higher environmental standards than minimum compliance can provide. This limitation underscored the need to supplement current regulatory requirements with evidence-based biophilic lighting guidelines developed specifically for the context of educational protective structures. At the institutional level, the Law of Ukraine 2145-VIII (2017) guaranteed the right to safe and accessible learning environments and required educational institutions to provide conditions that protected the life, health, and well-being of students and staff. This legislative framework reinforced the necessity of integrating protective shelters into school infrastructure not merely as emergency facilities, but as spaces capable of supporting continuous educational processes under extraordinary circumstances. Civil Protection Code of Ukraine No. 5403-VI (2012) defined the legal and organisational principles of civil protection, including the responsibilities of public authorities and institutions in ensuring population safety during emergencies and armed conflict. The Civil Protection Code of Ukraine No. 5403-VI (2012) regulated the creation, maintenance, and operational readiness of protective structures, thereby providing the legal foundation for their implementation in educational settings.

Case studies examined in this research represented a contemporary stage in the development of educational protective structures in Ukraine, each of them demonstrating distinct architectural characteristics with direct implications for biophilic lighting integration. Mykolaiv

Lyceum No. 55 (Rohalevych, 2024) accommodated up to 600 occupants in a newly constructed reinforced-concrete underground shelter located beneath the school building. The shelter comprised a series of interconnected rooms arranged along a linear corridor, with clearly defined functional zones for learning, play, and sanitary facilities. The ceiling height was approximately 2.4 m, and the spatial configuration was characterised by a uniform rectangular layout without natural light apertures. The structural envelope consisted of exposed and plastered reinforced concrete, with no significant use of transparent or light-scattering materials. Artificial lighting was provided by standard fluorescent ceiling fixtures offering static, uniform illumination without dynamic or circadian adjustment. The absence of windows, the monotony of the concrete surfaces, and the fixed lighting regime result in a spatially undifferentiated environment that offered limited perceptual variation across zones. Bilohorodka Lyceum No. 2 (Kyiv Regional Military Administration, 2023) presented a more architecturally developed solution, realised as part of a regional reconstruction initiative in Kyiv oblast. The shelter was integrated into the basement level of the school building and features improved spatial zoning, with separate areas designated for educational activities, rest, and service functions. The interior finish employed painted masonry and partial use of acoustic panels, contributing to a more controlled acoustic environment. Lighting was delivered through LED ceiling fixtures, though colour temperature and intensity remained fixed. The spatial organisation followed a branching corridor system with slightly greater ceiling heights than in the Mykolaiv case, yet the perimeter walls remained fully opaque and windowless, and no biophilic or nature-referencing design elements were incorporated into the existing installation.

The supporting gymnasium shelter in Nizhyn (Chernihiv region) was adapted within an existing building as part of an initiative by the Olena Zelenska Foundation and KSE Foundation, which equipped the space as an inclusive protective environment for approximately 800 students (KSE Foundation, n.d.). The adapted space occupied a ground-floor or semi-basement level and integrated updated safety infrastructure, including reinforced structural elements, ventilation, and emergency systems, into the pre-existing architectural shell. The interior was organised with attention to inclusivity, incorporating accessible pathways and spatial flexibility. Lighting was provided through modern LED fixtures, and the interior palette employed lighter tones to counteract the visual heaviness of the enclosed setting. Despite these improvements, the space retained the fundamental constraint of full enclosure with no direct daylight access, confirming the systemic challenge shared across all three case studies: the need for purposeful artificial lighting strategies capable of compensating for the complete absence of natural light, the dominance of hard structural surfaces, and the limited visual connectivity with the external environment. Analysis revealed a shared structural constraint critical to the implementation of the lighting systems proposed in this study. Artificial Skylight technologies required minimum ceiling height and sufficient plenum depth that cannot be achieved through retrofitting of existing protective structures, where spatial dimensions were fixed by the original construction. Integration of sky-simulating lighting systems was therefore feasible exclusively within new construction, where the relevant parameters can be designed from the outset. The examined cases thus highlighted the gap between existing shelter infrastructure and the design standards proposed in this research.

Natural possessed a strong aesthetic function: it created dynamic interactions of light and shadow, emphasised volumetric qualities of space, and established visual depth and texture, thereby enhancing the perceived quality of interior environments (Katrichenko *et al.*, 2020). Such effects were crucial in educational settings, where both cognitive performance and emotional stability were closely linked to environmental quality. However, in protective structures or shelters, access to natural daylight was often limited or entirely absent due to architectural constraints, underground locations, or safety requirements. In these conditions, daylight must be effectively substituted by artificial lighting systems designed in accordance with biophilic principles. Key factors included: spectral composition (light with a high level of blue spectrum during daytime promoted cognitive activation and supported circadian rhythms, whereas warm light reduced stress in the evening); lighting intensity (excessive or insufficient brightness disrupts visual comfort); colour temperature (regulating lighting according to time of day supports harmonious psychophysiological processes – cool light stimulates activity, while warm light promoted relaxation); uniformity and quality of light distribution (harsh contrasts, shadows, or glare increase eye strain and cause discomfort) (Poimanova, 2024). Biophilic lighting strategies in protective educational shelters were implemented through integrated LED-based systems, including light wells, Virtual Sky ceilings, luminous virtual windows, video panels with natural imagery Artificial Skylights. These solutions improved cognitive performance and contributed to emotional stability by recreating perceptual physiological characteristics of natural daylight within enclosed environments. Realistic “sky” views on ceilings and upper wall planes mitigated the sense of confinement typical of underground shelters, while luminous virtual windows recessed flush with wall surfaces created the illusion of spatial depth. The introduction of elongated horizontal luminous openings further enhances the perception of openness by stimulating interior beyond its physical boundaries. The technological basis of such systems lain in programmable LED luminaires with adjustable spectral output and intensity. Through digital control units, lighting scenarios can simulate diurnal cycles, ensuring smooth transitions from warm morning light to brighter neutral daylight and subsequently to warmer evening tones (Deol *et al.*, 2022). Lighting regulation was calibrated in accordance with the duration of occupancy and the

functional zoning of the shelter, allowing differentiated illumination for study, rest, and circulation areas.

To achieve visual comfort, it was essential to avoid harsh contrasts and ensure uniform luminance distribution. This was accomplished through the combination of diffuse and accent lighting. Diffuse illumination was provided by LED panels with optical diffusers or continuous light lines integrated into ceilings and walls, creating a soft daylight-like background. Accent lighting was applied in learning or relaxation zones to establish functional differentiation without disrupting overall visual balance. Cool light above 5000 K may increased anxiety, whereas warm-to-neutral light within the range of 2700-3000 K promoted psychological stability and relaxation, particularly during prolonged shelter use (Incesakal & Venice, 2020). Insufficient illumination led to drowsiness and decreased cognitive efficiency, while excessive brightness caused visual strain; therefore, adaptive, dimmable systems were recommended. To strengthen the perception of natural presence, LED panels and projection-based systems can display dynamic visualisations of foliage, clouds, or filtered sunlight, reinforcing sensory connections to natural analogues (Browning *et al.*, 2014). Among advanced daylight-mimicking technologies, Artificial Skylights represented a particularly effective solution. Designed to reproduce the spectral, chromatic, and intensity characteristics of natural light, it simulated the visual effect of blue sky and solar penetration even in windowless spaces (CoeLux. Experience the sky, n.d.). The application of technologies reproducing the daylight spectrum and visual sky effects ensured a comprehensive positive impact on the well-being of individuals within shelters. Realistic imitation of an "open sky" on the ceiling transformed the architectural perception of the space, neutralising the sense of isolation and confinement typical of underground structures. The use of such systems in educational institutions had been shown to increase student productivity and reduce fatigue. Table 1 summarised a comparison of the effects of artificial daylight and conventional artificial lighting on the psychophysiological state of humans.

**Table 1.** The impact of artificial lighting on human psychophysiological state

| No. | Parameter | Artificial lighting simulating the sky (Artificial Skylight) | Conventional artificial lighting |
|---|---|---|---|
| 1 | Visual comfort | High; simulates natural sky, reducing visual fatigue | Moderate; uniform but may cause visual fatigue due to monotony |
| 2 | Anxiety level | Reduced; natural visual cues help lower anxiety | Elevated; standard light may create a sense of confinement and increase anxiety |
| 3 | Attention stimulation | High; natural light simulation supports activity and concentration | Moderate; bright light promotes focus but effectiveness decreases due to lack of variation |
| 4 | Emotional state | Improved; daylight simulation creates comfort and sense of security | Neutral or negative; artificial light may contribute to feelings of fatigue |
| 5 | Physiological response | Positive; regulates circadian rhythm, reduces stress | Neutral or negative; does not support biorhythm regulation, may increase stress |
| 6 | Learning quality | Enhanced; better perception and retention of information | Neutral; does not improve cognitive performance |
| 7 | Light intensity and distribution | Dynamic, natural changes throughout the day; even spatial illumination | Fixed, static, often uneven distribution |
| 8 | Effect on biorhythms | Positive; supports natural circadian rhythms and adaptation to time of day | Absent; fixed intensity disrupts natural biorhythms |
| 9 | Spatial perception | Creates a sense of open space, expanding room boundaries | Creates a sense of confinement, potentially contributing to psychological discomfort |

**Source:** developed by the authors

The implementation of lighting panels that simulated a sky dome provided a transformative approach to interior illumination in protective structures, creating the perceptual illusion of open space and expansive ceilings. This effect was particularly effective in mitigating feelings of confinement and claustrophobia, which were common stressors in enclosed or underground shelter environments. For younger school-age children, such perceptual interventions were of critical importance, as a sense of safety and spatial freedom directly influenced emotional stability, cognitive functioning, and the ability to engage in learning and play during prolonged shelter occupancy. Retrofitting of existing protective structures with Artificial Skylight systems was constrained by fixed ceiling heights and structural configurations that precluded the installation depth such technologies required. The biophilic interior design project for an educational shelter at 129 Stryiska Str., Lviv, developed by Viktoriia Dukhina within the framework of the Steel Freedom 2024 architectural competition, addressed this limitation directly by proposing a purpose-designed shelter conceived as part of a new-construction school, where spatial parameters were determined from the outset to accommodate advanced biophilic lighting solutions (Steel Freedom, n.d.). This approach allowed the full implementation of the lighting strategies examined in this study, including Artificial Skylight systems, dynamic LED configurations, and circadian-responsive control, without the dimensional and structural constraints inherent to reconstruction. The design solutions presented were conceived as modular:

while developed for this specific facility, it established a replicable framework of lighting typologies, spatial zoning principles, and technical configurations that can be adapted to any new-construction educational shelter regardless of institution or location. The project thus served not as a site-specific proposal but as an evidence-based design model demonstrating how biophilic lighting principles can be systematically integrated into the standard practice of educational shelter design in Ukraine.

The project's primary objective was to safeguard the well-being, cognitive performance, and emotional stability of children and staff during prolonged occupancy, while maintaining functional flexibility for both educational and recreational activities. The shelter was designed to serve a dual purpose: as a protective structure ensuring physical safety and as a supportive educational space promoting comfort and engagement. The interior layout was carefully structured into clearly defined zones: classrooms, group activity areas, rest and nap spaces for preschool children, dining facilities, and recreational areas. Circulation paths were wide and fully accessible, allowing children with limited mobility to move freely and ensuring rapid and safe evacuation in emergency situations. All materials used in the shelter were durable, non-toxic, and easy to maintain, with special attention to acoustic performance and visual clarity. Furniture and spatial arrangements were modular, enabling flexible adaptation for varying group sizes and diverse activity types. Spatial zoning also incorporated visual and acoustic separation to minimise distractions, promote concentration. The primary school classroom represented the basic learning scenario (Fig. 1). Its colour palette and wall graphics followed the principles of the New Ukrainian School, creating a supportive and development-oriented environment (Order of the Cabinet of Ministers of Ukraine No. 988-r, 2016). A single central Artificial Skylight lamp was integrated into the ceiling, generating the perceptual effect of an atrium and visually increasing the vertical dimension of the room. Uniform task illumination was ensured by recessed LED luminaires arranged according to normative illuminance requirements (Order of the Ministry of Health of Ukraine No. 2205, 2020). The combination of diffuse skylight simulation and functional LED lighting provided balanced luminance distribution, reduced glare, and improved visual comfort.


**Figure 1.** Primary school classroom in shelter. View from the entrance (the basic scenario)
**Source:** developed by the authors

The corridor was designed in a more neutral chromatic range to maintain calmness and spatial continuity (Fig. 2). Instead of one dominant element, a sequence of smaller Artificial Skylight lamps was rhythmically arranged along the ceiling and alternated with linear LED fixtures. This modular system created distributed zones of perceived daylight, broke the monotony of an elongated underground passage, and enhanced spatial orientation. Through this integrated approach, Artificial Skylights operated as architectural instruments that improved perceptual openness and psychological comfort in protective educational environments. Central to the shelter design was the lighting system, which integrated biophilic principles to support both psychological comfort and cognitive efficiency. The main ambient lighting was provided through LED panels with adjustable colour temperature ranging from 2700 K to 6500 K. This allowed the creation of a baseline illumination level sufficient for educational activities, while closely simulating natural daylight enhancing overall visual comfort. For a classroom of approximately 70 $m^2$, the recommended configuration included 6-8 ceiling-mounted LED panels, strategically positioned to ensure uniform light distribution and accommodate furniture layout and activity zones. The luminaires were designed to reduce glare, prevent harsh shadows, and maintain a high level of visual clarity, all of which were essential for prolonged work and learning periods in confined spaces.

**Figure 2.** Primary school classroom in shelter. Corridor view (daylight)
**Source:** developed by the authors

In addition to primary lighting, three biophilic accent luminaires were integrated into the ceiling to simulate windows revealing blue skies or drifting clouds. These luminaires dynamically adjusted their spectral output throughout the day, transitioning from warm morning light to cooler midday illumination, thus replicating natural daylight cycles. Their architectural placement, centred within the ceiling plane and oriented to maximise upward luminous diffusion, reinforced the spatial impression of overhead openness and contributed to the visual differentiation of the learning zone from adjacent circulation and rest areas. Task-specific lighting was incorporated into learning and group activity areas through localised light sources, such as wall-mounted or desk lamps with a warm spectrum around 3000 K. These luminaires provided focused illumination optimised for reading, writing, and

group work, enhancing visual performance and comfort, while reinforcing functional zoning within the shelter. The placement of localised lighting considered ergonomic principles and sightlines, ensuring that users received sufficient illumination without creating excessive contrast or glare, which could increase visual fatigue or stress. Safety considerations were integral to the lighting strategy. Emergency luminaires with autonomous power supply were incorporated to guarantee a minimum illumination level during power outages and to act as orientation markers within the shelter. It was recommended to install 1-2 emergency luminaires per classroom to maintain visibility and support safe navigation under critical conditions. The combination of primary, accent, localised, and emergency lighting created a multi-layered illumination system that was both functionally robust and psychologically supportive. The proposed design also addressed visual perception and spatial cognition through biophilic strategies. By integrating dynamic lighting that emulated natural light variations and incorporating visual connections to natural elements such as sky and clouds, the design reduces the psychological impact of confinement typically associated with underground or enclosed shelters. Additionally, the integration of modular furniture and spatial organisation allowed the shelter to adapt to different group sizes, activities, and operational scenarios, further enhancing both functional efficiency and user comfort. This combination of spatial and lighting strategies supported a dual-purpose approach: ensuring physical protection, while simultaneously providing a psychologically restorative and educationally productive environment.

The primary biophilic lighting principles implemented in this project aimed to establish a naturalistic and psychologically supportive environment within the enclosed conditions of a school shelter. First, a perceptual connection with nature was achieved through dynamic adjustment of lighting parameters, allowing intensity and correlated colour temperature to vary according to time of day and user activity, thereby enhancing comfort and functional efficiency. The incorporation of Artificial Skylight technologies further reinforced this connection by simulating an open sky and providing diffuse light with high spectral fidelity. Second, the integration of natural elements and materials was ensured through a synergistic design approach, in which lighting interacts with biophilic components such as natural textures, vegetation, and environmentally inspired colour schemes to produce a coherent spatial experience. Localised directional lighting was used to emulate sunlight penetration or daylight patches, strengthening associative links to outdoor environments and enhancing perceived environmental connectedness. Third, the project applied health-supportive artificial lighting strategies based on uniform light distribution and daylight simulation. Even illumination was achieved through indirect lighting systems and luminaires with diffusing elements that eliminated harsh contrasts and glare. Artificial light sources reproduced the spectral characteristics and dynamic variability of natural daylight, while Human-Centric Lighting systems supported circadian rhythm regulation, improved concentration, reduced stress levels during prolonged shelter occupancy. Based on the findings of the analysed case study on shelter design, it is worth proposing changes for Mykolaiv Lyceum No. 55, Bilohorodka Lyceum No. 2, and supporting gymnasium in Nizhyn. To improve the conditions, it would be advisable to install artificial skylight systems and dynamic LED lighting, which could enhance pupils' psychological comfort and provide the necessary lighting for learning.

Studies on energy-efficient and biophilic lighting confirmed that integrated lighting strategies enhanced cognitive engagement and user comfort. O.C. Dewi *et al.* (2020) demonstrated that biophilic lighting increased spatial attractiveness and reading interest in social facilities, supporting the broader premise that lighting performed both technical and psychological functions simultaneously. The authors findings were particularly relevant to shelter design, where the absence of natural stimuli places the entire affective burden of the environment on the artificial lighting system. N. Natsir *et al.* (2021) and D.T. Miranda *et al.* (2024) established quantitative criteria for visual comfort in educational spaces, providing a normative reference against, which the lighting configurations proposed in this study can be evaluated. Y. Bian *et al.* (2023) further demonstrated the importance of adaptive daylight systems for maintaining visual comfort and view clarity in classrooms, reinforcing the argument that static illumination was insufficient for environments intended to support sustained cognitive activity. Empirical research substantiated the restorative effects of biophilic design on the psychological and physiological condition of users. L. Mengqi *et al.* (2025) demonstrated measurable stress reduction and improved cognitive performance in high school interiors incorporating biophilic elements, and notably identified curvilinear forms and nature-referencing materials as the primary drivers of restorative response, a finding that broadened the scope of biophilic intervention beyond lighting alone. J.-Y. Kim & S.-J. Park (2025) identified statistically significant correlations between biophilic design interventions in school common areas and reduced indicators of adolescent depression, underscoring the particular importance of such strategies in environments occupied by children under conditions of prolonged stress. F. Favero *et al.* (2026) confirmed that daylight-mimicking systems positively influenced mood and alertness during extended indoor occupancy, providing direct empirical support for the Artificial Skylight configurations proposed in the project component of this study. P. Creati *et al.* (2025) conceptualised lighting design as an active architectural instrument capable of shaping behavioural and cognitive outcomes in training environments, thereby framing it not as a secondary technical consideration, but as a primary design decision with measurable consequences. A.M. Obeidat *et al.* (2025) extended the discussion beyond institutional settings, demonstrating that biophilic integration in residential

environments significantly enhanced comfort, emotional stability, and perceived well-being; the transferability of these effects across building typologies reinforced the universal restorative potential of nature-inspired spatial strategies and supported their applicability to the high-stress conditions of shelter occupancy. Conversely, research specifically addressing protective structures continued to prioritise structural resilience and regulatory compliance over environmental quality. T. Malik *et al.* (2023) proposed multi-criteria optimisation models for civil shelter design in Ukraine, drawing on international precedents. While researcher's framework advanced the technical performance of protective facilities, psychological comfort and spatial quality were treated as secondary considerations subordinate to structural and logistical parameters. A. Jörgen *et al.* (2025) outlined contemporary design guidelines for civilian shelters in contexts of armed conflict, offering a rare systematic treatment of shelter architecture at the intersection of safety and habitability; yet biophilic integration was not addressed within their framework, and the qualitative dimensions of the interior environment remain outside the scope of their recommendations. This persistent gap between the technical and the human-centred dimensions of shelter design confirmed that the present study addressed a genuinely underexplored area, and that the development of evidence-based biophilic lighting guidelines for educational protective structures constituted a necessary contribution to both architectural research and design practice.

## CONCLUSIONS

The integration of biophilic design principles into the development of artificial lighting for protective structures in educational institutions demonstrably enhanced psychological comfort, emotional stability, and perceived safety for both students and staff. Case-study analysis of Mykolaiv Lyceum No. 55, Bilohorodka Lyceum No. 2, and the supporting gymnasium shelter in Nizhyn confirmed that existing facilities, despite their regulatory compliance and functional adequacy, shared a common set of spatial deficiencies: fixed low ceiling heights, fully opaque enclosures, static artificial lighting, and the absence of any nature-referencing design elements, that collectively produced an environment ill-suited to prolonged educational occupancy. The design analysed in the study effectively reduced anxiety, alleviated feelings of confinement and created an environment conducive to learning, relaxation and extended stays, by mimicking natural lighting conditions using biophilic lighting fixtures that replicated daylight cycles and sky patterns. The adoption of a multi-layered lighting strategy, including primary, accent, localised, and emergency sources, ensured that spaces can adapt flexibly to varying functional requirements, activity types, and occupancy durations.

Biophilic artificial lighting contributed not only to the functional and safety performance of protective structures but also transformed these spaces into dual-purpose environments that actively supported educational activities and the well-being of occupants. The results of the comparative analysis, case-study evaluation, and project-based experimentation demonstrated that dynamic lighting scenarios with adjustable correlated colour temperature (2700-6500 K), uniform luminance distribution, and daylight-inspired temporal modulation contributed to improved concentration, emotional stability, and perceived safety among users. The application of Artificial Skylight technologies and diffused LED systems was found to expand perceived spatial boundaries, reduced the sense of confinement typical of underground facilities, and supported circadian rhythm synchronisation, thereby strengthening both cognitive performance and psychophysiological resilience. Further research should concentrate on refining adaptive lighting algorithms and conducting longitudinal performance assessments to develop comprehensive, evidence-based guidelines for the design of multifunctional educational shelters grounded in biophilic and human-centred principles.

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# Елементи біофільного дизайну в захисних спорудах для освітніх установ

**Анотація.** Це дослідження розглядало актуальність принципів біофільного дизайну в системах штучного освітлення для освітніх сховищ, де відсутність природного світла та обмежені просторові умови можуть посилювати стрес і тривожність серед мешканців. Метою дослідження було виявити та обґрунтувати стратегії освітлення, що імітують властивості природного освітлення та підвищують комфорт користувачів у захисних навчальних середовищах. Методологічний підхід включав порівняльний аналіз сенсорних реакцій на різні сценарії штучного освітлення, оцінку параметрів освітлення, які відтворюють природні умови, а також вивчення дизайнерських технік, що застосовуються в контрольованих, безвіконних середовищах. Особлива увага приділялася ролі інтенсивності світла, кольорової температури, розподілу та часової динаміки в формуванні просторового сприйняття та емоційної стабільності. Було проаналізовано освітні сховища в Миколаївському ліцеї № 55, Білогородському ліцеї № 2 та спортивній залі в Ніжині, які були обрані через їх експлуатаційний стан та характерні просторові особливості. Хоча ці об'єкти демонстрували порівняно високий рівень технічної організації та дотримання нормативних вимог, аналіз виявив дефіцити, пов'язані з повною відсутністю природного денного світла, обмеженою візуальною взаємодією з зовнішнім середовищем та просторовою домінантою армованих бетонних конструкцій. Результати дослідження показали, що системи штучного освітлення, що включають м'яке дифузне світло, поступові переходи та динаміку, натхненну циркадними ритмами, значно покращували просторове сприйняття, знижували психологічний дискомфорт та сприяли відчуттю безпеки в закритих сховищах. Системи, що імітують денні коливання через контрольовані зміни яскравості та природні спектри кольорів, виявилися особливо ефективними у зниженні стресових показників та підтриманні когнітивної працездатності під час тривалого перебування. Інтеграція біофільних елементів освітлення сприяла функціональній трансформації захисних споруд, роблячи їх придатними не лише для надзвичайних ситуацій, але й для тривалих освітніх заходів. Практична цінність цього дослідження полягає у розробці дизайнерських настанов для інтеграції біофільного освітлення в освітні сховища, що підвищить їх функціональну стійкість та підтримуватиме психологічне благополуччя користувачів

**Ключові слова:** природне денне світло; штучне освітлення; психологічний комфорт; архітектура сховищ; безпека; динамічне освітлення

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# A simulation-methods for effective heat energy distribution in heating systems in public buildings

**Abstract.** The relevance of the research was determined by the existing problem of uneven heat distribution in top-down single-pipe heating systems in buildings, which led to overheating of upper floors and insufficient heating of lower floors, thereby negatively affecting indoor thermal comfort and energy efficiency. The purpose of the work was to analyse methods of improving the indoor microclimate and equalise room temperatures by ensuring uniform distribution of the heat carrier in a top-down designed single-pipe heating system in public buildings. This study used numerical simulation in COMSOL Multiphysics, a CFD software package, to examine the impact of a radiator connection scheme on the heat distribution in the heating system of a five-story public building. The modern vertical single-pipe heating system was examined in the study. System that was managed by valves on the higher floors was created, and the two were contrasted. The local heat flux, flow velocity, and room air temperature were all calculated. Each floor's radiators' temperature loss from the heat transfer medium was assessed independently. The findings demonstrated an obvious unequal heat distribution in the current heating system, with the upper floors overheating and the lower floors not receiving adequate heating. Following the implementation of the new plan, the system's efficiency increased by 21.62%, and the temperature of the heat carrier reaching the first floor increased from 47.813°C to 52.594°C. The practical significance of this study was that it provided an effective method for improving heat distribution in multi-story buildings by regulating flow using a bypass pipe in a single-pipe heating system, which increased thermal comfort and reduced energy consumption

**Keywords:** heat transfer; CFD-simulation; radiator heating system; energy efficiency; thermal comfort; bypass regulation

## INTRODUCTION

Since 2010, enhancing building energy efficiency and improving thermal comfort have become major policy priorities not only in Uzbekistan but also worldwide. The construction sector accounted for nearly 40% of global energy consumption; therefore, improving energy efficiency in buildings remained a key objective in modern engineering science (Global Alliance for Buildings..., 2018). In multi-story buildings with single-pipe heating systems, heat distribution presented a significant challenge, as the temperature of the heat carrier decreased along the vertical

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direction, leading to overheating on upper floors and insufficient heating on lower floors. Therefore, it was essential to simulate heat transfer processes occurring on indoor surfaces to evaluate building heat balance and improve heating system performance. Convective heat transfer on internal surfaces – such as walls, floors, and ceilings – played a crucial role in indoor air movement, heat transfer, and thermal comfort. ASHRAE (2021) presented information on heat exchange equipment as part of HVAC systems. The section on principles of heating, ventilating, and air conditioning provided essential technical guidance on heat transfer mechanisms across various HVAC configurations. ASHRAE (2022) outlined the ANSI/ASHRAE/IES Standard 90.1-2019, which set energy standards for buildings, excluding low-rise residential buildings. This standard was widely used to ensure that buildings meet energy efficiency requirements for improved sustainability and reduced energy consumption. Heat transfer processes under natural convection conditions exhibited complex hydrodynamic and thermal characteristics, making them difficult to describe accurately using analytical methods. As noted by J.N. Reddy *et al.* (2022), this complexity necessitated the precise determination of convective heat transfer coefficients to improve the reliability of building thermal simulations.

Heat exchange and airflow in enclosed spaces have been extensively studied using computational fluid dynamics (CFD), as reported by N. Serra (2023). However, many CFD models relied on standard wall functions derived from simplified geometries such as pipes or flat plates. As argued by P. Mičko *et al.* (2021), such simplifications may reduce the accuracy of simulations for realistic indoor environments, particularly in representing near-wall turbulence and temperature gradients. Studies by F. Alamdari & G.P. Hammond (1983) proposed empirical correlations for convective heat transfer coefficients under natural convection conditions, which remained widely used in building thermal modelling. More recent studies, such as M. Camci *et al.* (2023), have developed improved correlation models based on experimental and numerical investigations of convection on building surfaces. M. Singh & R.A. Sharston (2022) demonstrated that integrating adaptive convection algorithms into building energy simulation tools significantly improved prediction accuracy compared to conventional constant-coefficient approaches. Furthermore, integrating CFD methods with building energy models enabled a more comprehensive analysis of indoor heat transfer processes. P.V. Nielsen (2015) had also emphasised the importance of accurate modelling and optimisation of heating systems to improve indoor thermal conditions and reduce energy consumption. In particular, Y. Li *et al.* (2024) showed that coupling CFD with building simulation enhanced control strategies and overall system efficiency. Despite these advances, the analysis of vertical single-pipe heating systems in multi-story buildings remained insufficiently explored, particularly in terms of heat distribution along the building height. Therefore, this study aimed to investigate heat distribution in a multi-story building with a vertical single-pipe heating system using CFD modelling, with focus on flow redistribution and its impact on thermal conditions across different floors.

## MATERIALS AND METHODS

The study examined the thermal conditions of a typical classroom in the educational building of the Faculty of Architecture and Construction at Fergana State Technical University, located in Fergana, Uzbekistan. The building was a five-story reinforced concrete structure, with a total floor area of 2,963 m$^2$ and a volume of 8,517.45 m$^3$, typical for public educational buildings in the region. The building had a maximum heating load of 357,752 W, a heating load density of 120.75 W/m$^2$, and was characteristic of buildings in the region. In order to determine the thermal boundary conditions and indoor climate parameters, the study used the recommendations of EN 16798-1:2019 (2019) and ASHRAE (2022). National normative documents were used, such as SNK 2.08.02-23 (2024) and SNK 2.01.18-24 (2025). Numerical simulation of the flow and heat transfer in the room was carried out using the COMSOL Multiphysics software. In this regard, the continuity, momentum, and energy equations were solved using the Reynolds Averaged Navier Stokes (RANS) method along with the Standard k-epsilon model. Heat flux was determined (Kreider 2009) by the formula:

$$q = h(T_s - T_a), \quad (1)$$

where $h$ – heat transfer coefficient (W/(m$^2$·K)), $T_s$ – surface temperature (°C), $T_a$ – air temperature (°C). Nusselt number was determined by the formula:

$$Nu = \frac{hL}{k}, \quad (2)$$

where $h$ – heat transfer, $L$ – characteristic length, $k$ – thermal conductivity (W/(m·K)). Reynolds number was determined by the formula:

$$Re = \frac{\rho v L}{\mu}, \quad (3)$$

where $\rho$ – density (kg/m$^3$), $v$ – velosity (m/s), $\mu$ – dynamic viscosity (Pa·s).

The presented equations were used to evaluate the heat transfer characteristics of the radiator. The Reynolds number was calculated to determine the flow regime of the heat carrier, confirming turbulent flow conditions within the system. Based on this, the Nusselt number was obtained, which allowed the calculation of the convective heat transfer coefficient. Using this coefficient, the heat flux between the radiator surface and the surrounding air was determined. These calculated parameters were subsequently used to analyze the temperature distribution and assess the thermal performance of the radiator system. This model was used due to its stability and efficiency in simulating the flow in indoor environments. At the same time, the heat transfer in fluids and turbulent flow

interfaces in COMSOL have been used simultaneously to solve the heat transfer and fluid flow problems in the room. In the computational domain, a three-dimensional rectangular room was created. In the room, one radiator and one window were placed. At the boundaries, the surface temperature of the radiator was taken as 348 K, while that of the window was taken as 268 K. At the same time, the walls, floors, and ceilings of the room were taken at a temperature of 293 K (Fig. 1).

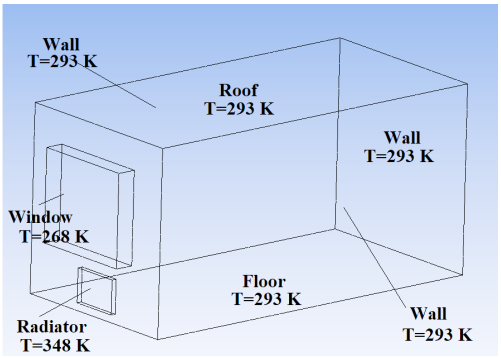


**Figure 1.** Computational domain and boundary conditions for the modeled room with radiator heating system
**Source:** developed by the authors

A computational mesh was created using COMSOL. In this regard, a high-resolution mesh was created in the areas close to the radiator and window. Also, in study were obtained the temperature and humidity data. The simulated values of heat carrier inlet and outlet temperatures, mean radiator temperatures, and indoor air temperatures were extracted for each floor and orientation (north and south) of the building, covering 30 measurement points across five floors. Bypass pipes equipped with valve regulation mechanisms were installed at the radiators' inlet and outlet junctions on the fifth, fourth, third, and second floors in the suggested configuration. In this study, bypass lines were implemented as alternative flow paths to regulate the distribution of the heat carrier. Instead of being completely discharged through the radiator, a predetermined portion of the heat carrier circulating through the upper floors was diverted downward via the bypass lines to the lower floors by carefully adjusting the valves built into these bypass pipes. This configuration was designed to improve thermal balance by redistributing the flow between the upper and lower floors.

## RESULTS AND DISCUSSION

The educational building of the Faculty of Architecture and Construction at Fergana State Technical University's heat supply system used a vertical top-to-bottom connection scheme. In this setup, a single-pipe distribution network was used to supply the heat carrier water to the system from the topmost (fifth) floor at an initial temperature of 70°C. The water then sequentially passed through the radiators placed on each floor. The system's radiators all had the same 840 W thermal capacity and were designed to use radiative and convective mechanisms to transfer heat from the circulating water to the indoor air. The Republic of Uzbekistan's regulatory document SanPiN 0341-16 (2016) stated that maintaining air temperatures in classrooms between 18°C and 21°C was advised for the best thermal comfort. However, real-world observations and simulation results have revealed notable departures from these regulations (Decree of the President..., 2025). In the current system, the lower floors, particularly the first and second degrees, experience a temperature drop to about 16°C, which was below the allowable comfort limit, while the upper floors' interior temperatures reached 23-24°C, resulting in an overheating state. The building's occupants experience inconvenience due to this heat imbalance (Fig. 2), which also degraded the indoor microclimate (EN 16798-1:2019, 2019).

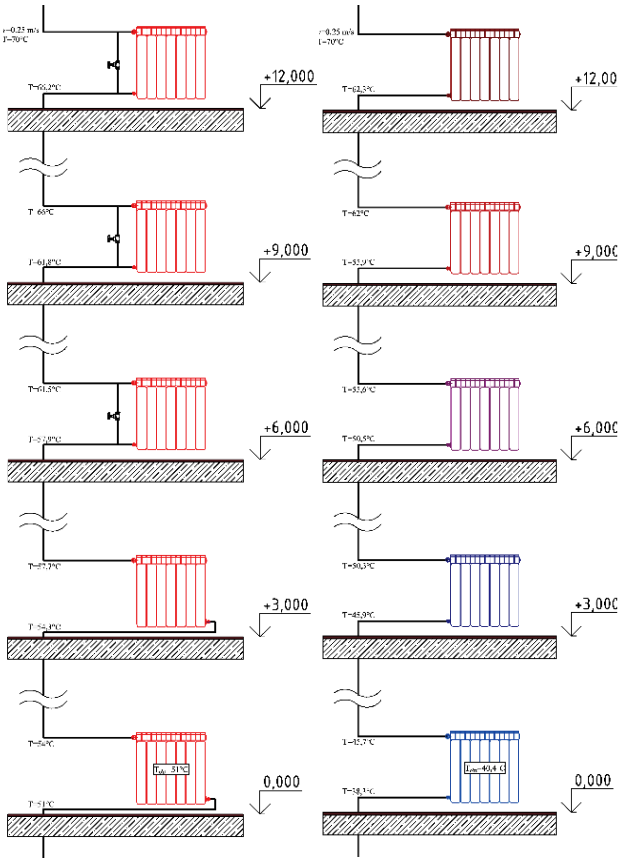


**Figure 2.** Schematic diagram of the heating system
**Note:** a – current system; b – the proposed system
**Source:** developed by the authors

The heat carrier's slow cooling as it descended the vertical riser was the primary cause of this drawback. The water temperature dropped considerably before it reached the lower heating devices because the majority of the thermal energy was released in the upper floors. Consequently, the upper floors received an excess of heat, while the lower floors were deprived of adequate heating capacity. The

authors S.V. Kim & R.D. Brown (2021) noted that this unequal heat distribution led to a crisis in the heating system's overall efficiency and served as the foundation for irrational energy resource use. The heat carrier reached the fifth-floor radiator at a temperature of 70°C, according to experimental and numerical research. At its outlet, the liquid's temperature dropped to 64.4°C after traveling through the radiator and transferring heat to the room's air (Table 1).

**Table 1.** Radiator inlet and outlet temperatures for each floor (existing system)

| Floor | Radiator entry T,°C | Radiator exit T,°C | Radiator average ΔT,°C |
|---|---|---|---|
| 5th floor | 70.000 | 64.400 | 5.600 |
| 4th floor | 64.213 | 59.453 | 4.760 |
| 3th floor | 59.262 | 55.184 | 4.078 |
| 2th floor | 54.993 | 51.247 | 3.746 |
| 1th floor | 51.056 | 47.813 | 3.243 |

**Source:** developed by the authors

The radiators on the upper floors (the fourth and fifth floors) released a lot of heat. There was a noticeable drop in the value of ΔT as the layers descend. The water temperature coming from the radiator on the first floor was only 47.8°C, which was insufficient to keep the building's comfort levels at their ideal levels. Furthermore, it was discovered that the radiator on the first floor had an average surface temperature of 45°C, which was much lower than the readings on the upper floors (Carella *et al.*, 2023). This redistribution results in the thermal energy that was previously used to create excess temperatures on the upper floors being effectively used to support the heating of the lower floors (Huang *et al.*, 2024). This was more than just a reallocation of flow; it was the recovery and reassignment of thermal energy that would otherwise cause upper-floor spaces to overheat, while lower floors were left insufficiently heated. The outlet temperature on the first floor had increased significantly in comparison to the current baseline configuration; it was previously recorded at 47.813°C, but it had reached 52.594°C, an improvement of about 4.8°C. The system's capacity to provide enough heat to the source was demonstrated by the radiator network's maximum temperature of 55.850°C (Table 2), which was recorded on the upper floors.

**Table 2.** Temperature difference in radiator

| Floor | Radiator entry T,°C | Radiator exit T,°C | Temperature difference in radiator (°C) |
|---|---|---|---|
| 5th floor | 70.000 | 66.576 | 3.424 |
| 4th floor | 66.385 | 62.668 | 3.717 |
| 3th floor | 62.477 | 59.908 | 2.569 |
| 2th floor | 59.717 | 56.034 | 3.683 |
| 1th floor | 55.850 | 52.594 | 3.249 |

**Source:** developed by the authors

The building's overall level of comfort had increased as a result of this thermal rebalancing, which had partially mitigated the upper floors' excessive heating and more evenly distributed heat downward (Fanger, 1970). The temperature distribution (°C) of the heat carrier inside the fifth-floor radiator was shown in Figure 3, a. Around 55°C was the temperature, at which the heat carrier entered the radiator through the upper inlet. As it passed through the radiator's internal channels, it progressively transferred thermal energy to the wall surfaces through convective and conductive mechanisms (Incropera *et al.*, 2006). The fluid's temperature had decreased to about 40°C by the time it reached the outlet at the bottom of the radiator, indicating an efficient thermal exchange of about 15°C over the radiator's length under normal operating circumstances. The figure's colour gradient illustrated the degree of heat exchange in the radiator's various zones, showing that thermal transfer was relatively more prominent in the centre.

To provide a quantitative justification of the heat transfer processes, key dimensionless and thermophysical parameters were determined. The Reynolds number was calculated using typical properties of the heat carrier ($\rho \approx 980$ kg/m$^3$, $\mu \approx 0.00047$ Pa·s at ~60°C), an average flow velocity of $v \approx 0.3$ m/s, and a characteristic length of $L \approx 0.02$ m. Accordingly, the value $Re \approx (980 \times 0.3 \times 0.02)/0.00047 \approx 12{,}500$ was obtained. This value significantly exceeded the critical threshold of 4,000, confirming a turbulent flow regime and aligning with the CFD results. Based on these data, the Nusselt number was estimated. For water with a thermal conductivity of $k \approx 0.65$ W/(m·K) and a characteristic length of $L \approx 0.02$ m, assuming a convective heat transfer coefficient in the range of $h = 300 - 600$ W/(m$^2$·K), the estimated value was $Nu \approx (400 \times 0.02)/0.65 \approx 12.3$. The obtained values of the convective heat transfer coefficient (h) confirmed this trend: in the baseline configuration, it decreased along the vertical riser, whereas in the modified

system it became more uniform. The calculation of heat flux (q) demonstrated that, in the existing system, thermal energy was predominantly concentrated on the upper floors, leading to overheating, whereas after modification a more even distribution was achieved. The consistency between the calculated parameters and the temperature data confirmed a reduction in the temperature gradient (from 22°C to 17°C) and an increase in overall system efficiency by 21.62%, indicating an improvement in heat transfer performance due to flow redistribution.

The cross-sectional area of the fins (green line) and the temperatures in the radiator's lower horizontal pipe (blue line) were contrasted in Figure 3, b. The graph illustrated how the temperature dropped as the heat carrier moves through the pipe, with local maximum values observed on the fins' surface. After implementation of the proposed bypass system, the temperature distribution in the 5$^{th}$-floor radiator became more uniform, as shown in Figure 3, c. This is further confirmed by the temperature variation along the radiator length (Fig. 3, d), where a more gradual temperature gradient is observed compared to the initial case. As shown in Figure 3, e, the temperature in the radiator outlet pipe decreased to 47.8°C by the first floor, while the velocity field in the 5$^{th}$-floor radiator (Fig. 3, f) indicates improved flow distribution due to the bypass configuration. The radiator's average temperature dropped to 41-42°C. The device's heating efficiency was reduced as a result of this temperature drop (Carella *et al.*, 2023).

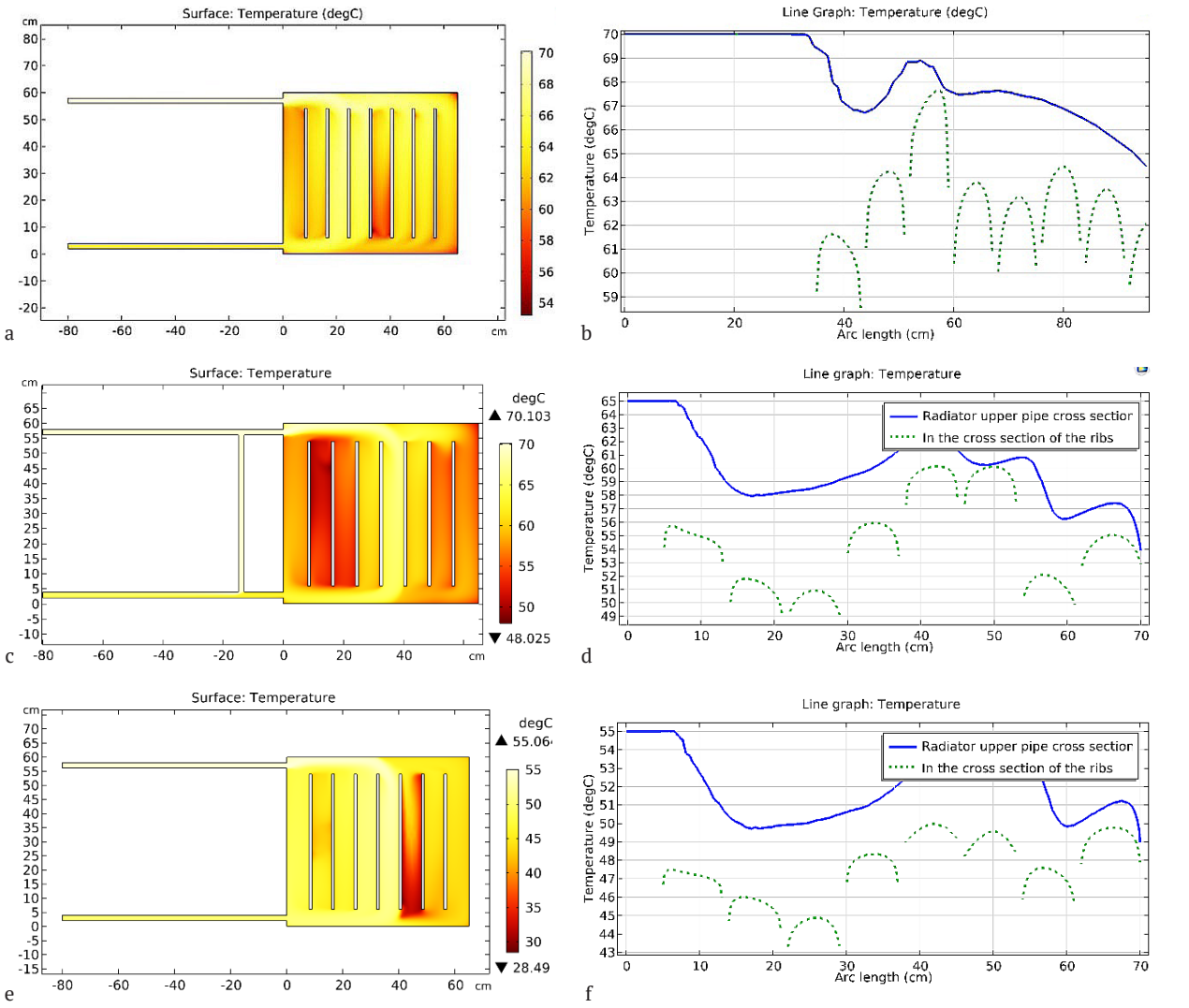


**Figure 3.** Simulation results for the radiator thermal and flow characteristics

**Note:** a – temperature distribution of the heat transfer fluid in the 5$^{th}$-floor radiator (baseline system); b – line graph of temperature variation along the radiator length (baseline system); c – temperature distribution in the 5$^{th}$-floor radiator after implementation of the proposed bypass system; d – line graph of temperature variation along the radiator length after implementation of the bypass system; e – temperature distribution in the 1$^{st}$-floor radiator (proposed bypass system); f – velocity field of the 5$^{th}$-floor radiator in the proposed bypass system

**Source:** SNK 2.08.02-23 (2024), SNK 2.01.18-24 (2025)

The bypass flow joined the horizontal outlet stream coming from the radiator (approximately 62-63°C, dark yellow zone) after descending vertically through the upper channel (approximately 63-70°C, light yellow zone). A localised turbulence zone forms at the point, where these two streams converge, and it was easily identifiable in the area, where vector density increased and flow directions suddenly changed course (Raftery *et al.*, 2024). The thermal dynamics controlling this process were further supported by the temperature profile of the combined coolant at the bypass mixing junction along the arc length. The temperature stayed relatively constant at about 62°C for the first 0-0.5 cm segment, suggesting a preliminary zone, where the two streams have not yet reached full intermixing. The temperature risen quickly to about 69.5°C within the 0.5 to 1.5 cm range, indicating strong thermal interaction between the convergent fluid streams. The temperature stabilised between roughly 69.5°C and 70°C after crossing the 1.5 cm threshold, indicating that the combined flow had reached a state of complete mixing and thermodynamic equilibrium, fully compliant with the basic law of conservation of energy (Alamdari & Hammond, 1983). Simulation results using CFD showed that there was a considerable thermal imbalance in the existing single pipe system. Under normal operation, the heat transfer fluid entered the fifth-floor radiator at about 70°C, gradually cooling down as it travelled down to the first floor, where it entered the radiator at a considerably lower temperature. Thus, the maximum internal temperature of the fifth-floor radiator was found to be 55.85°C, while the outlet temperature of the first-floor radiator was found to be only 47.81°C, a difference of 8.04°C, which caused overheating of the floors above and insufficient heating of floors below. With the installation of the suggested system of circulation control, the heat carrier was partially rerouted through bypass junctions installed at each floor, thus facilitating uniform heat load redistribution in the vertical circuit. It was defined a notable increase in the radiator outlet temperature on the first floor, from 47.81°C to 52.59°C, a difference of 4.78°C, which was the least favoured portion of the system. The ratio of the actual heat output to the theoretically maximum heat transfer under specific supply conditions was used to evaluate the efficacy of the heat supply system (Incropera *et al.*, 2006). The system's overall efficiency improved by 21.62% points, from 67.14% in the current configuration to 78.38% in the proposed system (Fig. 4).

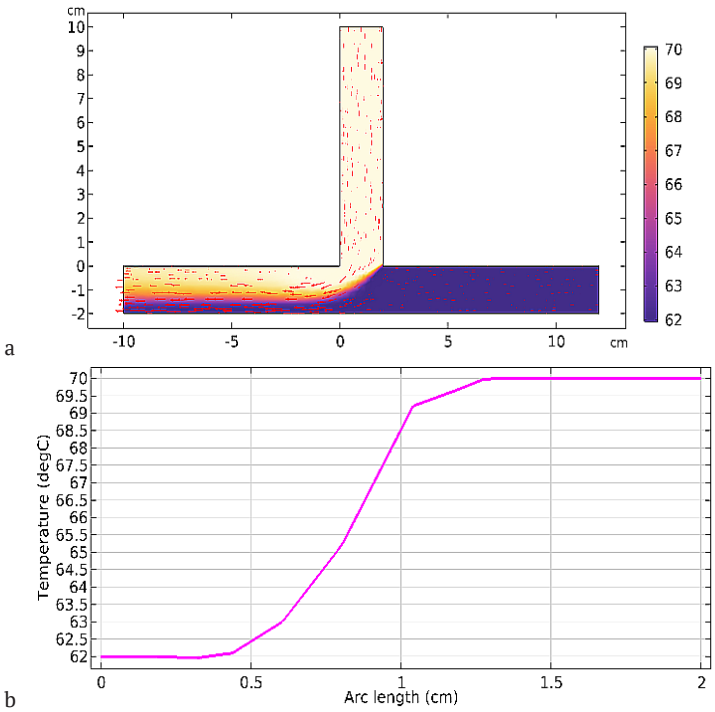


**Figure 4.** Thermal analysis of the rotary mixing junction

**Note:** a – the heat flow distribution model with the flow structure and velocity field at the rotary mixing junction; b – the temperature profile of the mixed coolant along the arc length at the bypass mixing junction

**Source:** developed by the authors

Due to unequal distribution and high exhaust temperatures on the upper floors, this growth demonstrated that a sizable amount of the thermal energy presented in the heat carrier was effectively transferred to building spaces without being wasted. Furthermore, as Figure 5 illustrated, the temperature loss along the radiator network dropped by 5°C from roughly 22°C in the existing system to roughly 17°C in the suggested configuration. Because of this reduction in heat loss, the heat carrier was able to move through the system with greater energy retention, allow-

ing for more effective use at the layer level. The redistribution of the circulating flow, which prevented excessive heat, was directly linked to the temperature drop. Release at any point in the circuit and maintains a more favourable temperature gradient throughout the entire network (Patankar, 1980).

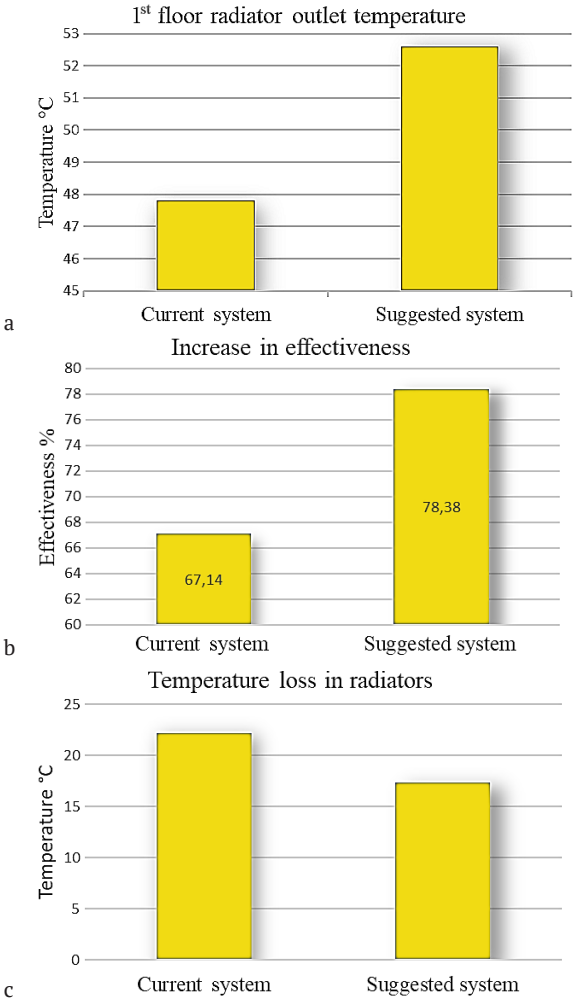


**Figure 5.** Comparison of current and suggested heating systems

**Note:** a – 1st floor radiator outlet temperature (°C); b – system heating effectiveness (%); c – temperature loss in radiators (°C)

**Source:** developed by the authors

The physical coherence of the suggested design solution was further supported by the velocity field analysis at the bypass mixing junction. E. Guelpa *et al.* (2023) noted that a localised turbulence zone formed at the junction of the bypass and radiator outlet streams, increasing convective mixing and hastening thermal equilibration between the two merging streams. The proposed bypass connection arrangement's hydrodynamic effectiveness and geometric efficiency were demonstrated by the temperature profile traced along the arc length at the mixing junction, which confirmed that full thermal equilibrium was reached within about 1.5 cm downstream of the junction. Consequently, compliance with established trends in thermal modelling of premises and optimisation of heating systems was confirmed. Specifically, the increase in radiator outlet temperature on the first floor, from 47.81°C to 52.59°C, was consistent with the results reported by, where the authors demonstrated that using CFD analysis of radiator geometry directly contributed to enhancing the precision of convective heat transfer predictions. The reduction of temperature loss between floors was consistent with the energy redistribution concept presented by M. Singh & R.A. Sharston (2022), where the authors emphasised that using CFD together with building energy models provided a more accurate description of heat transfer within buildings. Finally, the increase in thermal uniformity using bypass regulation was consistent with the study presented by I. Sarbu *et al.* (2022), where researchers reported considerable energy savings using partial redirection of flow in high-rise building heating systems. B.A. Aljashaami *et al.* (2024) conducted a systematic review of recent heating, ventilation, and air conditioning technologies based on renewable energy, substantiating their key role in achieving zero-energy buildings. The authors demonstrated that the integration of hybrid energy systems and intelligent control was a decisive factor in improving energy efficiency and reducing the carbon footprint of buildings. I. Bilous *et al.* (2025) developed a dynamic model for assessing energy efficiency and indoor climatic conditions, enabling a comprehensive analysis of thermal processes in buildings. The study showed that a systemic modelling approach provided more accurate optimisation of indoor environment parameters and energy consumption compared to static methods. Overall, the simulation results demonstrated that the proposed flow redistribution strategy significantly improved heat distribution across all floors. The thermal imbalance observed in the original system was reduced, particularly by enhancing heating conditions on the lower floors. These findings confirmed the effectiveness of the implemented regulation approach in achieving more uniform indoor thermal conditions.

## CONCLUSIONS

The results of the CFD simulation performed in COMSOL Multiphysics verified that the existing series-flow configuration led to overheating of the building's floors. The outlet temperature of the first-floor radiator was only 47.813°C, while the internal temperature of the fifth-floor radiator was 55.85°C, resulting in a thermal imbalance of 8.04°C. To resolve the above imbalance without replacing the entire system, a bypass regulation system was suggested, in which bypass pipes would be installed at the radiator connections on floors 2, 3, 4, and 5. Numerical simulation of the system showed a substantial improvement in heat distribution across the floors. The outlet temperature of the radiator on the first floor increased from 47.813°C to 52.594°C, an increase of 4.78°C.

This was the most disadvantaged area. The overall system heating effectiveness improved by 21.62%, from 67.14% to 78.38%. The total temperature loss across the heating network decreased from 22°C to 17°C. Analysis of velocity fields at the bypass mixing junction showed that full thermal equilibrium between the merging flows was attained within approximately 1.5 cm downstream of the junction, thus confirming the hydrodynamic efficiency of the proposed design. The proposed bypass method provided a cost-effective, structurally non-intrusive approach to enhancing energy efficiency in existing single-pipe heating systems. Future research directions could include experimental verification of the method under real operating conditions and optimisation of valve settings for various seasonal/occupancy scenarios.

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## FUNDING

None.

## CONFLICT OF INTEREST

None.

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## Методи моделювання для ефективного розподілу теплової енергії в системах опалення громадських будівель

**Анотація.** Актуальність дослідження зумовлена наявною проблемою нерівномірного розподілу теплової енергії в однотрубних системах опалення з верхньою розводкою в будівлях, що призводило до перегріву верхніх поверхів і недостатнього обігріву нижніх, негативно впливаючи на тепловий комфорт і енергоефективність приміщень. Метою роботи став аналіз методів покращення мікроклімату приміщень і вирівнювання температури шляхом забезпечення рівномірного розподілу теплоносія в однотрубній системі опалення з верхньою розводкою у громадських будівлях. У дослідженні було використано чисельне моделювання в програмному середовищі COMSOL Multiphysics для оцінювання впливу схеми підключення радіаторів на розподіл тепла в системі опалення п'ятиповерхової громадської будівлі. Досліджено сучасну вертикальну однотрубну систему опалення, сформовано та порівняно базову і модифіковану систему з регулюванням за допомогою клапанів на верхніх поверхах. Розраховано локальні теплові потоки, швидкість руху теплоносія та температуру повітря в приміщеннях. Окремо у роботі було оцінено температурні втрати теплоносія в радіаторах на кожному поверсі. Отримані результати засвідчили суттєву нерівномірність теплопостачання в наявній системі, з перегрівом верхніх поверхів і недостатнім нагріванням нижніх. Після впровадження запропонованого рішення ефективність системи зросла на 21,62 %, а температура теплоносія на вході до першого поверху підвищилася з 47,813 °C до 52,594 °C. Практична цінність дослідження полягає в обґрунтуванні ефективного підходу до покращення теплового розподілу в багатоповерхових будівлях шляхом регулювання потоку за допомогою байпасної лінії в однотрубній системі опалення, що сприяє підвищенню теплового комфорту та зниженню енергоспоживання

**Ключові слова:** теплопередача; CFD-моделювання; радіаторна система опалення; енергоефективність; тепловий комфорт; байпасне регулювання

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# The architecture of Drohobych railway station buildings

**Abstract.** The relevance of this study stems from a professional interest and the need to understand the processes that have shaped the architecture of Drohobych railway station, which has undergone changes over more than 150 years. Attention to railway stations and rail transport has intensified against the backdrop of the ongoing armed aggression against Ukraine for over 12 years. In this context, the importance of rail transport for evacuation, supply, defence and offensive operations is well recognised; consequently, railway stations are among the state's vital infrastructure. At the same time, drawing attention to the country's historical and material heritage requires further knowledge to ensure their protection. The aim of this study was to examine the architecture of Drohobych railway station from functional, territorial-spatial, planning, structural, social and artistic perspectives. Particular attention was focused on the architecture of Drohobych railway station as represented in the 1911 design project discovered in the Central State Historical Archives of Lviv. Based on desk-based research methods, comparative analysis, photographic documentation techniques, and field observations, a study was conducted of the dynamics of change in the station buildings at Drohobych. Important information was obtained from both published and media sources. The position of the first station building within the context of similar railway structures in this foothill region of Galicia was established, as well as the connection between station buildings and other, primarily public, architecture. This allowed for generalisations to be drawn – on the one hand, regarding the typical nature of railway station construction, and on the other, its uniqueness specifically to Drohobych. In particular, it has been established that the 1911 drawings clearly reveal two distinct design concepts: clear functional zoning and the social and spatial determinants of the station building and its grounds. The consideration of the territorial and spatial layout of the structures within the urban context is evident. The findings contribute to a broader understanding of railway station construction in the city, the region and the region's transport links. At the same time, they provide further grounds for exploring other sources and research directions. These and other materials and findings form the basis for the future use of such important historical structures against the backdrop of social, transport, technical and other changes

**Keywords:** building; station; railway; space; Galicia

## INTRODUCTION

Rail transport remains one of the priority modes of land transport. In Europe, its history dates back to the first half of the 19th century, which marked the beginning of the associated construction work. The passenger rail sector is undergoing constant development and improvement, which is reflected above all in the architecture of railway stations. Over the decades and centuries, a whole field of passenger building architecture has developed which, being linked to other types of public and residential architecture, embodies cutting-edge ideas and successful examples of completed projects. Interest in railway station architecture is relevant from various perspectives – the efficiency, safety and

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comfort of passenger transport; the formation of transport, social and commercial hubs in cities; the role of stations in the image of cities and towns; the preservation of monuments of public and transport construction, and so on. During wartime in Ukraine, rail transport has demonstrated its undeniable military, political, and social significance in national defence and protection. Timely evacuations from threatened areas enabled large numbers of citizens to be transported to safer locations and thereby saved. In this context, the railway station building in Drohobych deserves attention both as a monument to professional architectural thought and as a milestone in its development, representing a distinctive culmination of the monarchical era in the railway architecture of Galicia.

The architecture of 19th-century railway stations is of interest across various fields of research. German railway stations are examined in the work by J. Gympel (2020). It successfully showcases the stations themselves, which are substantively commented upon as distinctive reflections of different eras. The significant role of the architecture of these transport facilities is confirmed not only in a practical, everyday sense, but also in artistic, aesthetic, and historical-political terms. The "national space" in the railways of Czechoslovakia during the interwar period is discussed in the work by F. Jeschke (2021). Of particular interest is the study of the methods used to construct the national railway network within the physical landscape along the former routes of the Austro-Hungarian Monarchy. At the same time, the study highlights attempts to create a modern international transport network for the then-young state, which at that time included Subcarpathian Ruthenia/Carpathian Ukraine, corresponding to the present-day Zakarpattia region of Ukraine. The monograph by R. Kellermann (2021) addressed the philosophical and cultural foundations of the phenomenon of "waiting" within railway environments. The historical development of railway station buildings reflects the dynamics of this category during the period 1830-1935. The acceleration of travel processes opens up new avenues for research in this regard. The article by M. Nazaruk (2021) examined, within a historical context, the architecture of the railway stations at Holoby and Kovel in Volhynia (Lodomeria), which are notable works by the architect Oleksandr Verbytsky from the early 20th century.

There are references to contemporary issues in transport and railway station architecture. In particular, the article by V. Timokhin *et al.* (2023) discussed the design of underground spaces in transport interchanges. Such solutions facilitate the efficient use of land resources by freeing surface areas for pedestrian spaces, separating transport and pedestrian flows, providing the shortest routes between different modes of transport, and improving evacuation procedures when these spaces are used as shelters. In comparison with Leipzig and Kraków, the distinctive features and rational approaches to the development of Lviv's transport network are highlighted.

The visual publication by M. Oleksiienko (2025) deserved special attention, as it reveals the Ukrainian railway as a formative part of the landscape and demonstrates its not always obvious beauty. Through passenger services, freight logistics, industrial capacity and tourist appeal, the railway constantly connects the country's regions, transports goods, facilitates travel and brings people together. The author's personal background is noteworthy: originating from the Donetsk region, educated at the Kyiv-Mohyla Academy, and serving as a member of the armed forces.

The aim of this study was to examine the architecture of Drohobych's railway stations, with particular attention to the 1911 project, in terms of its functional, spatial, planning, structural, social and artistic aspects; to identify the most characteristic features of these buildings and establish their connection with other structures in the Pre-Carpathian region of Galicia.

## MATERIALS AND METHODS

The primary source material for this study consists of archival drawings from the Central State Historical Archive of Ukraine in Lviv (n.d.a; n.d.b), which include original plans of the Drohobych railway station from 1911, as well as photographs of existing railway structures in the cities of Drohobych, Lviv, Sambir, Stryi, Truskavets and Khyriv. In addition, illustrative materials from academic and media publications were used, which highlight the historical development of railway stations and their architectural design. The cartographic basis was derived from data in the "Ukraine Atlas of Railways" (Kopylova & Khilchevska, 2008) and satellite imagery available via Google's online platforms, which enabled the precise location and spatial orientation of the sites to be determined.

To collect field data, direct photographic documentation of contemporary structures was carried out, enabling an assessment of the condition and layout of the stations at various stages of their existence. Desk-based processing of archival drawings and cartographic materials ensured the systematisation of information regarding the functional and structural characteristics of the buildings. The comparison method was applied in two ways: asynchronous comparison allowed for the juxtaposition of the layouts, structural and artistic-stylistic solutions of railway stations from different years, revealing the dynamics of architectural development; synchronous comparison was used to contrast Drohobych's railway stations with other public architecture sites in Galicia from the early 20th century, which helped identify the typical and unique features of the structures.

Functional zoning and spatial layouts were analysed by detailing the internal blocks of the administrative, residential and passenger areas. This made it possible to establish interrelationships between the various elements of the complex and to assess their effectiveness in the context of the technological and social needs of the time. The analysis of structural solutions included a study of foundations, wall systems, floor slabs and roof structures, whilst methods of compositional analysis and artistic-stylistic evaluation made it possible to identify the characteristic features

of the facades, decorative elements and spatial composition of the building, as well as its place within the urban context. The application of a comprehensive approach, combining field observations, desk research using archival materials, comparative analysis and the evaluation of structural and artistic solutions, provided a holistic understanding of the architecture of the 1911 Drohobych railway station, its functional organisation and aesthetic expressiveness, as well as to identify its interrelationship with other buildings in the region and determine its uniqueness among the structures of that time.

## RESULTS

**Historical context.** The town of Drohobych was founded in the late 11th century in the foothills of the Carpathians within the territory of the Principality of Galicia. Subsequently, as part of the Kingdom of Ruthenia and later state formations, the city experienced all historical epochs that shaped the region. In 2026, it remains one of the administrative, industrial, educational, and cultural centres of Lviv region of Ukraine, with a population of around 75,000 (in 2020). Drohobych has a historic city centre layout characteristic of medieval European towns, with a central rectangular market square and a regular grid of streets (Rybchynsky, 2017). The city possesses a rich architectural and artistic heritage, partly due to various ethnic, religious, artistic and political influences. Due to its natural resources and trade links, the city has developed rapidly since ancient times into an important centre of trade and craftsmanship. Its own salt mines and proximity to oil deposits around the neighbouring town of Boryslav, as well as deposits near Stebnyk, made Drohobych, from the mid-19th century, a major centre for extraction, processing, crafts, trade, administration, culture and education. From the late 19th century, due to their healing water springs, Truskavets and Skhidnytsia developed into health resorts, transforming Drohobych into the regional centre of the conurbation, attracting and defining transport routes. This required reliable and convenient transport, initially provided by horse-drawn carriages and later by roads. However, the railway gave a major boost to the development of the town and the region.

Railway connections to Drohobych were established in 1872 with the construction of the "Dniester Railway" (Dniester Bahn; 112 km), which linked the towns of Khyriv, Sambir, Drohobych and Stryi. The Khyriv railway station is a junction through which the "First Hungarian-Galician Railway" (Erste Ungarisch-Galizische Eisenbahn (EUGE)) was laid in 1872, running from Peremyshl/Przemyśl via Zahiria/Zagórz, Lupkiv/Łupków, (now Poland) through the Vododilny Ridge tunnel (1874, border of the Crown Lands), Medgilabirtsi/Medzilaborce to the main line at Mykhalany/Michaľany station (now Slovakia).

Built as a double-track line from the outset, the First Hungarian-Galician Railway became the first crossing of the Carpathians and was of strategic importance, linking the Galician stronghold of Peremyshl with the territory beyond the Carpathians to the Hungarian-controlled lands, which were considered a deep rear. The railway enabled a fast and reliable connection across the mountain range in the north-eastern territories of the monarchy between its two parts – Austria and Hungary (in the sense of the names at that time). At the same time, this railway line was not on the very border, but at a sufficient distance from the eastern borders of the empire. Passing through Ukrainian ethnographic regions (Nadsyannya, Boikivshchyna, Lemkivshchyna), the section Nyzhankovychi – Dobromyl – Khyriv – Staryava is located in modern-day Ukraine. In its time, the First Hungarian-Galician Railway played a significant role in connecting the Priashiv/Prešov region with other historical lands of Ukraine, in particular, with the wider territory of Subcarpathian Ruthenia (Zakarpattia). (Vehesh, 2009).

At the same time, a branch line was laid from Drohobych to Boryslav (11 km), which from the mid-19th century became one of the world's largest centres of oil production. The Dniester Railway later became part of the "Galician Transversal Railway", completed in 1884-1885, running via Kraków/Čadca/Zwardoń – Nowy Sącz – Zahiria – Khyriv – Sambir – Drohobych – Stryi – Stanislaviv (from 1962 – Ivano-Frankivsk) – Buchach – Chortkiv – Husiatyn (Hrankin *et al.*, 1996; Bylina, 1999). The Galician Transversal Railway had a total length of 768 km and was a military transport project of Vienna to ensure connections between the western and eastern parts of the Crown Land of Galicia and Lodomeria to the eastern border on the Zbruch River. The line ran south of and approximately parallel to the already existing "Galician Railway of Archduke Charles Louis" (Galizische Carl Ludwig-Bahn, CLB), which already existed at that time: Kraków – Tarnów – Riashiv/Rzeszów – Peremyshl – Lviv – Ternopil – Pidvolochysk. In the event of war with Russia, the Transversal Railway was intended to facilitate troop and supply movements deeper within the territory, away from the frontier, through the mountainous and foothill regions (Tomin, 2011). In 1911, a line was laid from Drohobych to Truskavets (12 km), which was developing into a major health and leisure resort, and in 1912 a station was built in Truskavets. Consequently, the four railway branches made Drohobych station a regional hub. As of 2026, Drohobych is a junction railway station of the Lviv Directorate of the Lviv Railway.

Thus, the construction and operation of railway lines in this part of Galicia and neighbouring territories hold significant historical importance based on geographical, military, political, economic and other factors. The railway through Drohobych, its station and railway yard became the place and means of realising these processes. It is clear that the movement of goods and people required attention and proper architectural and construction implementation, which calls for a more detailed study.

**Layout of the railway station and the station building in Drohobych.** The railway station (1 Zluky Square) is situated in the eastern part of the city, approximately 2.5 km as the crow flies from the city centre. It comprises

a well-developed track network, which has been electrified since 1973, and railway facilities with associated structures. To the east of the station lies an industrial zone, whilst to the west of the tracks and the station are urban public and residential areas. M. Hrushevsky Street connects the station to the city centre, and in front of the station is a station square of approximately rectangular shape. Adjacent to the square is Vokzalna Street with a roundabout, and a wedge-shaped green square adjoining the station square. The station square features a coach station, as well as a stop for city buses and taxis (Fig. 1a).

At Drohobych station, there has been a railway station building since the construction of the Dniester Railway, known as "Drohobych Main (Station)" ("Large Station"). There was another station – "Drohobych City (Station)" ("Small Station") – near the junction of the Boryslav line with Truskavetska Street, which was demolished after the Second World War. During the imperial era, plans were drawn up to connect the two stations by tram, which was to run along Stryiska Street via the Rynok (Market) Square. However, the project was never realised (Pastukh, 1991). The main station building was similar to three other stations of the same type in the towns of Sambir, Stryi and Khyriv (Fig. 1b). The station in Khyriv has been preserved in its original form and has heritage protection status, whilst the remaining buildings, following the World Wars, continue to function only in altered forms (Fig. 1c). These stations are of the platform-side type, featuring side and island platforms with ground-level access.

According to the 1911 plans, the proposed railway station building was to be constructed in two phases. It was intended to occupy most of the station site, which at the time comprised five separate small structures on the northern side, and to create a new separate building on the southern side. Their replacement was planned for the First Construction Phase (I Bauperiode). The Second Construction Phase (II Bauperiode) involved replacing the existing passenger station building situated between the two planned structures, which was to be located in the middle. Judging by the drawings, the old station building was still in existence at the time the new one was being designed. Thus, a single large railway station building was to be created, combining an administrative and residential block (Bureaux u. Wohngebäude) to the north with three separate entrances – and a passenger block with through passages – to the south (Fig. 2). The overall dimensions of the structure were to be 116.7 m in length and 13.5 m in width along the main plane of the facades. The width of the adjacent boarding platform was to be 6.2 m. To the north of the station's passenger building, along the platform, there are two preserved separate station buildings – a two-storey service building, and opposite it, set back from the platform to the west, a three-storey residential building. These buildings are shown on the drawing under study and are still in use for their intended purpose.

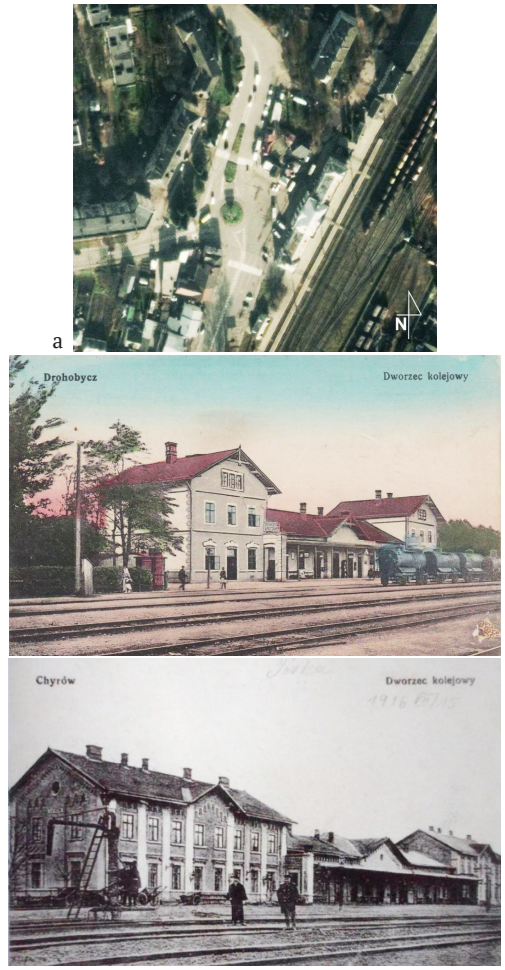


**Figure 1.** The railway stations of Drohobych and Khyriv
**Note:** a – a section of the railway station in Drohobych; b – the first railway station building in Drohobych. Photograph from 1915; c – the railway station building in Khyriv
**Source:** a – photo from Google (2025), b – Drohobych – railway station (2021), c – M. Kubinszki (2009)

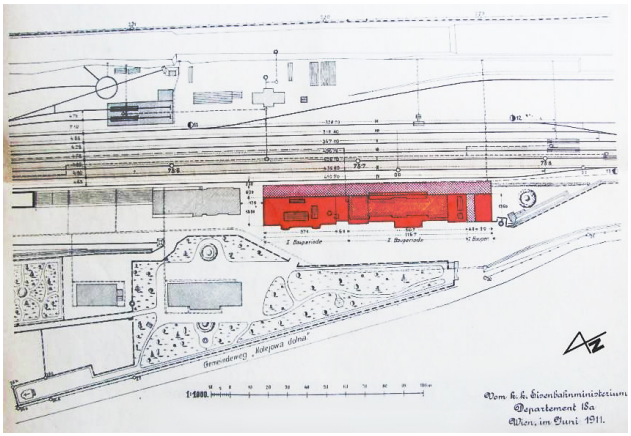

**Figure 2.** Detail from the drawing "Drohobych station. Station building design. Site plan"
**Source:** photo from Central State Historical Archive of Ukraine in Lviv, n.d.b)

The passenger area occupies a single level featuring a high-ceilinged ticket hall (Vestibül) (9.5 m), separate waiting rooms for 1st, 2nd and 3rd class passengers, and two separate dining rooms for the restaurant – one for 1st and 2nd class passengers near their waiting rooms and a separate room for 3rd class passengers. Access to the administrative and residential block was to be via the kitchen only, which was situated in two blocks at their junction. The passenger section of the building was planned to the south, as this provided closer access to the station forecourt and the city centre. For passengers, the connection between the platform and the station forecourt was to be provided in two ways – 1) a passage (entrance) to the platform through the building's passenger hall, past the ticket offices and the luggage drop-off area, and 2) exit from the platform via a covered passageway between this building and a small service building at the southern end of the entire structure (housing the concierge, baggage claim, post office and technical rooms) (Fig. 3a).

The administrative and residential block comprised two full storeys, a basement and an attic level. Two symmetrical stairwells were designed, with entrances from the station forecourt. A separate entrance from the northern end of the building led only to the workers' barracks (Arbeiterkaserne). Accordingly, the ground floor is occupied by service premises (railway station office, police, telegraph office, workers' barracks, training room) and the restaurant kitchen (Fig. 3b). The second floor comprises the stationmaster's accommodation with a separate access to the staircase (to the north) and two flats for staff and the restaurant manager – with another staircase (to the south) (Fig. 3c). The attic level was to have separate rooms for women and men (as a dormitory) with entrances from different stairwells.

The first level of the building was to have an enfilade layout in the administrative and residential block and a hall-corridor layout in the passenger block. The second and third levels of the administrative and residential block are residential, with an enfilade-corridor layout. The basement was located only beneath the administrative and residential block, accessed via staircases from two stairwells. This level was intended to house a fuel storage room and refrigerated food storage chambers; it also contained a laundry room, as well as offices (cubicles) for the station manager, the caterer and others. The passenger block of the building had no basements, but a duct for the heating network ran beneath the floor throughout it (width 1.2 m, height 1.6 m).

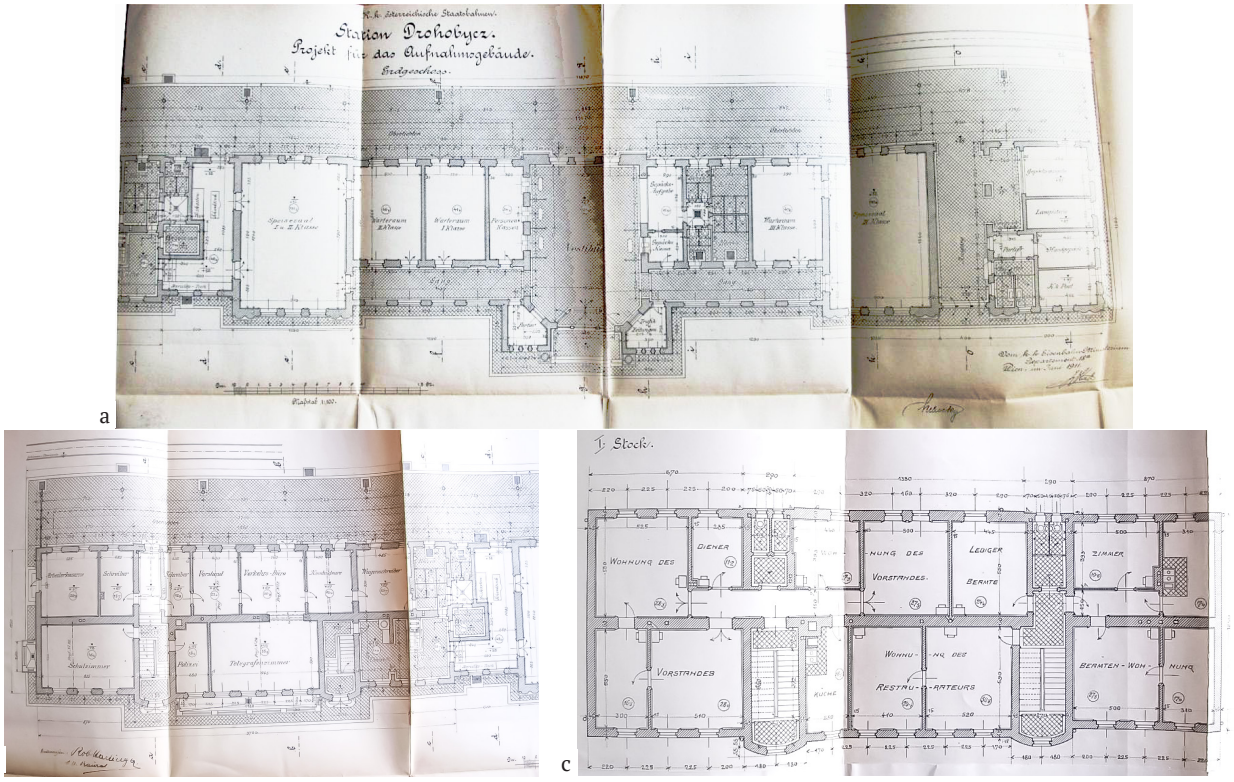


**Figure 3.** Floor plans of the Drohobych railway station building
**Note:** a – ground floor of the passenger block; b – ground floor of the administrative and residential block; c – first floor of the administrative and residential block
**Source:** Central State Historical Archive of Ukraine in Lviv (n.d.b)

Thus, the layout of the site and the station building features very clear functional zoning, a logical sequence of connections and the interconnectivity of the premises. They are almost entirely "enveloped" by separate "regular" defined spaces, rooms or halls according to their use. At the same time, there is a fairly clear distinction between the

background for movement and for stationary processes.

**Structural, technical and artistic design of the Drohobych railway station building.** The station building designed in 1911 was intended to have strip foundations and corresponding wall structures that were significantly wider than the perimeter of the walls of the first station building. Only the foundations of the two risalits of the first building are indicated as a single line along the facade on the platform side. The vertical wall structures were to have rectangular door and window openings; the basement level was to be vaulted, and the floor structure was to be supported by beams. The following structural systems were to be used: wall, post-and-beam and vaulted in the main body of the building; and a frame structure at roof level and in the canopy over the boarding platform. The high roof was to be constructed using a rafter and beam technique and envisaged a somewhat complex configuration in accordance with the layout and decoration. The stairwells of the administrative and residential block included straight flights of stairs and landings, connecting four levels – the basement, two storeys and the attic.

Water supply and drainage were compactly arranged across the two storeys of the administrative and residential block. Toilet facilities were located in both blocks of the building and were connected to the shore (adjacent) platform. Central heating was distributed on the ground floor of the blocks via an underground duct. Stove heating was designed for the second floor and the attic level of the administrative and residential block. A ventilation shaft was planned at the junction of the two blocks, adjacent to which were the toilet facilities and the kitchen. This shaft, without a roof covering, was to be enclosed and invisible from the outside. In the basement, on the north side beneath the classroom, a laundry room was planned with access from the stairwell.

The two blocks of the proposed building differ in number of storeys, length, roof dimensions and overall building outline. At the same time, the overall composition unites them (Fig. 4). The spatial axis along M. Hrushevsky Street, running from the city centre to the station, intersects the plane of the central risalit's facade at an angle of 56 degrees. It features a decorated portal and a tall tower-roof with a conical top on the passenger block of the station. The single-storey passenger block has a dominant visual form due to the central vertical axis (the risalit with the entrance portal and the tower with its finial) and the two symmetrical side risalits relative to this axis. The central vertical axis of the service block's facade is less pronounced, yet it reinforces the symmetry of its structure with two narrow risalits featuring entrances and a raised roof in the centre.

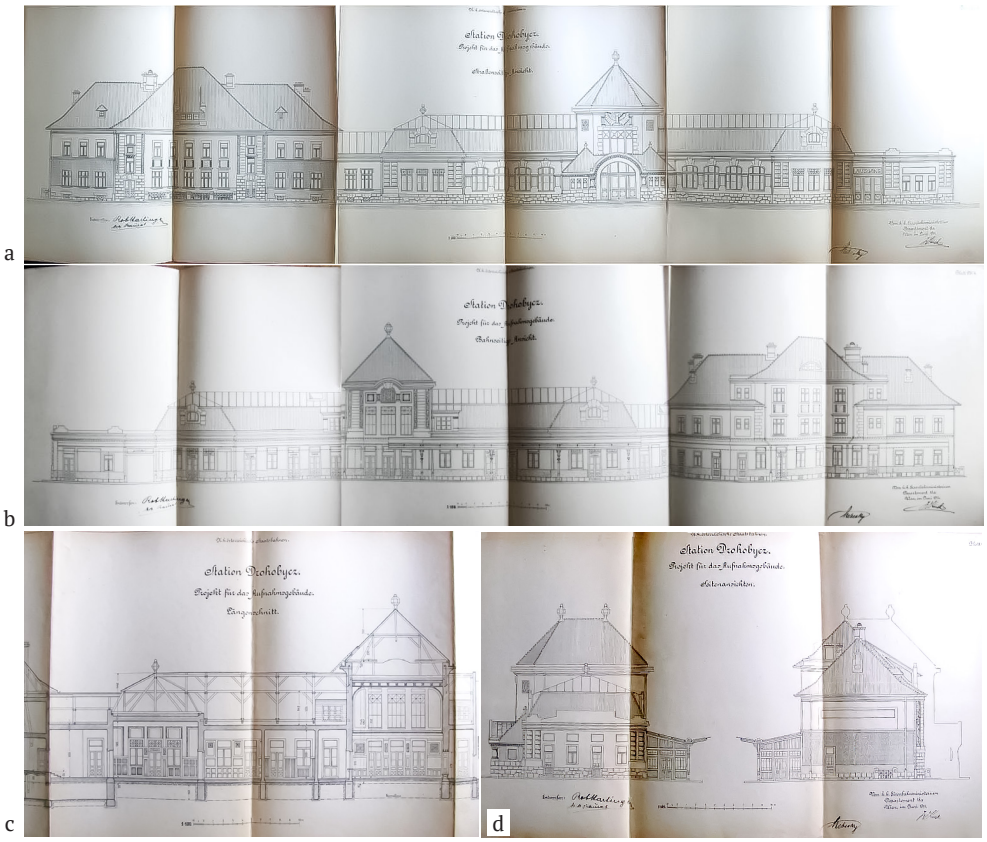


**Figure 4.** Blueprint of the Drohobych railway station from the 1911 design
**Note:** a – facade from the station square; b – facade from the track side; c – section showing the junction between the administrative and residential block (left) and the passenger block (right); d – side facades
**Source:** Central State Historical Archive of Ukraine in Lviv (n.d.b)

The similar rhythm of the vertical axes formed by the doors and windows on the facades of both blocks lends the building a strong visual unity. The compositional scale, understood as the degree of monumentality and perceived grandeur of the structure, is coherent throughout. The arched termination of the broad entrance portal to the passenger hall, together with the conical roof accent and the larger window openings, conveys a sense of importance and prominence in this part of the building. Various finishes are used on the external surfaces of the walls – smooth, decorative and rusticated. Due to the direct adjacency, the rhythm of the facade elements' articulation, and the similarity in the pitch of the roof slopes, there is a successful combination of two blocks that differ in function and size – the passenger and service blocks. At the same time, the facade facing the city centre – the station square – has greater visual prominence.

The overall volumetric and spatial structure of the station building is executed in a single style, combining features of rational (geometric) Modernism with those of the national Romanticism of Austria at the time. Unlike Secessionist techniques, the facades lack curved lines, plant motifs and additional ornate decoration. The elements and articulation of the facade lean more towards rationality, particularly in the station's service block. Such stylistic preferences developed around 1910. From the available drawings, one can partially see the artistic execution of the interiors, and particularly the ticket hall, which is usually a focal point for architects and artists when designing the interior.

On the surface of the wall of the main risalit above the entrance to the passenger block, there is a stylised depiction of a double-headed eagle – the coat of arms of the Habsburg Empire. Above the entrance to the building on the opposite side, facing the platform, a coat of arms is visible, which is likely associated with the city of Drohobych. The drawings show inscriptions on the facades of the passenger block in German indicating exits, toilets, waiting rooms and restaurant areas; most of the inscriptions are on the platform side. At the ends of the entire building, at the level of the second floor, there are spaces for station name signs; a long frame is clearly visible at the end of the administrative and residential block. It is possible that the inscription "Drohobych" was intended to be in two or three languages, as was customary in Galicia at the time.

A separate sheet shows the drawings for the finish of the walls and ceiling of the main passenger hall (lobby, Sheet No. 7). The building's cross-sections generally illustrate the attention paid to the interiors of the station building, the individual waiting rooms, and the two dining halls of the restaurant catering to three different classes of passengers (Sheet No. 5 in Fig. 4c; Sheets No. 8, 9, 10). It is likely that the station building in Drohobych was constructed entirely in accordance with the project under investigation. Unlike the drawing, it was given a mansard roof over the main passenger hall. No further detailed technical information regarding the architecture of the station building at that time has been found; however, there is a photograph with a caption in Polish – "From a journalistic trip: At the railway station in Drohobych" – in which the building under study can be seen in the background. This photograph was taken in the summer time of 1919, as the town was in the hands of the Ukrainian Galician Army (UGA) until 17 May (Fig. 5). In any case, the Drohobych railway station survived the First World War and the Ukrainian-Polish War in Galicia of 1918-1919, but was destroyed during the Second World War.

**Figure 5.** The Drohobych railway station building in 1919
**Source:** photo by S. Dąb-Biernacki (1919)

It is clear from all accounts that the station building employs a conventional load-bearing wall structure for the main structure itself, alongside a frame structure for the floor slabs and in the roof and attic levels. The sanitary and heating systems were constructed to the high standards of the time. The architectural design of the station building follows a logic rooted in the urban context, social needs, traditions and aesthetic tastes. Particular attention was paid to the proportions of the facades, the symmetry of the risalits and the shape of the roof, creating a harmonious visual image of the structure. Furthermore, the architectural solutions ensure a clear perception of the functional blocks and their interrelationships, emphasising the building's engineering and aesthetic integrity.

**The modern building of Drohobych railway station**. The current building is the third to be constructed and is situated on the same site as the first building from the 1870s, as well as the second, which was designed in 1911. This existing one- and two-storey building dates from 1954 and has a symmetrical layout with a central passageway running through the tall ticket hall and the side waiting rooms. The two outer two-storey side blocks at the ends contain service rooms. In the main hall, two spatial axes intersect perpendicularly: 1) a through-axis running through the building between the station forecourt and the platform, and 2) an internal axis connecting the enfilade of passenger halls and running parallel to the platform with the tracks. This is the very same compositional technique incorporated into the building designed in 1911. A characteristic feature is the uniform articulation of the facades by

tall, round-arched window and door openings. A distinctive feature of this building is the two external recessed longitudinal side niches behind the arcades on the columns, serving as waiting areas on the side of the boarding platform. A characteristic feature is the uniform division of the facades by tall round-arched window and door openings. The overall compositional and stylistic design corresponds to the "Soviet classicism" style prevalent at the time, featuring Renaissance and Baroque motifs in the small architectural elements (Fig. 6).


**Figure 6.** The existing building of Drohobych railway station
**Note:** a – view from the station forecourt; b – view from a railway carriage; c – section of the waiting room facing the ticket hall
**Source:** author's archive

It is clear that the existing railway station building in Drohobych was constructed as part of the wave of station-building projects across Ukraine following the Second World War, and reflects the way in which the new authorities of the time sought to establish their presence at the local level. This station is similar to other stations designed according to individual plans for stations in cities in western Ukraine: Zdolbuniv, Mukachevo, Rivne, Stryi, Chop and others, as well as to stations built to standard designs – Bryukhovychi, Volovets, Korolevo, Perechyn, Svalyava and others. Such buildings were erected throughout Ukraine, in many cases on the sites of former, destroyed.

**Functional, spatial and structural features.** Of the four stations on the former Dniester Railway, the station in Drohobych was to receive a new passenger and staff building. This was likely linked to the increase in passenger numbers and the laying of the railway line to Truskavets in 1911, which attests to the significant role and prosperity of the city and its agglomeration in the eastern crown lands. Similar "replacements" of existing station buildings had already taken place in Lviv (1904), Stanislaviv (Ivano-Frankivsk, 1906), Ternopil (1906) and Chernivtsi (1909) (Hrankin, 1996). In Volhynia (Lodomeria), amidst different political realities, a similar reconstruction took place at Kovel station (Nazaruk, 2021). Here, the new building (1907), along with the stations at Zhmerynka (1904) and Lviv in Galicia, were the most modern of their time due to the two-level design of the station buildings and the underground pedestrian passageway connecting to the boarding platforms (Hrankin, 1996; Rotchniak, 2021).

The layout of the site and the levels of the proposed station building in Drohobych is based on functional zoning and technological processes. There is a clear division of different activities and their locations. The administrative and residential block houses various operational functions on the ground floor – offices, a training room, police station, telegraph office, workers' quarters (workers' barracks) with their own separate side entrance, and part of the kitchen facilities. All railway service premises face the platform; the telegraph, police and kitchen premises face the station forecourt. Separate toilet facilities for office staff, kitchen staff and passengers are grouped together with entrances distributed throughout the building – for office and kitchen staff respectively, and from the platform side. Furthermore, the separation of toilet facilities by gender is provided only for the toilets on the platform side – for use by visitors and passengers. Food preparation areas for the restaurants are compactly arranged around a small enclosed courtyard to ensure good ventilation. The police room has a separate entrance from the stairwell and, at the same time, easy access from both the station forecourt and the platform. The post office and baggage claim areas are grouped near the external (southern) passageway between the platform and the station forecourt, adjacent to the passenger block.

In the passenger block of the building, two main perpendicular spatial axes for movement and customer service are clearly defined. One axis runs from the station forecourt to the platform, perpendicular to the tracks and through the building, with three ticket counters (on the left) and a baggage drop-off counter with a ticket office (on the right) located in the passenger hall. The second axis runs parallel to the platform and tracks inside the building, serving customer facilities (waiting rooms, restaurant areas, toilets). The axes intersect in the ticket hall, which facilitates orientation and movement.

The design of the railway station building in Drohobych demonstrates an attempt to combine two major functional blocks – the passenger and service areas – into a

single asymmetrical structure. This approach is rarely seen in the architecture of stations in Galicia or other neighbouring regions. A more common approach was a mirror-symmetrical overall layout along the central axis of the entrance to the passenger hall. This concept was apparently justified by the angular positioning of the spatial axis of the main city street, M. Hrushevsky Street, relative to the station building's facade. This visually distanced the taller and less visually prominent administrative and residential block, which had to stand behind the passenger block.

A similar approach to combining a single-storey passenger block with a two-storey service block of the station building was retained in the former, now disused but still standing, station building in Truskavets from 1912 (then known as "Truskawiec-Zdrój" station). Initially, the combination of the two blocks was rather contrasting in terms of their different sizes, number of storeys and their arrangement in the horizontal projection (plan). Subsequently, a symmetrical two-storey block was added to the opposite end of the passenger building, along with a second storey above the passenger block, giving it a more familiar mirrored appearance. Consequently, the resulting building resembles the early stations of the Dniester Railway – flanked at the ends by two taller service blocks on either side of a long, low passenger block (Fig. 1).

Thus, construction activity at the Drohobych railway station was higher than in other towns along the Dniester Railway, which can be explained by greater intensity of operations and high demand. The architecture of the station building was linked to stations in other towns of Galicia, which were also being rebuilt during the same period. At the same time, functional and compositional techniques are observed here that are not evident in other cases.

**Architectural and stylistic equivalents of the Drohobych railway station building.** At the beginning of the twentieth century, a considerable number of new railway station buildings appeared throughout the Crown Land of Galicia and Lodomeria (Volhynia), mostly replacing or supplementing existing facilities. These included stations in Bochnia, Lviv, Nowy Sącz, Stanislaviv, Tarnów, Ternopil, Truskavets, and others (Kubinszki, 2009; Rymar, 2009). A comparable new station building was also constructed in Chernivtsi, in Bukovina (Kubinszki, 2009). A common feature of these stations was the centrally positioned main passenger hall (vestibule), characterised by a lofty ceiling or vault and illuminated from both the station forecourt and the platform side through large, rounded upper-level windows. These windows, together with the hall itself, were externally emphasised by domed terminations or prominent high roofs, underscoring the importance of the building, expressing respect for passengers, and symbolically enhancing the status of the city. The architectural emphasis on the principal through-route of passenger movement and service within the station building – primarily associated with pre-journey activities – became a dominant spatial and compositional principle in station architecture for many decades.

This approach developed in various European countries from the late 19th century onwards, and despite structural and stylistic differences, the large, open-plan passenger hall of the station building remains the visually dominant architectural space. The Drohobych railway station building is very similar in its architectural design, for example, to a similar one in Darmstadt (Hesse) dating from 1912 (Radlbeck, 1981; Gerkan, 1996; Parissien, 1997). However, the main and essential space of any railway station has always been and remains the platform – the railway boarding platforms alongside the tracks. Contemporary railway station architecture pays significantly more attention to the design of platforms (Rotchniak, 2021).

In this context, the planned railway station in Drohobych reflected these early 20th-century trends, offering passengers, first and foremost, a large, light and artistically enriched main hall. On either side of this hall, with three ticket windows on one side and a ticket office and a luggage drop-off counter on the other, there were three separate waiting rooms for passengers of the three classes, each with adjoining dining rooms corresponding to their respective classes. It is noteworthy that the waiting room and dining room for third-class passengers (south wing) were on the opposite side from the first- and second-class facilities (north wing). One senses the project designer's attempt to ensure equality of opportunity for customers, taking into account the category of service payment: a shared main ticket and operations hall for all passengers and, at the same time, separate accompanying spaces.

Noteworthy is the small number of steps leading to the buildings of these stations on both sides – the concept of "accessibility" to the interiors and to the railway as a whole becomes both practical and symbolic. Stairs inside passenger station buildings from the turn of the century, if they exist at all, generally have no direct connection to the main hall and do not stand out in any particular way. For example, this is a significant and clearly visible feature in the changes to the layout of the two buildings of Lviv's main station: the first from 1861 and the second from 1904. The difference in floor level between the main hall of the planned station in Drohobych and its adjoining platform – as well as between the pavement of the station square – amounts to one to three steps. This brought the literal concept of a barrier-free space closer to reality over a century ago.

A characteristic feature of railway station building design around 1910 was the form of a high hipped roof with residential accommodation. Decorative gables were used on both long sides of the building. Two-storey station buildings, sometimes including habitable attic or mansard levels, can still be found at the stations of Boikivska, Vankovychi, Komarno, Staryi Sambir, Strilky, Rudky, and Yavora along the Lviv-Oboroshyn-Sambir-Sianky railway line. The buildings themselves follow a standard layout (two types) for the Imperial-Royal State Railways of Austria (K.k. Staatsbahn Normbauten) and were widespread throughout Cisleithania – the part of the Austro-Hungarian Empire under the authority of Vienna. Differences in the

finishing were used to adapt the buildings to the context of this, at the time, new architecture (Fig. 7).

**Figure 7.** Station buildings along the Lviv – Oboroshyn – Sambir – Sianky railway line based on the standard design of the imperial-royal Austrian railways
**Note:** a – Komarno station, view from a railway carriage; b – Rudky station, view from the station forecourt; c – Staryi Sambir station, view from a railway carriage; d – Strilky station, view from a railway carriage
**Source:** author's archive

The mountainous section of the Lviv – Oboroshyn – Sambir – Sianky railway line passes through the ethnographic region of Boikivshchyna, where vernacular architecture was characterised by buildings with steep roofs, predominantly covered with thatch. Consequently, the structural and plastic treatment of the high roofs of the railway station buildings helped them appear naturally integrated into the local architectural landscape (Fig. 8).

**Figure 8.** Typical 19th-century rural houses in the "Boikivshchyna" section of the Museum of Folk Architecture and Life in Lviv
**Source:** author's archive

The high longitudinal roof above the main passenger hall of the Drohobych station building was designed perpendicular to the principal axis of the building, thereby obscuring the view of the equally high longitudinal roof of the administrative and residential block (Fig. 10). In this way, the representational character of the public part of the building was emphasised in relation to the service functions. However, high roofs also became a favoured architectural motif in stations situated on the plains along the same railway line. Materials from the Central State Historical Archives of Ukraine in Lviv include drawings of the "Project for the reconstruction of the completely burnt reception (station) building at Velykyi Liubin station", in which a clear preference for high roofs on both the main station building and the ancillary structures can be observed (Fig. 9). A similarity can be discerned with the examples discussed above, particularly that of Rudky station (Fig. 7b).

Architectural and stylistic parallels to the Drohobych railway station can be seen in a number of public buildings in Lviv – the Lviv Puppet Theatre, administrative buildings on Shevchenko Avenue and Soborna Square, the technical college building on Josyf Slipyj Street, and others (Fig. 10). They appeared around 1910 and share architectural and sculptural similarities: fairly balanced and regular division of the facades by window and door openings, pilasters, and decorative elements; an active sculptural surface of the facades above the cornice line; the use of sculptural motifs; high roofs; and the accentuation of the building's corners and roof finials with "spike-like" sculptural elements, and so on. Visually, this architecture differs markedly from the

earlier eras of Secession and Historicism. It is widely represented in Lviv, notably in residential buildings on Halytska Square and on I. Franko Street, General M. Tarnavsky Street, K. Levytsky Street and others (Biriulov *et al.*, 2008).

**Figure 9.** "Project for the reconstruction of the completely burnt reception (*station*) building at Velykyi Liubin station"
**Source:** Central State Historical Archive of Ukraine in Lviv (n.d.a)

**Figure 10.** Public buildings in Lviv, constructed around 1910
**Note:** a – the building of the Lviv Regional Prosecutor's Office on T. Shevchenko Avenue; b – the south facade of the Technical College building (formerly the Grünwald College, 1910) on Josyf Slipyj Street
**Source:** author's archive

The stylistic approach to the railway stations of this historical era was generally realised in two main styles: 1) historicism with elements of early Modernism (Chernivtsi, Lviv, Stanislaviv, Zhmerynka) and 2) Modernism (Kovel, Ternopil). In this context, the architecture of the planned Drohobych railway station building is distinguished by features of rational (geometric) Modernism, the likes of which are no longer found on the railways of western Ukraine. At the same time, it was a striking example of this style of Modernism in Drohobych.

The Drohobych railway station building, designed in 1911, is perceived as a holistic complex comprising transport, public and residential functions. Through its constructional systems and technical installations, a wide range of different processes, the needs of various users, and the workplace and accommodation for staff are combined within a single building. Moreover, this building envelope is executed in refined artistic forms, displaying a distinctive stylistic expression. At the same time, visually, apart from the main passenger hall, the diversity mentioned is concealed through the rhythmic articulation of the facades by the arrangement of windows, doors and other elements, as well as the uniform plasticity of the walls. Consequently, the functional orientation and practicality of the processes within the spaces are enveloped by architectural techniques of visual unity that were traditional at the time. To put it simply, the ideas of functionalism had not yet gone beyond the accepted spatial, sculptural and structural frameworks. The overall impression of the architectural design of the Drohobych railway station gives the impression of a successful combination of the expressive and festive "palace" of the passenger block, and the more mundane "residential house" – the service section with accommodation for staff.

The execution of the architectural drawings for the Drohobych railway station building deserves special attention. They are presented mainly on a scale of 1:100 on sheets of thick paper of uniform format, which are folded in multiples and feature a consistent approach to the presentation of graphic materials. The drawings comprehensively depict the future structure through orthogonal projections of floor plans, elevations, sections and details, complete with corresponding captions and comments. The exquisite ink lines of the drawings and the standardised typeface create a perfect aesthetic image, just like that of the future station. The authors are indicated by

handwritten signatures in the bottom left corner of all drawing sheets. Most of the drawings indicate that the station was designed (drawn) by Rob Karlinger, Imperial-Royal Building Council (Entworfen: Rob Karlinger, k.k. Baurat), whilst some bear the handwritten signature of the architect G. Kulhavý, Imperial-Royal Chief Engineer (Arch. G. Kulhavý, k.k. Ob. Ing.). Some drawings bear the signatures of both individuals. The names of state institutions, officials' signatures, affixed postage stamps and official seals bearing various dates from 1911 to 1913 attest to the high level of detail and responsibility in the preparation of the drawings for the construction plans and approvals.

Based on the materials discovered and researched at the Central State Historical Archive in Lviv, and particularly the exceptionally well-preserved drawings, make it possible to reconstruct the station building designed in 1911 and destroyed during the Second World War. At least from the perspective of architectural conservation and restoration, such a task appears entirely feasible. Given its uniqueness in Galicia and indeed throughout Ukraine, this railway station building ought to have been restored and put back into use. However, in the realities of post-war devastation, a lack of resources, and, perhaps most importantly, a reluctance to restore this relatively new and, for its time, impressive structure, it was decided to build a new one. The Bolshevik ideology imposed upon the region was hostile to local achievements in culture and technology and sought to assert itself in the newly occupied territories through various forms of imperial standardisation. In this context, architecture, through construction activity, became a convenient instrument for propagating the "new world" and demonstrating visible "unity" and "grandeur" throughout the USSR and the countries within the Soviet sphere of influence. Examples of this can be seen throughout Ukraine, including in the western part of the country. As a result, a completely new and still-standing railway station building was constructed in Drohobych, which became one such symbol in the style of "Soviet classicism". Moreover, it possesses its own distinct character compared to other, similarly reconstructed railway stations in the Drohobych area from the post-World War II period – in Stryi and Sambir.

## DISCUSSION

Academic research into the architecture of railway stations covers cities and regions across many European countries, as such structures are found in virtually every one of them. Consequently, the authors of such studies are most often associated with those cities or countries. Virtually all publications on this topic follow a chronological approach. The chronology of the emergence, development and changes in railway stations forms the natural backdrop to such research. Generally speaking, the architecture of railway stations is examined in the context of railway construction; less frequently, studies focus on individual structures.

The publications by the teams of authors P. Hrankin *et al*. (1996) and Yu. Tomin *et al.* (2011) are of great importance for the study of stations in Galicia. In addition to the crucial historical aspect of the development of the railways in western Ukraine, these works contain a wealth of illustrative material and related information regarding the stations. They therefore provide a solid foundation for further architectural research. Railway stations possess both territorial and chronological relationships through the railway lines upon which they were established. Because these lines were often constructed within similar periods, their stations frequently exhibit related typological characteristics. Station architecture is inseparably connected with railway networks, which themselves constitute independent subjects of study. Since every railway line was constructed under specific circumstances, with particular objectives, clients, and builders, the architecture of its stations became a reflection of the needs, aspirations, and capabilities of both owners and users. Consequently, the linear relationship between stations and the railway routes they served is a key determinant of their architectural development.

A. Borovková's (2013) work explores the architecture of railway stations belonging to the Austrian Northern Railway Company. In this context, the work is significant because the Northern Railway was part of the rail network connecting the crown lands of Galicia and Lodomeria (Volhynia) during the imperial era. Trains from Lviv westwards to Vienna ran on the Karl Ludwig Railway, whilst the Northern Railway itself operated from Kraków. Individual stations, their buildings and railway stations are considered as independent structures within the architectural and urban planning context. Among the general studies of railway station architecture, the works of K. Radlbeck (1981), M. von Gerkan (1996) and S. Parissien (1997) are worth mentioning. These are significant in terms of the organisation of these structures, their characteristics, and changes in the development of railway station architecture worldwide, based on economic, social, political, geographical, technical, artistic and other factors.

The results of the study on the development of the architecture of the Drohobych railway station provide grounds for understanding its role both as a specific building and its place within the phenomenon of public transport architecture. Based on the materials from the aforementioned publications, it can be argued that the 1911 design of the Drohobych railway station building is one of the most successful of all the station's structures from a professional standpoint, as it combines the accumulated experience of construction from the preceding 50-70 years. This high architectural standard was achieved through a careful analysis of urban planning conditions, transport requirements, spatial organisation, functional arrangements, and the effective preparation and execution of the project itself. At present, however, this station building remains virtually absent from scholarly discourse.

Compared with other station buildings of the period, the Drohobych project appears particularly thoughtful and innovative. The functional division of the station into two interconnected blocks, justified by the urban context, was reinforced through spatial, compositional, and

stylistic means. This characteristic makes the station genuinely unique, at least within the regional context, while from the perspective of innovation it may be regarded as exceptionally advanced. Furthermore, the successive station buildings erected on the same site in Drohobych differed substantially from one another. Overall, the architecture of the railway station buildings of Drohobych contributes significantly to the field of research concerned with transport and public architecture.

## CONCLUSIONS

This article examines the architecture of the buildings at Drohobych railway station, focusing on the 1911 design, from historical, functional, spatial, planning, structural, social and artistic perspectives. Historically, railway connections in the Pre-Carpathian region of Ukraine began with the construction in 1872 of the Dniester Railway, which passed through Drohobych. The town was given one of the four standard stations on this railway. The 1911 design for the new Drohobych railway station, from the Central Historical Archive of Lviv, shows plans for a new building on the site of the original, which was subsequently realised. This new building was destroyed during the Second World War. The current Drohobych railway station building dates from 1954 and provides passenger services on three of the four existing railway lines.

The functional design of the proposed railway station in Drohobych in 1911 is based on two opposing considerations – 1) transport and station requirements arising from the needs and capabilities of the technical and technological processes of railway transport, and – 2) passenger and urban planning requirements, which combine location, access processes, and the preparation/conclusion of the journey. In this context, the organisation of the process of boarding and alighting from train carriages should have been reflected in the design of the railway platform. Instead, the presence of only a single side platform adjacent to the station building indicates that there was no such need at the time. The architects' full attention was focused on the station building, through which the railway of that era presented itself. In later times, architects turned their attention more actively to the railway platforms as well.

The building, designed with a focus on spatial layout, was intended to replace the previous one whilst retaining the main processes, circulation routes and building outlines. At the same time, these processes have increased in number, becoming more specific and clearly defined. In terms of layout, the processes are assigned to separate rooms, zones and circulation routes, which are most developed on the ground floor – approximately at the level of the platform and the station forecourt. At the same time, there is a noticeable grouping of spaces according to functional, technological, structural and social criteria. Structurally, the station's design is based on the traditional construction methods of the time, whilst technologically it incorporates the latest means and techniques to provide heating, cooling, ventilation, lighting, communications, water supply and drainage. All the technological and sanitary processes within the station building are spatially defined and logically arranged.

From a social perspective, the designed building reflects a clear division, broadly speaking, into: 1) staff of various services and 2) passengers. Service staff have their own entrances, zones and areas for waiting and working, without creating barriers or intersections between themselves and with passengers. Passengers of different classes are kept apart from one another, just as the movement routes of passengers and their luggage before and after the journey are separated. Furthermore, the building includes accommodation for staff of various services and ranks.

The artistic expression of the proposed station building demonstrates an understanding of compositional integrity within the then-contemporary stylistic forms of rational modernism and national romanticism. The external orderliness of the facades partly reflects the internal layout and function. There is a clear desire to create a positive impression on passengers, both within the premises and in the building's external appearance. The general character of the proposed "architecture of regulation" but also as an "architecture of expression". A connection has been established between the designed Drohobych railway station and other similar structures in the Pre-Carpathian region of Galicia. The design of the Drohobych railway station marks the final chapter in the history of active construction during the imperial period in Galicia. It is one of the defining stages in the subsequent development of this station, taking the form of the building that stands today.

Prospects for further research in this field may take several directions: further searches for materials in libraries and archives concerning the station and railway station in Drohobych, as well as in nearby towns; comparing similar structures with the architecture of their historical and territorial context; and examining how existing historic stations – which must undoubtedly be placed under heritage protection – should be integrated within the context of functional, social and other changes in transport and the community.

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# Архітектура будівель залізничного вокзалу Дрогобича

**Анотація.** Актуальність даного дослідження викликане професійним зацікавленням і потребою розуміння процесів формування архітектури залізничного вокзалу Дрогобича, який набував змін протягом більш як 150 літ. Увага до вокзалів, станцій та залізничного сполучення підсилюється на тлі існуючої збройної агресії проти України понад 12 років. У цьому контексті добре усвідомлюється вага колійного транспорту при евакуації, постачанні, обороні та наступі; відтак вокзали є одним із життєво важливих об'єктів держави. Водночас, звернення уваги на історичних і матеріальних цінностях країни потребують доповнення знань для їхнього захисту. Метою роботи було вивчення архітектури залізничного вокзалу Дрогобича в функціональному, територіально-просторовому, розпланувальному, конструктивному, соціальному та художньому аспектах. При цьому увага загострена на архітектурі залізничного вокзалу Дрогобича у проєкті з 1911 року, який виявлено у Центральному державному історичному архіві Львова. На основі камеральних методів досліджень, методу порівняння, прийомів фотофіксації, а також польових спостережень проведено дослідження динаміки змін будівель вокзалів станції Дрогобич. Важливу інформацію отримано як з опублікованих, так і з медійних джерел. Було встановлено місце першої будівлі вокзалу в ряді подібних споруд залізничних сполучень цього передгірського регіону Галичини, а також пов'язаність будівель вокзалів з іншою насамперед громадською архітектурою. Це уможливлює робити узагальнення – з одного боку про типовість вокзального будівництва, а з іншого, – його унікальність власне для Дрогобича. Зокрема встановлено, як у кресленнях 1911 р. виразними є дві виразні концепції проєкту – чітке функціональне зонування та соціальна і просторова детермінації будівлі й території вокзалу. Помітним є врахування територіального і просторового укладу споруд на містобудівному тлі. Отримані результати доповнюють загальне розуміння вокзального будівництва міста, регіону та сполучень краю. Разом з тим, появляються додаткові підстави для пошуку інших джерел і напрямків досліджень. Ці та інші матеріали й результати стають підставою для майбутнього використання таких важливих історичних споруд на тлі суспільних, транспортних, технічних та інших змін

**Ключові слова:** будівля; станція; залізниця; простір; Галичина

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# Typology of leisure facilities in public buildings in small towns in Ukraine

**Abstract.** The study aimed to identify the architectural, planning, functional and urban development criteria for classifying leisure-purpose buildings in small towns in Ukraine, and to justify the directions for their transformation in the context of contemporary public use, reconstruction and adaptation. The research methodology combined normative, functional-planning, typological, urban planning and reconstruction-engineering analysis with integrated modelling. The practical applicability of the proposed typological models was tested using the example of four leisure buildings in small towns in Ukraine: House of Culture in Kaniv, the Stebnyk People's House, the People's House in Bibrka, and the Zhovkva Municipal People's House. The results of the study showed that a house of enlightenment, a people's house, a house of culture, a club building and a cultural centre are not merely historical or institutional names for a single type of building, but reflect different models of public buildings, differing in their primary function, user composition, spatial core, level of multifunctionality, urban planning role and potential for transformation. The study established that the traditional club building in a small town was predominantly centred around a hall-and-stage complex; however, the modern needs of communities are driving a shift towards a multifunctional model, in which lobbies, club and training rooms, circulation spaces, technical areas, barrier-free entrances and adjacent public spaces become key elements. Five typological models of leisure building transformation have been summarised: a single-purpose hall building, a club and group building, a cultural and entertainment building with a developed stage and auditorium block, an adapted mixed-use public building, and a multifunctional cultural and leisure centre. The study established that the greatest potential for adaptation is in facilities where the hall area is combined with flexible spaces for everyday use. The practical significance of the findings lies in their potential application in the assessment, restoration and functional refurbishment of cultural and leisure facilities in small towns across Ukraine

**Keywords:** public building; public space; building typology; building functionality; cultural centre; community centre; leisure facility

## INTRODUCTION

The development of leisure facilities in public buildings in small towns across Ukraine is related to a reconsideration of the functional role of clubhouses, cultural centres, community halls and cultural centres within the urban environment. The research relevance is determined by the need to preserve the existing stock of public buildings and adapt it to contemporary scenarios of cultural, educational, communicative, youth and community use. In small towns, such facilities often serve a broader function than specialised leisure venues: they concentrate public ac-

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tivity, support local identity, create meeting spaces and remain integral to everyday urban life. Therefore, their typological analysis requires a historical-functional, architectural-planning, urban planning and reconstructive approach. Contemporary trends in the development of public building architecture demonstrate the growing importance of flexibility, multifunctionality, openness and the adaptability of space. L. Tiutina (2021) argued that 21st-century architecture is developing under the influence of new structural, technological and aesthetic possibilities, which are changing the nature of form-making and the spatial organisation of buildings. The latest architectural trends are linked not only to a visual renewal of form, but also to the search for materials, design methods and means of expressing the architectural environment. The issue of the functional and spatial organisation of public spaces is explored in the study by A. Davydov & S. Dvornikova (2024), in which recreational centres are considered as spatial systems combining various types of activity. The study emphasises the relationship between functional zones, the intensity of their interaction, and the alignment of the space with actual usage patterns. The issue of accessibility and inclusivity in the urban environment is explored in the study by N. Novoselchuk *et al.* (2025), where the universal design of urban spaces in Ukraine is analysed in relation to the needs of different user groups. The study concluded that accessibility is not limited to technical means of accessibility but depends on regulatory, organisational and spatial conditions, and should therefore be considered as a component of the architectural and planning organisation of the urban environment. The ecological and compositional dimensions of the regeneration of public spaces are elaborated upon by D. Chernenko & A. Davydov (2025). The authors found that vertical greening can enhance the quality of open spaces, humanise the built environment and strengthen the ecological component of architectural solutions.

In international academic discourse, attention has been focused on the inclusivity, adaptability and sustainability of the built environment. M. Zallio & P.J. Clarkson (2021) explored these issues in the context of accessibility, diversity, equality and user engagement in architectural design practice. The study establishes that accessibility should be viewed not as an additional technical parameter, but as a fundamental characteristic of the environment, within which a building is assessed not only by the composition of its spaces, but also by the clarity, safety and suitability of the space for various usage scenarios. The adaptability of buildings was examined in the study by E.R. Staehr *et al.* (2025), which explores the multidimensional nature of a building's adaptation to changing conditions of use. The results showed that adaptability was not limited to a one-off redesign but manifested in a building's ability to respond to changes in functional, technical and operational requirements. M.B. Hamida *et al.* (2022) interpreted building adaptability as a parameter of a circular approach, linked to the reuse of elements, the extension of a building's life cycle, and the preservation of its operational value. In the study, adaptability is considered not as a one-off redesign, but as a building's ability to maintain functional suitability under changing conditions. The issues surrounding sustainable design and the renewal of the built environment were explored through the interplay of energy efficiency, resource efficiency, material durability and the functional relevance of buildings. In this context, T. Poorisat *et al.* (2024) systematised the potential of sustainable design solutions and construction practices and demonstrated that the sustainability of the built environment was determined not only by technical characteristics but also by the building's ability to meet the long-term needs of its users. The urban role of sustainable design is elaborated upon in studies of post-industrial transformation. Using Katowice as a case study, K. Zwolińska-Glądys *et al.* (2025) demonstrated that the sustainable operational efficiency of buildings can be a factor in the regeneration of the urban environment, and that public facilities can serve as spatial and functional elements of this process. For small towns in Ukraine, this finding provides grounds for viewing club buildings, cultural centres and community halls not merely as leisure facilities, but as elements of the spatial renewal of the public environment.

Despite the existence of studies devoted to contemporary architectural trends, the functional and spatial organisation of public spaces, universal design, inclusivity, adaptability and sustainable construction, the issue of the typology of leisure facilities within public buildings in small towns in Ukraine remains insufficiently explored from an architectural and planning perspective. Existing approaches tend to focus on the cultural, social or organisational role of such facilities, whilst their spatial core, functional units, urban planning context, potential for renovation and structural and engineering adaptation require systematic consideration. This necessitates a shift from describing club buildings as cultural institutions to analysing them as public architectural objects capable of adapting their functional structure to the needs of small towns.

The study aimed to identify the typological characteristics of leisure facilities within public buildings in small towns in Ukraine, based on an analysis of their regulatory and conceptual status, functional and spatial structure, urban planning role, and potential for renovation and adaptation. To achieve this aim, the following tasks were set: to clarify the regulatory and conceptual status of leisure facilities within the system of public buildings in small towns in Ukraine; to establish the characteristics of their functional and planning structure; to identify typological models for the transformation of club buildings, cultural centres, community centres and cultural hubs, based on their urban planning role within the system of public spaces in small towns; and to justify the reconstruction, engineering and adaptation approaches to the development of such facilities as the basis for forming an integrated typological model of a public building in a small town.

## MATERIALS AND METHODS

The study was conducted using a combination of regulatory-interpretative, functional-planning, typological, urban planning, reconstruction-engineering and integrated-modelling approaches. The source base comprised regulatory and legal, regulatory and construction, classification, international and analytical materials governing the functioning, spatial organisation, accessibility, reconstruction and contextual development of public and cultural and leisure buildings in small towns in Ukraine. This methodological framework made it possible to consider a leisure facility not merely as a separate functional entity, but as an element of public infrastructure linked to the historically formed environment, pedestrian connections, open urban spaces and contemporary usage scenarios.

At the initial stage, the theoretical and conceptual framework of the study was established, and the scope of the analysis of leisure facilities within the system of public buildings in small towns was defined. Law of Ukraine No. 2778-VI (2010) and Resolution of the Cabinet of Ministers of Ukraine No. 984 (2012) made it possible to determine the institutional role of cultural establishments within the system of cultural services for the population, whilst NK 018:2023 was used to correlate such facilities with the classification categories of public buildings (Ministry for Communities and Territories Development of Ukraine, 2023). On this basis, the study distinguished between historical and contemporary names for leisure facilities – the house of enlightenment, the people's house, the house of culture, the club building, the cultural centre and the multifunctional cultural and leisure centre. This approach ensured terminological consistency for the subsequent functional, planning and typological analysis.

The functional, spatial and typological analysis was aimed at identifying the internal layout of club buildings, cultural centres, community centres and cultural facilities. The provisions of DBN V.2.2-9:2018 were applied to account for the general requirements for public buildings and structures (Ministry for Communities and Territories Development of Ukraine, 2018a), their spatial organisation, composition of premises and functional connections, whilst DBN V.2.2-16:2019 was used to analyse cultural, entertainment and leisure facilities, specifically auditoriums, stage areas, spectator areas, foyers, and auxiliary and technical spaces (Ministry for Communities and Territories Development of Ukraine, 2019). Within this section, the entrance area, foyer, auditorium, stage, club and teaching rooms, administrative block, technical and sanitary-domestic zones, as well as horizontal and vertical services were analysed. These parameters were used to determine the building's primary function, its planning core, the composition of main and ancillary spaces, the level of multifunctionality, and its capacity to support event, educational, club, exhibition, youth and community usage scenarios. The urban planning analysis determined the role of leisure buildings within the spatial structure of a small town. Law of Ukraine No. 2780-XII (1992) and Law of Ukraine No. 3038-VI (2011) were used to address general principles of planning, development and territorial development, whilst Order of the Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine No. 163 (2014) was used to specify design requirements for the reconstruction and functional adaptation of public buildings. The UNESCO (2011) recommendation on the historic urban landscape was drawn upon to interpret club buildings, cultural centres, community centres and cultural hubs as elements of the historically formed urban environment, local memory and community interaction in small towns. Within this section, the analysis covered the building's location in relation to central streets, squares, parks, pedestrian routes, neighbouring public facilities and the open space in front of the entrance.

The structural and engineering section of the methodology aimed to identify the spatial, technical and material requirements for adapting club buildings to modern standards. DBN V.2.2-40:2018 (Ministry for Communities and Territories Development of Ukraine, 2018b) and ISO 21542:2021 (2021) were used to assess accessibility, barrier-free circulation, entrance areas and sanitary facilities. ISO 20887:2020 (2020) was applied to analyse adaptability, planning flexibility and the potential for transforming spaces, whilst ISO 15392:2019 (2019) was used to account for the principles of sustainability, energy efficiency and the durability of material solutions. Based on this, renovation constraints were identified, in particular those related to the condition of load-bearing structures and service networks, accessibility, energy efficiency, sanitary and domestic facilities, and the possibility of changing functional scenarios without losing the building's cultural and spatial identity. To test the applicability of the typological models developed, open data on actual leisure facilities in small towns across Ukraine were utilised: The House of Culture in Kaniv, Cherkasy region; the Stebnyk People's House in Stebnyk, Lviv region; the People's House in Bibrka, Lviv region; and the Zhovkva City People's House in Zhovkva, Lviv region. Each facility was examined using a single analytical framework, which included institutional status, address or urban planning location, functional use, connection to public space, spatial planning structure, reconstruction constraints, and classification under the relevant typological model (Map of Modernism, 2023; Drohobych City Council, n.d.; Bibrka City Council, 2018). This approach was used to compare results and transition from description of individual buildings to the generalisation of recurring spatial and functional features. The systematisation of the obtained materials was conducted using an analytical matrix created in Microsoft Excel 365. The matrix compared the results of regulatory, functional-planning, urban planning and reconstruction-engineering analyses according to interrelated parameters: the primary function of the site, current usage, layout, spatial core, level of multifunctionality, nature of connection with the urban environment, accessibility, engineering constraints, material durability, reconstruction potential and adaptability. Based

on this, an integrated model of the typology of leisure facilities in public buildings in small towns of Ukraine has been developed, combining functional, planning, urban planning, reconstruction-engineering and adaptation-typological components.

## RESULTS

### Comparative analysis of historical and contemporary types of leisure facilities

Comparative analysis of the definitions and concepts underlying historical and contemporary types of leisure facilities has shown that the terms "house of enlightenment", "people's house", "house of culture", "club building" and "cultural centre" denote different models of public buildings, shaped by the historical period, primary function, user composition and spatial organisation. For small towns in Ukraine, this distinction is significant, as a single leisure facility often combines cultural, educational, communicative, entertainment and community functions. The House of Enlightenment and the People's House historically developed as educational and community facilities with a relatively compact layout, in which the central space was occupied by an assembly hall or a multipurpose room, complemented by a reading room, a library section, rooms for club activities and ancillary spaces. The House of Culture, in contrast to these types, developed as a centralised cultural and entertainment model with a distinct hall-and-stage core, a foyer, backstage, auxiliary, technical and club rooms. In its contemporary architectural interpretation, the club building occupies an intermediate position between the traditional cultural centre and the multifunctional cultural centre, as it can retain the auditorium-and-stage core, but at the same time requires flexible ancillary spaces, an accessible entrance area, convenient access routes and the ability to adapt the premises to various usage scenarios. A modern cultural centre is characterised by its extensive multifunctionality, within which the foyer, auditorium, club rooms and surrounding area function as interconnected elements of cultural, educational, exhibition, youth, service and community activities.

A comparison of regulatory and conceptual frameworks demonstrated that the historically established names of leisure facilities do not correspond directly to modern regulatory categories. Within the legal framework, such facilities are associated with public and cultural buildings that operate within the structure of settlements and provide cultural services to local communities. The organisational dimension is specified by provisions on the basic network of cultural institutions, within which leisure facilities in small towns are regarded as elements of the local cultural infrastructure. At the level of building typology, historical names correspond not to individual regulatory types, but to groups of public, cultural-entertainment and leisure buildings. The defining features of such a correspondence are the composition of the premises, spatial relationships, functional blocks, the nature of use and the role of the facility within the public service system. The classification level confirms the validity of interpreting traditional names as historically established variants of public buildings for cultural and leisure purposes, integrated into the modern building classification system. To compare the historically established names of leisure facilities with their current functional, spatial and regulatory meanings, the summarised results are presented in Table 1.

**Table 1.** A comparative analysis of the historical and contemporary types of leisure facilities in public buildings in small towns in Ukraine

| Historical or modern name of the site | Primary function | User characteristics | Base spatial elements | Modern normative compliance | Transformation vector |
|---|---|---|---|---|---|
| House of Enlightenment | Educational, cultural and educational, assembly | Local community, the intellectual community, and participants in cultural and educational initiatives | Meeting room, reading room, library or club room, ancillary rooms | Public building used for cultural and educational purposes; a facility comparable to cultural and leisure venues | Adaptation for a small-scale cultural and educational space or a space for community initiatives |
| Community Centre | Community, cultural, educational, and events-related | Residents, community organisations, amateur groups | Multipurpose hall, meeting rooms, club rooms, reading room, foyer or entrance area | Public building for cultural and leisure purposes, comparable to facilities within the basic cultural network | Reimagining as a community and cultural hub in a small town |
| House of Culture | Cultural and entertainment, mass leisure, club activities | City residents, creative groups, spectators, participants in public events | Auditorium, stage, foyer, backstage and technical areas, club rooms, administrative block | Cultural, entertainment and leisure facility within a complex of public buildings | Modernisation of the auditorium and stage area, foyer, technical systems and usage scenarios |
| Clubhouse | Leisure, communication, club, event | Local community, young people, creative groups, and participants in amateur activities | Hall, foyer, club rooms, administrative and ancillary rooms, utilities | Leisure facility or club within the system of public and cultural and entertainment buildings | Flexible zoning incorporating spaces for young people, education, exhibitions and community activities |

*Table 1. Continued*

| Historical or modern name of the site | Primary function | User characteristics | Base spatial elements | Modern normative compliance | Transformation vector |
|---|---|---|---|---|---|
| Modern cultural centre | Multi-purpose cultural, educational, exhibition, youth, service and community centre | Children, young people, adults, older people, community initiatives, creative communities | Multi-purpose or convertible hall, an exhibition and social foyer, educational and creative spaces, service areas, and an open public space | Multi-purpose community building for cultural and leisure activities | Integration of multiple functional scenarios within a single public facility |

**Source:** compiled based on Law of Ukraine No. 2780-XII (1992), Law of Ukraine No. 2778-VI (2010), Law of Ukraine No. 3038-VI (2011), Resolution of the Cabinet of Ministers of Ukraine No. 984 (2012), Ministry for Communities and Territories Development of Ukraine (2018a; 2019; 2023)

The analysis presented in Table 1 showed that the typology of leisure facilities in public buildings in small towns was not determined solely by the historical or institutional name of the building. A single name could encompass different planning contexts, whilst different historical types converged in terms of contemporary usage patterns. The main criteria for differentiation were the primary function, user composition, spatial core, set of premises, regulatory compliance and direction of future transformation. The House of Enlightenment and the People's House were centred on gatherings, education, reading and community interaction; consequently, their structure retained greater flexibility and was not always subordinate to a stage function. In contrast, the House of Culture had a hall-and-stage core geared towards mass events, which limited its everyday multifunctional use. The club building and cultural centre reflected a transition to a mixed model, where not only the hall and stage but also the foyer, club rooms, open spaces, accessibility and the possibility of changing the functional scenario took on typological significance. In small towns, this transformation was driven by the limited number of public buildings and the concentration of several functions within a single facility. Consequently, a modern cultural centre or a renovated club building was viewed as a multifunctional public facility that supported daily cultural, educational, communicative and community activities, rather than merely hosting occasional mass events.

Thus, a comparative analysis of regulations and concepts has shown that the transformation of leisure facilities in small towns across Ukraine was not merely a matter of changing names or administrative status. It was related to the reformation of the building's spatial core: from an assembly hall, an educational space or a cultural hall to a public structure that combined hall, club, educational, communicative, exhibition, service and open urban functions. This transformed a small-town leisure facility from a cultural institution into an architectural and planning system.

**The functional and spatial layout of the club building as the basis for a typological analysis**

A functional and spatial analysis of a club building in a small town has shown that its architectural structure is formed by a system of interconnected spatial blocks. In the traditional model, the main element was the auditorium, combined with a stage, foyer, and ancillary and technical rooms. In modern conditions, the typological differences between such facilities are determined not only by the presence of an auditorium or stage, but also by the nature of the interaction between the entrance area, foyer, club rooms, administrative block, service corridors, technical areas and the surrounding grounds. The auditorium retains its function as the spatial core, as it facilitates concerts, meetings, performances, ceremonies, public hearings, film screenings and other event formats. Its functional suitability depends on its ability to accommodate various usage scenarios. A layout based solely on the frontal "audience-stage" model limits the space's suitability for intimate, educational, exhibition or youth activities. In contrast, transformation, flexible furniture arrangement, zoning and technical retrofitting expand the hall's function into a versatile space for entertainment, communication, education and public use.

In the modern layout of a club building, the foyer serves more than just a distributional function. Whereas in the traditional model it provided access to the hall and a link to the cloakroom, sanitary facilities and service areas, in the transformed model it takes on the significance of an independent public space for exhibitions, informal gatherings, presentations, workshops and small events. This shift in the foyer's role marks a transition from a building dominated by auditorium use to a multifunctional cultural and leisure facility. Club, educational and creative spaces form the second level of the spatial organisation. In small towns, these ensure the building's daily use, whereas a large hall may be used only occasionally. The club block can accommodate musical, choreographic, theatrical, artistic, craft, educational, youth and community activities, reducing the facility's dependence on the calendar of mass events. Therefore, a building with a well-developed club block has greater adaptability than a facility in which most of the space is devoted to a single large hall.

Entrance area and circulation routes determine the building's accessibility and the logic of spatial orientation. For small towns, this is necessary due to a diverse user base: children, young people, adults, older people, members of creative groups, visitors to public events and representatives of community initiatives. Barriers at the entrance and poor connections to the pavement, square or public

transport stop reduce public accessibility. Horizontal and vertical circulation routes influence the ability to operate the main hall, club rooms, administrative block, sanitary and utility facilities, and technical rooms simultaneously. Administrative, technical, and sanitary and utility facilities do not constitute the main public space, but they determine the building's operational suitability. A lack of technical facilities, outdated engineering systems, the inconvenient location of sanitary areas, or poor connections between ancillary and main spaces limit the potential for transformation. In a modern cultural and leisure centre, these elements facilitate the organisation of mass, intimate, educational, exhibition, rehearsal and community-organisational modes of use. The adjacent public space should be regarded as an external extension of the building's spatial structure. In small towns, a club or community centre is often situated near the central square, the main street, a public garden, a park, or an administrative or educational hub. Consequently, the space in front of the building can be used for seasonal events, fairs, open-air concerts, community gatherings, exhibition installations, or simply as a place for residents to socialise. Thus, the functional and spatial structure of a leisure facility encompasses not only the internal organisation of the premises but also the system of external connections with the urban environment. The interrelationship between the main rooms of a small-town club building and its functional and spatial core is summarised in Figure 1.

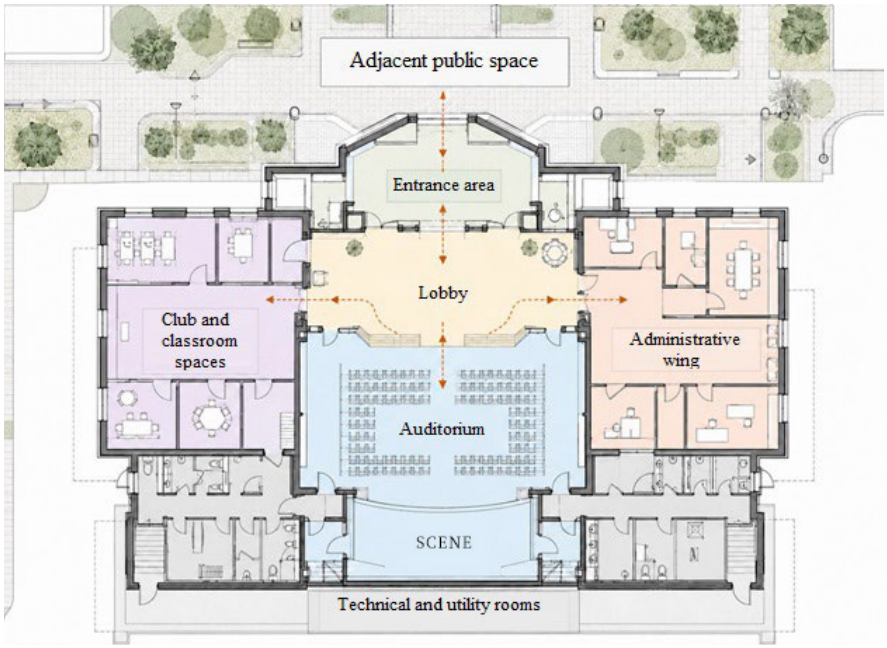


**Figure 1.** A generalised functional and layout plan for a club building in a small town
**Note:** diagram illustrates the interrelationship between the adjacent public space, the entrance area, the foyer, the main hall, the stage, the club and classroom areas, the administrative block, and the technical and sanitary facilities within the layout of a leisure centre in a small town
**Source:** compiled based on Ministry for Communities and Territories Development of Ukraine (2018a; 2018b; 2019; 2023)

Figure 1 shows that the functional and spatial structure of a small-town club building is multi-layered. Its core remains the auditorium and stage area; however, the building's contemporary suitability is determined by the interaction between the auditorium, foyer, club rooms, administrative block, technical areas and the adjacent public space. The systematic nature of these connections distinguishes a functionally developed leisure facility from a building that retains only a formal cultural and entertainment purpose. The most stable components of the club building are the auditorium, stage, entrance area and main service routes. They form the basic layout structure and determine the primary type of the facility. The most transformable components are the foyer, club rooms, ancillary rooms and the surrounding space. These zones provide the ability to adapt the building to new usage scenarios without completely altering its structural framework. Therefore, in typological analysis, it is necessary to distinguish between buildings not only by name or period of construction, but also by the nature of the interaction between stable and transformable functional blocks. The analysis has shown that the traditional hall model remains suitable for small towns provided its spatial resources are utilised in regular scenarios. In the absence of flexible spaces, the building functions primarily as a venue for occasional large-scale events. A well-developed system of ancillary and open spaces transforms it into a space for ongoing public use, in which the leisure facility fulfils not only an event-based role but also a daily communicative and educational function.

Thus, the functional and spatial layout of a club building forms the basis for its typological classification. The composition of its spatial components, the nature of their interconnections, and their adaptability determine whether the building remains a single-purpose hall or evolves into a multi-purpose cultural and leisure centre. For small towns in Ukraine, this approach makes it possible to assess leisure facilities not by their formal name, but by the building's capacity to support various modes of public use.

**Typological models for the conversion of leisure facilities into public buildings in small towns**

Typological analysis of functional and planning characteristics has shown that the transformation of leisure facilities into public buildings in small towns in Ukraine is related to changes in spatial structure, the expansion of usage scenarios, and the redistribution of the roles of the hall, club, communicative, administrative, technical, and open public components. For a significant proportion of these facilities, the original form remains that of a hall-based club building; however, the contemporary functioning of such buildings is determined not only by the presence of a hall or stage, but by the ability to support event, educational, exhibition, youth, communicative and service formats. In small towns, this is due to the concentration of several public functions within a single facility, which requires a shift from a single-purpose layout to a more flexible spatial and functional organisation. The study identifies five typological models: a single-purpose hall building, a club and group building, a cultural and entertainment building with a well-developed stage and auditorium area, an adapted mixed-use public building, and a multi-functional cultural and leisure centre.

The single-purpose hall building serves as the basic model for a leisure facility in a small town, in which the majority of the spatial layout is organised around an assembly hall, auditorium, stage or performance area. This type of building facilitates meetings, concerts, ceremonies and other large-scale events, but has limited potential for day-to-day use. Its potential for renovation is determined by reforming the foyer, ancillary rooms and technical areas, and by the possibility of adding small spaces to the building for club, educational or community activities.

The club and activity centre building reflects the shift towards the regular use of a leisure facility by various user groups. In this model, the main hall is combined with club, educational, creative or administrative spaces, ensuring organisation of classes, meetings, rehearsals, small events and educational activities without altering the basic layout. The cultural and entertainment building, with its well-developed stage and auditorium complex, retains its event-oriented focus. Its transformation involves the modernisation of the auditorium, stage, backstage areas, acoustics, lighting, ventilation, evacuation routes, engineering systems and barrier-free access, as well as the addition of spaces for regular cultural and community activities. An adapted mixed-use public building is characterised by the reuse of existing public infrastructure. Its layout does not necessarily have a classic auditorium-stage core, but can accommodate intimate, educational, exhibition, consultation, youth and community formats, provided it meets acoustic, technical, evacuation and accessibility requirements. A multifunctional cultural and leisure centre combines auditorium, educational, exhibition, youth, communication, administrative, service and open public components within a single spatial and functional system. In this model, individual zones can be used in parallel or sequentially depending on the event, educational, community or service scenario. Typological models identified differ in terms of their primary function, spatial core, composition of rooms, degree of multifunctionality, potential for renovation, and suitability for use in small towns. A summary is provided in Table 2.

**Table 2.** Typological models of the transformation of leisure facilities in small towns in Ukraine

| Characteristic | Single-purpose hall building | Club and society building | Cultural and entertainment venue with a well-equipped stage and auditorium | Adapted mixed-use public building | Multifunctional cultural and leisure centre |
|---|---|---|---|---|---|
| Primary function | Meetings, concerts, celebrations, public events | Cultural, leisure, club, educational and creative activities | Theatre, concert, entertainment and cultural events | Combination of cultural, educational, administrative, youth-related or community functions | Wide range of cultural, educational, exhibition, youth, communication and support activities |
| Planning core | Auditorium or performance hall | Hall with a club area | Auditorium and stage area | System of multi-purpose spaces without a dominant stage | Integrated social and communicative core |
| Main rooms | Auditorium, stage or performance area, foyer, ancillary and technical rooms | Hall, foyer, club rooms, teaching or creative spaces, administrative block | Auditorium, stage, backstage, foyer, technical, sanitary and administrative facilities | Multi-purpose rooms, meeting areas, learning spaces, a small hall, and service and administrative facilities | Multi-purpose hall, an exhibition and social foyer, creative and learning spaces, youth rooms, service areas, and an open public space |

*Table 2. Continued*

| Characteristic | Single-purpose hall building | Club and society building | Cultural and entertainment venue with a well-equipped stage and auditorium | Adapted mixed-use public building | Multifunctional cultural and leisure centre |
|---|---|---|---|---|---|
| Level of versatility | Limited by the fact that most functions are concentrated in a single hall | Determined by number, size and flexibility of small rooms | Designed for event-driven use, with the option to add regular functions | Depends on zoning and compatibility of various functions within existing structure | Ensures the building can be used in a variety of time and operational modes |
| Reconstructive potential | Reformation of foyer, ancillary and technical areas | Adaptation of space for educational, youth and creative activities | Modernisation of auditorium, stage, sound system, lighting, technical services and accessibility. | Redevelopment covering structural layout, technical condition and safety requirements | Flexible zoning, phased refurbishment and expansion of functions |
| Typical restrictions | Irregular use, dependence on event-driven operation, limited spatial flexibility | Limited space for ancillary rooms, outdated utilities, and a lack of flexibility in small rooms | Cost of technical upgrades, the complexity of redesigning the hall core | Incompatibility of the primary structure with cultural and leisure scenarios, acoustic and evacuation constraints | Need for integrated management, engineering upgrades and a coordinated spatial plan |
| Benefits for small towns | Beneficial provided it is supplemented with everyday functions | Suitable for regular use with different community groups | Suitable as a municipal cultural and events centre | Suitable for towns and cities with a shortage of specialist public buildings | Suitable as a model for building a community hub in a small town |

**Source:** compiled based on Law of Ukraine No. 2778-VI (2010), Resolution of the Cabinet of Ministers of Ukraine No. 984 (2012), Ministry for Communities and Territories Development of Ukraine (2018a; 2018b; 2019; 2023), ISO 15392:2019 (2019), ISO 20887:2020 (2020)

The data in Table 2 show that the typological differences between leisure facilities in small towns are determined by the ratio of the main hall area to ancillary spaces, the level of multifunctionality, and suitability for renovation. A single-purpose hall building is primarily geared towards event use, whereas club-and-circle, adapted mixed-use and multi-functional models facilitate regular cultural, educational and community activities. For small towns in Ukraine, a multifunctional cultural and leisure centre can be considered a model in which hall, communication, educational, exhibition, youth and service spaces are combined within a single public facility. The applicability of the established typological models has been refined based on an examination of leisure facilities in small towns in Ukraine, for which institutional status, address, functional use or reconstruction context are recorded in open sources. Four examples were used for the analysis: the House of Culture in Kaniv, Cherkasy region; the Stebnyk People's House in Stebnyk, Lviv region; the People's House in Bibrka, Lviv region; and the Zhovkva City People's House in Zhovkva, Lviv region.

The House of Culture in Kaniv, Cherkasy region, represents a transition from a traditional cultural and entertainment venue to a multifunctional cultural and leisure centre (Fig. 2). According to materials from the Cherkasy Regional State Administration, the Kaniv House of Culture was intended to host clubs of various kinds, exhibition halls and spaces for literary evenings, whilst the building was to serve as a Shevchenko Cultural Centre for the cultural, educational and artistic needs of the community. The spatial and functional structure of such a facility encompasses event, club, exhibition, educational and youth components. Its urban planning role is related to the formation of a public hub within the city, whilst the reconstruction context relates to the completion of works, technical commissioning and the adaptation of the large hall structure to everyday usage scenarios. According to the proposed typology, this facility belongs to the category of a multifunctional cultural and leisure centre with a cultural and entertainment core. The Stebnyk People's House in the town of Stebnyk, Lviv region, listed within the structure of cultural institutions under the Drohobych City Council as a separate cultural facility, corresponds to the club-and-circle model of a leisure centre. Official records confirm the presence of amateur associations, interest groups and a municipal choir, as well as the use of the space for exhibitions and youth events. This indicates a combination of a hall or auditorium with rooms for regular creative, educational, club and community activities. Its location on T. Shevchenko Square defines its role as a local community hub for a small town. Adaptation constraints for this type of building relate to engineering upgrades, accessibility, the flexibility of small spaces, and the possibility of concurrent use by different user groups. According to the established typology, the Stebnyk People's House belongs to the club-and-circle model with the potential to expand into a multifunctional cultural and leisure centre (Fig. 3).


**Figure 2.** The House of Culture in Kaniv, Cherkasy Region
**Note:** a) – exterior; b) – interior
**Source:** Map of Modernism (2023)


**Figure 3.** Stebnyk Community Centre, Stebnyk, Lviv Region
**Note:** a) – exterior; b) – interior
**Source:** Drohobych City Council (n.d.)

The People's House in the town of Bibrka, Lviv region, reflects the transformation of a historically established public and cultural institution (Fig. 4). Documents from the Bibrka Town Council record the establishment of the Bibrka Town Community Centre, and in the community's reference materials it is listed among educational and cultural institutions alongside the music school, the children's and youth creativity centre, and the library. The use of the building for exhibitions and public events indicates its educational and community-oriented function. The spatial and functional structure of the building comprises an assembly or multipurpose hall, rooms for cultural and educational activities, and ancillary spaces. From an urban planning perspective, the People's House functions as a component of the local cultural and educational environment of a small town. Adaptation constraints are linked to enhancing the functional flexibility, accessibility and technical suitability of the premises for various formats of use. According to the proposed typology, the People's House in Bibrka belongs to the category of club and community centre buildings with the characteristics of a public and cultural centre of local significance.

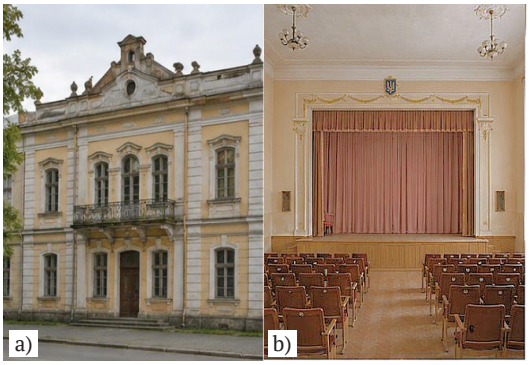


**Figure 4.** Community Centre, Bibrka, Lviv region
**Note:** a) – exterior; b) – interior
**Source:** Bibrka City Council (2018)

The Zhovkva City People's House in Zhovkva, Lviv region, demonstrates the use of a people's house as a municipal community hub (Fig. 5). Official documents from the Zhovkva City Council record the use of the facility as a reception centre for internally displaced persons during a crisis, which attests to the expansion of its function beyond its cultural and leisure purpose. In the planning documents of the culture department, the Zhovkva City People's House is also presented as a separate institution. Spatially, the building combines assembly, communication and auxiliary areas, which can be used for events, organisational and social activities. Its location in the centre of a small historic town emphasises the importance of the entrance area, the façade, accessibility and connections to pedestrian routes. According to the typological model, this building falls under the category of an adapted mixed-use public building, as its current use encompasses cultural, communicative and socio-public functions. The spatial-functional comparison of actual leisure facilities is supplemented by a visual analysis of their external appearance, entrance area and interaction with the surrounding public environment. This analysis correlated the typological model not only with the functional composition of the building, but also with its urban planning role, the nature of access, the organisation of the façade plane and its connection to the central public spaces of a small town.


**Figure 5.** Zhovkva Town Community Centre, Zhovkva, Lviv Region
**Note:** a) – exterior; b) – interior
**Source:** Bibrka City Council (2018)

The examples examined demonstrate a combination of features from several typological models within a single building. The Kaniv House of Culture is structured as a multifunctional cultural and leisure centre with a cultural and entertainment core; The Stebnyk People's House and the People's House in Bibrka correspond to the club-and-circle model with local community functions; the Zhovkva City People's House represents an adapted mixed-use community building. A comparison of these buildings shows that their potential for reconstruction and functionality is determined by the ratio of the main hall to smaller rooms, the foyer, the entrance area, the technical condition, the level of engineering upgrades, and the connection to the city's central public spaces. Consequently, it is advisable to classify leisure buildings in small towns according to their spatial and functional structure, urban planning role, level of multifunctionality, and ability to support various scenarios of public use. The formal name of a building does not reflect the full range of its functions, as cultural centres and community halls can combine event, educational, exhibition, youth, communicative and social scenarios. For small towns in Ukraine, this typology makes it possible to determine the direction of public building renovation, addressing existing spatial structure, local community needs and the potential for creating a sustainable community hub.

**The urban planning role of leisure facilities in the structure of small towns**

An urban planning analysis of leisure facilities in small towns in Ukraine has shown that a clubhouse, a cultural centre, a community centre or a cultural centre cannot be viewed merely as individual public buildings with an internal layout of rooms. Their role is determined by their position within the urban fabric, their connection to pedestrian routes, the central square, open public spaces, educational, administrative and service facilities, as well as their ability to form a local hub of urban activity. In small towns, this role is amplified by the limited number of public buildings and the concentration of several functions within a single cultural and leisure facility. In the spatial structure of a small town, a leisure facility is usually situated near the centre, the main street, a square, a park, a public garden or a cluster of administrative and public buildings. This location is linked to the need for accessibility, visibility and the inclusion of the facility in residents' daily routes. When situated near a square or main street, the building supports not only event-based activity but also the everyday use of the surrounding space. In this case, its architectural role extends beyond its internal function: the facility serves as a landmark, a meeting place, an element of urban memory and a spatial hub for social interaction.

For small towns, a model in which a leisure facility is integrated into a system of open public spaces is functionally sound. The area in front of the building, a square, a pedestrian zone, a courtyard or the area near the entrance can serve as an external extension of the cultural centre. They are used for seasonal concerts, fairs, exhibitions, public gatherings, children's and youth events, temporary installations or informal socialising. In such circumstances, the foyer, entrance area and surrounding space form a transitional zone between the street and the interior. The urban planning role of a cultural centre also depends on its connection to other public facilities. In small towns, a community centre or cultural centre is often located next to the town hall, library, school, art school, park, memorial site, public transport stops or retail and amenities. Such proximity creates the conditions for a community cluster. With convenient pedestrian links, barrier-free routes and clear spatial orientation, the leisure facility does not operate in isolation but as part of the city's service system. The reconstruction status of such facilities in small towns is varied. Some club buildings were established in a historically valuable environment, some within the system of Soviet mass cultural construction, and some in converted public or administrative buildings. Their renovation must therefore incorporate not only functional requirements, but also the context of the surrounding development, the scale of the street, the skyline of the city centre, the character of the façades, the proportions of open space, and local historical memory. In this regard, the UNESCO (2011) guidelines on the historic urban landscape highlight club buildings, community centres and cultural centres as components of a historically formed urban environment, rather than merely as functional facilities. The regulatory and urban planning framework provides grounds for assessing leisure buildings as elements of the settlement's planning organisation. NK 018:2023 can classify such facilities under categories of public buildings; however, this is insufficient for a typological analysis. The key parameters of urban integration are façade activity, accessibility of the entrance, connection to a square or main street, the potential for using the surrounding area, pedestrian accessibility, and the capacity to accommodate various scenarios of public activity. To summarise the spatial connections between a leisure facility and elements of the urban environment in a small town, a diagram of its urban integration has been drawn up, as shown in Figure 6. Figure 6 summarises the spatial connections through which the leisure facility is integrated into the system of open public spaces and everyday routes in a small town. Its urban integration is determined not only by its location in the central part of the town, but also by the quality of pedestrian access routes, the openness of the entrance area, and its connection to the square, the park, the main street and neighbouring public facilities. The transitional zone between the entrance and the space in front of the building determines the level of interaction between the leisure facility and the urban environment. A barrier-like or spatially disorganised entrance weakens this connection, whereas an active entrance area encourages brief stays, meetings, waiting and the hosting of small events. The urban significance of a leisure venue also depends on its ability to support activity at different times of day. A traditional club building, geared primarily towards

evening or festive events, has a limited impact on everyday urban life. In contrast, a cultural centre with diverse usage scenarios creates a more even distribution of activity across public space, attracts a variety of user groups and sustains activity in the centre of a small town beyond major events. Thus, the urban planning role of leisure facilities in small towns is determined by the creation of local community hubs linked to pedestrian routes, open spaces, neighbouring amenities and historically developed built environments. The typological value of a club building or cultural centre increases when the facility not only fulfils a cultural and leisure function, but also supports daily community activity, spatial orientation and the connectivity of the urban environment.

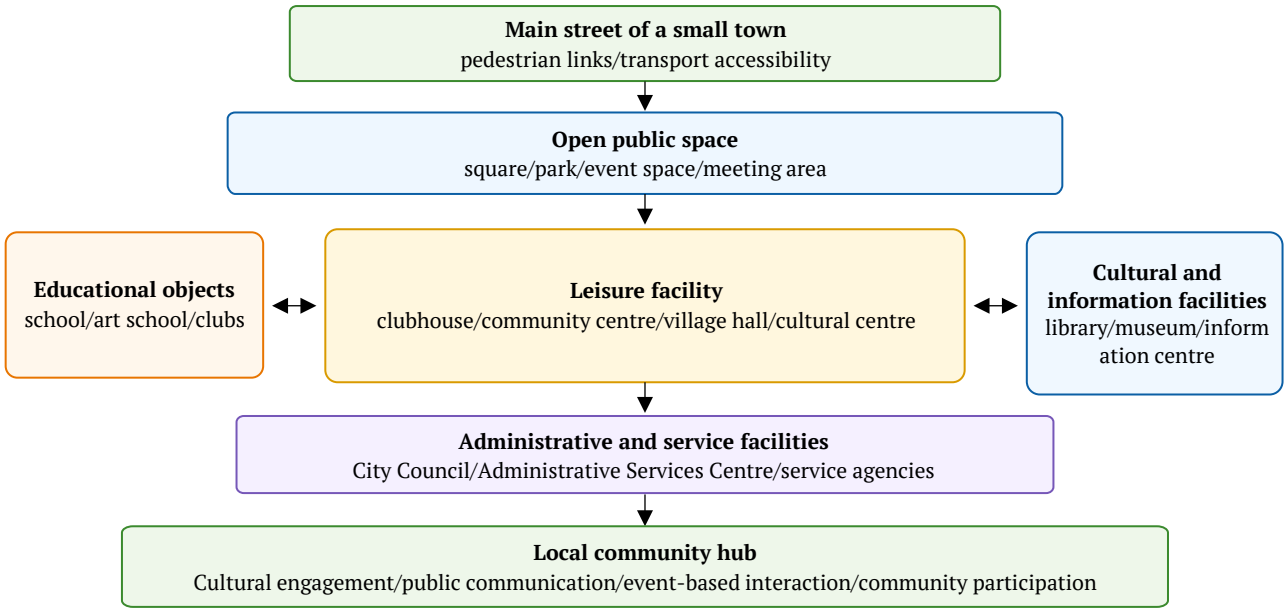


**Figure 6.** Architectural and urban planning scheme for integrating a leisure facility into the environment of a small town
**Source:** compiled based on Resolution of the Cabinet of Ministers of Ukraine No. 984 (2012), Ministry for Communities and Territories Development of Ukraine (2023), Map of Modernism (2023)

### Structural, engineering and material aspects of adapting club buildings

An analysis of the structural, engineering and material parameters of club buildings in small towns in Ukraine has shown that their adaptation is not limited to façade refurbishment or localised repairs to individual rooms. The typological significance of reconstruction lies in harmonising the spatial structure, engineering systems, accessibility, acoustic and lighting comfort, energy efficiency and material durability. If the barrier-like entrance area, inflexible hall layout, outdated services, poor acoustics and low energy efficiency are retained, the building's suitability for public use remains limited, even if it has a large hall or a favourable urban location. The main constraint on the renovation of club buildings stems from the disconnect between contemporary usage scenarios and the outdated spatial and technical layout. A layout focused primarily on the hall and stage does not always support the simultaneous work of several groups, intimate formats, educational sessions or public meetings. Therefore, the renovation involves combining technical upgrades with increased spatial flexibility.

The entrance area is the first zone that determines the actual accessibility of a building. Typical barriers include high steps, narrow doorways, awkward vestibules, a lack of ramps or lifting devices, and poor wayfinding. Addressing these issues involves creating a level or barrier-free entrance, expanding the entrance area, incorporating tactile elements, providing clear visual wayfinding, and ensuring a safe connection to the external space. The main hall retains its role as the primary spatial resource of the club building, yet it is often the area that exhibits the greatest resistance to change. Rigid seating arrangements, poor acoustics, outdated stage equipment, inadequate lighting and limited flexibility reduce the number of possible uses. In a modern model, the hall must support concert, theatre, lecture, exhibition, forum and community formats. Appropriate solutions involve flexible zoning, upgrading lighting equipment, improving acoustics, modernising the stage, and enabling rapid reconfiguration of the space. The refurbishment of the foyer aims to enhance its spatial flexibility and operational quality. To this end, adequate lighting, transparency in the entrance area, wear-resistant materials, and the ability to accommodate temporary exhibitions, information displays and movable furniture are essential. Under these conditions, the foyer supports not only through traffic but also short stays and small-scale events. Club rooms, classrooms and ancillary spaces require refurbishment, incorporating lighting, ventilation, acoustic insulation, thermal conditions and the ability to quickly reconfigure the layout. Lightweight partitions, movable fur-

niture, wear-resistant flooring, localised lighting and updated utility connections enhance the adaptability of these areas without the need for a radical overhaul of the building. Utility networks are a factor that determines the limits of functional adaptation. Outdated heating, power supply, ventilation, water supply, lighting and fire protection systems complicate the use of the building in different modes. A cultural and leisure centre should be able not only to host a large event in the main hall, but also to ensure simultaneous operation of several smaller spaces. This requires the improvement of electrical networks, energy-efficient lighting, ventilation for spaces with varying levels of use, safe evacuation routes and a stable thermal environment.

The material choices for the renovation of club buildings are driven by durability, operational reliability and harmony with the urban context. For facades, key considerations include insulation, reducing heat loss, protecting the building envelope, and replacing windows and doors without compromising the building's architectural integrity. For interior spaces, wear-resistant floor coverings, acoustic panels, materials to improve the lighting environment, durable wall finishes, movable partitions, and furniture suitable for intensive use are significant. In small towns, material refurbishment should maintain the cohesive image of a public building and avoid creating a fragmented effect of modernisation. The functional transformation of club buildings requires the coordination of spatial, engineering and material solutions, as their interaction determines the possibility of the building's continued use as a modern leisure facility. The main directions for the adaptation of such facilities are systematised in the form of a diagram in Figure 7.

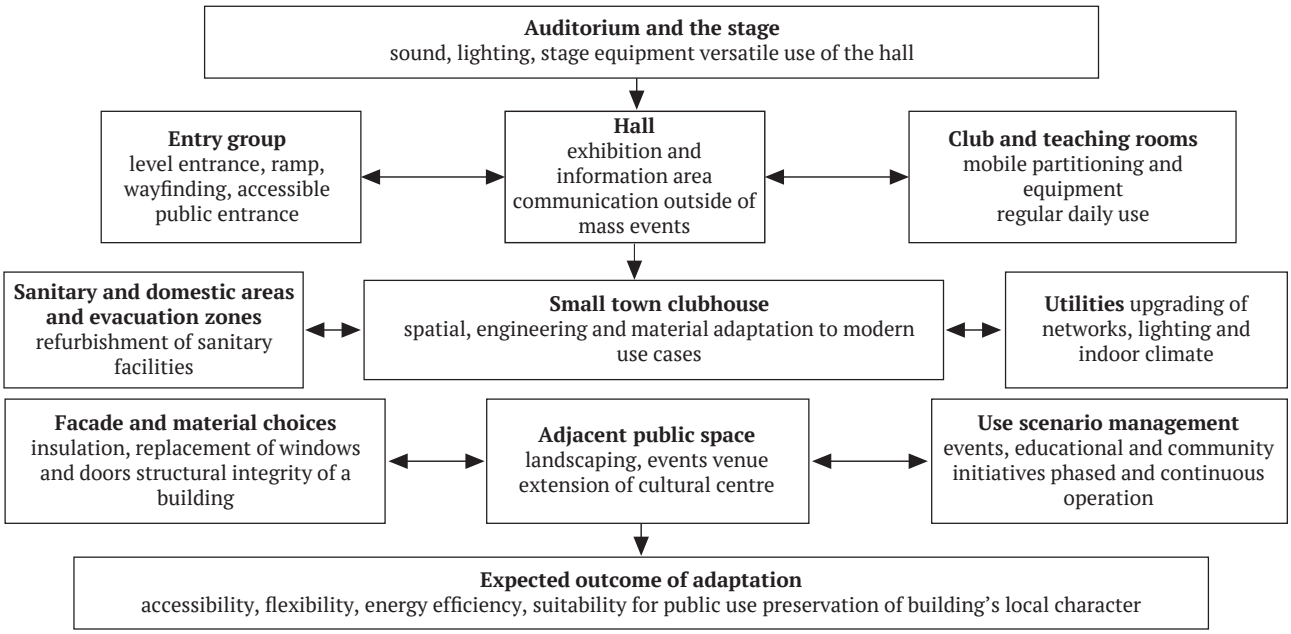


**Figure 7.** Reconstruction and engineering plan for the adaptation of a club building in a small town
**Note:** diagram illustrates the relationship between problem areas in the club building and the structural, material and functional solutions designed to improve the building's accessibility, flexibility, energy efficiency and suitability for public use
**Source:** compiled based on Ministry for Communities and Territories Development of Ukraine (2018a; 2018b; 2019), ISO 15392:2019 (2019), ISO 20887:2020 (2020), ISO 21542:2021 (2021)

An analysis of the data in Figure 7 shows that the adaptation of a small-town club building is systematic in nature and is not limited to the local refurbishment of individual rooms or structural elements. The entrance area, foyer, auditorium with stage, club and educational rooms, sanitary and evacuation zones, service networks, façade solutions, adjacent public space and the management of usage scenarios form an interconnected reconstruction structure. Its coherence determines the building's accessibility, functional flexibility, operational safety, energy efficiency, public suitability and ability to support cultural, educational, event and communication scenarios. Consequently, the reconstruction of such buildings should combine technical upgrading, spatial adaptation and the creation of a multifunctional cultural and leisure environment, integrated into the urban fabric of a small town.

**An integrated model of the typology of leisure facilities in public buildings in small towns in Ukraine**

Synthesis of the results of the regulatory-conceptual, functional-planning, typological, urban planning and reconstruction-engineering analyses has shown that the typology of leisure facilities in public buildings in small towns in Ukraine cannot be determined solely based on the facility's name or its original purpose. The actual type of leisure facility is determined by the interrelationship

between its functional composition, spatial organisation, urban context and suitability for reconstruction. This ensured a transition from a terminological classification to an integrated typological model. The first level of the model forms the functional block. It reflects not only the list of cultural, educational, youth, exhibition, communication, service or mixed uses, but also the extent to which these are spatially accommodated. The analysis showed that the functional suitability of a leisure facility is determined not by the number of stated areas of activity, but by the correspondence between these areas, the composition of the premises and the actual modes of use. Therefore, the functional block is linked to the building's actual capacity to support several forms of public activity. The second level is the planning block. It encompasses the spatial core of the building, ancillary zones and the nature of the connections between them. Within the integrated model, the planning structure is viewed not as the sum of the premises, but as a system that determines the level of monofunctionality, combined use or multifunctionality of the facility. The ratio of the main spatial core, ancillary spaces, services and adaptation zones makes it possible to determine whether a building retains a rigid specialisation or is capable of supporting multiple uses.

The third level relates to the urban planning context. At this level, the assessment focuses not only on the physical location of the facility, but also on its integration into the network of urban routes, open public spaces, neighbouring service facilities and the historically developed environment. The urban planning component shows whether the leisure facility functions as a local element of a small town's public infrastructure, or remains a spatially isolated building with limited impact on the urban environment. The fourth level comprises the structural and engineering component. It reflects the building's ability to support contemporary usage scenarios through engineering reliability, accessibility, energy efficiency, acoustic and lighting comfort, safety, material durability and operational sustainability. The analysis showed that reconstruction potential is not limited to the physical condition of the structures. It is determined by the extent to which the building's spatial, technical and material parameters can be aligned with its functional and urban planning purpose. The fifth level constitutes the adaptation and typological outcome. The combination of the functional, planning, urban planning and reconstruction-engineering blocks makes it possible to determine the actual type of leisure facility: a single-purpose hall building, a club and community centre, a cultural and entertainment building with a well-developed stage and auditorium block, an adapted mixed-use public building, or a multi-functional cultural and leisure centre. These models are not strictly separate, as in small towns they may combine, overlap or gradually transition to one another during the reconstruction process. An integrated approach makes it possible to determine not only the current state of a site, but also the direction of its future adaptation. To summarise the results obtained and visualise the interrelationship between the functional composition, spatial organisation, urban planning context and reconstruction-engineering suitability of leisure facilities, an integrated typological model has been developed, as shown in Figure 8.

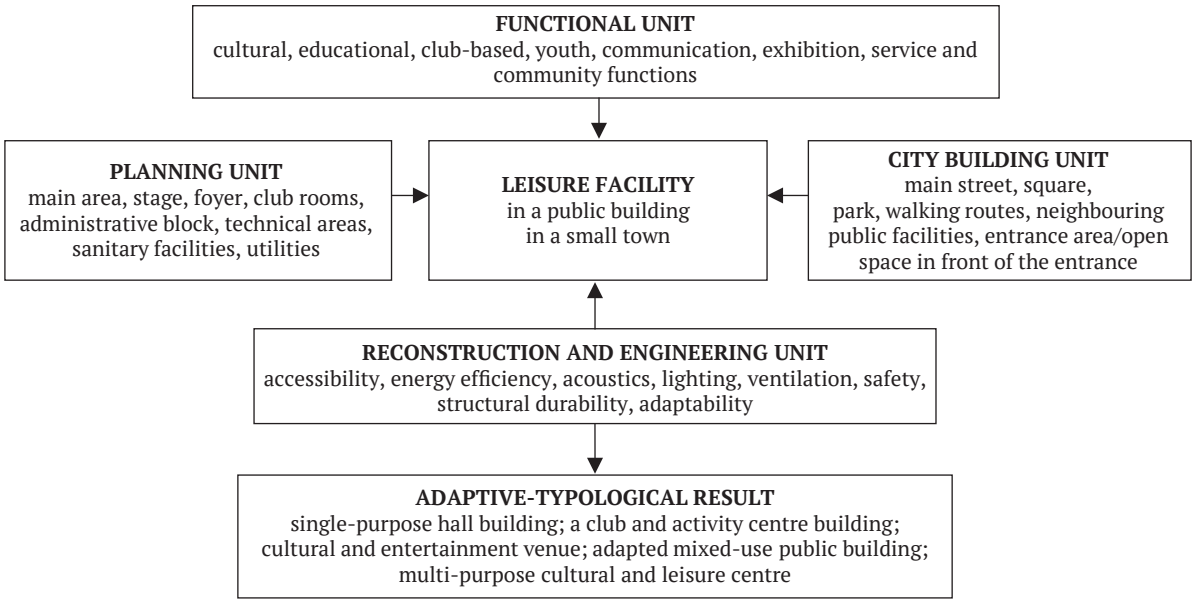


**Figure 8.** An integrated model of the typology of leisure facilities in public buildings in small towns in Ukraine
**Source:** compiled based on Law of Ukraine No. 2780-XII (1992), Law of Ukraine No. 3038-VI (2011), Order of the Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine No. 163 (2014), Ministry for Communities and Territories Development of Ukraine (2018a; 2018b; 2019; 2023), ISO 15392:2019 (2019), ISO 21542:2021 (2021)

The summary presented in Figure 8 shows that the typological status of a leisure facility is determined not by a single characteristic, but by the interplay between its functional composition, planning flexibility, urban integration and suitability for renovation. A large central hall alone does not ensure the building's full adaptability unless it is complemented by accessibility, engineering reliability and connectivity with the urban environment. At the same time, a compact structure can support various usage scenarios provided that its spatial, technical and urban planning characteristics are harmonised. The integrated model demonstrates that the typological renewal of community centres in small towns can be achieved not only through new construction but also through the phased adaptation of existing cultural centres, community halls and other public facilities. As a result, the model can be used to determine the actual type of facility and outline the directions for its future reconstruction.

## DISCUSSION

The findings revealed that the typology of leisure facilities within public buildings in small towns in Ukraine was determined not by the historical name of the building or its original cultural purpose, but by a combination of architectural and planning, functional, urban planning, engineering, and functional-spatial characteristics. A club building, community centre, house of culture or cultural centre could not be regarded merely as a hall-type structure for individual events, as their contemporary suitability depended on their ability to support various scenarios of public, cultural, educational and communicative use. Therefore, the typological classification of a leisure facility was determined by the coordination of its planning core, multifunctionality, accessibility, connection to open urban space, potential for renovation and operational reliability. In this interpretation, a public building in a small town emerged as a local spatial node where cultural, social, engineering and urban planning logic formed an interdependent system. This conclusion is consistent with the views of P. Lényi (2015), who regarded the cultural centre as public infrastructure capable of bringing together various forms of activity. This comparison explains why the multifunctionality of club buildings, community centres and cultural centres emerged as a condition for preserving their functional relevance. An analysis of the spatial role of leisure facilities revealed that the cultural centre influenced not only the building's functional programme but also the organisation of the surrounding environment. This is consistent with the study by O. Dmytrash & I. Kopylyak (2016), in which cultural centres were linked to the formation of contemporary architecture in the university environment and the broader spatial influence of public functions. The comparison revealed a common approach to the cultural centre as an environmental factor, but clarified the scale and type of facilities: in small towns, this logic applied not to a specialised element of the educational environment, but to a local public hub integrated into everyday urban life.

A comparison with studies on the adaptation of existing buildings for new uses showed that the refurbishment of club buildings could not be viewed merely as a series of repair works. This is consistent with the systematic review by F. Vafaie *et al.* (2023), in which the success of a building's reuse was linked to the alignment of functional, technical, social and contextual factors. This comparison revealed why the typological suitability of a leisure facility was determined not by the mere fact of preservation or repair, but by the interplay of planning flexibility, accessibility, engineering reliability, material durability and connection to the urban environment.

An analysis of the revitalisation of leisure facilities revealed that the renewal of their function could not be separated from user scenarios and the long-term serviceability of the building. This is consistent with the study by É. Savoie *et al.* (2025), where revitalisation of historic buildings through adaptation to new uses was linked to the harmonisation of heritage, function, environment and user needs. The comparison explained why, for club buildings, community centres and cultural centres in small towns, it was not only the change in functional content that proved decisive, but also the ability to transition from occasional event-based use to regular community activity. The typological generalisation also clarified process-oriented approaches to the adaptation of historic buildings. In the study by F. Arfa *et al.* (2024), the adaptation of such buildings was examined as a sequential process with defined stages, tools and verification through case studies. A comparison showed that, for leisure-oriented public buildings in small towns, reconstruction should be viewed not only as a process of transformation but also as a basis for a typological interpretation of its outcome. This explained why the same building could be interpreted differently depending on the relationship between its functional composition, planning core, urban integration and suitability for reconstruction and engineering. Therefore, the integrated model supplemented the reuse process diagrams with an architectural-typological assessment tool. Typological analysis revealed that the adaptation of the existing building stock in small towns could not be reduced to a choice between preserving a building and replacing it with a new one. For club buildings and cultural centres, the decisive factor was whether renovation could change the mode of use, ensure accessibility, update the building services infrastructure, and integrate the building into residents' daily routes. This conclusion corresponds with the study by I. Serhiiuk & I. Kalakoski (2023), which, using the example of post-industrial buildings in Ukraine, demonstrated the tension between demolition, refurbishment for public use, and adaptation to new functions. This comparison explained why, for leisure buildings in small towns, the dilemma of preservation had not only an economic or heritage dimension, but also a typological one: the fact of preserving a building did not guarantee its public relevance. The reinterpretation of club buildings as a resource for the further development of territories is

consistent with the study by V. Yatsenko *et al.* (2024), in which the adaptation of historic rural school buildings in the Poltava region was linked to preservation, new function and the contemporary suitability of the buildings. For leisure facilities, this approach was used in a different type of public building – clubhouses, community centres, cultural centres and cultural hubs. Their adaptation required not only a change of function, but also a rethinking of the auditorium and stage area, the foyer, club rooms, technical areas and the surrounding public space as interconnected elements of a modern cultural and leisure centre.

In the context of historic small towns, the analysis showed that the renovation of a public building could not be viewed in isolation from the town's spatial structure. This is consistent with the study by N. Leshchenko (2023), in which restoration and reconstruction were linked to the sustainable development of historic small towns and the preservation of the urban environment. This comparison explained why the typological value of the club building was determined not only by its internal structure, but also by its connection to the square, the main street, pedestrian routes, the open space in front of the entrance, and neighbouring public facilities. The urban planning dimension of the typology was specified through a comparison with studies on the revitalisation of open public spaces in small towns. A. Jaszczak *et al.* (2021) correlated regeneration of public spaces in small towns within the Cittaslow network with increased public engagement, the quality of the outdoor environment and urban identity. The comparison demonstrated that open space could not be regarded merely as a background element to a leisure facility. For small towns, the area in front of a building, a square, a pedestrian route or an entrance plaza extended the functional and spatial structure of the facility beyond its physical boundaries. The issue of cultural sustainability was linked to research on the adaptation of cultural sites to new uses.

In the study by D.K. Amro *et al.* (2023), the conversion of a traditional house into a cultural centre was analysed in terms of cultural continuity, user perception and the preservation of the building's significance. This is consistent with the conclusion that the cultural sustainability of a leisure building in a small town was determined not only by the preservation of symbolic or material value, but also by its ability to support current scenarios of cultural, educational, communicative and civic activity. This comparison explained the link between cultural sustainability and planning flexibility, urban integration, and the building's suitability for reconstruction and engineering. The material-contextual dimension of the typology showed that the sustainable reuse of small-town club buildings could not be assessed solely based on the building's technical condition. The decisive factor was the coordination of material solutions, planning structure, urban context and modes of public use. This conclusion corresponds with the study by S. Mazzetto (2022), where the reuse of historic buildings was examined through a combination of environmental, socio-economic and socio-cultural parameters. This comparison explained why façade renovation, insulation, the replacement of translucent elements, or the use of wear-resistant materials should be interpreted not as isolated technical measures, but as components of the typological adaptation of a public building. An analysis of accessibility revealed that it could not be limited to the regulatory presence of individual barrier-free elements. For leisure facilities in small towns, accessibility was defined as a spatial system encompassing the route, entrance, facilities, wayfinding, sanitary and domestic areas, and the surrounding area. This finding is consistent with the systematic review by A. Gupta *et al.* (2025), in which accessibility standards and universal design principles were linked to the quality of use of open public spaces. The comparison explained why accessibility in the typology of leisure facilities should be considered not only as a social requirement, but as a criterion for the regular use of the building by different groups of residents.

This conclusion was further explored through a comparison with a critical review of urban accessibility within the framework of universal design. M. Papanicolaou *et al.* (2025) correlated the accessibility of the urban environment with experience of movement, use of space and interaction with urban elements. The results applied this logic to public leisure buildings, demonstrating that the central location of a club building or cultural centre did not guarantee its actual openness to the community if the entrance area remained a barrier, the routes were inconvenient, and the connection to a square or park was spatially disorganised. This comparison clarified the difference between a facility's location in the city centre and its actual inclusion in everyday urban life. This conclusion was further confirmed by a study of accessibility barriers in an urban environment focused on the proximity of everyday services. A. Ramírez-Saiz *et al.* (2026) demonstrated that the spatial proximity of a facility did not equate to an accessible experience for users with disabilities, as route obstacles, surface conditions, terrain, navigation and the organisation of the environment could significantly restrict usage. For small towns in Ukraine, this thesis was specified as follows: a leisure facility could be located in the centre but remain functionally isolated from urban life without barrier-free access, clear wayfinding, accessible entrances and connections to open public spaces.

The integrated model also demonstrated that the typological suitability of a leisure facility was determined not only by the formal characteristics of the building, but also by the extent to which the space corresponded to the actual ways in which different population groups used it. This conclusion is consistent with the review by Z. Zhang *et al.* (2025), in which the correspondence between people and the environment was considered one of the key areas of analysis of the built environment. This comparison elucidated the architectural dimension of this correspondence: for club buildings in small towns, it was shaped by a combination of functional composition, planning flexibility, accessibility, engineering reliability and urban

integration. A comparison with universal safe design approaches made it possible to clarify the role of safety in the typological assessment of leisure buildings. S.-Y. Baek & B.-Y. Jeong (2021) compared universal design and universal safe design through the interplay of accessibility, safety, usability and sustainability. The comparison confirmed this logic, but specified it at the level of individual functional and spatial components: the entrance area, circulation routes, sanitary and utility facilities, evacuation routes, the stage and auditorium block, and engineering systems. This demonstrated that safety and accessibility were not merely secondary requirements for the building, but influenced its actual capacity to function as a modern cultural and leisure centre.

An analysis of the functional and spatial structure revealed that the inclusivity of a leisure facility depended not only on the accessibility of the building, but also on the extent to which its layout created the spatial conditions for different user groups to participate in the everyday cultural life of a small town. This is consistent with the study by F. Pasenidou (2026), which considered architecture as a factor in the inclusion of users within the educational environment. Despite the difference in subject matter, the comparison confirmed a common thesis: space is not a neutral context for activity, but influences opportunities for access, orientation, communication and engagement. For leisure facilities, this logic was specified through the role of the foyer, club rooms, study rooms, the entrance area and the adjacent public space. The Ukrainian context of an inclusive urban environment was further correlated with the study by V. Bulatov (2025), in which aesthetic principles were considered in relation to the formation of an inclusive urban environment. The results obtained were consistent with this position regarding the interpretation of navigation, entrance areas, tactile elements, facade expressiveness and visual orientation as components of accessibility. At the same time, the study clarified that for club buildings in small towns, these solutions could not be viewed merely as elements of landscaping or decoration. These factors were associated with the typological suitability of the building, as they determined its openness to the community, the clarity of its spatial organisation, and its ability to accommodate various scenarios of public use. The resulting typological generalisation showed that public leisure buildings in small towns could not be assessed solely based on their functional composition or hall capacity, as their suitability was determined by accessibility, operational reliability, the quality of the indoor environment, their connection to open public space, and the sustainability of usage scenarios. This conclusion is consistent with the findings of M. Zinoski *et al.* (2025), where the architecture of public buildings is considered as a transformative model linked to health, sustainability and the quality of urban life. This comparison explains why club buildings, cultural centres, community halls and cultural centres in small towns should be analysed not as isolated functional entities, but as spatial hubs of everyday public activity.

The structural and engineering module of the integrated model demonstrated that ventilation, lighting, acoustics, thermal conditions, sanitary facilities and safe utilities determined not only the operational condition of the leisure building, but also the feasibility of its regular use by various population groups. This is consistent with the findings of H. Liu *et al.* (2023), where healthy buildings are linked to air quality, thermal, lighting and acoustic comfort, safety, life cycle and interdisciplinary coordination of solutions. This comparison confirmed that engineering parameters in the typology of leisure facilities should be considered not as secondary technical characteristics, but as conditions for the building's functional suitability. The material and energy dimension of the results showed that the sustainable renovation of club buildings in small towns should not rely on the direct transfer of complex technological solutions, but on a realistic adaptation of the building envelope: reducing heat loss, insulating facades, upgrading translucent elements, protecting the building envelope, and using durable materials without compromising architectural integrity. This conclusion is consistent with the study by W. Wang *et al.* (2023), in which green roofs, facade systems and integrated photovoltaic solutions are considered as components of a building with zero energy consumption and reduced environmental impact. The comparison showed that, for small towns in Ukraine, energy efficiency should be viewed not as a standalone technical objective, but as part of a reconstructive and typological transformation of leisure facilities, covering resource, structural and contextual constraints.

The findings as a whole, when compared with contemporary academic approaches, have shown that the typology of leisure facilities within public buildings in small towns in Ukraine developed as an integrated architectural and planning system, rather than as a formal classification of historical names or original functions. Functional composition, planning flexibility, urban integration, accessibility, engineering reliability, material durability and suitability for renovation determined a building's ability to support various scenarios of public use. The transition from a single-purpose hall building to a multi-functional cultural and leisure centre depended on the coherence of the hall area, foyer, club and educational rooms, entrance area, services, technical zones and the adjacent open space. Reconstruction-engineering and material solutions acquired typological significance when they ensured accessibility, a comfortable indoor environment, energy efficiency, safety, operational sustainability and the preservation of the building's architectural integrity. Consequently, the further development of club buildings, cultural centres, community centres and cultural hubs should be related to the phased adaptation of the existing public building stock, in which the renewal of the internal structure is aligned with the building's role in the urban environment, pedestrian accessibility, the open space in front of the entrance and the needs of daily public activity.

## CONCLUSIONS

Consequently, the typology of leisure facilities within public buildings in small towns in Ukraine should be determined not by the formal name of the building, but by a combination of functional, spatial-planning, urban planning, renovation-engineering and material characteristics. The House of Enlightenment, the People's House, the House of Culture, the club building and the cultural centre reflect different stages in the development of public and cultural infrastructure and different models of spatial organisation. Their transformation is associated with a redefinition of the building's spatial core, the composition of its premises, the nature of its users, and the facility's capacity to support various scenarios of public activity. The traditional club building in a small town was predominantly organised around a hall-and-stage core, geared towards mass events, concerts, meetings and celebrations. At the same time, the contemporary needs of communities require a multifunctional model, in which the typological quality of the building depends on the interaction between the main hall space and the communication, club, educational, administrative, technical and open public areas. It is the nature of these connections that determines whether the building remains a single-purpose hall or takes on the characteristics of a modern cultural and leisure centre. The study identified five typological models for the transformation of leisure facilities: a single-purpose hall building, a club and group building, a cultural and entertainment building with a well-developed stage and auditorium area, an adapted mixed-use public building, and a multifunctional cultural and leisure centre. The study established that the greatest potential for adaptation exists in facilities where the hall area is combined with flexible spaces for regular use, and the surrounding area is integrated into the system of urban public connections.

An urban planning analysis has shown that a leisure facility in a small town becomes a key local community hub provided it is connected to the central square, the main street, pedestrian routes, and educational, administrative and cultural facilities. A structural and engineering analysis confirmed that the adaptation of such buildings must go beyond cosmetic refurbishment to encompass accessibility, the modernisation of utility networks, energy efficiency, acoustic and lighting comfort, flexible zoning, durable materials and the improvement of the surrounding area. An integrated synthesis of the results demonstrated that a promising model for the development of leisure facilities in small towns is a multifunctional cultural and leisure centre, which can be established not only through new construction but also through the systematic adaptation of existing club buildings, cultural centres and community halls. The applicability of the proposed typological logic is illustrated by examples of leisure buildings in small towns in Ukraine, in particular the House of Culture in Kaniv, Cherkasy Oblast; the Stebnyk Community Centre in Stebnyk, Lviv Oblast; the Community Centre in Bibrka, Lviv Region, and the Zhovkva Community Centre in Zhovkva, Lviv Region. An examination of these sites has shown that the greatest potential for adaptation lies in buildings where the hall-and-stage core can be supplemented by spaces for regular club, educational, social and community use. A limitation of the study is the theoretical and analytical nature of the research and the absence of a quantitative assessment of the completed renovations. Further research should focus on expanding the sample of sites, comparing actual reconstruction practices, and developing practical criteria for assessing the functional and planning adaptation of leisure buildings in small towns in Ukraine.

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# Типологія дозвіллєвих закладів у громадських будівлях малих міст України

**Анотація.** Метою статті було виявити архітектурно-планувальні, функціональні та містобудівні критерії систематизації будівель дозвіллєвого призначення в малих містах України й обґрунтувати напрями їх трансформації в умовах сучасного громадського використання, реконструкції та адаптації. Методологія дослідження поєднала нормативний, функціонально-планувальний, типологічний, містобудівний і реконструктивно-інженерний аналіз з інтегральним моделюванням. Практичну придатність запропонованих типологічних моделей уточнено на прикладі чотирьох дозвіллєвих будівель малих міст України: Будинку культури в Каневі, Стебницького Народного дому, Народного дому міста Бібрка та Жовківського міського Народного дому. Результати дослідження показали, що дім просвіти, народний дім, будинок культури, клубна будівля та культурний центр не є лише історичними або інституційними назвами одного типу об'єкта, а відображають різні моделі громадської будівлі, відмінні за провідною функцією, складом користувачів, просторовим ядром, рівнем поліфункціональності, містобудівною роллю та потенціалом трансформації. Установлено, що традиційна клубна будівля малого міста переважно формувалася навколо зально-сценічного блоку, однак сучасні потреби громад зумовлюють перехід до поліфункціональної моделі, у якій важливими стають фоє, гурткові й навчальні приміщення, комунікації, технічні зони, безбар'єрна вхідна група та прилеглий громадський простір. Узагальнено п'ять типологічних моделей трансформації дозвіллєвих будівель: монофункціональну зальну будівлю, клубно-гурткову будівлю, культурно-видовищну будівлю з розвиненим сценічно-глядацьким блоком, адаптовану громадську будівлю змішаного використання та багатофункціональний культурно-дозвіллєвий центр. З'ясовано, що найбільший адаптаційний потенціал мають об'єкти, у яких зальна частина поєднана з гнучкими просторами повсякденного використання. Практичне значення результатів полягає в можливості їх використання під час оцінювання, реконструкції та функціонального оновлення культурно-дозвіллєвих будівель малих міст України

**Ключові слова:** громадська будівля; громадський простір; типологія будівель; функціональність будівель; будинок культури; народний дім; дозвіллєвий заклад

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# Fortifications of Ganja: A historical and architectural study

**Abstract.** The aim of the study was to analyse the historical development and architectural characteristics of the fortifications of Ganja from late antiquity to the late medieval period. Particular attention was paid to the relationship between the city's defensive structures, its changing urban morphology, and the environmental conditions of the Ganja-Chay River valley. The research combined architectural analysis, archaeological excavation data, stratigraphic analysis, radiocarbon dating, and the study of historical written and cartographic sources in order to reconstruct the evolution of the city's defensive system. The findings indicated that the fortifications of Ganja developed in several chronological phases and were adapted to changing military, political, hydrological, and seismic conditions. The evidence demonstrated the use of layered stone-and-brick masonry, differentiated tower types, and complex wall-building techniques that reflected both local construction traditions and broader regional fortification practices. Stratigraphic observations and radiocarbon analyses helped clarify the sequence of construction and rebuilding, while comparative analysis with fortified cities of the Caucasus and the Middle East highlighted the architectural distinctiveness of Ganja. The results further demonstrated that the city's defensive system evolved incrementally through repeated phases of reconstruction rather than as the product of a single building campaign. Archaeological evidence confirmed that riverbank fortifications performed both military and hydrological functions, protecting the settlement from enemy attacks and erosion caused by the Ganja-Chay River. The study also differentiated between archaeologically documented remains, later reconstructions, and comparative visual sources, thereby reducing the risk of treating illustrative material as direct evidence. The practical value of the study lies in providing a scholarly basis for conservation, restoration, and historically grounded reconstruction of medieval fortification systems in Azerbaijan

**Keywords:** fortification architecture; defensive structures; masonry techniques; urban morphology; cultural heritage

## INTRODUCTION

The territory of modern Azerbaijan preserved an important corpus of fortified settlements, whose architectural study contributed to the wider history of urban defence in the South Caucasus. Recent scholarship had increasingly approached fortifications through the combined lenses of heritage conservation, urban morphology, and material analysis. S. Li *et al.* (2024) examined the development of cultural-heritage conservation planning and showed how historical urban layers need to be analysed as part of a long-term planning system. The authors demonstrated that effective conservation planning requires the integration of archaeological evidence, urban development policies, and stakeholder participation rather than focusing exclusively on individual monuments. Reseacrhers also concluded that preserving historical stratification improves the resilience of historic cities and supports sustainable urban management by maintaining the continuity of cultural landscapes. J.P. Jara Molineros *et al.* (2022) discussed the interpretation of heritage and underlined the importance of reading built fabric through both conventional and less visible material

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traces. Scientists' study argued that architectural heritage should be interpreted through a combination of physical structures, construction techniques, and intangible historical evidence, allowing hidden phases of building development to be identified. The authors further emphasised that this approach improves the accuracy of conservation decisions by recognising multiple historical layers embedded within architectural monuments. M. Hasanov *et al.* (2022) analysed the administrative and political organisation of Caucasian Albania and provided historical context for fortified urban centres in the region. The study demonstrated that the political and administrative system directly influenced the distribution of fortified settlements and their defensive functions. It also showed that major urban centres served simultaneously as administrative, military, and economic hubs, explaining the strategic importance of fortified cities such as Ganja. M. Pashayeva (2021) connected the history of Albania with broader cultural traditions relevant to architectural development. The author argued that the evolution of urban culture and architectural forms in Caucasian Albania was closely associated with long-standing regional traditions and intercultural exchange. The research highlighted the continuity of construction practices that influenced later medieval architectural development across Azerbaijan. N.H. Viki & H. Al-Harithy (2024) demonstrated how historic-city regeneration can be informed by the architectural value of defensive ensembles. The authors' findings showed that successful regeneration strategies should preserve the spatial integrity of defensive systems while adapting them to contemporary urban needs. Researchers further argued that historic fortifications should be considered active components of urban identity rather than isolated archaeological remains. O. Spārītis (2022) emphasised the methodological importance of balancing conservation and interpretation in the study of medieval architecture. The author concluded that restoration should preserve the authenticity of surviving fabric while clearly distinguishing original structures from modern interventions. The study also stressed that careful interpretation of archaeological and architectural evidence is essential for avoiding speculative reconstructions of medieval monuments. However, the existing literature tended to discuss Ganja either within broad historical narratives of Caucasian Albania or through separate archaeological observations, without sufficiently integrating construction technology, urban morphology, defensive function, and later historical transformations into one architectural interpretation. Within this context, Ganja occupied a special place because its fortifications reflected a long urban history extending from early settlement layers to the medieval expansion of the city. J.V. Baghirzade (2020) noted the significance of early medieval political structures for understanding regional urban centres, and G.G. Nagiev (2020) specifically discussed medieval Ganja as a fortified city shaped by defensive and social organisation. Additional studies on Ganja's late medieval architectural heritage and written sources confirmed the importance of archival, archaeological, and historical evidence for reconstructing the city's development, but it do not fully resolve the architectural sequence of its walls, towers, masonry types, and riverbank defensive structures. The novelty of the article lain in treating Ganja's fortifications as a layered defensive system and in combining field-based architectural description with stratigraphic, cartographic, historical, and comparative evidence. This approach made it possible to distinguish documented remained from reconstruction hypotheses and to explain, why the city's defensive architecture changed across different historical periods. The aim of this study was to examine the historical development of the city of Ganja and its fortifications and to analyse the architectural and construction features of its defensive walls and towers. The study pursued three objectives: 1) to analyse the principal historical stages in the development of Ganja's fortifications; 2) to identify the architectural and construction features of the fortress walls and towers; 3) to evaluate the role of fortifications in the defense and urban development of Ganja. Accordingly, the article addressed the following research question: how did the defensive architecture of Ganja evolve in response to changing political, urban, constructional, seismic, and hydrological conditions?

## MATERIALS AND METHODS

This study used a multidisciplinary approach to analyse the historical development and architectural features of Ganja's fortifications. The analysis was organised chronologically in order to trace the development of Ganja's fortifications from the early settlement horizon to the ancient, early medieval, post-earthquake, later medieval, and early modern phases. The research combined architectural analysis, archaeological excavation data, and historical documentation in order to reconstruct the city's defensive system from antiquity to the medieval period. Archaeological data were drawn from published excavation materials and surveys relating to Ganja Mound, the ancient city of Arran, and the preserved remains of defensive structures in and around Ganja, including evidence from stratigraphic layers, masonry fragments, towers, walls, bridges, and riverbank fortifications. The documentary base included the geographical description of Strabo, medieval narrative accounts, published archaeological reports, and historical maps and plans used for the reconstruction of the city's layout, particularly for understanding the regional geography, settlement patterns, and trade routes of the South Caucasus (ToposText, n.d.). As the surviving remains were fragmentary and belong to different construction phases, the evidence was assessed according to source type: excavated masonry and stratigraphy were treated as primary architectural evidence. Historical texts and maps were used to reconstruct urban context; and comparative examples were used only to clarify typological and constructional parallels. The following analytical procedures were applied:

1) Examination of stone and brick types, mortar composition, and construction techniques.

2) Stratigraphic analysis, published dating evidence, including available radiocarbon data from associated archaeological contexts, and the comparison of construction techniques across different masonry phases.

3) Analysis of historical maps, plans, and reconstructions to assess the layout, phasing, and spatial evolution of the defensive structures.

4) Comparison of Ganja's fortification styles with those of other contemporary fortified cities to identify similarities and differences in architectural approaches.

5) Materials were examined through architectural description and published archaeological evidence in order to identify their constructional role, visual characteristics, dimensions, and use in different parts of the defensive system.

6) Examination of burnt bricks, cobblestones, and tuff stones used in the masonry, including their dimensions, composition, and placement techniques.

7) Mortar types, including lime, clay, gypsum, and mixed mortars, were considered as indicators of construction technique, repair phases, and possible chronological differences in the masonry.

Selected sources, including the miniature "The Construction of the Castle of Khawarnaq" from Nizami's Khamsa, were used only as comparative material for understanding construction practices in the broader medieval Islamic architectural context and not as direct evidence for Ganja. The study also referred to the cities of Derbent, Ani and Tbilisi, as well as selected defensive parallels from Babylon. The data relating to these cities were used not to establish direct influence, but to identify recurring defensive principles. The comparison with Babylon was retained only as a typological parallel for the defensive treatment of the riverbank, rather than as evidence of historical borrowing. The study acknowledged the fragmentary nature of some archaeological data and therefore relies on cross-checking between excavation evidence, construction analysis, historical sources and cartographic materials.

## RESULTS AND DISCUSSION

Azerbaijan contained a significant body of fortified settlements and defensive structures that were essential for understanding the architectural history of the South Caucasus. The historical geography of Caucasian Albania also provided important context for understanding the emergence of fortified urban centres in the Ganja region, including their strategic relationship to communication routes, river systems, and territorial organisation (Mamedova, 1986). The architectural and planning composition of fortifications was determined by defensive logic, construction technology, and the topographic conditions of the site. This interpretation was consistent with broader archaeological studies of fortified settlement systems in the South Caucasus, which demonstrated that defensive architecture often influenced settlement organisation, territorial control, and patterns of urban development (Hammer, 2014). In the case of Ganja, the historical urban development of the fortified city can be reconstructed through archaeological evidence, preserved masonry, and comparative analysis with other fortified centres in the Caucasus and the Middle East. The comparison was especially relevant for Derbent (Russia), Ani (Turkey), and Tbilisi (Georgia), where wall systems and towers demonstrated similar principles of perimeter defence, although Ganja possessed distinctive local masonry patterns and construction solutions. To preserve the chronological logic of the analysis, the results were presented according to the main stages in the development of Ganja's fortifications: the early settlement horizon, the ancient and early medieval fortified town, the 9$^{th}$-11$^{th}$-century defensive system, the post-earthquake rebuilding phase, the 12$^{th}$-13$^{th}$-century expansion, and later medieval and early modern transformations.

The documentation and classification of architectural monuments through digital methods have also been recognised as important tools for preserving and analysing historic defensive architecture, particularly, where surviving remains were fragmentary and required reconstruction from archaeological and documentary evidence (Comneno, 2020). The results also supported contemporary approaches to heritage conservation planning, which emphasised the integration of historical layers, archaeological evidence, and urban development processes in the management of historic sites (Li *et al.*, 2024). In the end of the 18$^{th}$-first half of the 19$^{th}$ century of the Caucasus developed in different political contexts, studies of strategic defensive systems in the region demonstrated the continuing importance of fortified lines, controlled access points, and territorial defence in shaping settlement networks and regional security landscapes (Çaycıoğlu, 2022). Figure 1 demonstrated the principal masonry patterns used in the fortifications of Ganja and showed how the combination of fired brick, stone, and mortar generated both structural stability and a distinctive visual language. The masonry should therefore be read not only as a technical solution, but also as evidence of the Arran architectural tradition, in which constructional logic and decorative surface treatment were closely connected.

**Figure 1.** Stone-and-brick masonry patterns in the defensive walls of Ganja
**Source:** based on R. Amenzadeh (2024)

The development of construction techniques reflected several chronological stages in the evolution of Ganja's fortifications, including the early settlement phase, the formation of a fortified town in the ancient and early medieval periods, the reconstruction following the earthquake of 1139, and the later medieval rebuilding and reinforcement of the defensive system. Understanding of building materials, particularly stone and fired brick, and of their texture, colour, and tectonic behaviour allowed builders to create walls with both defensive strength and architectural expressiveness. These material and constructional choices also shaped the spatial organisation of the city, influencing the positioning of gates in relation to major access routes, connections to bridges across the Ganja-Chay, the formation of trade routes, the delimitation of urban expansion, and the relationship between the citadel, residential quarters, craft districts, and riverbank fortifications. In construction, baked brick, fine-grained limestone, marble, river stone, crushed stones of different sizes, and lime, clay and gypsum mortars, as well as timber and iron elements, were used. The distinctive use of fired brick, stone, and mortar in Ganja found parallels in material studies of other medieval fortifications, where scientific analysis of construction materials and surface finishes had shown how the selection of local resources contributed to both structural performance and architectural expression (Holakooei *et al.*, 2020).

The specific shape of the brick, along with its coloristic, textural, and plastic qualities, defined the continuous motifs of the tectonic development of planes and surfaces. It inspired the creation of intricate relief patterns in brickwork, while the structuring of the material and the reinforcement of its strength properties through jointing techniques enabled the artistic expression of patterns such as "Herringbone" and "Ganja masonry". The integrity of the artistic and architectural image of the construction was determined by the structure and character of limestone, a natural building material with excellent physical and technical parameters such as moisture resistance, thermal conductivity, and durability. The earliest stage identified in the archaeological record preceded the formation of the medieval fortified city and provided the basis for understanding the later continuity of occupation and defensive organisation. Architectural and archaeological research indicated that the earliest settlement horizon in the Ganja area dates to the 3rd millennium BC and that later fortified phases developed above earlier cultural layers. Stratigraphic analysis made it possible to distinguish successive occupation layers and to identify episodes of wall construction, repair, and rebuilding through differences in masonry, mortar composition, and depositional sequences. Radiocarbon dating of organic inclusions from associated archaeological contexts was used to correlate these stratigraphic layers with approximate chronological periods, thereby refining the dating of individual construction phases and confirming that some defensive structures belonged to different episodes of development rather than to a single building campaign (Allahverdiyeva, 1995). These data showed that the defensive system developed incrementally rather than as a single campaign and that the later medieval fortifications reused and transformed earlier spatial and constructional traditions. The archaeological evidence for these early construction phases and their spatial organisation was illustrated in Figure 2.

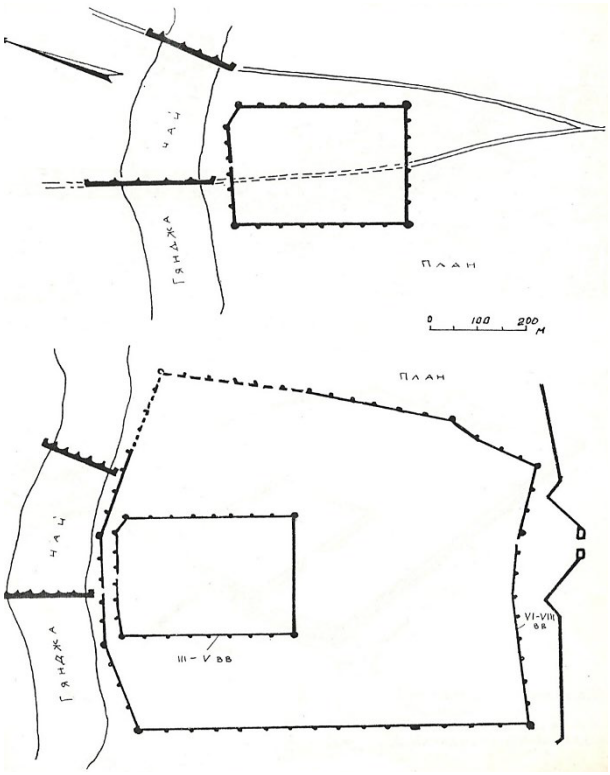


**Figure 2.** Fortification remains at Ganja Mound, 3rd-8th centuries
**Source:** based on S. Allahverdiyeva (1995)

So, early fortification horizon of Ganja and were significant because it demonstrated continuity in the occupation and defensive organisation of the site before the later medieval rebuilding phases represented in Figure 3. The figure presented the excavated plan of the fortified settlement, including the defensive perimeter, enclosed interior area, and associated structural elements identified during archaeological investigations. These two plans illustrated different stages or sectors of the fortified complex and showed the relationship between the enclosure walls and the surrounding landscape, including the nearby river corridor. The documented spatial arrangement and scale of the early defensive system provide archaeological evidence of organised fortifications that existed before the later medieval reconstructions. These data are therefore important for reconstructing the successive development of Ganja's defensive architecture and urban layout.

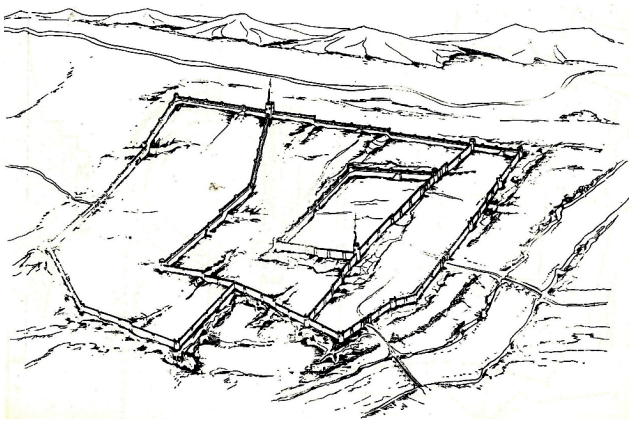

**Figure 3.** Reconstructed plan of the fortified settlement of Ganja, 9th-11th centuries
**Source:** based on S. Allahverdiyeva (1995)

The next stage of the analysis concerned the ancient and early medieval context of Ganja and its relationship with the wider riverine and trade network of Arran. In 1988, archaeologist R.J. Akhmedov discovered and examined the ruins of the pier of the ancient city of Arran, located in a bay on the right bank of the Kura River, 4 km in a straight line from the ancient settlement of Ganja. According to Strabo's descriptions, this city had a significant port trade with neighboring countries, particularly India (Topos-Text, n.d.). This evidence was relevant to Ganja because it situated the settlement within a wider network of riverine and overland exchange, helping to explain, why fortified control of movement corridors was architecturally and politically important. Within this ancient phase, the fortified city already demonstrated a regular defensive layout and a developed system of walls, towers, and gate structures. The ancient fortress city of Ganja, dating back to the first centuries AD, was designed as a closed regular quadrangle. Its walls and powerful corner towers were oriented to the cardinal points and feature numerous half-towers (Alikberov & Mudrak, 2020). The citadel walls, constructed from river boulders and layered with baked brick. On either side of the gate stood gate towers, and above the gate were three drains for pouring boiling water or burning oil. The description of drains was retained as a functional interpretation of defensive architecture and should be read together with the evidence for gate towers and elevated fighting platforms (Gippert, 2023). It should be noted that the city was not situated directly on the bank of the Ganja-Chay River but was located 175 meters inland. The fortress area covered approximately 10 hectares. The inner citadel, constructed of adobe walls, was surrounded by an outer wall made of cobblestones interspersed with red and white stones brought from neighboring regions. The masonry of the towers featured a complex geometric pattern. The fortress walls were built of cobblestones set in lime mortar, with individual well-fired bricks and large slabs of red tuff bricks, approximately 75×75×40 cm in size, incorporated in specific parts of the wall. These bricks were laid vertically on the sides and horizontally on the top and bottom. Rows of stone and brick masonry alternated parallel with each other, covering the surface of the surviving observation tower, giving it a picturesque appearance.

The first quadrangular tower was designed with a slightly tapering top using the Ganja masonry method, which combined burnt red bricks and cobblestones in lime mortar. This masonry technique involved inserting cobblestones into a "cage". These "cages" were arranged in parallel rows, spaced four to five rows of bricks apart, with stones inserted into them. The seams along the entire perimeter of the tower were covered with lime mortar. Inside, the tower had a round shape, built of raw bricks without straw admixture (the bricks in the tower measured 28×28×5 cm and 30×30×6 cm). The combination of a quadrangular exterior and circular interior was architecturally significant because it increased the mass and stability of the tower, while creating a more efficient internal space for circulation and defence. These features indicated the defensive purpose of the tower, which accommodated throwing weapons on its upper platform alongside patrol soldiers. At the corners of the tower, the nature of the masonry changed for greater strength, with cobblestone rows replaced by rows of brick. The second quadrangular tower was primarily constructed from river cobblestones. In its foundation, the cobblestones were bound with lime mortar, and above, a combination of lime and clay mortar was used. The change in mortar composition suggested either a phased construction process or later repair work, and it should be interpreted cautiously as evidence of chronological complexity rather than as proof of a single building campaign. This type of combined cementing material was discovered for the first time in Azerbaijan, indicating that the tower's construction or restoration took place at different times. The seams were not filled with mortar. Inside this tower, the masonry featured both cobblestones and burnt bricks, which were inserted into the wall in various positions to form different patterns.

So, comparative studies of medieval defensive structures demonstrated that variations in masonry layout, bonding techniques, and wall construction may reflect different construction traditions, functional requirements, or phases of rebuilding. In this context, the absence of a herringbone arrangement in the cobblestone masonry of the second tower suggested a construction approach distinct from other documented defensive structures and should not be interpreted solely as a chronological indicator (Antipov, 2019). These quadrangular towers are rare among the defensive structures discovered in Azerbaijan. The distinctiveness of the rectangular towers and their aesthetic appeal indicated that the architects aimed to provide these structures with both strong strategic significance and artistic expressiveness. The city walls approaching the tower, constructed using Ganja masonry, were adobe on the inside and lined with cobblestone armour on the outside. The cobblestone lining was one meter thick, while the adobe

was five meters thick, with the cobblestone part of the wall rising above the battle path in the form of stone merlons. The dressing of the masonry of both walls was achieved by having rows of cobblestone masonry merged into the adobe at certain points. These walls, which reliably protected the city, testify to the extraordinary abilities and profound knowledge of military-strategic art possessed by Azerbaijani architects. Coastal fortifications, resembling armour, protected the city from riverbank erosion and consisted of a slightly inclined stone-brick wall with half-towers. The walls were laid with cobblestones on an extremely durable, now petrified, solution, with different types of masonry used in the cladding. Only pure masonry was observed in the coastal towers (Fig. 4).

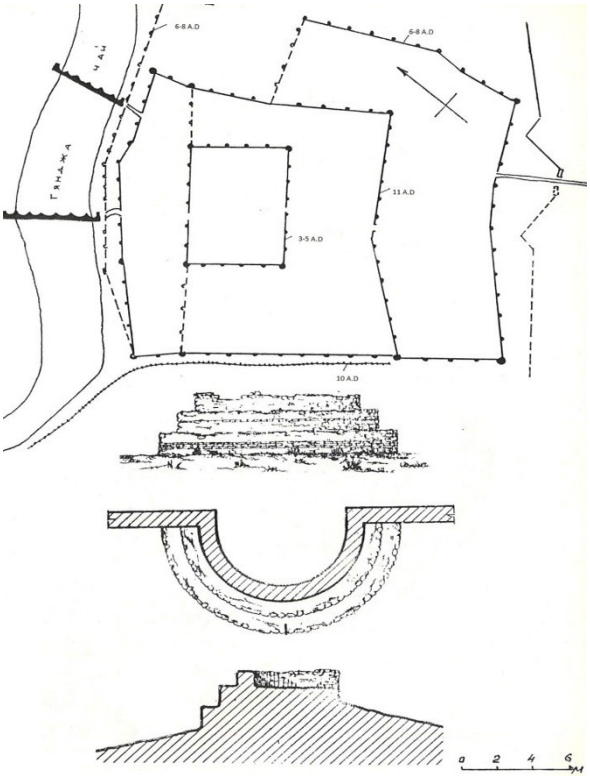


**Figure 4.** Defensive structures of Ganja Mound, 9th-11th centuries
**Source:** based on S. Allahverdiyeva (1995)

The riverbank defences were especially important because it showed that Ganja's fortification system responded not only to military threats, but also to hydrological risk, including erosion and changing river dynamics. This interpretation was consistent with later descriptions of Ganja's location along the Ganja-Chay River and of surviving fortress walls close to the river corridor. It should be noted that a similar method of protecting the coast with a continuous line of fortifications was also found in the history of ancient Babylon. The advantageous location of Ganja contributed to its rapid growth and transformation into one of the most strongly protected and prosperous cultural centres of the Near East. Plan of the fortified enclosure together with sectional drawings of defensive elements illustrated the relationship between the outer defensive wall, the enclosed central area, and the tower structures. The lower drawings showed the constructional form of the fortifications, including the profile of the wall, the semicircular tower configuration, and the arrangement of masonry elements. The figure was important because it provided archaeological evidence for the construction techniques, spatial organisation, and defensive features of the settlement during the 9th-11th centuries. The separation of these figures clarified the distinction between archaeological evidence and historical reconstruction. Figure 5 presented the reconstructed spatial configuration of the later 12th-13th century defensive system.

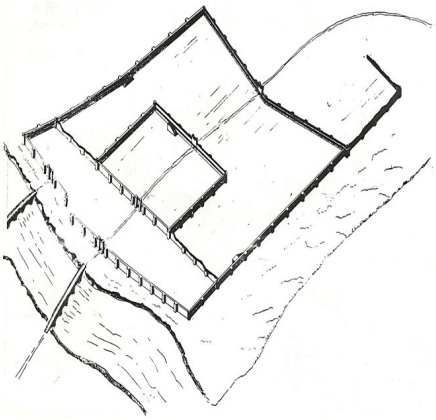

**Figure 5.** Reconstructed fortification layout of Old Ganja, 12th-13th centuries
**Source:** based on S. Allahverdiyeva (1995)

Reconstructed layout of the fortified settlement during the 12th-13th centuries showed the enlarged defensive perimeter, the position of the inner fortified zone, and the relationship between the fortifications and the surrounding landscape. The reconstruction demonstrated how the defensive system expanded in response to urban growth and how the walls enclosed a larger settlement area than during the 9th-11th centuries (Allahverdiyeva, 1995). A subsequent phase of development is associated with the 9th-11th centuries, when the defensive system was reconstructed and adapted to the changing political and urban conditions of the region. In the 9th century, fortifications damaged during political instability were reconstructed, and the city was enclosed by a new wall with semicircular intermediate towers placed at approximately 20-metre intervals. The masonry displays decorative treatment, including traces of herringbone arrangement. The regular spacing of towers indicated an organised defensive concept, in which visual surveillance, flanking fire, and structural rhythm were integrated into a single perimeter system.

The miniature "The Construction of the Castle of Khawarnaq" (Herat, 1494), preserved in the manuscript of Nizami's Khamsa and commonly attributed to Kamal al-Din Bihzad, was relevant here not as direct evidence for

Ganja, but as a comparative visual source illustrating construction practices in the broader architectural culture of the late medieval Islamic world. The original visual source was the Herat manuscript of Nizami's Khamsa, with the relevant folio widely identified as Construction of the Castle of Khawarnaq, painted by Bihzad and preserved in the British Museum, Or. 6810 (Gray, 1961). In the foreground of the miniature, mortar troughs, construction platforms, and lifting devices were depicted, helping to interpret the organisation of labour and the technical processes associated with the erection of large masonry structures. This historical context clarified the late 9th- and 10th-century strengthening of Ganja's defensive role before the later 12th-13th-century expansion. By approximately 944-951 CE, after the destruction of Barda and the reorientation of regional trade routes, Ganja emerged as the principal urban centre of Arran, resulting in an increased strategic need for fortified defences and urban expansion (Nagiev, 2020; Hasanov, 2025). The resulting need for strengthened defence led to fortifications on the left bank of the Ganja-Chay. The left-bank city was laid out as an irregular rectangle oriented south-north and enclosed by a double wall with semicircular towers. This arrangement was illustrated in Figure 6.

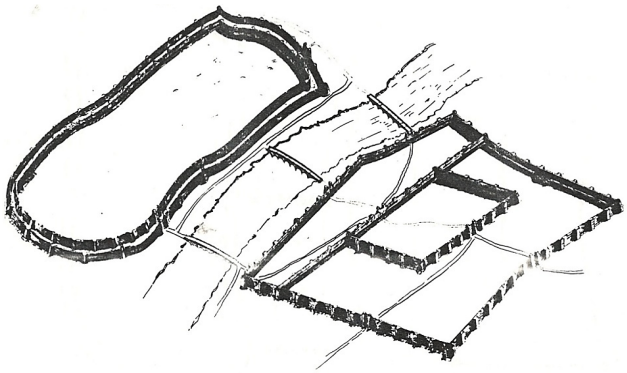

**Figure 6.** Plan of the ancient settlement of Ganja, 12th-13th centuries
**Source:** based on S. Allahverdiyeva (1995)

The next major chronological turning point in the development of Ganja's fortifications was the earthquake of 1139, which created the need for rebuilding and structural adaptation. Ganja was severely affected by the earthquake of 1139 and was restored shortly afterwards, a process that coincided with renewed handicraft production, trade, and agricultural activity. The earthquake was relevant to the architectural argument because historical and seismological sources described the 1139 event as a major destructive episode near Ganja, after which rebuilding and defensive reorganisation became necessary. As of 2026, one of the southern towers of the left-bank sector has survived; this hollow corner tower had a diameter of 13.50 m, walls 2.15 m thick, and radially oriented through-holes measuring 18-20 cm in diameter. Comparable openings were recorded at Khanega on the Pirsagat River and at old fortresses in Nakhchivan, Shamakhi, and Ordubad, where it was interpreted as structural devices related to seismic conditions. In this context, the through-holes may have functioned as anti-seismic relieving devices, constructional ties, or ventilation and drainage features; their exact role required further material and structural analysis. The coastal fortifications on the left bank were less substantial than those on the right bank and were preserved in a more fragmentary condition in the archaeological record (Allahverdiyeva, 1995). The later medieval and early modern stages showed that the defensive system continued to be modified in response to new political and military circumstances. At the end of the 14th and the beginning of the 15th centuries, Ganja came under the rule of Timur. In 1587, the city was taken by the Ottomans, who undertook strengthening works around the area of modern Ganja. In 1606, Shah Abbas I captured the fortress and ordered the construction of new public buildings and the rebuilding of the defensive walls (Guliyev, 2016).

Surveys of the fortress walls, bridges, Kyagriz canals, and cultural layers discovered under the foundations, along with other data, indicate that Ganja was not relocated but continuously inhabited, rebuilt, and expanded on its original site along the banks of the Ganja-Chay River, near three old bridges. The construction of fortress walls, bridges, and residential and public buildings utilised a variety of abundant local building materials, including clay and adobe bricks, cobblestones of different sizes and colours, rubble stone, red tuff, reeds, and the magnificent Chilikdag marble stone. Burnt bricks of various square sizes were especially prevalent. Eleven types of adobe bricks, differing in thickness and dimensions, and twenty-one types of burnt bricks were identified in the masonry (Fig. 7). The mortars used for brick and stone masonry were diverse, incorporating gyza, lime, sand, gravel, and pebbles, with seam thicknesses ranging from one to eight centimeters. The internal masonry was extensively reinforced with mortar, creating a robust monolith that is difficult to dismantle.

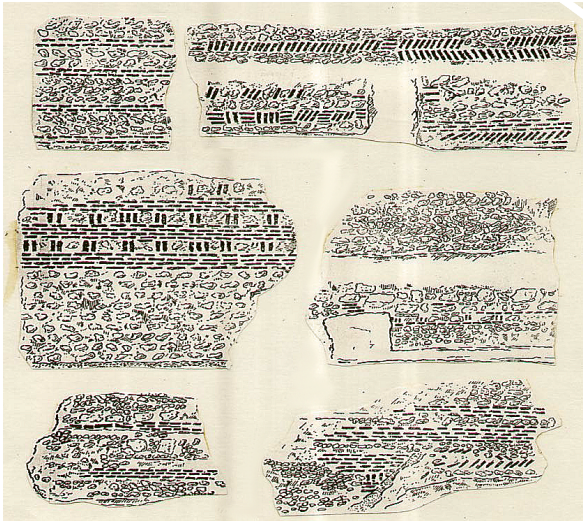

**Figure 7.** Types of wall masonry in Old Ganja, 12th-13th centuries
**Source:** based on G.G. Nagiyev (2020)

After the post-earthquake recovery, the 12th-13th centuries marked a phase of urban expansion, during which the fortified system became closely connected with suburbs, gardens, cemeteries, craft areas, and transport routes. In the 12th-13th centuries, Ganja was surrounded by suburbs and gardens and occupied an area estimated at approximately 12-16 km$^2$ including the suburban belt. Two kilometres southeast of the settlement were ancient burial mounds, and the same area also contained a 12th-13th-century cemetery associated with the burial place of Nizami. The architectural analysis of fortifications in this period showed that wall surfaces were articulated by elements that established scale, proportion, and rhythm, while the broader political consolidation of Azerbaijani territories in the later 15th century contributed to the strengthening of defensive architecture in urban centres such as Ganja, Barda, and Shabran. Archaeological evidence indicated that these cities developed gradually from earlier settlements rather than appearing suddenly as fully formed urban foundations. This gradual development was central to the interpretation of Ganja: the city's fortifications should be understood as a palimpsest of rebuilding, repair, expansion, and adaptation rather than as the product of a single chronological moment.

## CONCLUSIONS

The study demonstrated that the fortifications of Ganja developed through several historical phases and that their masonry, towers, wall systems, and urban layout reflect a high level of technical adaptation to changing political and environmental conditions. The combined use of archaeological evidence, architectural analysis, historical documents, and cartographic comparison made it possible to reconstruct the defensive evolution of the city with greater precision. The principal contribution of the article was the integration of architectural, archaeological, and urban evidence into a single chronological interpretation of Ganja's defensive system. The analysis showed that the city's fortifications combined military functionality, material experimentation, response to riverine and seismic conditions, and a distinctive aesthetic treatment of masonry. The study showed that the architectural character of Ganja's fortifications was defined by the systematic use of layered stone-and-brick masonry, differentiated tower forms, and construction techniques specifically adapted to the local geological and hydrological environment. It also established that the spatial organisation of the defensive system influenced the historical development of the city by shaping the relationship between the citadel, residential quarters, transport routes, riverbank fortifications, and surrounding urban landscape. Further research should focus on three directions: expanded radiocarbon sampling and finer stratigraphic recording in order to refine the chronology of successive construction phases; GIS-based and 3D digital reconstruction of the fortification system and its relationship to the urban fabric; broader comparative study with fortified cities of the Caucasus and the Middle East in order to define more precisely the local and transregional characteristics of Ganja's defensive architecture.

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## CONFLICT OF INTEREST

None.

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## Фортифікації Гянджі: історико-архітектурне дослідження

**Анотація.** Метою дослідження було проаналізувати історичний розвиток та архітектурні особливості фортифікацій Гянджі від пізньої античності до пізнього середньовіччя. Особливу увагу було приділено взаємозв'язку між оборонними спорудами міста, змінами його урбаністичної морфології та природними умовами долини річки Гянджа-Чай. Дослідження поєднувало архітектурний аналіз, дані археологічних розкопок, стратиграфічний аналіз, радіовуглецеве датування, а також вивчення історичних писемних і картографічних джерел з метою реконструкції еволюції оборонної системи міста. Отримані результати засвідчили, що фортифікації Гянджі розвивалися в кілька хронологічних етапів і пристосовувалися до змін військових, політичних, гідрологічних та сейсмічних умов. Матеріали дослідження продемонстрували використання шаруватої кам'яно-цегляної кладки, різних типів башт і складних технік зведення мурів, які відображали як місцеві будівельні традиції, так і ширші регіональні практики фортифікаційного будівництва. Стратиграфічні спостереження та радіовуглецевий аналіз допомогли уточнити послідовність будівництва й перебудов, тоді як порівняльний аналіз з укріпленими містами Кавказу та Близького Сходу дав змогу підкреслити архітектурну своєрідність Гянджі. Результати також показали, що оборонна система міста формувалася поступово, через повторювані етапи реконструкції, а не як результат однієї будівельної кампанії. Археологічні дані підтвердили, що прибережні укріплення виконували як військові, так і гідрологічні функції, захищаючи поселення від ворожих нападів та ерозії, спричиненої річкою Гянджа-Чай. У дослідженні також розмежовано археологічно задокументовані залишки, пізніші реконструкції та порівняльні візуальні джерела, що зменшує ризик трактування ілюстративного матеріалу як прямого доказу. Практична цінність дослідження полягає у формуванні наукової основи для консервації, реставрації та історично обґрунтованої реконструкції середньовічних фортифікаційних систем Азербайджану

**Ключові слова:** фортифікаційна архітектура; оборонні споруди; техніки кладки; урбаністична морфологія; культурна спадщина

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# Implementing a human-centred block-based urban planning method in the Ukrainian context: The case of Kharkiv

**Abstract.** The relevance of this study is determined by the need to adapt human-centered, block-based urban planning approaches to the Ukrainian urban planning context shaped by post-Soviet spatial development patterns and the challenges of post-war urban recovery. The aim of the article was to identify the specific features of implementing K. Pålsson's human-centred block-based urban planning method within Ukrainian architectural and urban planning practice. The research combined a theoretical analysis of the method's origins and components in the European urban tradition with an experimental workshop-based test conducted on a post-industrial site in Kharkiv. The results demonstrated the overall applicability of the method to the Ukrainian context. The most successfully reproduced principles included the urban block structure, continuous street frontage, human scale, and the integration of green structure, while the balance between private and public space was generally understood but implemented with varying degrees of consistency. Mixed-use development and the organisation of streets and squares were implemented partially. The most challenging principles were spatial sequences, the hierarchy of public spaces, and the reduction of the role of freestanding buildings. The study indicated that the method requires not direct transfer, but staged adaptation to local professional traditions, regulatory conditions, and the socio-spatial context. The findings also showed that the workshop functioned not only as an educational format, but as an empirical test of the method's operationality in the Ukrainian context. The practical value of the study lies in the potential application of its results in educational workshops, territorial redevelopment projects, and the development of method guidelines for Ukrainian communities

**Keywords:** urban morphology; urban blocks; participatory planning; workshop-based experiment; post-Soviet urban context

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## INTRODUCTION

In contemporary urban planning, a clear shift can be observed from technocratic models towards human-centred approaches, where priorities increasingly focus on the quality of everyday space, human scale, spatial accessibility, social integration, and user participation in shaping the urban environment. In this context, the concept of the humane city, or human-centred urbanism, gains particular significance as an alternative to approaches that primarily assess urban development through transport efficiency, density, or economic indicators. Normatively, this trend aligns with global sustainable development frameworks, which emphasise the need for inclusive, safe, and resilient cities, as well as with contemporary approaches to people-centred urban development (United Nations, 2015).

Recent studies confirm the growing need for operational tools for human-centred planning. Evidence from Barcelona provided by K. Pérez *et al*. (2025) suggests that superblock models can improve perceived well-being, reduce noise exposure, and enhance social interaction, although the effects depend on the local context of implementation. D. Rojas-Rueda *et al*. (2024) emphasised that within the 15-minute city discourse, proximity to basic services and reduced car dependency positively affect health and social interaction; however, these approaches do not automatically eliminate the risks of inequality and spatial exclusion. At the same time, Z. Allam *et al*. (2024) point out that the rapid policy uptake of these approaches is outpacing their scientific operationalisation and validation across different contexts.

Another important direction of research concerns the preservation of urban identity, the role of the historic urban landscape, and the continuity of morphological structures. M. Ripp *et al*. (2025) demonstrate that the integration of heritage into contemporary planning can enhance the sustainability of urban development and environmental quality, provided it is implemented through intersectoral and participatory approaches. However, a study by J. Gregorowicz-Kipszak *et al*. (2024) shows that mixed-use development, active ground floors, and accessibility do not emerge automatically from block-based urban form but depend on broader socio-economic and regulatory conditions.

Particular attention should be paid to studies addressing the procedural dimension of human-centred planning. A review by J. Pearson *et al*. (2025) demonstrates that participation, co-design, and placemaking produce tangible outcomes only when supported by well-structured, repeatable, and carefully organised procedures, rather than functioning as a formal act of stakeholder involvement. This is especially important for research that seeks to evaluate not only the declarative value of a given approach but also its practical operability.

For Ukraine, this issue acquires additional relevance due to the post-Soviet inertia of professional thinking, the need to reconsider models of residential development, and the challenges of post-war urban recovery. Under these conditions, particular importance is attached to the study of methodologies capable of integrating morphological coherence, human scale, mixed use, a balance between public and private spaces, and user participation in planning processes. One such methodology is the approach developed by K. Pålsson (2023; 2025), which is grounded in human-centred, block-based logic of urban organisation.

Despite the substantial body of contemporary research, the implementation of specific human-centred methodologies of block-based design in post-Soviet conditions, particularly in the Ukrainian context, remains insufficiently explored in academic literature. There is also a lack of research on how such methodologies can be tested through experimental participatory formats and how the results of such testing can be interpreted through the lens of local professional thinking, regulatory frameworks, and urban realities.

The aim of the study was to identify the specific features of implementing Karsten K. Pålsson's method in contemporary Ukrainian architectural practice. The objectives of the study are: to determine the origins and components of K. Pålsson's method within European urban planning; to analyse the reproduction of K. Pålsson's principles in the work of Ukrainian architects during the experimental workshop; to interpret the results of the experimental projects in the context of adapting the method to contemporary Ukrainian practice.

## LITERATURE REVIEW

Contemporary academic literature relevant to the research topic forms several interrelated directions. The first concerns human-centred models of urban development, in which the humaneness of the environment is associated with accessibility, everyday use of space, health, and social interaction. M. Nieuwenhuijsen *et al*. (2024) argue that the superblock model can improve environmental conditions, liveability, health, and well-being through traffic reduction, increased green space, and support for active mobility and social interaction; however, its outcomes depend on the scale and context of implementation. A. Wandl & B. Hausleitner (2021) further show that the level of mixed use depends on the morphology of dispersed urban territories and requires coordination of planning decisions across different urban scales, rather than merely the local "addition of functions". I.A. Tănase & C.M. Povian (2025) identify a gap between geographical proximity and the actual possibility of accessing services due to existing route and environmental barriers, emphasising that "proximity" does not equate to "accessibility", particularly for vulnerable population groups.

The second direction is related to urban morphology, the preservation of identity, and the role of historically formed structures. K. Wang & K. Fouseki (2025) argue that the sustainable development of historic urban environments requires adaptive and context-sensitive strategies capable of reconciling the preservation of cultural continuity with contemporary transformations.

For the purposes of this study, this direction is particularly important, as it allows block-based development to be considered not merely as a spatial form, but as a historically and socially conditioned structure of the city. This is supported by Ukrainian academic discourse, in particular by Y.V. Idak (2006), who, using the example of Lviv, provides a detailed historical and typological substantiation of the urban block as an integral spatial system encompassing urban fabric morphology, spatial hierarchies, and the interaction between built form and the street –square structure of the city. This approach directly corresponds to the concept of genius loci – the "spirit of place" – which, in the works of K. Pålsson, is interpreted as the necessity of considering history, local character, and the spatial logic of the city in the course of its transformation. In this study, this provides grounds for considering block-based development not only as a morphological model but also as a tool for preserving and reinterpreting urban history and identity.

The third direction is constituted by studies focusing on the procedural dimension of human-centred planning. P. Wacnik *et al*. (2025), in a systematic review, demonstrate that the effectiveness of participatory design is determined not by the mere fact of involvement, but by the sequencing, repeatability, and quality of the applied techniques. G. Slingerland & N.B. Hansen (2025) argue that urban placemaking initiatives often fail to explicitly relate participatory mechanisms to intended outcomes, which makes their effects difficult to evaluate. In this sense, a participatory workshop can be interpreted not only as an educational or consultative format, but also as a means of empirically testing the operationality of a planning methodology.

For Ukraine, these international discussions acquire an additional dimension due to post-Soviet planning inertia, a growing demand for block-based urban structures, and the post-war challenges of urban resilience. Within the Ukrainian context, particular importance is attached to studies that establish the local typological, historical, and practical foundations for researching block-based development, including under conditions of wartime transformation. O.A. Kryzhantovska *et al*. (2020) substantiate the potential of high-density, low-rise block-based development as a comfortable model of the residential environment. I. Dreval (2022) emphasises the need for conceptual frameworks for the revival of Ukrainian cities in the post-war period and highlights the importance of an integrated urban vision for Kharkiv. D. Popovych (2023) proposes a methodology for the reconstruction of intra-block spaces within the historic urban fabric, focusing on shared improvement, greening, and the reinterpretation of courtyard spaces. T.M. Apatenko & O.S. Bezliubchenko (2024) systematise the advantages and disadvantages of block-based development, although they do not address its participatory and procedural aspects, whereas L. Shvets (2025), based on the case of Kharkiv, expands this discourse through the categories of housing policy, urban resilience, community participation, and the restoration of residential environments.

Thus, the literature review indicates that both international and Ukrainian studies provide a sufficient basis for examining block-based and human-centred development; however, they do not offer a comprehensive answer to the question of how a specific European methodology of block-based design can be implemented within the Ukrainian post-Soviet context. It is precisely this gap that determines the logic of the subsequent research.

## MATERIALS AND METHODS

The study was conducted within a qualitative-interpretative research strategy with elements of an applied urban experiment. The logic of the study combines a theoretical analysis of human-centred approaches to urban planning in the European context of block-based urban development with an empirical examination of the possibilities for implementing K. Pålsson's method in Ukrainian architectural and urban planning practice. The structural and logical model of the study is presented in Figure 1, while the workshop process is presented in Figure 2.

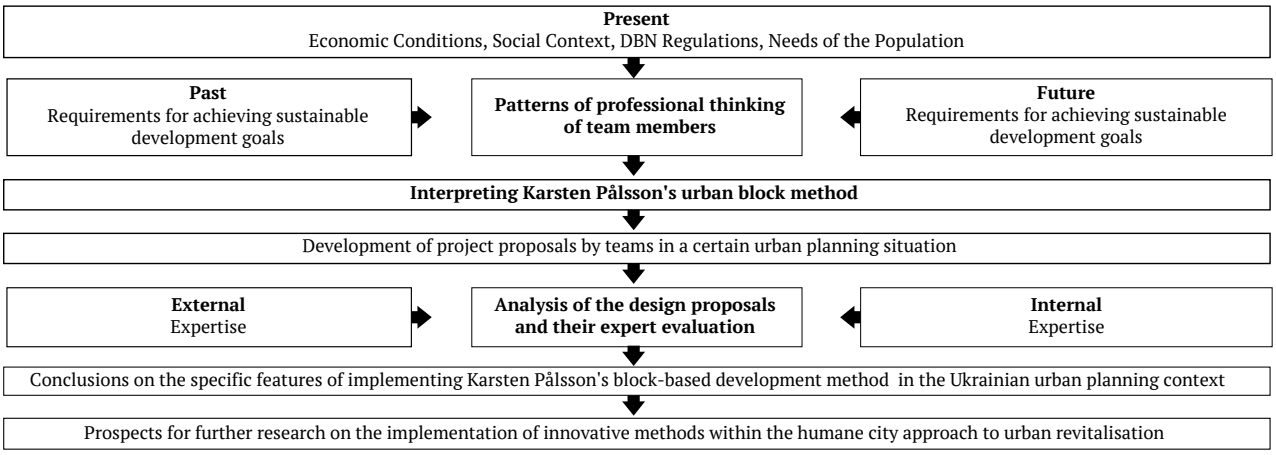


**Figure 1.** The structural and logical model of the study

**Source:** prepared by authors

**Figure 2.** The process of the Workshop (LUF, Lviv, 2025)
**Source:** prepared by authors

The study consisted of three main stages. At the first stage, an analysis of academic publications, regulatory and conceptual documents, and professional materials related to human-centred planning, block-based development, urban morphology, participatory practices, and post-war urban recovery was conducted. At this stage, the methods of analysis, comparison, systematisation, and generalisation were applied, making it possible to identify the key principles of a humanistic approach to urban space formation, as well as to identify K. Pålsson's method as a distinct object of research.

The examination of the origins, components, and specific features of K. Pålsson's method, as well as its integration into the European urban planning context, has shown that the author builds this method upon the principles of the "organic" development of medieval European cities and classical urbanism, as presented in the works of Camillo Sitte, Kevin Lynch, and Gordon Cullen, as well as on the critique of modernist planning articulated in the works of Steen Eiler Rasmussen, Jane Jacobs, Christopher Alexander, Jan Gehl, and others. In this context, K. Pålsson's method is understood as a contemporary adaptation of the European tradition of the block-based city, grounded in the principles of human scale, pedestrian accessibility, street-and-square hierarchy, mixed use, the balance between private and public space, and the preservation of historical heritage.

This makes K. Pålsson's method comprehensible to Ukrainian architects familiar with international scientific and professional experience. It incorporates the majority of contemporary approaches to shaping the urban environment that have emerged in different European countries. For this reason, the method became the principal subject of the experimental part of the study. During the experiment, K. Pålsson's method was presented through K. Pålsson's own design projects, including urban regeneration schemes for the Svømmehals and Lindevang quarters, as well as projects of new urban development, such as Refshaleøen Øst and Lynetteholmen in Copenhagen (Fig. 3). This analysis demonstrates how the theoretical principles of the block-based city are implemented in contemporary European practice through the integration of morphological continuity, spatial coherence, resident participation, and adaptation to current urbanisation challenges. It also provides a basis for comparing the European logic of the method with the specific features of its experimental application in the Ukrainian context.

The second stage of the research had an empirical character and consisted of conducting the workshop "Applying a Danish approach in master plans: Workshop for Ukrainian cities' chief architects", which took place in the summer of 2025. The experimental basis of the study was a training-design seminar during which participants tested the principles of K. Pålsson's method on a specific site in Kharkiv. Thirty-six participants took part in the workshop, including architects, chief architects of municipalities, urban managers, and representatives of territorial communities from different regions of Ukraine. The sample had a purposive expert character, as participants were selected from among professionals directly involved in residential environment formation and urban development. The participants were divided into six groups of six persons each.

All groups worked under identical conditions. For the task, participants were provided with drawings of the study area at a scale of 1:2000, sketching paper, and drafting materials. Prior to the practical work, participants attended an introductory lecture by K. Pålsson, in which the objectives of the workshop, the content of the task, and the key principles of the method, as presented in the manual "City design" (Pålsson, 2025), were outlined. The workshop was moderated by Liudmyla Shvets with the participation of Iryna Dreval. Each participant received a copy of the manual as supporting material. Some participants were already familiar with K. Pålsson's approach through his publications (Pålsson, 2023) or had participated in an earlier workshop (LUF 2024, Lviv).

The duration of the practical session was three hours, after which each group presented its own conceptual master plan proposal. The site selected for the experimental design was the territory of the former "Serp i Molot" industrial plant in Kharkiv. The selected urban planning situation is typical of many Ukrainian cities today. By the end of the twentieth century, a considerable number of industrial areas had lost their original functions and turned into vacant sites. However, their location within the intermediate urban zone, together with the presence of transport infrastructure and engineering networks, gives them significant

urban development potential. In accordance with the workshop task, the groups approached the site as a post-industrial reserve for urban development.

The site is located in the eastern part of the city, within an established industrial-residential zone, in proximity to major road infrastructure and railway networks. Its area is approximately 64 hectares. The site is bounded by major urban roads, the railway network, and the Nemyshlia River. The terrain is predominantly flat, the soils are technogenically altered, and green spaces are fragmented. From the perspective of the experiment, the main feature of the site is the absence of existing buildings and clearly defined natural constraints. This condition focuses attention on external urban planning factors and significantly simplifies the application of K. Pålsson's methodological principles (Fig. 4).The urban planning model adopted for the organisation of the site was based on the provisions of the current Ukrainian State Building Regulations "Planning and Development of Territories" (DBN B.2.2-12:2019, 2019). According to this framework, the site corresponds to the classification of a residential "microdistrict", where pedestrian accessibility to everyday services is defined within a 500 m radius – clause 5.8 (DBN B.2.2-12:2019, 2019). Including a full range of local service facilities and density limits of 150-450 people/ha – clause 6.1.16, – the projected population is 20,000-25,000 residents.

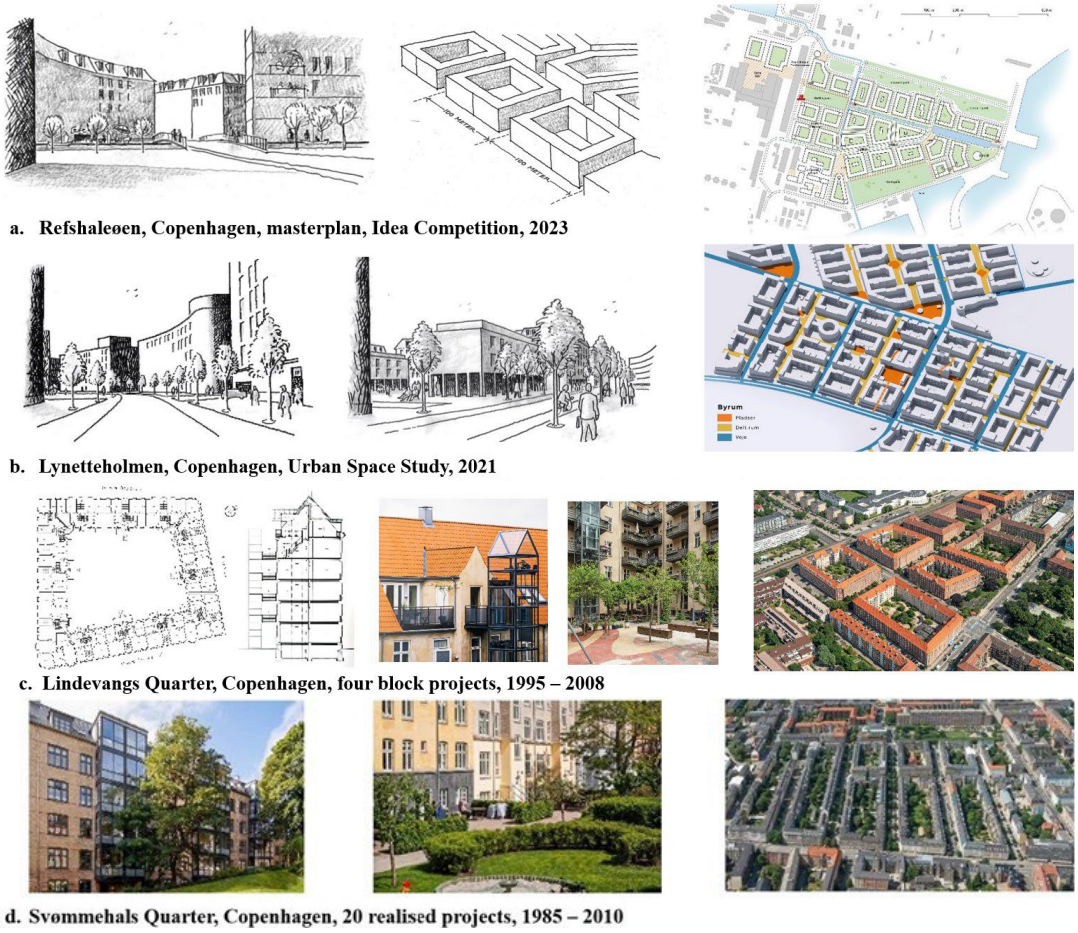


**Figure 3.** Project examples by K. Pålsson

**Note:** a – Refshaleøen. The masterplan design focuses on combining urban block design with quality spatial sequences and squares in a mix-use modern city area on a human scale. Principles: Cultural heritage, townhouses, streets and squares, private and public, mix-use city, spatial sequences, human scale and green structure; b – Lynetteholmen. Urban space Study for a planned new artificial island in Copenhagen to make room for more housing etc. Principles: Cultural heritage, townhouses, a basic structure of streets and squares, private and public areas, mixed city and human scale, as an alternative to proposed and high-rise building; c – Lindevangs. Transformation and modernisation of 1920s blocks with new bathrooms, kitchens, elevators/lifts, new housing area under the roofs and green yards, Principles: architectural unity and new green yards; d – Svømmehals. Transformation and modernisation of apartment of housing in 1900-blocks, illustrating the potentials and sustainability of urban block structures. Principles: maintaining/keeping architectural unity, improving housing quality by extensions with new kitchen- and bathrooms- towers, improving green yards and streets

**Source:** prepared by K. Pålsson (2023; 2025)

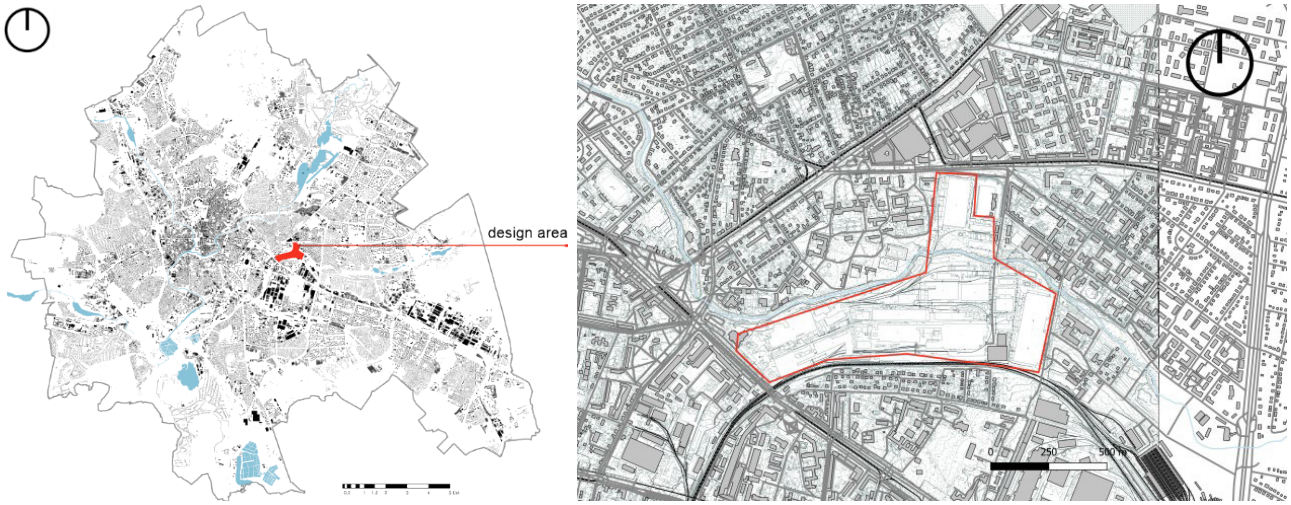


**Figure 4.** Urban planning conditions of the project site location
**Note:** a – design area in the city structure; b – design area in the district structure
**Source:** prepared by authors

At the third stage, the evaluation and interpretation of the workshop results were carried out. For this purpose, a comparative analysis of the conceptual proposals was conducted based on ten key principles of K. Pålsson's method: (1) cultural heritage and the urban block; (2) street-front development; (3) streets and squares; (4) the balance between private and public spaces; (5) mixed use; (6) human scale; (7) spatial sequences; (8) diversity; (9) architectural coherence; and (10) green structure.

The evaluation was performed from two perspectives: external and internal. The external assessment was based on expert comments provided by the author of the method regarding the degree to which its principles were reproduced in the participants' proposals. The internal assessment consisted of interpreting the results from the perspective of the Ukrainian professional environment, regulatory conditions, and historically formed patterns of design thinking. The design proposals were not evaluated according to predefined urban planning criteria, since the focus of the experiment was on the specific features of applying K. Pålsson's method in the course of solving design tasks within an urban situation characteristic of contemporary Ukraine. Accordingly, the study is limited to the analysis of K. Pålsson's method itself and the results of its application during the experiment. The proposed methodology enables the replication of the research process under comparable conditions, including a similar participant sample, an identical design task, a fixed set of evaluation principles, standardised workshop materials, and a dual framework for interpreting the results.

## RESULTS AND DISCUSSION

The experimental part of the study resulted in design proposals developed by six teams. These proposals reflected the participants' understanding of both the specific characteristics of the site and the principles of K. Pålsson's method. The tasks related to the functional and spatial organisation of the microdistrict territory were successfully addressed and complied with normative requirements, which was largely due to the strong professional composition of the teams. At the same time, the proposals differed in terms of their structural and functional organisation (compact or fragmented), the degree of internal and external spatial connectivity, morphological characteristics (building height, density, and block size), and the organisation of public spaces, including landscaped areas (Fig. 5).

The analysis and evaluation of the proposals were conducted in the context of the defined aim and research methodology. Thus, the degree of implementation of the ten principles of K. Pålsson's method across the six workshop group proposals is presented in Table 1. Thus, the principles of K. Pålsson's method that were most successfully reproduced include the block-based structure, human scale, and the green organisation of the territory, while the principle of balancing private and public space was implemented to a lesser extent. Nearly all teams proposed residential blocks proportionate to the street and courtyard, as well as spatial solutions in which internal courtyards compensate for the public character of the street network. Some projects included active ground floors, commercial functions along selected main streets, and green pedestrian connections. The results obtained correlate with contemporary research by I. Avila-Palencia & J. Lutzu (2024) and M. Bruno *et al.*, 2024linking the humaneness of the urban environment to the combination of accessibility, social interaction, mixed use, and the quality of everyday space.

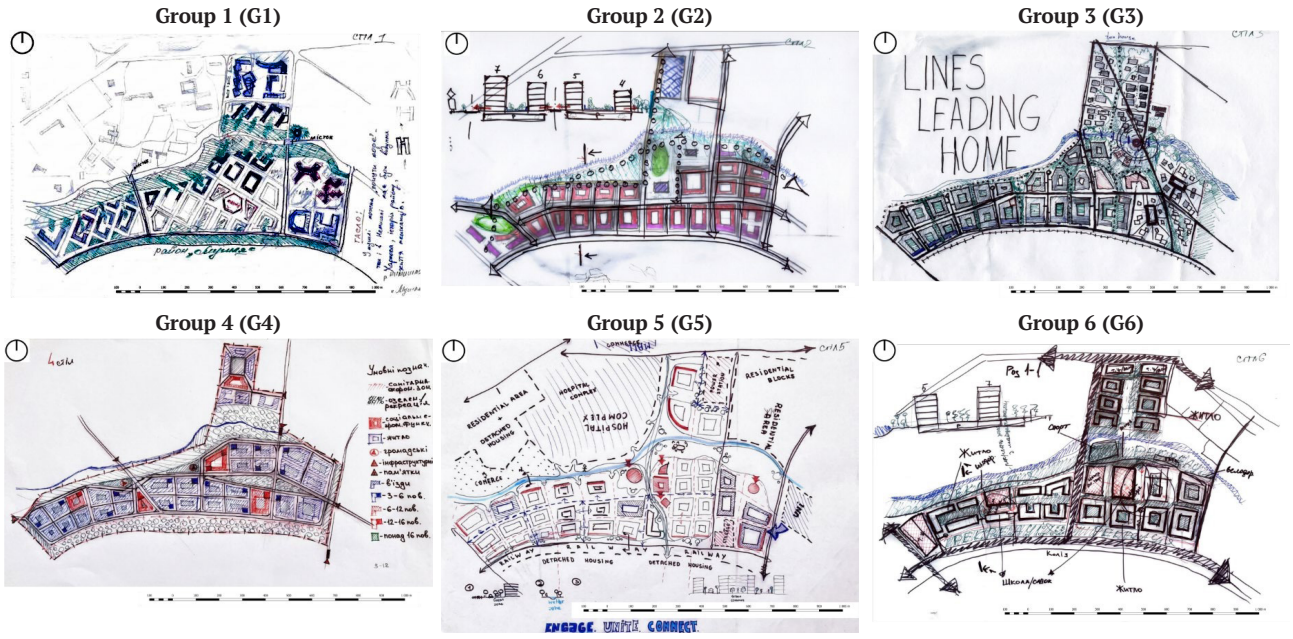


**Figure 5.** Conceptual proposals of the six workshop participant groups (LUF 2025, Lviv)

**Note:** Group 1 (G1) emphasises the orientation of residential streets toward the embankment, which serves as the main planning axis, as well as the creation of a compact service centre; Group 2 (G2) proposes an even distribution of urban blocks and service elements along an internal communication axis, combined with underground parking facilities; Group 3 (G3) suggests combining block-based development with traditional single-family housing and a compact public centre; Group 4 (G4) proposes a varied building height within the block-based structure and vertical accentuation of public service locations; Group 5 (G5) emphasises planning connections with the adjacent territory and an even distribution of blocks with integrated service elements; Group 6 (G6) proposes combining block-based development with residential complexes linked by an internal boulevard

**Source:** prepared authors based on workshop materials (LUF 2025, Lviv)

**Table 1.** Degree of implementation of the ten principles of K. Pålsson's method across six workshop group proposals

| No. | Principle | G1 | G2 | G3 | G4 | G5 | G6 | General interpretation |
|---|---|---|---|---|---|---|---|---|
| 1 | Cultural heritage / urban block | ± | + | + | + | + | ± | Most groups adopted the urban block as the main planning unit; Groups 1 and 6 retained more open or detached-building logic in parts of the site |
| 2 | Street-forming building frontage ("townhouse" logic) | + | + | + | + | + | ± | In most proposals, buildings form the street edge and are directly oriented toward the street |
| 3 | Streets and squares | ± | ± | ± | ± | ± | ± | Street grids were generally present, often close to the recommended 100 m module, but hierarchy of squares was not developed in any proposal |
| 4 | Balance of private and public spaces | + | ± | ± | ± | ± | ± | All proposals worked with the courtyard/street distinction, but several blocks were too small or had unclear boundaries between public paths and private courtyards |
| 5 | The mixed-use city | ± | + | ± | ± | + | ± | Mixed use was declared in all proposals, but more clearly articulated in Groups 2 and 5 |
| 6 | The human scale | + | + | + | ± | + | + | Human scale was generally respected; Group 4 introduced corner towers that weakened this principle |
| 7 | Spatial sequences | – | – | – | – | – | – | Street layouts were mostly too linear and lacked sufficient variation, enclosure, and sequential spatial experience |
| 8 | Diversity | N/E | N/E | N/E | N/E | N/E | N/E | Social and typological diversity could not be fully assessed at workshop concept stage because it depends on later implementation |
| 9 | Architectural unity | N/E | N/E | N/E | ± | N/E | N/E | Architectural unity could not yet be fully evaluated; Group 4 partially addressed it through a repeated corner motif |
| 10 | Green structure | + | + | + | + | + | + | Green courtyards, waterfront green zones, pedestrian links, and green corridors appeared in nearly all proposals |

**Legend:** + = implemented clearly; ± = implemented partially; – = weakly implemented / not implemented; **N/E** = not evaluable at this stage.

**Source:** prepared by authors based on workshop materials (LUF 2025, Lviv)

At the same time, a number of principles were implemented only partially. None of the proposals fully articulated a hierarchy of squares and public open spaces, and in most cases the street network remained overly uniform, lacking sufficient variation and spatial articulation. Spatial sequences, which in K. Pålsson's method are intended to create a progression of experiences and visual diversity during movement, were weakly expressed. Some teams also retained a tendency towards the use of freestanding buildings or open compositions, which contradicts the logic of a coherent urban block. This suggests, as noted V.A. Lipianin & T.O. Milash (2018), that Ukrainian participants more readily perceive the structural basis of the block-based approach than its more complex compositional and experiential components. Particular attention should be given to the principle of mixed use. Although almost all teams declared a combination of residential, service, and commercial functions, the depth of elaboration of this aspect varied significantly. In most cases, mixed use remained at the level of a general functional concept rather than a spatially detailed scenario integrating different types of activity within the block. This finding is consistent with C. Crosas *et al*. (2024) studies, demonstrating that mixed use is not an automatic outcome of block-based development but depends on broader economic, transport, and social conditions.

The external expert assessment also revealed that the limited duration of the workshop significantly influenced the depth of implementation of certain principles. This partly explains the lack of detailed elaboration of squares and their hierarchy, the variability of street types, and more complex spatial relationships. However, these limitations do not diminish the analytical value of the experiment; rather, they indicate directions for further work. These include the need for multi-stage workshops, more detailed design of the urban block as a fundamental unit, a stronger focus on functional mixing, and targeted training in the principles of structuring systems of squares and public spaces. The results also indicate that the participatory workshop format performed not only an educational but also an analytical function. The work of mixed teams made it possible to identify which principles of the method are reproduced intuitively and which require specific explanation and methodological guidance. In this context, the workshop can be considered an empirical test of the method's operability in the Ukrainian context. This conclusion is consistent with A. Akbulut Basar (2024) and P. Ng *et al*. (2024) researches on participatory design, which emphasises that the value of participation lies in the procedurally organised collective development of solutions rather than in the nominal involvement of participants.

To explain the selective perception of individual principles, a retrospective historical-comparative analysis of the development of block-based and microdistrict planning in Ukraine was also applied (Fig. 6). This made it possible to interpret the workshop results through the prism of three temporal horizons – past, present, and future – and to identify how the legacy of Soviet urban planning, the current regulatory framework, and the orientation towards contemporary European approaches influence the adaptation of the method. To further specify this influence, the historical experience of residential development in Ukraine was analysed as a factor shaping contemporary professional thinking among architects. The analysis focuses on three stages in the development of residential urban areas: block-based development of the first half of the 20th century (Fig. 6a), residential development of the second half of the 20th century, including both early and late stages (Fig. 6b, 6c), and post-Soviet transformations of the late 20th and early 21st centuries (Fig. 6d). This approach reveals which planning techniques, spatial concepts, and regulatory frameworks have been retained in professional thinking and may influence the contemporary perception of block-based urban logic.

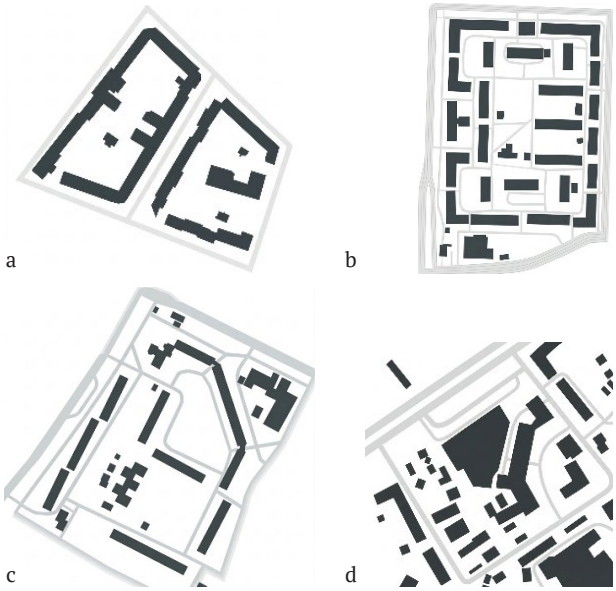


**Figure 6.** Historically formed types of residential development in Ukraine
**Note:** a – block-based development of the first half of the 20th century; b – microdistrict model of the second half of the 20th century (early stage); c – microdistrict model of the second half of the 20th century (late stage); d – post-Soviet transformations of the late 20th and early 21st centuries
**Source:** prepared by authors

The analysis showed that block-based development of the first half of the 20th century, despite the limitations of rigid functional organisation under conditions of suppressed social activity, established within professional culture an understanding of the street, square, block, and architectural ensemble as integral elements of the urban environment. In contrast, the model of the second half of the 20th century established a different spatial logic – large-scale open spaces, strict functional zoning, internal access roads, and the weakening of the role of the street as a social space.

In the post-Soviet period, this was further complemented by spontaneous transformations of ground floors, courtyards, and green areas, as well as by the predominance of a developer-driven logic focused on individual buildings or residential complexes over the logic of forming a coherent urban district. Consequently, the contemporary perception of the principles of block-based development according to K. Pålsson's method in Ukraine combines remnants of historical block-based experience from the totalitarian period, the inertia of modernist thinking, and new orientations associated with European human-centred approaches.

The interpretation of the results from an internal perspective demonstrates that the assimilation of the method's principles is largely determined by historically formed professional thinking. Principles related to the urban block, street network, courtyard, and human scale are grounded in the historical experience of Ukrainian urban planning and are therefore perceived relatively easily. In contrast, principles that require more complex spatial hierarchies, integrated scenario-based thinking, or a more flexible interpretation of streets and squares encounter the inertia of post-Soviet planning logic. This confirms that the adaptation of European human-centred approaches in Ukraine cannot be reduced to the simple transfer of formal design solutions. These results can be further explained through the historically formed multilayered nature of professional thinking in Ukraine. Principles related to the urban block, street network, courtyard, and human scale partially draw on the experience of block-based development of the first half of the 20th century. At the same time, the weaker reproduction of the hierarchy of squares, spatial sequences, and more complex scenario-based forms of urban space organisation may be associated with the prolonged dominance of the model of the second half of the 20th century, within which the street and square lost their role as fully fledged socio-spatial structures.

Post-Soviet practices of both infill and large-scale object-based development have further reinforced the orientation towards individual buildings or residential complexes rather than the formation of a coherent urban district. To better understand these results, it is important to consider not only the participants' immediate design solutions, but also historically formed conceptions of the residential environment that continue to influence contemporary professional thinking. For this reason, the results of the experiment were additionally interpreted through the prism of the main stages in the development of residential construction in Ukraine. This makes it possible to relate individual principles of K. Pålsson's methodology to those spatial frameworks that potentially support or, conversely, complicate their perception and practical implementation (Table 2).

**Table 2.** Historical layers of professional thinking and their influence on the perception of K. Pålsson's principles in Ukraine

| Historical stage | Dominant components of professional thinking | What potentially supports implementation | What potentially complicates implementation |
|---|---|---|---|
| **Block-based development of the first half of the 20th century** | Urban block, street, square, ensemble, clearly defined street frontage, as well as simplified models of everyday life and principles of microdistrict planning | Perception of the block as an integral spatial unit, human scale, and the role of the street within a spatial hierarchy of built form elements | Perception of the block as a factor of suppression of social activity, and the clear geometry of spaces as signs of totalitarianism |
| **Models of residential development in the second half of the 20th century** | Large-scale open spaces, rigid functional zoning, complex internal spatial structures, internal access roads, and the dominance of transport infrastructure, along with a reduced role of the residential street | Understanding of the residential environment as a complex system integrating development, services, and green spaces | False positive assessment of significant internal spaces, lack of a distinction between private and public spaces; insufficient understanding of the diversity of forms of public spaces |
| **Post-Soviet transformations (late 20th – early 21st century)** | Infill development of high density, residential complexes, commercialisation of ground floors, fragmented urban development, comfort-oriented and multifunctional housing environments | Organisation and partial preservation of transport infrastructure, functional mixing, increased attention to environmental quality, and differentiation between private and public spaces | Reinforces orientation to a separate object instead of preserving a holistic territory, contributes to the fragmentation of spaces and the dominance of developer logic |
| **Future stage of post-war recovery based on new urbanism principles** | Human-centeredness, resilience, spatial flexibility, multifunctionality, environmental sustainability | Supports the adaptation of block-based logic, public spaces, mixed use, participatory practices, and a more integrated approach to urban recovery | Inertia of previous models, regulatory constraints, lack of practical experience in implementing new approaches, and the risk of formal rather than substantive adoption of new urbanism principles |

**Source:** prepared by authors

To summarise the workshop results, the principles of K. Pålsson's method were systematised according to the manner in which they were reproduced in the Ukrainian context. This interpretation makes it possible to identify which principles were intuitively adopted by the participants, which were only partially implemented, and which require additional methodological support or could not be fully reproduced within the workshop format (Table 3).

**Table 3.** Interpretation of the implementation of K. Pålsson's principles in the Ukrainian workshop context

| Category | Principles | Interpretation in the Ukrainian context |
|---|---|---|
| **Intuitively reproduced principles** | Urban block; street-forming frontage; balance between private and public spaces; human scale; green structure | Correspond to a clear spatial logic and partially resonate with existing professional understandings of block-based development, street organisation, courtyard space, and low- to mid-rise residential form |
| **Partially reproduced principles** | Hierarchy of streets and squares; mixed-use development | Mostly implemented in a simplified form: street networks lack hierarchy, and public spaces lack typological diversity. Mixed use was often declared but remained schematic rather than spatially integrated at the block level |
| **Principles requiring methodological support** | Spatial sequences; reduction of freestanding buildings; architectural coherence; diversity | Require more developed compositional thinking, longer design time, and a clearer understanding of how urban form, ownership structure, architectural coordination, and lived experience interact in implementation |
| **Principles limited by the workshop format** | Diversity; architectural coherence | These aspects largely depend on later stages of the design process, including detailed development, ownership models, and architectural articulation, and therefore could not be fully tested within a short conceptual workshop |

**Source:** prepared by authors

Thus, the results of the study confirm that K. Pålsson's method has the potential to be implemented in Ukrainian architectural and urban planning practice; however, its practical application requires adaptation to local professional, regulatory, and socio-spatial contexts. The fundamental morphological elements of the block-based city are reproduced most successfully, whereas more complex compositional, functional, and procedural components require additional methodological support. This constitutes the main contribution of the study to the ongoing discussion on the transferability of human-centered European approaches to the post-Soviet context of Ukraine.

## CONCLUSIONS

The study has demonstrated that the tested block-based, human-centred planning method is generally understandable and suitable for initial application in the Ukrainian professional context. The Kharkiv workshop, focused on the post-industrial "Serp i Molot" site, showed that most participants were able to reproduce the core structural principles of the approach, including closed or semi-enclosed urban blocks, continuous street frontage, a regular street network, human scale, and the integration of green structure. This confirms that the basic morphological logic of block-based urban development is relatively accessible to Ukrainian architects and planners.

At the same time, the workshop revealed that more complex principles were implemented only partially. These include the hierarchy of squares and public spaces, the variability of the street network, spatial sequences, and the deeper functional integration of activities within the block. The proposals also showed that the distinction between private and public space, although generally understood, was not equally developed across all groups. These results suggest that Ukrainian participants more readily adopt the structural basis of the method than its compositional, scenographic, and scenario-based dimensions. The findings also confirm that implementation in Ukraine should be understood not as a direct transfer of the method, but as its adaptation to local professional traditions, regulatory frameworks, and the legacy of Soviet planning. In this sense, the workshop functioned not only as an educational format but also as an empirical test of the method's operability in a Ukrainian urban context.

Overall, the tested approach can provide a valuable basis for more coherent and human-centred urban transformation in Ukraine, particularly in post-industrial redevelopment and post-war reconstruction. However, its practical application requires staged adaptation, further methodological support, and broader use of participatory, multi-stage design formats.

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## CONFLICT OF INTEREST

None.

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# Впровадження людиноцентричного методу квартального міського планування в українському контексті: приклад Харкова

**Анотація.** Актуальність цього дослідження визначається необхідністю адаптації людиноцентричних підходів квартального міського планування до українського містобудівного контексту, сформованого пострадянськими моделями просторового розвитку та викликами повоєнного відновлення міст. Метою статті було визначення особливостей впровадження людиноцентричного методу квартального міського планування К. Полссона в українську архітектурну та містобудівну практику. Дослідження поєднувало теоретичний аналіз походження й складових цього методу в європейській містобудівній традиції з експериментальною апробацією у форматі воркшопу, проведеного на постіндустріальній території в Харкові. Результати засвідчили загальну придатність методу для українського контексту. Найуспішніше були відтворені такі принципи, як квартальна структура міста, безперервний фронт забудови вздовж вулиць, людський масштаб та інтеграція зеленої структури, тоді як баланс між приватним і публічним простором загалом був зрозумілий учасникам, але реалізовувався з різним ступенем послідовності. Змішане функціональне використання територій та організація вулиць і площ були реалізовані частково. Найскладнішими для впровадження виявилися принципи просторових послідовностей, ієрархії публічних просторів та зменшення ролі окремо розташованих будівель. Дослідження засвідчило, що цей метод потребує не прямого перенесення, а поетапної адаптації до місцевих професійних традицій, нормативних умов і соціально-просторового контексту. Отримані результати також показали, що воркшоп виконував не лише освітню функцію, а й був емпіричною перевіркою операційності методу в українському контексті. Практична цінність дослідження полягає в можливості застосування його результатів в освітніх воркшопах, проєктах територіального редевелопменту та під час розроблення методичних рекомендацій для українських громад

**Ключові слова:** міська морфологія; міські квартали; партисипативне планування; експеримент на основі воркшопу; пострадянський міський контекст

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# Integration of protected spaces into the structure of residential buildings in the face of constant military threat

**Abstract.** In the context of a constant potential threat to the civilian population, housing acquires the functions of a primary security environment, which requires a revision of the principles of its spatial planning organisation. The purpose of the study was to substantiate approaches to integrating protected spaces into the structure of residential buildings and determine the principles of their functional zoning in the context of long-term military threats. The study used methods of analysis of scientific sources, comparative analysis of planning decisions, generalisation of statistical data, spatial and functional modelling, and the method of included (participant) observation. The necessity of revising the conventional scheme of functional zoning of apartment premises under conditions of constant military threat was substantiated. It was proposed to adapt the spatial and hierarchical model of protected areas developed in the author's previous studies to the structure of a multi-storey residential building. The use of the structural core of the building as a basis for ensuring the evacuation and safety of engineering systems was justified. The expediency of redistributing the functional purpose of premises with the transfer of night stay zones to a zone with a high level of protection, close to the structural core of the building, was substantiated. The role of the internal buffer zone (bathrooms, dressing rooms, corridors) as spatial elements that reduce the impact of shock waves and debris was determined. It was proved that the facade area has the lowest level of protection and is used as a day space. An additional level of protection can be provided by applying an external energy-absorbing layer (balconies, loggias, facade systems). It was shown that the proposed approach contributes to the development of a more compact planning structure, which positively affects the energy efficiency of buildings, creating prerequisites for improving the energy efficiency of buildings. The scientific originality of the study consists in adapting a multi-level spatial and hierarchical model of protected areas of buildings to the structure of the residential environment and improving the principles of functional zoning of housing in accordance with the level of security of premises. The practical significance of the study lies in the possibility of applying the results obtained in the design of new residential buildings, adapting the existing housing stock, and in developing recommendations for improving the level of safety of residents by integrating protected spaces into the structure of residential buildings

**Keywords:** spatial and hierarchical model; residential environment; protection of the civilian population; functional zoning; protected space; multi-storey residential buildings

## INTRODUCTION

The years of the Russian-Ukrainian war (2014–2026) have shown that residential buildings in Ukraine are increasingly viewed not only as places to live, but also as environments designed to provide a basic level of protection in the event of a military threat. The experience of operating housing stock in the face of air alarms, rocket

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and drone attacks revealed problems related to the safety of residents and the possibility of their rapid movement to protective structures. These problems are particularly acute in multi-storey buildings, a significant part of which was designed without considering the long-term impact of military risks. This makes it necessary to find new approaches in which protected spaces are considered as a component of the building structure, and not as a separate element of the civil protection system.

The nature of contemporary military threats has led to a rethinking of the role of the residential environment as a space not only for living, but also for security. A. Chudzińska *et al*. (2025) noted the need to create new standards for protected spaces that combine the requirements of safety, sustainable development and everyday use. In Ukrainian studies, considerable attention was paid to the use of existing housing stock to increase the level of protection of the population. A. Bochkovskyi *et al*. (2025) explored areas for improving civil protection structures based on modern construction technologies, structural solutions, and life support systems. A significant amount of research was devoted to architectural, planning, and structural solutions of protective structures. H. Getun *et al*. (2023) defined the basic principles of spatial planning organisation of shelters, functional zoning, and their placement in the structure of buildings. M. Kyryliak *et al*. (2024) noted that contemporary approaches to the design of civil protection structures should focus on flexible spatial solutions adapted to different types of buildings and use cases.

In international studies on the war in Ukraine, protected spaces are increasingly considered as part of the everyday environment. A separate area of research is devoted to the international experience of organising the protection of civilians. S. Lee & S.-Y. Kim (2024) noted differences in approaches to integrating shelters into the structure of buildings and cities. M. Shapiro & N. Bird-David (2017) showed that in Israel, protected areas have become an integral part of the living environment. S. Malliiani & O. Slietsov (2025) and M. Chodorowski (2026), analysing the experience of Ukraine, Finland, and Israel, confirmed the prospects of Integrated protected spaces as one of the areas of development of contemporary residential typology. Studies of integrated approaches to civil protection also confirm the effectiveness of this area. A. Bubela & A. Osadchyi (2026) noted that integrating protected spaces into the structure of buildings reduces the time to reach a secure location. A. Jörgen *et al*. (2025) identified spatial accessibility, rapid shelter achievement, versatility, and adaptability to various threat scenarios among the basic principles of such systems. M.A. Jurczak & M. Tunkiewicz (2026) noted that improving the level of public safety requires not only new construction, but also risk-based reconstruction of existing shelters and integration of protective functions into the existing urban environment.

Further development of this area is presented in studies on the integration of protected spaces into residential buildings. O. Filonenko & D. Nikolaienko (2025) substantiated the feasibility of installing individual protective premises in extensions to multi-storey residential buildings, and M. Bordun *et al.* (2024) proposed the concept of multi-storey residential buildings with safety capsules integrated into the housing structure. The proposed approaches confirmed the gradual transition from the design of individual protective structures to the integration of the protective function into the residential environment. Despite a significant amount of research devoted to the organisation of shelters and civil protection structures, most of them consider such spaces as separate engineering objects or underground structures that function independently from residential development. A significant part of contemporary research focuses on the humanitarian, psychological, regulatory, or technical aspects of protecting the population, while the issues of integrating protected spaces directly into the functional and planning structure of residential buildings and their impact on the development of modern housing typology remain insufficiently studied.

The purpose of the study was to substantiate the principles of integrating protected spaces into the structure of residential buildings and determine their role in the development of modern housing typology in the context of long-term military threats. To achieve this goal, the following research objectives were defined: to analyse the current conditions of functioning of the residential environment in conditions of constant military threat; to investigate the international and Ukrainian experience of integrating protected spaces into residential architecture; to determine the principles of functional zoning of residential buildings considering different levels of space security.

## MATERIALS AND METHODS

The study was carried out within the framework of an architectural and typological approach, according to which a residential building is considered as a spatial system, the functional organisation of which changes under the influence of new operating conditions and safety requirements. The theoretical basis consisted in the concepts of integration of protected spaces into the living environment, international experience in designing security rooms and protective rooms, and a multi-level spatial and hierarchical model of protected areas of buildings and structures developed by the author (Zhydkova, 2026).

The source base of the study was made up of regulatory and technical documents of Ukraine in the field of residential building design DBN V.2.2-15:2019 (2019), DBN V.2.2-5:2023 (2023), DBN V.2.6-31:2021 (2021). These documents were used to assess the requirements for safety, functional zoning of housing, natural lighting, and energy efficiency of buildings when forming proposals for integrating protected spaces into the structure of the residential environment. The study also used international regulatory documents and recommendations regulating the organisation of protected spaces in the structure of buildings: FEMA 453 (2006), FEMA P-361 (2006), FEMA P-320 (2014), ICC 500 (2020), Civil Defence Shelter Act of

Singapore (1998). The Home Front Command's guidelines (2026) on the selection and organisation of sheltered spaces were used to analyse the Israeli experience.

The study was conducted in several consecutive stages. At the first stage, the analysis of the regulatory framework and scientific sources was carried out to identify contemporary approaches to organising the protection of the population in the residential environment. Special attention was paid to the requirements for the placement of protected spaces, the time of access to them, the conditions of people's stay, and the possibilities of integrating protective functions directly into the structure of residential buildings. Architectural and typological analysis was used to investigate the planning structure of residential buildings and identify potential areas suitable for performing protective functions. The analysis considered the location of the premises relative to the external facades, the nature of the structural scheme of the building, the possibility of autonomous functioning of individual premises, and the availability of escape routes. The comparative method was used to compare different models of integration of protected spaces into the living environment. The study compared Israel's MAMAD and MAMAK (Home Front Command, 2026), Singapore's Household Shelter and Storey Shelter, the American Safe Room and Shelter-in-Place approach (FEMA, 2019; FEMA P-361, 2021), and the Ukrainian practice of organising public protection. The comparison criteria were the level of integration into the structure of the building, functional use in peacetime, accessibility for residents, the length of autonomous stay, and the nature of threats from which protection is provided.

To assess the impact of military threats on the functioning of the residential environment, a generalisation of statistical data on air alarms on the territory of Ukraine was used. Analysis of data from Air alarm statistics in Ukraine (n.d.) allowed assessing the frequency and duration of periods of danger and characterise the conditions of functioning of the residential environment in conditions of constant military threat. At the final stage, spatial and functional modelling was applied, which was based on a multi-level spatial and hierarchical model of protected zones. Modelling determined possible levels of potential security of premises depending on their location in the building structure and form proposals for functional zoning of the residential environment. The level of potential security was considered as a relative characteristic of the space, which was determined by a set of indicators, including the location relative to external facades, the presence of structural protection, the availability of a protected area, and the possibility of people staying during short-term and long-term threats.

## RESULTS AND DISCUSSION

In international practice, the term "safe room" is used to refer to a specially equipped, protected room designed for people to take shelter in for a short period during emergencies. In the United States, the requirements for such spaces are defined by FEMA P-361 (2021), FEMA P-320 (2014), FEMA 453 (2006), and ICC 500 (2020), which regulate their structural stability, performance, and human safety criteria. Unlike typical Cold War underground storage facilities, the American approach is largely based on the concept of a local protected space (safe room), integrated into a residential or public building and capable of providing "near-absolute life safety" during extreme events. The current FEMA guidelines also demonstrate the transition from an exclusively evacuation response model to a shelter-in-place concept. Research on decision-making between evacuation and shelter-in-place shows that in the dynamic development of a dangerous situation, staying in an internal protected space can be a safer alternative to evacuation (FEMA, 2019; He *et al.*, 2025).

The most consistent models for integrating protected spaces into the residential environment are implemented in Israel and Singapore. In Israel, a system of MAMAD-type shelters is in use – integrated safe rooms within the structure of a flat, which are used as ordinary living spaces in everyday life, most often as a bedroom or a room belonging to one of the residents. During an air alert, other residents of the apartment use this room as the main shelter space. In addition to individual MAMADs, collective protected floor-level rooms (MAMAK) are also used. The Home Front Command regulations define the requirements for the placement, design characteristics, and functioning of such spaces, effectively integrating protective functions into the structure of the residential typology (Home Front Command, 2026). A similar approach is used in Singapore, where household shelters and story shelters are integrated into the structure of residential buildings at the regulatory level (Civil Defence Shelter Act of Singapore, 1998). In most cases, the household shelter is located directly in the apartment and is used as a storage room or auxiliary utility room, combining the functions of everyday use and public protection (Singapore Civil Defence Force, 2021; 2023).

Along with the concepts of safe room and shelter-in-place, the term panic room is also used – a reinforced interior in the structure of a residential building, designed to temporarily protect people in the event of an external threat. In design practice, such premises are characterised by reinforced enclosing structures, autonomous life support systems, protected entrances, and the possibility of short-term sheltering-in-place (Panic Room Installation..., 2025). Panic rooms, as a rule, have an individual character and do not form a separate architectural and typological system of housing. They are mainly focused on local security scenarios and do not provide for a long stay of people or functioning in the face of large-scale military threats.

The modern war in Ukraine has actualised the issue of integrating protective functions into the residential environment and adapting buildings to conditions of constant potential threat. The regulatory framework for the organisation of civil protection of the population in Ukraine consists of the Code of Civil Protection of Ukraine (2012) and DBN V.2.2-5:2023 (2023), which define the

requirements for the organisation of civil protection structures. The results of the analysis show that the key problem of the existing strategy for the protection of civilians is the focus on short-term emergencies. The strategy provides for the movement of the population during the alarm to normalised protective structures located within a certain radius of accessibility (300-500 m). However, the response time to an alarm, even in the western regions of Ukraine furthest from the enemy, does not exceed 5-6 minutes, according to the spatial model of the "war rose" proposed by A. Pleshkanovska & T. Zhydkova (2026). Under such conditions, moving to normalised protective structures becomes significantly more difficult, and for low-mobility groups of the population it often becomes impossible. This indicates that the existing defence strategy does not correspond to the real time, space and functional characteristics of the contemporary military threat. According to the statistics of the resource Air Alarm Statistics in Ukraine (n.d.), since the beginning of the full-scale invasion, as of April 24, 2026, the total number of alarms for the eastern regions of Ukraine, in particular Kharkiv, Zaporizhzhia, and Donetsk oblast, was more than 7 thousand (Fig. 1).

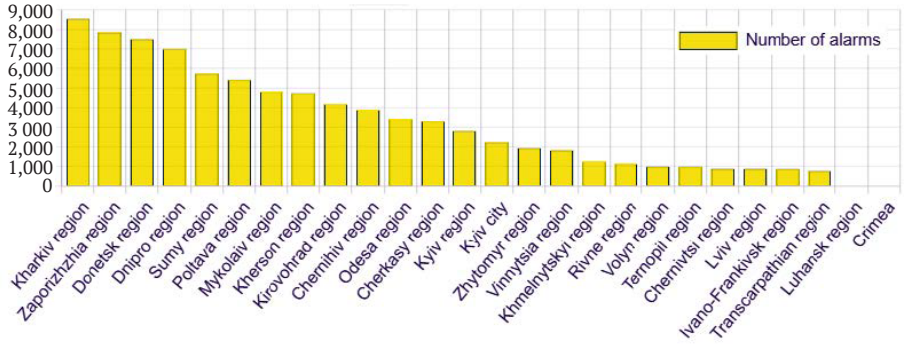


**Figure 1.** Number of air alarms as of 24.04.2026
**Source:** Air Alarm Statistics in Ukraine (n.d.)

The average duration of an alarm signal exceeds one and a half hours, and its repeatability on some days reaches eight times a day. A comparative analysis of the hourly number of alarms showed that a characteristic feature for all regions of Ukraine is an increase in the intensity of threats in the evening and at night (Fig. 2). This shows that the military threat is not episodic, but repeated and prolonged in nature and directly affects everyday scenarios for the use of the residential environment.

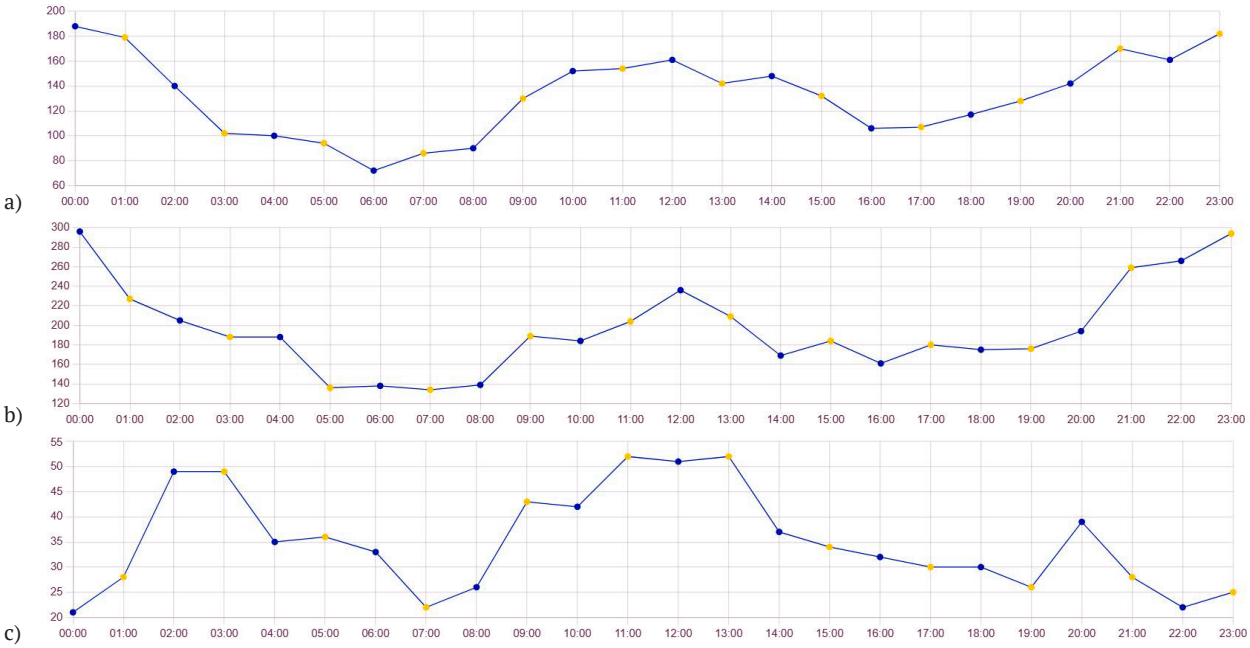


**Figure 2.** Number of air alarms hourly as of 24.04.2026
**Note:** a) Odesa Oblast; b) Kyiv Oblast; c) Lviv Oblast
**Source:** Air Alarm Statistics in Ukraine (n.d.)

Thus, the conditions of contemporary war form a different reality of human life: the threat is constant, repetitive, and unpredictable, which makes it impossible for housing to function according to the logic of "peaceful living + occasional shelter". Under these conditions, residents are forced to stay in their own apartments during air alarms and missile strikes. Under such conditions, residential buildings actually begin to perform the function of a primary security environment, which significantly increases the requirements for the level of security of their architectural and planning structure. In addition to the immediate threat to the life and health of the population, repeated air alarms significantly affect the daily functioning of the residential environment. A special feature of modern warfare is that the greatest intensity of threats occurs in the evening and at night, when housing performs the functions of rest and sleep. Long-term preservation of this situation changes the requirements for the organisation of living space, since a significant part of the population is forced to spend night time in conditions of increased risk or repeatedly move to protective structures. Under such conditions, safety ceases to be considered exclusively as a function of external protective structures and begins to influence the principles of forming the residential environment itself. This makes it necessary to review conventional approaches to functional zoning of apartments and integrate protected spaces directly into the structure of residential buildings.

The study by V. Hakala *et al*. (2025), K. Peltonen *et al*. (2025) and W. Carter (2025) showed that prolonged exposure to military danger is accompanied by a deterioration in the psychoemotional state of the population and requires the development of a safe environment for everyday stay. Under such conditions, not only civil protection structures are of particular importance, but also the level of protection of the residential environment itself. Thus, housing takes on a dual function, combining the living space and the basic security space. This makes it necessary to review the traditional principles of functional zoning and consider the level of potential security of premises when designing residential buildings. The spatial planning structure of most modern single-section multi-storey residential buildings is based on the presence of a central structural core, where vertical communications (staircase and elevator node) and the main engineering networks of the building are located. Access to apartments is provided through extra-apartment corridors. In the traditional scheme of functional zoning, living rooms – bedrooms, children's rooms, living rooms, and kitchens – are placed along the external contour of the building.

Previous studies have proposed a multi-level spatial and hierarchical model of protected areas of buildings and structures (Zhydkova, 2026). In this study, the concept of security level was used as a relative architectural and planning characteristic of a space. The proposed model is conceptual in nature and is not intended to determine the actual resistance of structures to explosive loads. As part of this study, it was used to analyse the location of premises in the structure of a building and identify areas with different levels of potential security depending on their position relative to the facade, the number of structural obstacles, and proximity to the structural core of the building. Issues of the actual level of protection require separate engineering studies.

According to the proposed model, the residential floor is divided into several zones, separated from each other by internal walls and partitions. The level of potential security of premises consistently increases from the facade of the building to the staircase and elevator node (Zhydkova, 2026) located in the central part of the building (Fig. 3). Analysis of damaged residential and public buildings in Kyiv and Kharkiv, carried out based on field surveys and included observation, showed that the nature of destruction of individual premises largely depends on the number of consecutive structural elements between the external environment and the internal space of the building. Therefore, balconies and loggias can serve as an additional buffer layer between the external environment and the apartment. That is why summer rooms are considered as an additional spatial level between the facade and the interior of the apartment. The nature of their impact depends on the design of the building, the type of damage, and the location of damage and requires further experimental and computational verification. In most modern monolithic-frame residential buildings, columns, pylons and inter-storey floors are load-bearing, while external walls perform mainly enclosing functions. Within the framework of the proposed model, rooms located along the facade are considered as those that are the first to perceive the influence of external damaging factors.

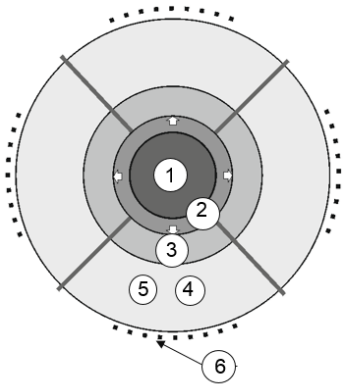


**Figure 3.** Spatial planning structure of existing multi-storey buildings (floor diagram)
**Note:** 1 – escape routes; 2 – extra-apartment corridors; 3 – entrance hall, dressing rooms, bathrooms; 4 – common area – kitchen, living room, study; 5 – private area – bedrooms, children's rooms; 6 – summer rooms (balconies, loggias)
**Source:** developed by the author

Sanitary and hygienic rooms are usually located in the interior of the apartment and are separated from the facade by other rooms. The availability of plumbing equipment, ceramic coatings, and glass elements does not give grounds to consider them as specially protected spaces

without additional adaptation measures. According to the findings of previous studies (Zhydkova, 2026), the highest level of potential protection within a residential floor is provided by corridors outside individual apartments, separated by load-bearing walls, and areas directly connected to the stairwell and lift lobby. It is these spaces that can be considered as the basis for integrating protected areas into the structure of residential buildings. This zone is formed by the load-bearing structures of the building and is characterised by the highest level of protection, since it has minimal contact with the external environment and provides the possibility of evacuation of people in case of partial destruction of the building, provided that alternative power sources for elevators are available. This area also houses a network of internal building services with a horizontal distribution system to each appartment, which ensures that the water, heating and electricity supplies to the undamaged part of the building are maintained in the event of damage to part of the building. When using apartment-by-apartment distribution systems for engineering networks, this creates prerequisites for maintaining the functioning of intact parts of the building in the event of local damage to its individual sections (Fig. 4). During field surveys, cases were recorded when the external elements of enclosing structures suffered major damage, while the internal contours of the premises suffered less damage. In particular, in buildings with double glazing, the outer row of glass was destroyed in rare cases, while the inner row remained intact.

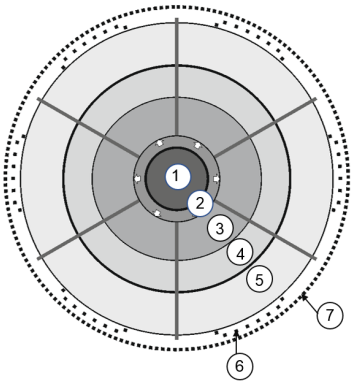


**Figure 4.** A spatial and hierarchical model of safety zones within the structure of a multi-storey building (floor plan)
**Note:** 1 – protected core (escape routes, utilities); 2 – intermediate zone (extra-apartment corridors); 3 – zone with a high level of protection (entrance hall, bedrooms, children's rooms); 4 – zone with an average level of protection (bathrooms, dressing rooms, storerooms, corridors); 5 – facade zone (kitchens, living rooms, offices) – low level of protection; 6 – summer rooms (balconies, loggias); 7 – facade systems
**Source:** developed by the author

A similar principle can be traced in the designs of balconies and loggias, which form an additional spatial layer between the external environment and living spaces. Within the proposed spatial and hierarchical model, balconies, loggias, terraces, and facade systems are considered as the external level of spatial protection of the building. This assessment is conceptual in nature and reflects the features of the spatial organisation of the building, and not the actual resistance of structures to specific types of damage, which requires separate engineering studies. In this study, additional glazing of loggias and balconies is considered as a protective shell – an additional structural layer located between the source of possible damage and the main structures of the building. Within the framework of the proposed concept, individual elements of such a shell can have a sacrificial character and be designed for local damage or destruction during external influence. It is assumed that this will allow localising some of the damage within the external contour of the building. These proposals are conceptual in nature and require further experimental and computational verification.

This approach allows ensuring the continuity of life of the civilian population in conditions of constant potential threat, combining the requirements of safety, functionality, and psychological comfort. Furthermore, in bedrooms and children's rooms, it is advisable to provide an alternative escape route from night stay areas. In everyday life, communication with all the premises of the apartment is provided through internal corridors, or directly, and in case of destruction of the premises of the facade zone, an evacuation exit close to the entrance door is used. Thus, within the residential floor, a hierarchical system of levels of protection of premises is formed, in which the safest rooms are located in the central part of the building surrounded by load-bearing structures, while facade and open spaces are characterised by the lowest level of protection. The presence of protected areas within apartments does not exclude the need to use specialised protective structures in case of high-intensity threats. However, it provides an additional level of daily security and reduces dependence on the need for immediate movement to shelters. The proposed spatial and hierarchical model has the potential not only to increase the level of protection of the residential environment, but also to improve its economic and energy characteristics. The development of a more compact planning structure and increasing the depth of the building helps to improve the ratio of the internal volume of the building to the area of external enclosing structures. Accordingly, the area of facades through which the main heat losses occur decreases, which is consistent with the general principles of energy-efficient building design laid down in DBN V.2.6-31:2021 (2021).

In addition, the concentration of more apartments around one staircase and elevator node allows one staircase and elevator node to serve a larger number of apartments. This contributes to a more rational use of communication spaces and engineering infrastructure, and also allows partially compensating for additional costs associated with increasing the level of protection of the residential environment. The introduction of a multi-level system

of protected spaces allows distributing protection functions between different levels of the residential environment, depending on the nature and level of the threat. In this case, the protection of the population is provided not only through civil protection structures, but also through the use of internal spaces of the building with different levels of potential security. Simultaneously, civil protection structures remain the main means of protecting the population during long-term or most dangerous scenarios. Simultaneously, individual elements of the spatial and hierarchical system, subject to appropriate design, can potentially provide a level of protection comparable to the requirements for the simplest shelters, and in some cases – approach individual requirements for anti-radiation shelters. Final confirmation of this possibility requires separate engineering and calculation studies. Under such conditions, there is a need for a more flexible organisation of the public protection system and allows partially distributing protective functions between the building and specialised protective structures.

The results obtained indicate that the security factor is beginning to play the role of one of the determining factors in the development of the contemporary housing environment. If during the 20th-beginning of the 21st century, the development of housing typology took place mainly under the influence of social, demographic, economic, sanitary, and energy requirements, then present-day conditions of military danger form a new group of requirements related to ensuring the safety of the population directly in the place of residence. In contrast to the conventional approach, in which housing was considered primarily as a living space, and the protection function was assigned to separate civil protection structures, current conditions require consideration of a residential building as an element of a multi-level security system. In this case, not only the presence of a shelter becomes important, but also the spatial organisation of the building itself, the ability to quickly transition between zones with different levels of potential security, and the adaptation of functional zoning to conditions of constant threat. The proposed approach actually changes the traditional logic of functional zoning of housing. In most modern apartments, long-stay rooms, in particular bedrooms and children's rooms, are placed along the facade, since it is there that the standard indicators of natural light and insolation are provided (DBN V.2.5-28:2018, 2018). The results of the study indicate that from the standpoint of safety, it is most appropriate to place the premises of night stay closer to the structural core of the building. That is, the security factor begins to influence the principles of functional zoning of housing on a par with the requirements of insolation, lighting, comfort, and energy efficiency.

An important consequence of the proposed approach is a change in the role of internal communication and auxiliary spaces. Corridors, walk-in closets, storerooms, and other rooms that have conventionally been considered auxiliary take on the importance of buffer zones between the external environment and rooms where people stay for a long time. Accordingly, the role of the facade shell of the building is also changing, which is considered not only as a enclosing structure, but also as the first spatial level of protection. The results obtained allow considering the integration of protected spaces as one of the promising areas for further development of residential typology. This does not involve replacing civil defence shelters, but rather creating an additional layer of everyday safety through the rational spatial organisation of the residential environment. This approach is especially relevant for multi-storey buildings in large cities, where access to normalised protective structures is often limited, and a significant part of the population is forced to stay in their own homes during air alarms. The proposed model has a conceptual character and reflects primarily the architectural and planning patterns of the establishment of protected spaces. The issues of actual stability of structural systems to explosive loads, the effectiveness of protective shells and quantitative assessment of the level of protection require separate engineering studies and can become the direction of further scientific developments.

The results obtained are partially consistent with the conclusions of I.O. Yurchenko (2025), who considered the basements of residential buildings as a reserve for expanding the fund of civil protection structures, and A.V. Hasenko *et al*. (2025), who noted a significant shortage of protective structures and uneven location in existing residential areas. The study showed that in conditions of repeated air alarms and limited response time, the development of a network of underground shelters does not solve the problem of timely access of the population to protection. In contrast to these studies, the paper suggests considering the problem at the level of the architectural and planning structure of a residential building and using the building itself as an element of the civil protection system. The results of the study are also consistent with the findings of K. Brackstone *et al*. (2026) on the need to consider the specifics of development and the needs of different population groups. The analysis showed that the level of potential security depends on the location of the space relative to the outer shell and the structural core of the building, which gives grounds to consider a residential building as a system of spaces with different levels of protection. Conclusions of M. Howlett *et al*. (2025) on the use of underground spaces as elements of wartime social infrastructure was also confirmed. The results of the study indicate that in conditions of prolonged and repeated air alarms, protective functions cannot be limited only to underground structures, but should be integrated into the structure of residential buildings.

Thus, a comparative analysis showed that the problem of protecting the population in the face of military threats cannot be considered only through the expansion of the network of underground shelters. It is important to move from separate protective structures to an integrated system of safe spaces within a residential building. The most promising approach is that the architectural and planning structure of the house considers different levels of security

of premises, depending on their location, accessibility, and connection with the structural core. This allows considering a residential building not only as an object of residence, but also as an element of the everyday civil protection system. In this context, security becomes one of the key factors for the further development of housing typology.

## CONCLUSIONS

The study showed that the current conditions of constant military threat make it necessary to move from the traditional approach, in which the protection of the population is provided mainly by individual civil protection structures, to the integration of the protective function into the structure of residential buildings. The analysis of international experience confirmed the prospects of this approach for the development of modern residential architecture. Based on the results of the study, a multi-level spatial and hierarchical model of protected areas of a residential building was proposed, which includes seven levels of security. The main criteria for their development are the spatial position of the premises relative to the external contour of the building, the number of protective barriers between a person and the source of damage, the functional purpose of the premises, and the possibility of their use during various scenarios of military threat. In contrast to existing approaches, the proposed model allows assessing the level of security of the entire planning structure of a residential building, and not just individual protective rooms or structures.

It was established that the application of the proposed model changes conventional approaches to functional zoning of housing. Rooms of long-term stay of residents, primarily bedrooms and children's rooms, should be placed in areas with the highest level of potential security. Kitchens, storerooms, and other auxiliary rooms can serve as a buffer layer, while living rooms, loggias, balconies, and rooms along external facades require additional architectural and structural protection. Communication nodes are considered as the basis for forming the internal protected core of a residential building. Further research should be aimed at developing a methodology for quantifying the level of security of individual areas of a residential building, substantiating architectural and planning solutions for different types of housing, and adapting the proposed model to public buildings.

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## CONFLICT OF INTEREST

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# Інтеграція захищених просторів у структуру житлових будівель в умовах постійної воєнної загрози

**Анотація.** В умовах постійної потенційної загрози для цивільного населення житло набуває функції первинного середовища безпеки, що потребує перегляду принципів його об'ємно-планувальної організації. Метою роботи було обґрунтування підходів до інтеграції захищених просторів у структуру житлових будівель та визначення принципів їх функціонального зонування в умовах тривалих воєнних загроз. У дослідженні використано методи аналізу наукових джерел, порівняльного аналізу планувальних рішень, узагальнення статистичних даних, просторово-функціонального моделювання, а також метод включеного (учасницького) спостереження. Обґрунтовано необхідність перегляду традиційної схеми функціонального зонування приміщень квартир умовам постійної воєнної загрози. Запропоновано адаптацію просторово-ієрархічної моделі захищених зон, розробленої в попередніх дослідженнях автора, до структури багатоповерхового житлового будинку. Обґрунтовано використання конструктивного ядра будівлі як основи забезпечення евакуації та збереження інженерних систем. Обґрунтовано доцільність перерозподілу функціонального призначення приміщень із перенесенням зон нічного перебування у зону з високим рівнем захисту, наближену до конструктивного ядра будівлі. Визначено роль внутрішньої буферної зони (санвузли, гардеробні, коридори) як просторових елементів, що зменшують вплив ударної хвилі та уламків. Доведено, що фасадна зона має найнижчий рівень захисту та використовується як простір денного перебування. Додатковий рівень захисту забезпечується шляхом застосування зовнішнього енергопоглинаючого шару (балкони, лоджії, фасадні системи). Показано, що запропонований підхід сприяє формуванню більш компактної планувальної структури, що позитивно впливає на енергоефективність будівель що створює передумови для підвищення енергоефективності будівель. Наукова новизна дослідження полягає в адаптації багаторівневої просторово-ієрархічної моделі захищених зон будівель до структури житлового середовища та удосконаленні принципів функціонального зонування житла відповідно до рівня захищеності приміщень. Практична цінність роботи полягає у можливості застосування отриманих результатів при проєктуванні нових житлових будинків, адаптації існуючого житлового фонду, а також у розробці рекомендацій щодо підвищення рівня безпеки мешканців шляхом інтеграції захищених просторів у структуру житлових будівель

**Ключові слова:** просторово-ієрархічна модель; житлове середовище; захист цивільного населення; функціональне зонування; захищений простір; багатоповерхові житлові будівлі

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