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Architectural and artistic features of the Church of the Most Holy Mother of God Cathedral in the village of Remeniv, Lviv region

Abstract. The relevance of this study lay in the investigation of the Church of the Cathedral of the Most Holy Mother of God in the village of Remeniv, Lviv region, which belonged to the Galician authentic architecture of the early 20th century. Its design was based on the Byzantine cross-shaped structural type of churches, stylistically combined with traditional Ukrainian art. The purpose of the study was to analyse the spatial and planning structure of the church and to identify its characteristic architectural and artistic features. The research methodology was based on a comprehensive approach, using both theoretical and empirical research methods, including historical-architectural analysis (stylistic and architectural-compositional). This article was the first to explore the architectural-spatial structure of the Church of the Cathedral of the Most Holy Mother of God in Remeniv. The study identified the characteristic features of architectural expression, which were primarily manifested in the church's planning, its compositional, stylistic, and plastic solutions. It had been found that the architectural image of the Church of the Cathedral of the Most Holy Mother of God reflected the stylistic and constructive features typical of churches in Western Ukraine in the early 20th century. The plastic and stylistic design of the iconostasis and side altars of the church had also been analysed. It had been established that the church under investigation had significant architectural and artistic value, reflects national identity in architecture, and belongs to the cultural heritage of Ukraine. The monument not only reflected the spiritual and national cultural worldview of society during a specific historical period, but also demonstrated a high level of craftsmanship, building skill, and artistic quality. The practical value of this research lay in the application of its findings in the theory of Ukrainian architecture and in the further study of this sacred heritage site

Keywords: nave; facades; altars; church interior; paintings; iconostasis; stained glass windows

INTRODUCTION

In the social life of the Ukrainian people, churches played a special role as the main spiritual and cultural centres of society. Accordingly, great attention was paid to the artistic decoration of the shrines. Church architecture had special architectural imagery, stylistic richness, artistic and compositional features, and cultural and religious significance.

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Ukrainian churches are rich with architectural forms, compositional and constructive solutions, and have a majestic harmony created by ancient architects according to canons. Depending on the level of artistic craft and construction skill, the sacred building acquired artistic expressiveness. The Ukrainian churches built at the end of the 19th and the beginning of the 20th centuries had characteristic architectural, constructive, and artistic features that speak eloquently about that period. At the beginning of the 20th century, the Ukrainian Church actively supported artists, architects, and artists, and stimulated the development of contemporary art. The study of the peculiarities of the national architecture of Ukrainian churches at the beginning of the 20th century and their influence on the development of sacred architecture as a whole became especially relevant. Such churches included the Church of the Cathedral of the Most Holy Mother of God in the village of Remeniv near Lviv. The study of the church represented a cognitive aspect in the study of the national sacred architecture of the specified period.

The study of national identity in the sacred art of Galicia in the first half of the 20th century was devoted to the work of M. Studnytska & R. Studnytskyi (2021). The search for the national style of the churches of Western Ukraine was studied by O. Diachok (2020). N. Novoselchuk (2022), examining Ukrainian modernism in the context of overall cultural development, characterised churches in the Poltava and Kharkiv regions. B. Cherkes *et al*. (2019) analysed the work of western Ukrainian architects from the late 19th to early 20th century, noting the national church identity in their sacred heritage while considering the latest trends in European construction. In their work, B. Cherkes & O. Dyachok (2019) analysed the state of preservation of sacred structures in small towns and villages in the lands of Galician Podillia. O. Herii (2021), studying national ornamentation in the interiors of churches in Western Ukraine from the late 19th century, established that artists used medieval ornamentation combined with traditional Ukrainian patterns in their church decorations. S. Olianina (2019) in her work, studied the volumetric structure of monumental Ukrainian iconostases and the factors influencing their architectonics. M. Pelekh (2022) thoroughly investigated the stylistic and iconographic features of iconostases and altars of churches in Galicia in the period after the Zamoyski Cathedral. Artistic and figurative aspects and features of the manufacture of classical stained glass windows were studied by I. Gakh (2019).

The purpose of the article was to analyse the architectural-spatial structure and artistic qualities of the Church of the Cathedral of the Most Holy Mother of God in the village of Remeniv, Lviv region, to identify the characteristic features of the architectural-artistic solution of the church and to determine the value of the monument.

MATERIALS AND METHODS

The methodology of the study of the Church of the Cathedral of the Most Holy Mother of God in Remeniv, built at the beginning of the 20th century, was based on the application of general scientific (empirical, theoretical) and special professional methods and reveals ways of understanding the architectural and artistic image of the temple. At its core, the study contained a scientific search for studying the regularities of building a church in existing situational conditions, its artistic solution in the absence of a source base about the sacred structure under study.

The visual inspection of the sacred architectural monument carried out at the first stage of the study made it possible to determine the range of urgent problems of the phased study and allowed to schematically record the planning and spatial structure of the Church of the Holy Mother of God in Remeniv. The analysis of literary sources made it possible to determine the level of study of the object. In the process of analysing cartographic sources, it was possible to determine the topographic conditions of the area in which the Church of the Cathedral of the Most Holy Mother of God in Remeniv was built. By analysing archaeological excavations conducted on the territory of the village of Remeniv, its ancient origin of the cultures of the Early Scythian period, the Chernyakhiv and Princely periods (11th-13th centuries) was determined (Konoplia & Oprysk, 2009). Using the method of art analysis, the artistic features of the early 20th-century church architecture and decorative decoration were revealed, and the artistic value of the temple was determined. On the basis of the analysis of artistic and plastic means of solution, the characteristic features of architecture and artistic features of the solution of the Remeniv church were determined. The compositional analysis made it possible to reveal the volumetric architectural and constructive structure of the Church of the Cathedral of the Most Holy Mother of God and to reveal the regularities of its compositional solution. The stylistic analysis made it possible to study the individual features of the architectural and artistic solution of the church architectural monument. On the basis of the conducted stylistic and compositional analysis, the theoretical part of the study of the Church of the Cathedral of the Most Holy Mother of God in the village of Remeniv, Lviv Region was formed to study the features of the sacred building of the beginning of the 20th century.

RESULTS AND DISCUSSION

The ancient village of Remeniv of the Early Scythian, Chernyakhiv and Princely Cultures (11th-13th centuries), located on both sides of the Dumnytsia River, a tributary of the Poltva River, 21 km from the regional centre – the city of Lviv and 21 km from the Kamianka-Buz district centre (Konoplia & Oprysk, 2009) (Fig. 1). The village is located in favourable natural climatic conditions for population living and farming. Remeniv is located in the western part of the territory of modern Ukraine. The road from Lviv to Volyn passed near the village of Remeniv. The first mentions of the village date back to 1399. In 1649, the village had four acres of land, and the village belonged to Teofila Danylovych and Jacob Sobieski (the parents of the Polish

king Jan III Sobieski). The village was repeatedly resold and passed to different owners, whose estates suffered from frequent fires due to the disobedience of the village community (Laba, 2020).

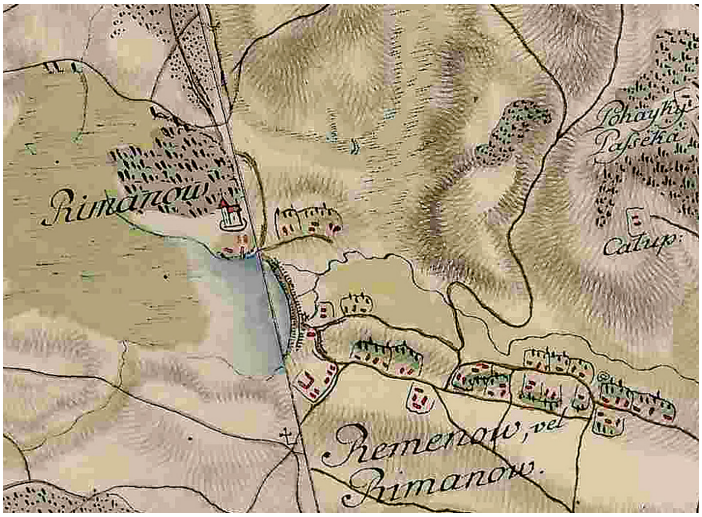

Figure 1. The original Church of the Cathedral of the Most Holy Mother of God on the map of F. von Mig in the village of Remeniv
Source: Remeniv – detailed printable paper map (n.d.)

On the western outskirts of the village of Remeniv, on a hill, stands the majestic Orthodox Church of the Cathedral of the Holy Virgin (Fig. 2), which dominates the village buildings. The establishment of the feast of the church of the Cathedral of the Most Holy Mother of God belongs to the early times of the Christian Church. In the 4th century, Bishop Epiphanius of Cyprus, as well as Saint Ambrose of Mediolanus and Blessed Augustine, in their teachings on the Christmas of Christ, combined the praise of the newborn baby Jesus with the praise of the one who gave birth to him – the Virgin Mary. The Cathedral of the Holy Mother of God is celebrated on the second day after Christmas. This celebration was established by the VI Ecumenical Council held in 681. The holiday glorifies the Mother of God and celebrates all the privileges given by God to the Virgin Mary: incarnation, virginity, and motherhood.

Figure 2. Church of the Cathedral of the Most Holy Mother of God on the topographic map of the village Remeniv
Source: Satellite map of the village Remeniv (n.d.)

The brick church was built in 1908 according to the project of the architect Kazimir Rychytskyi (Kazimezh Zhechytskyi) next to the original wooden church (Slobodian, 1998) as a Greek Catholic temple. Since July 31, 1991, the church had been registered as an Orthodox Church of the Cathedral of the Most Holy Mother of God

of the Kyiv Patriarchate, and since 2019 the church had been functioning as part of the Lviv-Sokal Diocese of the Orthodox Church of Ukraine (OCU). Initially, a wooden church was built in Remeniv in 1726 in honour of the Flight into Egypt of the Blessed Virgin Mary (Fig. 3). It was consecrated by the dean of Kulikiv, Father Ivan. The date of construction was engraved above the entrance door of the church and also indicated in the inventory of 1838 (Laba, 2020). The wooden church was three-log, one-story, the square log of the nave at the dome turned into an octagonal shape, oriented with the altar to the east. The plan of a three-log church with three log cabins arranged in a straight line from east to west had been known in the Ukrainian tradition of wooden church building since the 16th century (Antonovych, 1925). The three-story church in Remeniv was covered with one high dome above the middle log. The dome and the roofs above the babynets (women's vestibule) and altar were covered with shingles. The material for building the church was oak and pine. The floor of the temple was laid with boards. The church had an iconostasis decorated with carvings with four icons of the first tier. In the altar on the throne was a carved ark There was a carved ark (ostensorium) for storing the Holy Mysteries of Antimins with relics. The altar was decorated with a large central icon of the Nativity of Christ on a wooden base in the shape of a sphere in a wooden carved frame. The image of the Transfiguration of the Lord on canvas was placed above the altar. On the left, in the wall transom, there was credence table, above which was placed an icon of the Virgin Mary on a wooden base, next to the Shroud, painted on canvas. The church had a carved wooden iconostasis, which was restored in 1874. The church was bright and spacious with two oak doors – from the west and from the south. When the wooden church was dismantled in 1910, the iconostasis was sold in the village of Zibolka (Laba, 2020).

Figure 3. The original wooden Church of the Cathedral of the Most Holy Mother of God in the village of Remeniv, 1726
Note: dismantled in 1910
Source: V. Slobodian (1998)

There was a cemetery near the church, surrounded by a fence, to which a gate from the priest's garden and a door from the street led. A wooden belfry was placed on the side, sheathed with boards and covered with shingles, covered with a shingle roof, which had 3 bells. In 1906, due to the dilapidation of the wooden church, the parish committee headed by the rector of the church J. Ivanets decided to build a new brick church. Priest J. Ivanets asked the architect Kazimierz Zhechytsky to develop a project and estimate for a single-domed brick church. However, the community and other members of the parish committee wanted the church to have three domes over the narthex, nave, and altar. Priest J. Ivanets decided that the church should have one main dome and two front domes above the narthex. At the same time, an agreement was concluded with the church builder Vasyl Spodenko from Olesk, and materials (lime, brick, stone, and sand) for the construction of the new church began to be brought. In the spring of 1907, the construction of a new brick church in honor of the Cathedral of the Holy Virgin began next to the old wooden church. The construction of the temple was completed on November 7, 1908, although the finishing works continued until August 4, 1909 (Laba, 2020).

It was worth noting that Kazimierz Zhechytskyi was born in 1875 in Ivanivka, graduated from the architectural faculty of the Lviv Polytechnic, after which, in order to deepen his knowledge, he travelled to Germany, Italy, and France. He also developed the projects of the Church of the Transfiguration of the Lord in the village of Potorytsia, Sokal district (1909, destroyed in 1964) (Slobodian, 1998), in the village of Sknyliv, Zolochiv district (Laba, 2020) and the church in Sokolovtsi, Buska district (1904) (Lewicki, 2005). The Church of the Cathedral of the Most Holy Mother of God in Remeniv is located on a hill, on the outskirts of the western part of the village, and is the main town-planning dominant and is well visible from a long distance. Stairs leading to the church from Zarichna Street lead to a well-arranged courtyard, in the centre of which the church is located.

The architecture of the church was executed in the style of historicism of the beginning of the 20th century, characteristic of the Western Ukrainian region. According to the compositional solution, it is a three-part, three-bay cross-domed temple with a central high dome on an octagonal drum above the central cross and two baths crowning the corner towers adjacent to the nave (Figs. 4, 5). The three domes symbolise the Holy Trinity, and their bulbous shape symbolises the flame of a candle. All domes were crowned with crosses, which were a symbol of Christ's victory over death. According to the shape of the building, the brick church of the Cathedral of the Most Holy Mother of God was cruciform in plan, oriented with the altar to the north with the sacristy and palamarnya (a special room in the church for storing things that were used for the service and in which order the palamar), symmetrically attached to the east and west, and a small narthex adjoins it from the north. This orientation of the vaulted part of the temple was conditioned by the urban planning situation existing at that time. The Church of the Cathedral of the Most Holy

Mother of God in Remeniv had its own architectural and planning peculiarities, which were manifested in the proportionality and ratio of the various structural parts of the temple: narthex, nave, altar, as well as the nature of the domed finish. Proportionally, the narthex was very small compared to the nave and the altar. The cruciform shape of the plan indicates that the basis of the Christian church was the Lord's Cross, through which the faithful acquire salvation (Kodin & Panov, 2008). In the interior of the temple, there were three arms of a spatial cross, rectangular in plan, with the lateral ones short, and the southern one elongated, twice as long as the lateral ones. The apse was pentagonal, pierced by two arched windows, decorated with stained glass windows of the Mother of God with the baby Jesus in her arms and Christ the teacher.

Figure 4. Church of the Cathedral of the Most Holy Mother of God in the village of Remeniv, 1908
Source: V. Slobodian (1998)

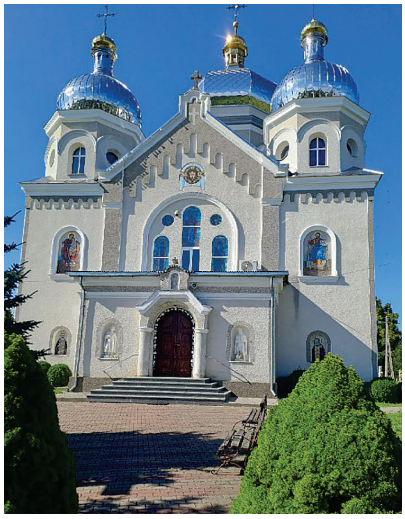

Figure 5. The modern view of the Church of the Cathedral of the Most Holy Mother of God in the village of Remeniv
Source: photo by the authors

From the outside, the apse was crowned with a hollow lantern. All arms were of the same height and ended externally with triangular pediments decorated with dentils, triple elongated arched windows arranged in arched niches, and mosaic icons above them. All the mosaic icons on the facades of the church were made by the artist Mykhailo (Surname unknown). The central volume of the church was stretched along the north-south axis.

The main southern front facade with a protruding narthex was accented by a triangular pediment with triple elongated stained-glass windows in an arched niche, a mosaic icon of the Savior Not Made by Hands in a medallion. The main facade was flanked by two two-story towers topped by domes on octagonal drums. The towers on the first tier were decorated with mosaic icons in arched frames (they used to be windows). The octagons of the tholobate of the second tier of the towers cut through alternating arched and round windows. The characteristic features of the architectural and spatial structure of the Cathedral of the Most Holy Mother of God were that it appealed to Sophia of Kyiv with its domed two towers, and to the wooden Ukrainian churches with its three-spire.

A wide staircase led to the temple. The entrance to the church was highlighted by a portal decorated with two symmetrically placed columns, a wide broken cornice, a figured pediment with an icon of the Resurrection of Christ in a small elongated arched niche and symmetrically placed deep arched niches with sculptures of Saints Volodymyr and Olga. The towers on the main facade had their purpose: one tower served as a belfry, the other – for storing church items. Since 1991 only choristers climb the spiral staircases in the towers.

In order to understand the architectural and spatial solution of the church, it was worth noting that the creed and dogmatics in Orthodox churches in all regions of Ukraine remained unchanged, but there was regional specificity in the ritual sphere, which arose as a result of interaction with national cultures, therefore elements of local national culture, traditions, and rituals were included (Krasilnikova, 2017). As a result of Galicia being under the rule of Austria-Hungary, there was a religious and cultural borrowing of rites, and a religious and cultural phenomenon of ritual and artistic decoration of temples was created. In this way, regional peculiarities of the organisation of church life appeared, which, in turn, was reflected in the architectural and artistic structure of the temples, where icon painting, carving, and sculpture were combined both in the interior and in the external stylistic solution of the temples of the Eastern rite.

It should be emphasised that at the beginning of the 20th century, the architects of Galicia turned to the ancient national history of culture and Christian faith. They embodied the innovative ideas of temple construction, using the wealth of means of Christian architecture of previous periods. In the architectural image of the cross-domed three domes Church of the Cathedral of the Holy Mother of God, the architect K Zhechytsky managed to combine the

traditions of historical styles and Ukrainian national art, using elements of the spatial and plastic solution of brick and wooden architecture (Studnytskyy, 2014). A characteristic feature of the planning-spatial solution of the cruciform Remeniv church was the emphasised centrality with a high central dome above the middle cross, complemented by two identical but smaller domes above the towers, which symbolised the mysterious Divine presence in three hypostases: the Father, the Son, and the Holy Spirit.

The interior of the church had harmonious and rich decorative decoration. It was full of side altars on both sides of the iconostasis in the spacious arms of the temple, sculptures of Jesus Christ and the Virgin, a tetrapod in front of the iconostasis, a pulpit (a kind of pulpit), church objects: analogies, transoms in the northern part of the nave with unique iconographic images of scenes of the Passion of Christ, wall frescoes of saints, icons which gave the inner space a special spiritual sublimity. The solemnity of the interior was emphasised by the height opening of the volume of the church (Fig. 6). The central high dome above the central cross, resting on four powerful pylons, was decorated with ornamental belts, story frescoes on evangelical themes and religious symbols. The drum of the dome was pierced by arched windows, through which streams of light poured in and created the impression of an unattainable "firm sky". In the sacral space under the dome of the temple, people in joint prayer were filled with heavenly bliss. The unity of the internal space in the church was perceived as indivisible, integral, and harmonious.

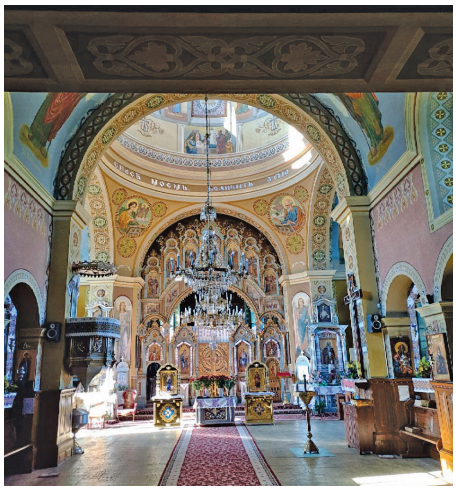

Figure 6. The interior of the Church of the Cathedral Most Holy Mother of God in the village of Remeniv
Source: photo by the authors

The main spiritual architectural and artistic accent in the interior of the temple was the five-tiered iconostasis (Fig. 7) on the elevated sole. Placed in a semicircular vault, the iconostasis of the church was made in the style of "national romanticism", where the icons in the iconostasis were depicted in pictorial movement, filled with spirituality and harmonious aesthetics. The architectural scheme of the iconostasis of the Cathedral of the Holy Mother of God, made in accordance with canonical requirements, had its own artistic features. The clear, expressive structure of the iconostasis, the vertical and scaled construction of its lower and upper tiers, the canonicality of the iconography, the noble harmonised rhythmicity of the decor, and the national identity of the carving with the use of Hutsul and Boikos ornamental motifs created its individual imagery (Stepovyk, 2008). The entire surface of the iconostasis was turquoise, and the columns between which the icons were placed were covered with ornaments of Hutsul and Boikos motifs. The first tier of the iconostasis was uniquely designed, where the four icons of the Mother of God with the child Jesus, Christ the teacher, Saint Nicholas, and the Nativity of Christ, were finished in a peculiar way, were finished with figured decorative pediments decorated with religious symbols in medallions and floral ornaments, crowned with crosses. The royal gate with the image of the scene of the Annunciation and the four evangelists Matthew, Mark, Luke, and John at the corners of the cross in small medallions and the deacon's door – with the image of archdeacons Lavrentiy and Stephen were made in the national modern style with the use of geometric carvings of Boikos ornamental motifs. In the decor, openwork geometric carving was combined with small flat carving floral ornament and bouquets of lilies – a symbol of the purity and holiness of the Virgin Mary. In the plastic solution of the iconostasis, the impact of the new structure scheme is felt, when the tier of the twelfth feasts was separated from the first row and forms an arch (Tymkiv, 2012). Thanks to the arched space above the first tier, a view of the throne icon and the altar opened. The national motif was present in the decoration of the third tier, where between the icons of the apostles, separated by narrow columns, Hutsul and Boikos geometric ornaments were used.

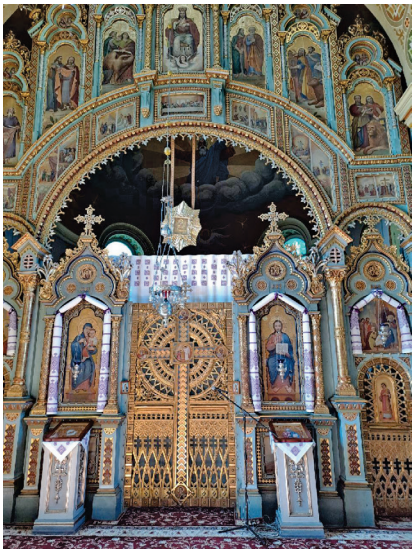

Figure 7. Iconostasis of the Church of the Cathedral of the Most Holy Mother of God in the village of Remeniv
Source: photo by the authors

The internal space of the altar part of the temple was canonically and aesthetically resolved. Behind the iconostasis in the main altar part of the church, where the Holy Liturgy was performed and the bloodless sacrifice was offered, the holy throne was placed in the centre, on which the Sacrament of Holy Communion (holy eucharist) was performed. On the throne, the ark in the form of a seven-domed temple impressed with its scale and artistic solution. Behind the throne was a mountain place, and above it was a throne icon. On the left in the corner was a proscomidia table. Two stained-glass altar windows with a full-length image of Christ the teacher and the Virgin with Jesus, through which the sun's rays shone with coloured reflections, carried a religious meaning in the space of the altar and were perceived by people as divine light.

Additional side altars in the nave of the church were characteristic of churches of the 19th and early 20th centuries. They consisted of a small throne and an altar image in a decorative ark, which complemented the iconography of the iconostasis in the interior. The side altars of the Church of the Cathedral of the Most Holy Mother of God were originally dedicated to the "Heart of Christ", "The Perpetual Help of the Mother of God", and the icon of "Saint Nicholas". Since 1991, the side altars in the Church of the Cathedral of the Most Holy Mother of God were dedicated to the Annunciation of the Virgin Mary, the Great Martyr Barbara, Jesus Christ, and the prophet Elijah (Figs. 8, 9). The side altars were a continuation of the first tier of the iconostasis with identical architecture and national symbols that have survived to the modernity. The space under the dome and the walls of the temple with arches were decorated with frescoes of saints and stories on the Gospel theme and traditional ornaments with religious symbols.

Figure 8. Side altar of the Annunciation of the Virgin Mary in the village of Remeniv
Source: photo by the authors

Figure 9. Iconostasis of the Cathedral of the Most Holy Mother of God in the village of Remeniv
Source: photo by the authors

The church was decorated with modern stained-glass windows made by Bohdan Zadorozhny. Stained glass, as a special type of monumental and decorative art that originated in the Middle Ages and was actively developed in church architecture (Zadorozhny, 2013), was perceived by man as Divine light, something unearthly, which contributed to the elevation of his spiritual state. At the end of the 19th century and to the beginning of the 20th century, stained glass windows in the modern style were widely used in the western regions of Ukraine in the temples of the Western and Eastern rites. The stained-glass window was mounted on a metal frame made of pieces of glass (coloured, with a textured engraving, etching, etc. surface, painted with special paints) with the help of a lead or plastic tape that fills the seams between them (Marder, 1995). Special attention was drawn to the stained-glass windows of the Cathedral of the Most Holy Mother of God, which impressed with their aesthetics, composition, colouring, and artistic expression, making a powerful emotional impression on the believer. The stained-glass windows of the church were made in the Tiffany technique (Figs. 10-12). When using the "Tiffany" technique, pieces of glass are cut according to a given sketch, wrapped around the perimeter with copper foil, and soldered with tin. Its name comes from the creator Louis Comfort Tiffany. Stained glass windows of the "Tiffany" technique were characterised by a more detailed, sophisticated pattern and thinner and more refined lines. B. Zadorozhny in the stained-glass windows of the Remeniv Church combined the "Tiffany" technique, painting on glass and sintering at 640 degrees, as a result, the subject stained-glass windows acquired a picturesque character.

Figure 10. Stained glass windows in the altar of the Mother of God and Christ the teacher
Source: photo by the authors

Figure 11. Stained glass composition in choirs
Source: photo by the authors

Figure 12. Stained glass windows of the Intercession of the Virgin Mary, St. Amfilochius and St. Job of Pochaiv, in the choirs of the Cathedral of the Most Holy Mother of God in the village of Remeniv
Source: photo by the authors

The stained-glass windows in the altar with the image of the Mother of God with the child Jesus and Christ (Fig. 9) the teacher and the stained-glass composition in the choirs of the church with the image of the Intercession of the Most Holy Mother of God and Saints Job and Amfilochius of Pochaivsky (Figs. 10, 11) attracted attention with their spirituality, peacefulness, colour, aesthetics, composition and artistic expression. The belfry was an obligatory volumetric and spatial element through which the temporal organisation of the spiritual life of believers was carried out. The modern belfry, located from the east in front of the church, with three arched openings in which bells were suspended. It was a complementary spatial dominant of the temple complex. The territory of the Church of the Cathedral of the Most Holy Mother of God was surrounded by a fence around the perimeter.

The Church of the Cathedral of the Most Holy Mother of God in Remeniv, Lviv region, which remained largely unexplored in terms of architectural and artistic aspects, belonged to the churches of the early 20th century and was built in the Art Nouveau style. It was worth emphasising that Ukrainian churches in the Art Nouveau style were built during the period of socio-political and national upsurge and activation of the clergy, the emergence of artistic movements, which contributed to the development of education, science, architecture and art (Studnytska & Studnytskyi, 2021). Many architectural researchers had conducted research on churches in the Art Nouveau style in Ukraine, who, while revealing the characteristic features of modernist churches, emphasised the originality of their architectural and artistic solutions. H. Bobosh (2004) substantiated the formation of a new Ukrainian style of modernist churches based on an analysis of socio-political events and the emergence of artistic movements that took place in the late 19th and early 20th centuries in Galicia and characterised the distinctive architectural features of the temples of that time.

R. Hnidets (2007) argued in his research that since Galicia in the second half of the 19th and early 20th centuries was the centre of national revival with a high spiritual and cultural outlook of society, this prompted architects to search for new forms in church architecture based on national traditions and medieval innovations, which demonstrated new volumetric and spatial and compositional solutions of temples in the style of Ukrainian modernism. During this period, the most acceptable for Ukrainians was the neo-Byzantine style, which prompted the viewer to reflect on the origins of Christian culture in Ukraine. B. Cherkes *et al*. (2019), based on a thorough analysis of Ukrainian churches in the Art Nouveau style, emphasised the search by architects for national identity in sacred architecture, taking into account the latest trends in European construction. They proved that one of the main principles of the development of form was stylisation under folk art, "eclecticism", interpretation of historical prototypes, which contributed to the formation of a new Ukrainian style. N. Novoselchuk (2022) characterised the national

identity of Ukrainian architecture of the early 20th century, emphasising the new European influence on its development, which led to the emergence of new volumetric, spatial, artistic and compositional solutions of churches, the latest technologies and advanced engineering achievements.

The churches of the Galician region also had characteristic features of interior decoration with a characteristic ornamental and iconographic character. O. Herii (2021), studying the ornamentation of church interiors of the 19th and early 20th centuries, emphasised that artists used medieval ornamentation with the introduction of national motifs in the decoration of temples. Art critic D. Stepovyk (2008), in a thorough study of the stylistic concept of the development of the Ukrainian icon, argued that the Ukrainian tradition did not blindly imitate Byzantine or Latin models, but positively viewed the spiritual image and expressed a universal and national ideal subordinated to spiritual beauty.

All the above-mentioned researchers came to the conclusion that the new style of Ukrainian modernism in church architecture, which was adapted to a significant number of churches in the Galician region, had an original character with a variety of architectural expressiveness using the best features of previous eras, which were manifested in the neo-Romanesque and neo-Baroque styles. A distinct national identity was observed in the architectural and spatial arrangement of Ukrainian churches of modernism in Galicia. In the vast majority of Ukrainian modernism churches were single-nave (less often three-nave) and had a cross-shaped spatial structure with one central or three domes, combining the Byzantine cross-domed tradition and elements of Galician folk architecture. The philosophy of building modernist churches was based on the harmony of architectural forms, aesthetics, and a departure from historical styles in favour of developing a new original style with diverse architectural expressiveness, using the best features of previous eras and national elements (Denysenko *et al.*, 2022).

Such features were inherent in the Church of the Cathedral of the Most Holy Mother of God in Remeniv at the beginning of the 20th century. In the architectural and spatial structure of the church, architectural and artistic features characteristic of the Art Nouveau style were revealed (Veres, 2022), supplemented by peculiar decorative elements that give an original character to the architectural and artistic expressiveness of the church. It had been established that the basis of the construction of the Church of the Cathedral of the Most Holy Mother of God in Remeniv was a Byzantine cross-domed structure with two towers on the front facade. The neo-Romanesque decor of the church facades was emphasised by neo-Romanesque dentil elements on all triangular pediments of the church, compositions of arched windows, mosaic icons, sculptures of Saints Volodymyr and Olga in semicircular niches of the main facade, and an entrance portal with half-columns. Two towers on the main front facade, typical of the Romanesque style, were borrowed by Ukraine from Germany, which indicates the architect Kazymyr Zhechytskyi's familiarity with European trends in sacred construction, which were adapted in the architectural image of the Remeniv church. It had been established that the interior decoration of the Church of the Cathedral of the Most Holy Mother of God in Remeniv contained a synthesis of arts: decorative carving, monumental painting of the temple, iconostasis, side altars, decorative elements of national symbolism and ornament, which were a vivid expression of national art, Ukrainian traditions and rituals and created a unique, unrepeatable ensemble of the interior of the temple (Tymkiv, 2012). The interior of the Remeniv church was designed in the Ukrainian neo-Byzantine style, complemented by unique national decorative elements of Boyko and Hutsul folk ornamentation in the decoration of the iconostasis and side altars, which gave the building an original character. It had been proven that one of the main principles of the search for the architectural form of the church in Remeniv was the national originality of church architecture, which combined the Byzantine cross-domed tradition, European neo-Romanesque trends and elements of national ornament, which with its architectural image encouraged the development of the Ukrainian modern style.

CONCLUSIONS

In the process of researching the Orthodox Church of the Cathedral of the Most Holy Mother of God in the village of Remeniv, Lviv Region, the architectural, planning and artistic features of the temple were revealed, combining traditional and innovative ideas in the construction of the temple. The construction history and artistic traditions of decoration of the investigated Remeniv church were considered. On the basis of the analysis of the planning and spatial structure of the church, characteristic features of architectural expressiveness were determined, which were manifested in the centrality of the cruciform shape plan of the early 20th-century church with a central dome above the middle cross and two towers above the narthex, crowned with identical domes. The architectural-spatial image of the Church of the Cathedral of the Most Holy Mother of God was characterised by distinct stylistic features typical of the churches of Western Ukraine at the beginning of the 20th century: tripartiteness, cruciformity and centricity, vertical opening of the space, ending with a high dome and complemented by two domes above the towers of the main facade, the shape of a bulbous dome ending. The interior decoration of the church was characterised by a combination of icon painting, national carvings, and sculptures. In the process of analysing the plastic and stylistic solution of the iconostasis of the investigated church and its side altars, distinctive features were determined in their architecture, imbued with national ideas, enriched with Ukrainian folk Hutsul and Boikos motifs of carving, colouring, and ornamentation. A combination of mosaic images of saints, sculptures, and decorative elements represented the artistic decoration of the church facades. The monument reflected not only the high spiritual and cultural worldview of the society of a certain historical era, but also the level

of artistic craft, construction skills, and artistic qualities and therefore constituted the national cultural heritage of Ukraine. The historically formed architectural and artistic image of the Church of the Cathedral of the Most Holy Theotokos in Remeniv demonstrated the characteristic features of the architecture of Ukrainian modernism of the Galician region and served as a vivid example for further research into the specifics of its characteristic features.

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Архітектурно-мистецькі особливості церкви Собору Пресвятої Богородиці в селі Ременів Львівської області

Анотація. Актуальність статті полягає у дослідженні церкви Собору Пресвятої Богородиці у селі Ременів Львівської області, яка належала до галицької автентичної архітектури початку XX ст. В основу її проектування було покладено візантійський хрещатий конструктивний тип храмів, стилістично поєднаний з традиційним українським мистецтвом. Мета дослідження – проаналізувати об'ємно-планувальну структуру церкви та виявити її характерні архітектурно-художні особливості. Методологія дослідження ґрунтувалася на комплексному підході з використанням як теоретичних, так і емпіричних методів дослідження, зокрема історико-архітектурного аналізу (стилістичного та архітектурно-композиційного). У статті вперше досліджено архітектурно-просторову структуру церкви Собору Пресвятої Богородиці в Ременові, визначено характерні риси архітектурної виразності, які насамперед проявилися у плануванні храму, його композиційному, стилістичному та пластичному вирішенні. Встановлено, що в архітектурному образі церкви Собору Пресвятої Богородиці знайшли відображення стилістичні та конструктивні особливості, характерні для храмів Західної України початку XX ст. Проаналізовано пластичне та стилістичне вирішення іконостасу та бічних вівтарів храму. Встановлено, що досліджувана церква має значну архітектурно-мистецьку цінність, відображає національну ідентичність в архітектурі та належить до культурної спадщини України. Пам'ятка не лише відобразила духовний та національно-культурний світогляд суспільства в певний історичний період, але й продемонструвала високий рівень майстерності, будівельної вправності та мистецької якості. Практичне значення дослідження полягає у застосуванні його результатів у теорії української архітектури та у подальшому вивченні цього об'єкта сакральної спадщини

Ключові слова: нава; фасади; вівтарі; інтер'єр церкви; розписи; іконостас; вітражі

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Architectonics of primary source as the basis for stylisation in the interior design

Abstract. The search for style in object spatial design constitutes the major component of the conceptual project design and, therefore, the problem of establishing scientifically based principles of stylisation of historical style as the primary source in modern interior is relevant. The aim of the article was to conduct the analysis and determine the significance of preserving the architectonics that formed the stylistic features of primary source. In the process of stylisation of authentic analogues for the interior design and object environment, the algorithm of reproducing style or stylistics for its correct perception by recipients was developed. The historiographical and comparative analyses were applied to evaluate the modern stage of research on the topic, the conceptual and stylistic tendencies, and the argumentation. In particular, the special method of morphological analysis was used to identify and confirm the architectonic structure of primary sources of style and their impact on the integrity of modern stylistic experiments. In the process of research, it was discovered that colour, material, and texture were important, but not defining, when it comes to determining certain stylistic identification. To recognise an ornament or decoration that characterised stylistic affiliation, it was enough to reproduce its main linear drawing, preserve the means of formation, characteristic angles, and proportions. Additional details enrich visual image, but do not alter the result of identification. Similar situation can be observed, while identifying the style in the architectural environment. Unlike both decorative elements and works of art in their "pure" form, the architectural and spatial environment had multiple important functions, and aesthetics was not the main one among them. Therefore, the analysis of morphological structure and architectonics of primary source with the help of form generation allowed creating the functional and aesthetic environment in space. The philosophical and conceptual approach of reinterpreting primary source rather than only "analogues" of project design expanded the interpretation field for a modern project designer, who with the adequate help of modern technologies has the possibility to create an associative image of the author's inspiration. The practical value of the research consisted

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in elaborating the methodological approaches to analysis and interpretation of architectonics of primary sources as the basis for stylisation in the modern interior design. The outlined conceptual principles of stylisation can be introduced into professional practice of interior designers, architects, and decorative artists, as well as into educational programmes for design and art disciplines

Keywords: form; visual code; morphological structure; transformation; associative image

INTRODUCTION

In modern society, the request for historical stylisation of interior remained relevant. The world and Ukrainian scientific society possessed a large amount of scientific and popular science information about the visual characteristics of architectural constructions and the interior of their inner space that determined their style in different historical periods. The most accessible articles in popular science periodicals refer to characterisation of modern interiors with stylisation of a historical style or a certain ethnoculture, were aimed at popularisation of creativity of separate designer groups, but contain the signs of subjectivity. It discouraged fledgling designers from searching for their personal creative conceptions and evoked in customers certain visual and semantic associations with the corresponding set of interior elements for its stylistic interpretation (Modern classic design elements..., n.d.).

Scientist O. Gutorov (2023) analysed modern stylistic tendencies in interior design, studied features of the leading styles, and outlined the conclusions that appeared to be useful for practicing designers, architects, and students in corresponding specialties. The author I. Bondar (2020) claimed that reproduction of the already proven techniques of ethnostyle interpretation remained popular in the modern design practice of ethnic stylisation of interiors. The studies of I. Yurchenko (2024) discussed the topic of understanding the role of ornament interpretation for the identity of modern Ukrainian object design and arrangement. V. Radomska (2020) reviewed the role and genealogy of ornament in architecture and object spatial design as one of the crucial features of structural change in architectonics, interior space, and development of functional arrangement. As based on archival documents, the authors M. Selivachov *et al.* (2023) presented the conceptual vision of ornament compositions of Vasyl Krychevskyi (created in 1920s-1950s) as "algebraic task". Also, the differentiated studies of ethnocultural heritage, which constituted the significant part of scientifically proven factual information about style of primary source, were noteworthy. A. Dyachenko (2024) analysed the peculiarities of decorating interiors with folk art handcrafted items in Ukraine in the 20th century. I. Dyda (2025) outlined the analytical conclusions on how modern design preserved and reproduced aesthetic, symbolic, and artistic features constituting the basis of decorative art. Primary attention was paid to how modern design reflected moral values and worldview of different cultures through the prism of decorative elements, including symbolism, ornament composition, figurative composition, and colour theory.

O. Dyda (2022) focused on ethnodesign and ethnic styles in modern interiors, which arose from the desire to preserve and creatively reinterpret cultural and artistic achievements of different nations, while analysing integration of folk art in architectural and interior design of the 20th century with the emphasis on modern approach – how to preserve visual recognisability of symbolism, ornament composition, moral and aesthetic features of identity, while creating a new space. The comparative analysis of significance of colour for perception and identification of objects as not merely natural phenomenon, but also as a complex cultural construction, which became a universal tool for combining archetypes of space and time, was explored in the monograph of M. Pastoureau (2000). Researcher's statements that there existed no transcultural truth about colour certified that colour was primarily a social phenomenon and, therefore, its usage became a tool of not only the aesthetic part of any project design. O. Pylypchuk *et al.* (2021) studied the properties of colourful surfaces of art objects as the means of creating harmonious and identifiable architectural environment. The research results also included the definition of theories and discussion of the reasons for the limited application of theoretical ideas in the field.

As based on received data, the authors outlined the model reflecting the presence and active application of theories that form the knowledge base of professionals in the area of object spatial design. Modern well-known design companies referred to the theoretical fundamentals. For example, V. Sukhytskyi (2020), the head of object design studio SV & Partners, published the important classification of object design segments on the company website and this allowed determining the priorities for the future project designers – what criteria and tasks they will be solving. For example, if a future designer was opting for an object design for High Market Level, he had to create a series of design products that would correspond to the world-famous designers or the eminent design studios (for small and medium-sized factories, family-run enterprises). This type of object design demonstrated author's artistic style and expensive finishing materials, which were mainly included into the complex of interior decisions for an individual customer or a company. Concerning other segments, this was a small in terms of quantity segment with considerably high prices for project design. This segment offered practically no discounts and stock leftovers, since everything was customised according to individual orders of a design or architectural bureau for direct

customers. This type of space was oftentimes complemented by unique art objects (boutique hotels, sacred space,). It certified that the requirements for stylistic features of project design and their creativity required the profound work of a designer with the primary source of inspiration (Gutorov, 2023). It did not locate scientific researches that would directly refer to the role of preserving the structure of architectonics of style as the original and primary source of stylisation for the correct identification of interior design style. The aim of the article was to identify the role of primary source in the process of stylisation. Given the aim, the main objective was to substantiate the assumption that one of the defining factors of forming new and modern interpretation of the previously established one was the morphological analysis of architectonic structure, the juxtaposition of peculiarities of proportioning segments into an integral scheme.

MATERIALS AND METHODS

The research was conducted on the basis of systematic approach with the application of theoretical and empirical methods. The empirical basis was constituted by observation and photo fixation of the objects of folk architecture and ethnographic decoration, located on the territory of Klymentii Sheptytskyi Museum of Folk Architecture and Rural Life in Lviv (Official website of Clementii Sheptytskyi..., n.d.); the structural decorations and compositional features of the existing Lviv facades of urban historical architecture, and the modern samples of transformation of historical style elements by foreign designers – interior of Splitec Building, Croatia (architects of BLP Architects), home cinema in the style of neoclassical interior and residential interior (2024, design by Rita Chraibi), which vividly displayed the experiments with classical styles and their constructions (Rita Chraibi, 2025).

The general research methodology was structured into certain stages: the analysis of scientific and theoretical sources – works in architectonics, stylisation, traditional culture and modern interior design; the definition of the notion of "primary source" in the context of interior design – elaboration of typology of primary sources (architectural objects, decorative and applied arts, natural forms); the research of primary sources architectonics – structural and plastic analysis of forms, proportions, compositional principles; the determination of stylisation principles – study of design strategies of transformation of forms and meanings in modern interior; the development of author's suggestions – creation of sketches, conceptions or models of interior decisions on the basis of architectonics of selected primary sources; the evaluation of results – analysis of efficiency of suggested decisions in project design practice and educational process at the Department of Design and Architecture Fundamentals in Lviv National Polytechnic University.

The method of hypotheses and assumptions was applied to develop the research strategy. At the stage of analysing materials, the comparative, structural, functional, and typological methods of research were used, which allowed the authors to identify the most significant architectonic features of primary source; for the work with ornament structure and determination of its stylistic identification, the morphological analysis and the graphological method of research were applied. The graphological characterisation of construction, proportions, and scale of architectonics of selected analogue (the morphology) – ornament, facade, architectural details, characteristic rhythm and silhouette – ensured the best possibility for designer to create and interpret the prototype that would reproduce the most characteristic components, but, at the same time, would not contradict the modern aesthetic and form generation tendencies. A person, as the main recipient of space arrangement, was endowed with psychological, emotional, and physical abilities and, therefore, it was reasonable to take into account the research conclusions of other related branches of science that studied the mechanism of perceiving elements of the surrounding environment.

The notion of architectonics as the basis of interior stylisation was researched with the help of the elementary theoretical and structural genetic analysis and synthesis, which allowed determining the cause-and-effect relationship. In the process of analysis and systematisation of visual source materials, the principle of modularity was applied to avoid excessive detailing and focus attention on major characteristics; the principle of hierarchy was applied to single out primary and secondary elements of influence on the formation of associative image of style; the principle of functionality combined architectonic structural characteristics of the environment with its primary purpose. The evaluation of theoretical research conclusions was conducted during completion of practical tasks within the lecture course of "Stylistics in interior" academic discipline. The completion of project designs under the unifying topic in order to form the corresponding associative image of stylistics, for example, public interior with the elements of "gothic" or "ethnostylistics of Eastern Podillia region" historical style, certified the relevance of applying the methodology of observation, experiment, and modelling. There was no direct work with people and, therefore, the specification of ethical standards was not required.

RESULTS AND DISCUSSION

Throughout human history, there have occasionally been requests to introduce into new buildings the elements of style elaborated much earlier. The phenomenon of historicism in architecture has always existed and continues to be present as one of the forms of expressing artistically the category of the past in the modern architectural space. The topic and the tendencies of integrating historical styles into the modern architectural practice were systematically researched by S. Linda (2013) and I. Dyda (2025). Meanwhile, the positioning of styles of the past in the interior arrangement was studied by J.F. Pile (2005). If to review the architectural construction and inner space of building as an integral whole, it became clear that architectonics

of interior has the same stylistic peculiarity, as stated by V. Chepelyk & Z. Moisieienko-Chepelyk (2000) and I. Burchak & V. Shmelov (2022). One of the challenges connected with historical or ethnical stylisation of interior was the temptation to copy separate authentic elements, the excessive attention to details combined with the necessity to use for this purpose some modern materials with different visual and constructive properties. This provoked critical feedback regarding "being outdated" and "false" and even rejection of the idea of any historical stylisation in modern design practice (Tretyak *et al.*, 2017). The author R. Arnheim (2004) conducted the comparative analysis of the significance of form and colour for perception and identification of objects and stated that form constituted a better means of identification than colour and that perception was an inborn ability or acquired during learning process.

The question whether the principle of automatic focus of "style" has always been visually synchronised with the arrangement of inner environment remained the topic for discussion and the stimulus for research. To adequately evaluate an interior, recipient should have relevant information regarding characteristics of the interpreted style. However, the identification of style was conducted at two levels: conscious, when a person evaluates forms, material, details, symbols of ornament; and subconscious, when a person perceives general emotional image of an interior that can coincide or, on the contrary, contradict certain imaginary "myth" about the particular style created by society or specific person. An emotional image was perceived and formed quickly within the first few minutes of seeing an interior design. It was based on what a person notices first in the surrounding environment, objects, and figures – form, proportions, and general flair. After that, perception and evaluation of details (surface texture, ornaments, artistic decoration, and symbolism of images) took place. The authors I. Yurchenko & R. Bida (2011) and O. Khodak & O. Savchuk (2016) were involved into studying and interpreting folk ornament. Significant attention was paid to its morphological structure and modern transformation within the context of searching for personalised author's approach, elaborating modern patterns. Colour, material, texture, other visual properties were important, but not the main ones for identification of an ornament. To recognise a Greek meander, it was enough to recreate its main linear pattern, preserve the means of its formation and characteristic right angles. Additional details enrich the visual image, but do not alter the result of identification.

Similar situation was encountered with identification of style in architectural environment. However, contrary to ornaments and works of art in its "pure" form, architectural environment has multiple functions important for a person and aesthetics was not the main one among them. Both historical architectural styles and ethnic architectural characteristics of folk architecture appeared as a result of interaction of multiple factors. The final architectural image of a building in any historical period was influenced by landscape, climate, security questions (in their wide meaning), building materials and constructions, economic situation, actions of authorities, architectural fashion, and, with respect to their material resources, people created an optimal for them architectural environment that would correspond to their aesthetic preferences and priorities in colour, ornament, and environment composition. It can be found multiple examples, when the choice of a particular colour, shape of a roof or method of homestead area planning, which have become traditional for a certain region, were explained not necessarily by the aesthetic considerations, but by the objective reasons. For example, the planning and composition of Hutsul "grazhda house" was created in response to dangers of the surrounding natural environment (it is important to note that even a doghouse was built by Hutsuls on a slightly elevated platform and was surrounded by a fence made of vertical columns) (Fig. 1).

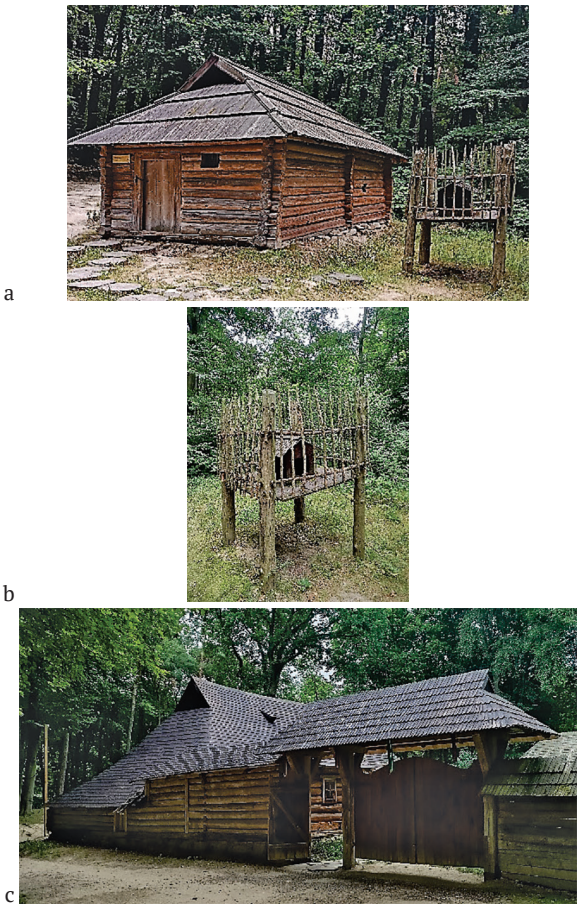

Figure 1. House and household buildings in Hutsul region
Note: a, b – barn and doghouse, Zamahora village, Verkhovynskyi district, Ivano-Frankivsk region; c – "grazhda" house, Verbovets village, Kosiv district, Ivano-Frankivsk region, end of the 19th century
Source: Official website of Clementii Sheptytskyi Museum of Folk Architecture and Rural Life (Shevchenkivskyi Hai) (n.d.)

Exemplary was the influence of climate peculiarities on form and proportions of houses in folk architecture of different countries. For example, in hot and dry conditions of

North Africa and Asia Minor, there was an established tradition to cover houses with flat roofs-terraces, while moderate Central European climate prompts local population to construct high sloping roofs that can ensure rapid removal of rainwater and snow. In different traditions, there were different height proportions between walls and roof. For example, the folk architecture of Balkan countries was characterised by significantly smaller angle of roof slopes and, consequently, their height. Meanwhile, in the Alps, where there was much more rain, the increased height of a roof and its slope results in different proportions between roof and walls on building facades. The traditional Ukrainian architecture was characterised by a four-pitched roof construction, but the correlation between roof height and height of visible part of the wall facade differs depending on regional climate peculiarities (Fig. 2).

a

b

c

Figure 2. Examples of traditional Ukrainian houses with four-pitched roofs, regional variations of correlation between roof height and facade

Note: a, b – Central and Northern Ukraine (Polissia region, Podillia region); c – Western Ukraine (The Carpathians, Hutsul region)

Source: Interior of a Ukrainian houses from different regions (2019)

In Western Ukraine (the Carpathians, Boikivshchyna region, Hutsul region), a roof had a significant slope and was higher than the visible part of a wall in order to ensure efficient removal of snow and protection from moisture; the upper part of facade was oftentimes smaller than wall plane and was framed by wide "skaps", "besidas", and covering (Fig. 2, c). In folk buildings of Central and Northern Ukraine (Polissia region, Podillia region), constituent components of roofs were less steep and the correlation between roof height and visible wall was more balanced, which was optimal for moderate climate; mazankas (or clay buildings) have low ridges and oftentimes smaller roof as compared to walls (Fig. 2, a, b). Regarding this, V. Karmazyn-Kakovsky (1972) noted that "... in old houses... the ratio between the height of walls and the height of a roof was 3:6 in regions with frequent rains and approximately 3:5 in villages where the quantity of rains was more moderate". The rich dark colour of walls of residential buildings ("Falun red"), traditional for Scandinavian ethnic landscape, was popular because red-brown paint of the local manufacturer (from the copper mine in Falun), known since the end of the 16th century, was for a long time the cheapest and the most accessible one, unlike the imported white paint (Not only Falu red – the colours of Scandinavian..., n.d.), which only very wealthy people could afford, and which was the sign of wealth of the house owner.

Decorative architectural elements that were identified by average people as belonging to certain style were only one of the characteristics of style, which can be introduced into the interior under condition of preserving proportions of other structural elements that form together the primary source style. The research specifically mentioned the desire of stylisation of certain historical style, rather than creation of postmodern interior, where separate historical inclusions have an absolutely different grotesque and figurative role. Since proportions and correlations between separate architectonic elements of certain historical style were not accidental, but appeared as a result of constructive properties of materials, out of which they were initially made (in primary source), it's alteration at designer's sole discretion was particularly noticeable in the already stylised interior. A person, who was generally familiar with architecture of certain style feels the fakeness and exploitation incapacity of similar constructions and understands that it would be impossible to implement it using authentic original materials. Such design mistakes were particularly noticeable, while attempting to stylise Ancient Greek or Ancient Roman classic interior because these cultures created a very precise system of proportional correlations between elements of an order and, apart from that, the architecture of Renaissance, Baroque, Classicism, and later on Historicism since the early 15th century and till the middle of the 20th century strictly followed these proportions changing primarily the details of decoration, material, order size, but not such constants as intercolumniations, correlation between column radius and its height, slope angle of antique eagle or construction of entrance portico proportions. It was considered acceptable to add a cartouche to an eagle cornice (as it was

made during Baroque period), but the angle of its slope remained unchanged.

Modern materials used in interior design often have significantly better construction properties that those of the authentic historical primary source style. In modern interior, it was enough to have only two or three columns to support a plastic or metal ceiling beam, not six ones as it would be necessary in Ancient Greece, where builders used lacunar marble slabs for ceilings; modern metal vault arch can bear not directly on an abutment, but on a console protruding from the wall. However, if designer aimed to stylise the environment of certain historical period, he should not reveal the fact those architectonic elements were made of materials that were new and non-characteristic for the interpreted period. Even if instead of Greek Doric columns there were round metal abutments, but the proportions between their width and height were preserved and the distance between abutments corresponded to the classic formula, it's will be perceived more realistically as elements of classic order system, rather than plaster capitals with all decorative details placed on columns that were disproportionate to their size and located at the distance equal to or greater than the height of the space. An interesting example was constituted by the interior of Splitec Building – a modern residential and office space in Croatia (BLP Architects) that demonstrated metal or concrete columns stylised using classic proportions; architectural elements (beams, ceilings, vaults) supported not by quantity, but thanks to the rational usage of modern materials; visually readable reference to the classics without literal copying of details; corbels and preservation of order aesthetics via proportions rather than decorations (Fig. 3). Such modern approach demonstrated the technique, where classical style was preserved despite modern steel abutments and beams, minimal quantity of columns, but thanks to the classical and proportional space organisation, even though the used materials were absolutely modern. New Classical movement and Neoclassical interior design also used modern materials and forms, while disregarding ornament, but preserving the principles of symmetry and proportions: columns may be decorative, but may also serve supporting function and be made of modern materials, concrete, composites. It was important to understand how separate architectonic errors devalue design work, for example, in composition of entrance portals on building facades or on doors in the inner space, when authors ignore the so-called "non-overhang rule" of the classical order system. The "rule" appeared as the result of using stone marble constructions and took into account properties of this particular material. If the order system had appeared as a part wooden log or frame construction, the overhanging of the part of beam protruding beyond the abutment would have been perceived as granted (as in the case of wooden gates in folk architecture) (Fig. 1, c). It was important to note that a number of modern design suggestions of interior in "classical" style demonstrated conceptual and terminological uncertainty of general image, which displayed the kind of collage of Greek and Roman architectural heritage. They had absolutely different principles of construction: ancient Greeks used post and beam system, while Romans focused on usage of arches and vaults. Combination of these construction principles in one building could not be observed in any specific period of the historical past and, therefore, it cannot claim to be a primary source for stylistic interpretation in the present.

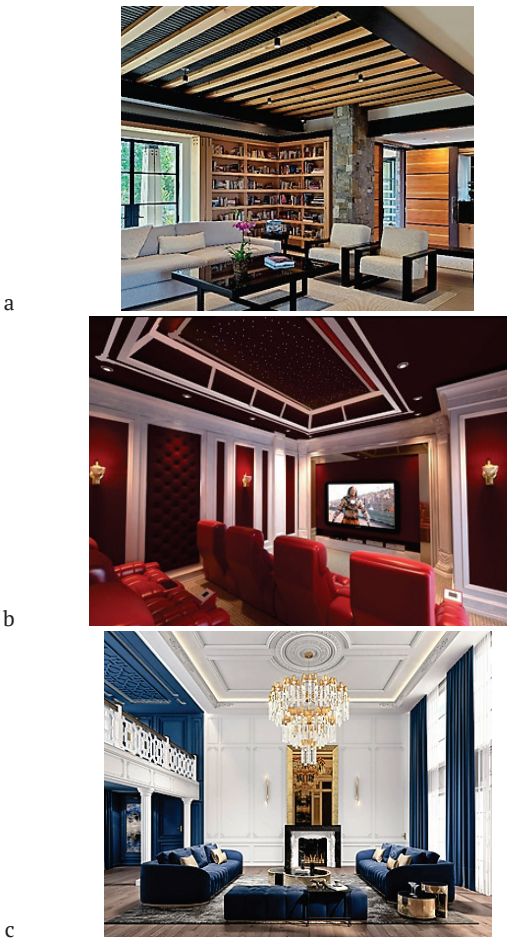

Figure 3. Examples of modern usage of historical stylistics
Note: a – interior of Splitec Building, Croatia (BLP Architects); b – home cinema in Neoclassical interior; c – residential interior, 2024 (design by Rita Chraibi)
Source: based on S.A. Clemons & M.J. Ekman (2011), Rita Chraibi (2025)

A person physiologically perceived the surroundings in a certain way regardless of whether it was constituted by architectural constructions, elements of nature or living beings, for example, people. It was not a coincidence that in habitology there existed a clear sequence of describing a person that needs to be recognised in the direction from general to specific as based the features that an observer involuntarily notices first of all. A person perceived the environment, particularly elements of

interior design, following the same sequence. First of all, attention was drawn to structural elements, method of their arrangement in space, form, and proportions. During the first visual contact, recipient notices the availability or absence of posts, arches, vaults, their arrangement in space, proportional correlations between separate elements of interior. It allowed identifying, which exactly historical style was chosen by designer as primary source. During lengthier stay in the interior, there was the chance to verify correctness of "first impression" by means of taking a closer look at decorative details located on main structural elements of space, ornaments on furniture, individual works of decorative and applied art that complement the stylistic image of interior.

When studying forms, it was necessary to take into account the major important factors, which allowed detecting and outlining characteristic features of the selected style more systematically. According to this principle, it was possible to characterise forms in architecture and in its main structural architectonics. In general, forms should be reviewed and analysed from a few aspects that include geometric, functional, and aesthetic components. Here were some of them: geometric form – simple shapes, such as square, rectangular, circle, triangular, were often used to ensure functionality and ease of perception; complex forms – the use of organic, asymmetrical, or fluid shapes grants a building or space architectonics a more dynamic outlook. Proportions were an important aspect that determines correlation between different parts of a building or space. According to S. Syomka (2013), proportional connections contributed to harmony and aesthetic attractiveness. Functionality was the necessary component of practicality of architectural design product. It was this category that oftentimes determined the form and the purpose of a building. The category of practicality implied that the form of a building determined its purpose and interior arrangement. For example, residential buildings have functional and simple forms to ensure convenience of room location, while public or cultural buildings may have more complex and vivid forms to reflect their meaning. Space arrangement and formation of room architectonics in a building depended on the internal functional division. Forms may help with space zoning, lighting, and ventilation, and their aesthetics and expressiveness create the style that can become a modern replica of historical styles (classicism, modernism, minimalism, deconstructivism). This fact influenced the perception of building and interior. The category of expressiveness deals with the formation of emotional influence through architectonics of form, where an important role was played by interaction with the surrounding environment and usage of contrasts or harmony. In form generation, the analytical component of architectonics of certain style helped determining the compositional priorities and regularities – symmetry as reflection of elements in a building grants the feeling of balance, tranquillity, and order, while asymmetry servers for creating more dynamic and nonstandard forms that can provoke interest and draw attention. It should not ignore the role of materials and textures in perception of style. Their appropriate usage or adequate substitution will help form the character of a building and object spatial design by means of adding them different textures and tactile effects. It will also help create special influence on perception of form by means of determining the atmosphere of space (Boichuk, 2019; Bondar, 2020). Integration with the surroundings, the so-called contextuality, was an important factor of harmonisation and adaptation to natural, urban, and social environment, which was particularly important in terms of environmental compatibility and modern orientation towards sustainable development. These characteristics of forms in architecture interact with each other helping to create not only functional, but also aesthetically appealing buildings and spaces, which can become important elements of cultural heritage. In case of using forms and principles of form generation, there existed the possibility to compile and analyse formal characteristics with a fairly high degree of accuracy, which, in its turn, allowed forming personal interpretation with the correct accent components of the selected style. Trying to compare the perception of form with the perception of colour, it can confidently state that form was a better tool of identification than colour. In the case of form, it was necessary to analyse formal characteristics with a significantly high degree of accuracy. Therefore, the analogies between the outlook and the expression of forms go beyond the framework of assumptions. It was easy to conduct the comparative analysis, when there was the task to determine from the viewpoint of theory and history of art, why the forms painted by Raphael differ from those of Durer. However, while dealing with the aspect of colour, the analysis was based primarily on guesses, why the blue colour was prevailing in the works of Picasso in the beginning of the 20th century, and why Van Gogh was using a lot of yellow paint (Arnheim, 2004). To acquire positive results in forming author's transformation of authentic elements, it was suggested to rely on a certain algorithm and sequence of searching for the aesthetic and stylistic component of design project. In this context, it was evaluated and introduced the sequence algorithm of completing the practical task "Sketch design of interior in ethnostylistics" into the educational process of Lviv Polytechnic National University. The main principle of this approach consisted in acquiring skills of using in practice the analytical methodologies of studying the general architectonics of element structure of historical and ethnic styles (Fig. 4).

To introduce inspired historical and ethnographic decorations, forms, and silhouettes into interior environment, it was no less important to apply the determined tools of the main methodologies or their conscious methodological combination. For optimal approach, it was recommended to use: ornamental method, method of interpreting decorative techniques, method of personal interpretation and experience of style transformation (Fig. 5).

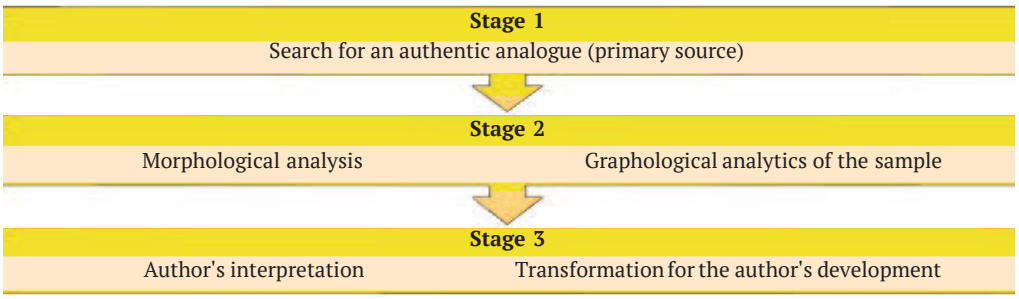

Figure 4. Algorithm of working with analogue (primary source) for design project
Source: developed by the authors

Ornamental method	Method of interpreting decorative techniques	Method of styling and using the experience of style transformation
● The method of decorating object spatial surfaces and interior elements with ornamental motifs, symbols, and colour	● The tool for forming structural and textural elements in object spatial design (silhouettes, 3D effects, special techniques, surface textures)	● The tool for finding own presentation based on graphological analysis of the chosen ethnic or historical motif of the source

Figure 5. Methods of working with analogue primary source for the search for style in object spatial design
Source: based on I. Yurchenko & R. Bida (2011)

The most widespread method was the method of ornamentation. It consisted in decorating architectonic object spatial surfaces and interior objects with the determined ornamental schemes or their significantly "interpreted" replicas. The accessibility of the method usually results in the emergence of bad taste, kitsch, and levelling off the authentic architectonics, as specified by R. Shmagalo (2020). As a part of modernisation, multiple designers started mixing certain stylistic or ethnographic elements, distorting identity, regional and stylistic value of the primary source. However, designers have the possibility to apply the wide range of theoretical scientific knowledge and modern technologies, while not excluding the empirical observation of original primary sources in archive and museum resources.

The method of interpreting decorative techniques was an interesting applied tool for forming structural and textural elements in object spatial design, in particular, for creating accent art objects. Such art objects can be the main dominants determining the stylistic canvas of space decoration, as well as the special elements of author's specificity awareness. The method of using the experience of style transformation was the most creative and artistic method of forming new stylistic direction in interior space, which was based on the experience of transforming and reinterpreting the complex architectonics of the original, the code of national heritage of certain ethnoculture or historical style (direction). The synthesis and successful author's interpretation of authentic architectonic determiners practically transform and create the style in design project allowing the formation of new relevant modern tendencies that identify the success of a designer, a creative group or a brand (Fig. 6). Creative works of Vasyl Krychevskyi, the Ukrainian architect and designer, confirmed the extended possibilities of integrating archaic authentic samples in their modern interpretation. The constructive dilemma and controversy regarding the topic of decorating the facade of Poltava zemstvo in "non-existent" Ukrainian style, where an indeed highly artistic component was combined with social and political sentiments, was solved by the project of V. Krychevskyi. The author's extreme perfection in architectural composition, drawing, fresh and intuitive command of decorative means of folk art as based on its profound knowledge allowed him to outline the solution of the problem in a more original and appealing manner than his opponents (4 competition projects). However, the interior decoration of a building conducted without supervision of the author, in particular, the paintings by S. Vasylkivskyi, do not completely correspond to the project and their style falls out of the ensemble. This was the example of different interpretations of "national" style. Using the materials of O. Khodak & O. Savchuk (2016), it was analysed the artistic arrangement of the House of Historical Section at the All-Ukrainian Academy of Sciences in Kyiv (project design of Professor V. Krychevskyi). In 1927, the Historical Section received a special building and the need to arrange and decorate rooms in accordance with the specificity of scientific establishment emerged. In the design of the 20th century, which was mainly created by architects, walls and floors of rooms were decorated with heavy stucco mouldings and cornices in certain classical styles; later on artists filled in the empty space with landscapes or figurative genre scenes. After that, rooms were filled with overly large and oftentimes not comfortable pieces of furniture – the

more ornaments, carvings, stucco moulding, and gilding, the better. In his new interpretation of re-arranging the spaces in order to serve the public purpose, V. Krychevskyi applied the unusual method of decorating walls with fabric that featured author's unique scheme of block printing and with pine construction elements. On the top of ceiling panel, the walls were covered with homespun (peasant) canvas with meander ornament, known since the Palaeolithic era. In the architectonic interpretation of Krychevskyi, the meander was presented on the background of complex interaction between simple lines and diagonals that were rhythmically united with the wavy drawing on the pine panel. The canvas stretched between pine slats eliminated the unnecessary acoustic effect of the hall. Benches, placed along the walls, were monumentally connected with the stylistics of panels (Fig. 7).

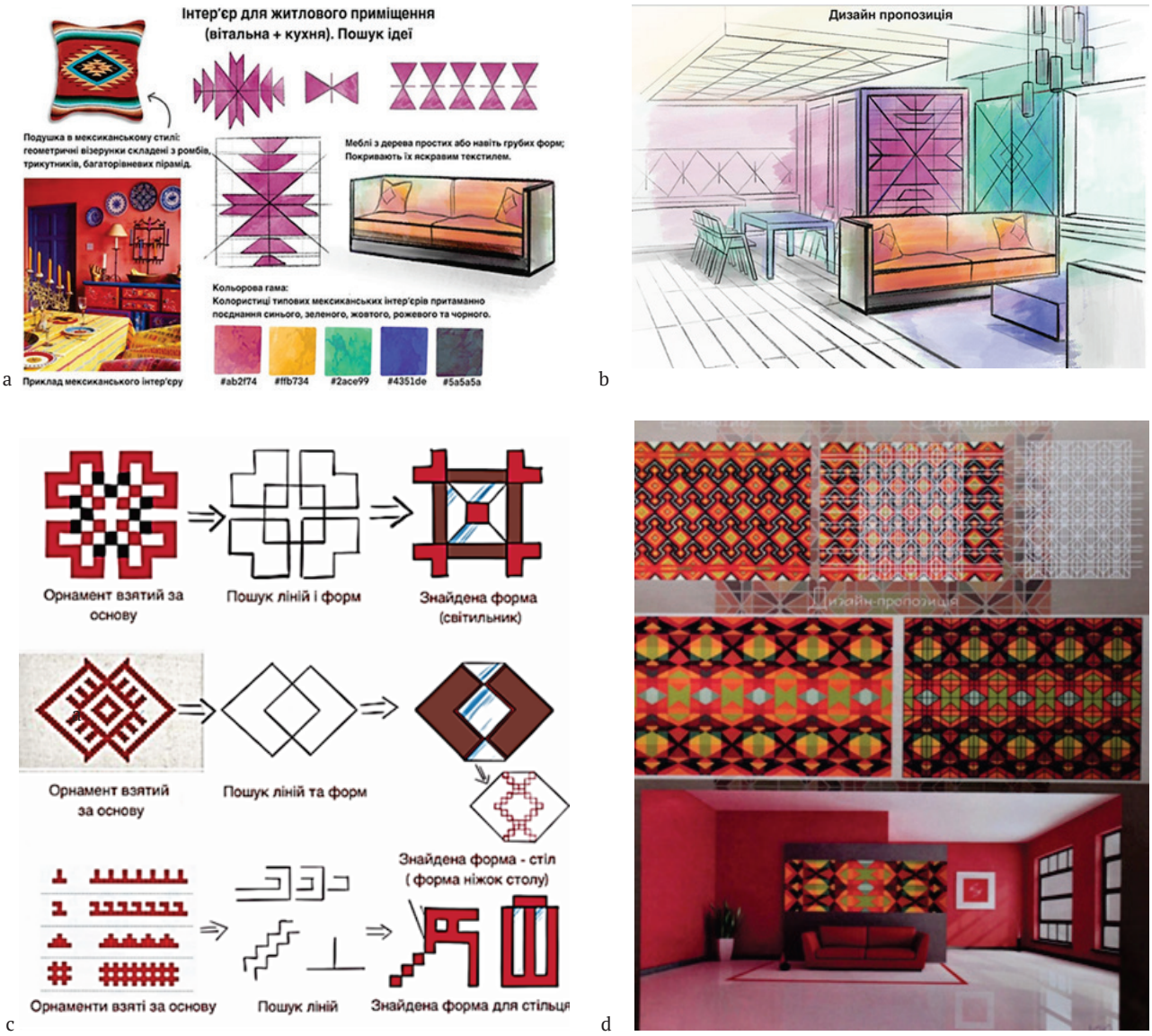

Figure 6. Results of applying graphological method in morphological analysis of ornament scheme structure
Note: a – determination of analogues, graphological analysis of selected ethnic style (Mexico); b – design sketch proposal; c – algorithm of search and formation as based on ornamental motif of Ukrainian ethnic region (Polissia region); d – creation of art object in interior as based on ethnic regional embroidery (Hutsul region). Translated from Ukrainian: a – interior of residential building (living room + kitchen). Search for an idea. A pillow in Mexican style: geometric patterns consisting of rhombuses, triangles, multi-level pyramids. Wooden furniture of simple or even rough forms, covered with bright textiles. Example of Mexican interior. Colour palette: typical Mexican interiors are characterised by combination of blue, green, yellow, pink, and black colour; c – ornament taken as the basis → search for lines and forms → selected form (lamp); ornament taken as the basis → search for lines and forms → selected form – table (form of table legs); ornaments taken as the basis → search for lines and forms → selected form – chair
Source: developed by authors

Figure 7. Examples of usage and interpretation of architectonics of ethnic motifs in design projects of interiors by V. Krychevskyi

Note: a – sketch of exposition of Ukrainian art exhibition, 1931; b – House of the Historical Section at the All-Ukrainian Academy of Sciences in Kyiv (1927), Room 6. Office of the Head of Institution; c – Room 3. Office of Primitive Culture; d – Room 2. Meeting room, front part with presidium table

Source: based on O. Khodak & O. Savchuk (2016)

It constituted an interesting example of using handmade elements in execution of the wall panel that illustrated the plot of Ukrainian dumas and historical songs. Straw was used as artistic material and its golden natural shine and texture harmoniously complemented the general warm tone of the room. Despite the limited resources, such as straw and two or three paints, the composition was striking by its expressiveness and play of textures (Fig. 7, c). The smallest details of decoration of the Historical Section were subordinated to the general organisational plan. Even though cheap materials, such as canvas, pine and birch boards, were used, they managed to avoid decorations, effects, and conventional forms. This demonstrated the consistent ability to ensure rational artistic design that would correspond to the function of space or building and the needs of contemporary life.

During designer's work on determining conception and stylistics of design project, the first stage was usually constituted by the search for analogues, so-called "reference". Nonsense and "analytical failure" were particularly common at this stage. At the first stage of creation, it was necessary to analyse, what had already been implemented in the world and Ukrainian space previously. However, prototypes and ready-made analogues start "owning" and "being visualised" by an author (a fairly active and negative practice in the educational design project). In this case, the sequence algorithm was elaborated incorrectly and the most important stage was being missed, which was the appeal of a project designer to authentic samples, artefacts, and original prototypes corresponding to the selected stylistics, ethnic features or style in all constituent components of the notion. An author attempted to improve and interpret the already tested cover version or imposed philosophy of style perception. The tendency was vividly manifested in the use of Ukrainian and world ethnic heritage to form new "interpretation" of ethnic and regional specificity and culture. Therefore, the graphological method of researching morphological structure of analogue architectonics for designing objects of object spatial purpose, applied art, architecture, landscape, allowed using proportions and form generation that would characterise the original markers of stylistic adherence and creation of new versions without literal "citing" or levelling off the peculiarities of structural patterns that "to a certain extent globalise" the project and do not allow developing personified competitive Ukrainian design.

The question of forming project colour map proved to be no less debatable. If to take into account only the established scientific knowledge about colour division and laws of its perception, the range of questions and limitations arises. Colour plays an important psychological, emotional, aesthetic, and characteristic function in the society surroundings. The practical experience certified that not only scientific regularities of perception and application of colour spectrum served as an efficient tool for designers. V. Danylenko (2005) pointed out that the analysis and positioning of Ukrainian design in the global context of artistic and design culture demonstrated data regarding the established principles. To confirm the statement, V. Abizov & S. Syomkin (2023) in their research defined the major characteristics of creating modern ethnic design, for example in restaurants, and highlighted the main characteristic features of different ethnic peculiarities in arranging interior of food and drink venues as based on the analysis of creativity of Ukrainian and foreign designers. In modern

reality, designers used the advice and trend suggestions of the Pantone colour system or Pantone matching system, which was the system of colour selection developed back in the middle of the 20th century. The colour system was developed by the company Pantone Inc. Pantones were widely used in printing and all typological directions of space design for selection of colours during the process of printing with the help of mixed and triad paints. This "beneficial" service standardised visual component of space architectonics, since it presupposed "flawless" local plane or element that was deprived of spontaneity and naturalness. Modern object design, in terms of its typology, constituted a heterogeneous notion and included specialised segments (Danylenko, 2005). The development of object spatial design of the "premium class" category ("gallery" object design) was characterised by the format of separate authorial items with vividly expressed individual ideas and technical tools. In this case, semantic accents and colour palette were subordinate exclusively to the author's experience and artistic intuition. The main idea of such projects was the artistic and decorative component of architectural spaces. Such items were produced in limited quantities (3 to 10 items) mainly by a design author or a small creative team. The cost of such items was estimated as for an object with "the name". Craft object design was the format of small series of personalised design items produced by the designer himself and his micro team in a small workshop or an authorial manufactory. Such items harmoniously combined practical and accent decorative functions in the residential or public space. V. Sukhytskyi (2020) specified that small commercial lots of goods (10 to 200 items) and personalised author's approach to each produced item were the main features of craft object design. Therefore, if a designer planned to occupy this niche field, the approach to using tools and factors for establishing creative environment should be carefully staged and methodologically structured. Ideally, all segments of project should be combined as an ensemble, where form, texture, and colour were subordinate to the architectonics of inspiration source.

Another debatable direction was related to the very definition of the notion of historical stylisation in object spatial environment. Historical stylisation was often understood as the obligatory detailed reproduction of decorative elements characteristic for the selected style. It can be assumed that critical perception of the idea of historical stylisation in modern architectural space, which was popular among some practicing architects and was justified by the reluctance to create a "cheap imitation" of the historical style and, consequently, showed disrespect to the real architectural heritage, was the result of underestimating the meaning of proportions and architectonic logics of the authentic style of primary source for the creation of the corresponding associative image in the new environment (Linda, 2013). The construction scheme, which was free of decorative details but preserves the tectonic logics and corresponding proportions of the selected historical style, enabled the possibility of provoking certain figurative associations and demonstrated the modern approach to environment design. Similar approach was demonstrated by Antoni Gaudi in his "Sagrada Familia" in Barcelona, where the style of Art Nouveau acquired the gothic flavour not by means of imitating gothic details, but thanks to the construction proportions. The specificity was also pointed out by the authors R. Kiuntsli *et al.* (2024).

Also, there were discussions regarding understanding the role of ornament in architecture and object spatial design and the problem of ornament genealogy as one of the important features of structural change in architecture and interior space. In their research, V. Radomska & I. Tyrpych (2012) studied the philosophy of form generation of ornaments in the works of the artist from Halychyna region Modest Sosenko (1875-1920). It was developed in the context of the "new ornament" theory during the digital technologies age and at the background of classical forms of psychological and aesthetic perception, functionality, and purpose of an ornament. In this context, according to A. Rigel and A. Loos, and with particular emphasis on the idea of irrelevance and rejection of ornament, there were discussions whether an ornament has the right to exist in modern art and design. Back in the early 20th century, A. Loos (1908) stated that an ornament was the manifestation of primitive thinking that became needless in the civilised society and slowed down the development of culture. The author believed that a modern person should eliminate excessive decorations since true aesthetics should be based on functionality and purity of forms. However, it was important to remember that A. Loos (1908) wrote his work during the times, when modernism aimed to ruin the old canons. The researcher did not deny the ethnographic or historical value of an ornament, but, in his opinion, an ornament in architecture and industrial design of the 20th century distracted attention from the main part, which was form, function, material. The author dreamt about an "empty wall" that would speak for itself. The researcher believed that it was a mistake to think exclusively about an ornament, while mentioning the style. The true greatness of the modern view in the early 20th century was that humanity was no longer capable of creating new ornaments, overcame an ornament and learnt to get along without it. A. Loos (1908) argued that the society was on the eve of the new century, when the best predictions would come true – cities of the 20th century would be spacious and with local wall planes. However, researcher did not take into account people, so called "friends of antiquity", who were in favour of humanity continuing to remain under the "tyranny" of an ornament. A. Loos (1908) believed that an ornament was no longer bringing joy to a modern person. Depending on their personal taste, modern people recognised or rejected an ornament of ancient or exotic civilisations, but they did not create new ones and saved their imagination for other purposes. The statement sounds rather radical, but the theory of de-ornamentation triggered the new interpretation and usage of ornaments in architectural design practice. Visual cultures of different nations were built as

based on an ornament that not only decorated, but also had a deep symbolic meaning. For example, in traditional Ukrainian art, an ornament was the language and the code of identity. However, humanity lives in the world of hyper visual culture, where images and signs acquired new meanings. In the 20s of the 21th century, designers reinterpreted an ornament and transformed it into a communication tool or an accent of cultural heritage. An ornament returns not as a decoration, but as a content, it was not a crime, it was not obligatory. Everything depended on context, purpose, and values. It was worth distinguishing meaningless decoration from intentional symbolism, so, A. Loos (1908) gave a handle for critical thinking.

The authors Y. Tretyak *et al.* (2017) paid particular attention to such characteristics as colour palette, materials, corresponding decoration, ornament, specific "style indicators", such as specific details of wall finishing, shape of separate furniture elements, decoration objects. R. Hnidets (2024) studied the influence and the means of interpreting Ukrainian traditional sacred architecture in modern design and architectural practices of construction and decoration of churches. In art theory researches, particularly in the article of O. Hanotska & V. Maslak (2022), the focus of attention was placed on the compositional and semantic structure of ornaments of different ethnographic regions. The conclusions of the authors V. Abizov & S. Syomkin (2023) were particularly important in the context of the research topic. The authors analysed the integration of folk art into the architectural and interior design of the 20th century with the emphasis on modern approaches to preserving symbolism, ornamentation, moral and aesthetic features in the creation of space. In general, there were a lot of researches on the regularities of the process of perception of environment and separate architectural and art objects. B. Cherkes (2008) explored the associations that environment evoked in those, who perceived it, particularly concerning the spirit of place, memory, identity. The large group of original sources, including the work of J.F. Pile (2005), was constituted by the scientific studies of the history of architecture and art formation, creation of different styles in architecture. The researcher O. Bodnar (2012) presented the peculiarities of creative and research process in the design and architecture of the 1960s-1980s. A. Boichuk (2019) outlined certain scheme and focused on the factor of sequence in the innovative design that allowed analysing objectively the regularities of interpreting historical styles in the architectural space and object spatial design, its philosophical and social tasks.

Therefore, the research focused on the role of using artefact authenticity in modern object spatial environment as the carrier of historical and ethnocultural traditions. The consistent coverage of the interrelation of an artefact in the interior identification system made it possible to reveal its generating identification function in the design of modern object forms. The exploratory stages and the methods of experimental modelling of the architectonic structure of primary source for its application in modern design became particularly significant. An important aspect of creating author's proposals was constituted by the methodology of object spatial form generation with the application of specific methods that allowed creating alternatives of original functional items.

CONCLUSIONS

For recipients to recognise the interior design stylisation in the selected historical or ethnic style, it was important to accurately reflect the regularities of architectonic structure construction and proportional correlation between its constituent components. Despite their objective significance, decorative elements, ornamental details and other style indicators of primary source performed merely a complementary role in the process of forming the associative image of interior. The analysed projects revealed that in the modern design practice there was a steady tendency to reinterpret historical and ethnocultural codes in the spirit of new aesthetic sensitivity. The main features of such interiors were: integrity of architectonics that was based not on literal reproduction of historical forms, but was an intellectual reconstruction of space, where plastics, proportions, scale, and module were correlated with authentic archetypes. The important aspect was the dialogue between tradition and modernity, in which designers combined local ethnostylistic motifs with minimalistic decisions forming the semantic field that was capable of evoking associations without direct citations. More generalised tools of symbolism and contextuality were used, while historical and ethnic motifs and their structure were adapted with respect to location of urban or rural environment, sacred or secular space.

The specificity of modern object spatial design consisted in materiality as the means of visual narration and rejection of imitations, wide usage of natural materials, which were perceived as "true" carriers of culture and allowed reflecting structural features of primary sources in a more authentic manner. New interior, the design of which accurately reproduced architectonic regularities of the corresponding historical style of primary source, may be identified as interpretation of certain historical style without its supplementation with decorative and ornamental details. Inaccurate adherence to authentic proportions and construction regularities hindered the process, even despite the availability of supplementing decorative elements. It would be appropriate to apply the principle of the primary nature of proportional correlations and structural construction as compared to other decorative characteristics during the process of stylisation of primary source ornament, regardless of its type, since the structure and its parameters allowed identifying the adherence of decorative element and its symbolic meaning. During the process of creative stylisation of interior or separate element of object spatial environment, it was critical to rely on the analysis of architectonical, structural, decorative characteristics of authentic primary source in order to achieve original author's conceptions, avoid false interpretations and the danger of their dissemination. The conclusions and

methodological findings of the research were tested during the educational process at the Department of Design and Architecture Fundamentals in Lviv Polytechnic National University during completion of students' practical tasks in the discipline "Stylistics in interior". The research opportunities included the search for artistic and design transformation of historical, ethnocultural and archetype primary sources and their interpretation as the creative method of semantic "re-writing" of traditional forms, symbols and materials in modern context.

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Архітектоніка першоджерела як основа стилізації в дизайні інтер'єру

Анотація. Пошук стилю в предметно-просторовому дизайні складає найбільш вагому частку концептуального проєктування, тому проблема розробки науково обґрунтованих принципів стилізації історичного стилю як першоджерела в сучасному інтер'єрі є актуальною. Мета статті – провести аналіз та виокремити значення збереження архітектоніки, що формує особливості стилю першоджерела. В процесі стилізації автеничних аналогів для дизайну інтер'єру та предметного середовища було створено алгоритм передачі та ретрансляції стилю чи стилістики для коректного сприйняття його реципієнтами. Для з'ясування сучасного стану дослідженості теми, концептуально-стилістичних тенденцій та визначення аргументацій було застосовано історіографічний та порівняльний аналіз. Зокрема, для виявлення та підтвердження архітектонічної структури першоджерел стилю і їх впливу на цілісність сучасних стильових експериментів використано спеціальну методику морфологічного аналізу. В процесі дослідження вдалось з'ясувати, що колір, матеріал, текстура важливі, проте не головні в питанні визначення певного стилістичного ідентифікату. Щоб упізнати орнамент чи декор, який характеризує стилістичну приналежність, достатньо відтворити основний його лінійний рисунок, зберегти спосіб формування і характерні кути, пропорції. Додаткові деталі збагачують візуальний образ, проте не змінюють результат ідентифікації. Подібна ситуація з ідентифікацією стилю в архітектурному середовищі. На відміну від декоративних елементів, як і від мистецьких творів у «чистому» вигляді, архітектурно-просторове середовище мало багато важливих функцій, і естетика серед них не була основною. Тому досвід використання аналізу морфологічної структури – архітектоніки першоджерела за допомогою формотворення дозволило створити функціонально-естетичне середовище у просторі. Філософсько-концептуальний підхід переосмислення першоджерела, а не лише «аналогів» дизайн-пропозицій, розширило інтерпретаційне поле сучасного проєктанта, який в коректній синергії з сучасними технологіями має можливість створити асоціативний образ своєї авторської інспірації. Практична цінність дослідження полягає в розробці методичних підходів до аналізу та інтерпретації архітектоніки першоджерел, як основи для стилізації в сучасному дизайні інтер'єру. Запропоновані концептуальні принципи стилізації можуть бути впроваджені в професійну практику дизайнерів інтер'єрів, архітекторів і митців декоративного мистецтва, а також у навчальних програмах дизайнерських і мистецьких спеціальностей

Ключові слова: форма; візуальний код; морфологічна структура; трансформація; асоціативний образ

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Modern trends in the evolution of the functions of Christian temples in world design practice

Abstract. The relevance of the research was to study the transformation role of religious buildings in modern society, in their multifunctionality. The aim of the article was to identify the nomenclature of secular functions that have appeared in the structure of modern world temples. The article considered examples of modern world Christian churches in terms of their multifunctionality development for performing, not only religious, but also public functions. Attention was paid to the architectural and planning features of combining different functions in one complex: religious, cultural, educational, commercial, office. There were presented the results of the analysis of the balances of the areas of different groups of premises in the objects, which may be useful for Ukrainian architects, when designing modern Ukrainian churches. The article emphasised the need for introducing new methods of disseminating spiritual knowledge, which required modern approaches to the design of sacral buildings. It was focused particular attention on the topic of integrating public functions into temple architecture, revealed that the building of a spiritual and retreat centre, which combined various social functions, should be designed for visitors comfortable biding as well as effective internal space organisation. It was proposed an approach to designing temples as multifunctional structures that also served as public spaces. Examples of modern sacral architecture in Europe (Italy, United Kingdom, Norway), the USA and China were given, their functional properties were analysed. The practical significance of this study is based on the application of a comprehensive approach to church design in the context of modern global architectural and social trends

Keywords: modern architecture; church; sacrality; multifunctionality; planning; premises; area

INTRODUCTION

Sacral architecture had always played an important role in the life of the city. Temples were not only a place of prayer, but also a centre of cultural, educational and social life of the community. In areas, where the sacral tradition had deep historical roots, temples had always remained symbols of spirituality, culture and social unity. At the same time, the functions of sacral architecture have evolved, responding to changing social needs and challenges of the time. Modern sacral architecture was developing in the conditions of globalisation, secularisation and new social challenges. Modern temples, in addition to fulfilling traditional religious tasks, integrate new functions into their

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structure that respond to the needs of the modern society. The changes indicated the desire of temples to remain relevant centres of social life.

Scientists O. Sleptsov & Y. Dunaevskiy (2020) focused on the problem of the emergence of the first church complexes, the functional and spatial-planning organisation of churches and their complexes. The authors also analysed the compositional and architectural-artistic solutions of Christian spiritual centres. Researchers O. Vodotyka & L. Savenok (2017) typified the experience of construction of churches in Ukraine within the framework of historical evolution. The authors drawn attention to the modernisation of the architectural typology of Orthodox churches, and to the methodology for calculating the capacity and area of the main premises of the parish church. The scientists made proposals for the formation of the spatial solution of sacral buildings. O. Druzdiev (2021) analysed sources on the history of the Garrison church of the Holy Apostles Peter and Paul (former Jesuit church), discovered in the fund collections of the Vasyl Stefanyk Lviv National Scientific Library. The author M. Khokhon (2020) collected, systematised and revealed new insights into the operation and historical development of the defensive structures of Bernardine Order monasteries in Western Ukraine. Researcher also identified the location, dimensions, and architectural and planning characteristics of the monasteries' fortifications. Researcher O. Diachok (2021) analysed the volumetric and spatial compositions of some sacral buildings, showed that the search for modern symbols that would reflect the national character in church building to create new modern images of the Ukrainian Church continues. For the first time, data on some modern churches in the territory of Western Ukraine were introduced into scientific circulation. Scientist O. Diachok (2020) investigated the architecture of sacral complexes in the territory of modern Ternopil region, which was shaped by a combination of complex socio-political factors.

The author O. Sleptsov *et al.* (2021) analysed and formulated the characteristic features of traditional Ukrainian landscape design, which had authentic roots and was based on minimal interference in the existing natural environment and its maximum use to enhance the properties of architecture. Researcher identified traditional and innovative elements in the landscaping of modern Ukrainian Orthodox churches. Scientists H. Shevtsova & H. Ponomarenko (2020) demonstrated the importance of preserving ancient Ukrainian churches, which carried the genetic memory of the nation, supplement data on the development of sacral architecture, and opened the way for further research. Researchers concentrated on the contribution of the artistic and creative elite to the formation of national identity; highlighted challenges in developing Ukrainian identity linked to historical heritage; examined the impact of social and political factors on Ukrainian sacred architecture, and explored how architecture can visually represent the image of the national church.

K. Holubchak (2021) focused on the architectural and urban planning aspects of spiritual retreat centres, particularly in the context of religious tourism in Europe. The author analysed the modern state of religious tourism in Ukraine and proposed a model for its development by establishing a network of spiritual retreat centres. Researchers B. Cherkes & O. Dyachok (2019) analysed the preservation of sacral buildings in small towns and villages on the lands of Galitsky Podillya. Scientists showed the state of a large number of churches and synagogues in an abandoned state. Although there were many studies and publications devoted to sacral architecture, most of them focused on either historical temples, or only on one specific type of temples public functions. The peculiarities of the development of functions related to religious ones, especially implemented in modern foreign temples, during 1991-2025 not given enough attention. The purpose of the article was to identify the nomenclature of non-religious functions that had appeared in the structure of modern world temples, to determine the relative parameters of premises groups that ensured the implementation of these functions, and the approximated ratio of the areas of these premises.

MATERIALS AND METHODS

To achieve the aim of this study, a systematic approach was applied to the analysis of scientific literature, architectural and conceptual frameworks, plans related to sacral architecture and its socio-cultural significance. Graphical method was used to visualise the functional zoning of temples, schemes of interaction of sacred and secular space, analysis of visitor flows. This allowed to clearly present the complexity and flexibility of spatial organisation. To study the main architectural structures, the source ArchDaily (n.d.) was used in the research. In addition, the main material for the study was the works of K. Holubchak (2017; 2021). Particular attention was paid to minimising environmental impact and applying the latest technologies for monitoring and desing planning. Correlation methods was used to identify connections between the functional structure of temples and such factors as the size of the community, location, denominational affiliation, year of construction. This allowed to draw reasonable conclusions about the patterns of development of temples in the urban context. Analysis allowed for an objective assessment of the multifunctionality of temple structures, their degree of openness, and their ability to adapt to the various needs of the community. This approach provided a comprehensive understanding of methodical planning, design, and construction of sacral spaces (like temples, churches, mosques, or synagogues) based on coherent principles – spiritual, symbolic, cultural, and functional. It helped to ensure that the architecture not only served religious functions, but also reflected theological, cosmological, and ritualistic significance.

The study was focused on the analysis 7 architectural objects: Community church Knarvik, Presbyterian church (USA), Church and Community Centre in Castel di Lama, The parish complex of San Martino parish in Bergamo, Mei

Li Zhou church in China, Korean Presbyterian church, Stanbruck Abbey. It was analysed ritual functionality of these buildings, their spiritual and theological foundations, stylistic elements and symbolic content. This foundation was enriched by contemporary research on the sociocultural function of religious buildings, which allowed for a deeper interpretation of the role of temples in the formation of the community identity. The criteria for selecting sources gave preference to materials that highlighted modern world Christian churches, with a focus on the analysis of their multifunctionality development and the influence of regional factors on architectural creativity. Priority was given to publications from the 2010-2025 period, taking into account fundamental research in the field of modern sacral architecture.

RESULTS

The church strives to be a universal space for the children and youth safe upbringing, a local centre for believers meetings, as well as to promote the development of art, music and cultural enrichment of parishioners. Sacral architecture had deep historical roots, reflecting the multifaceted nature of its tasks in the life of the community. Traditionally, temples served not only as sites of spiritual worship, but also as key hubs for social and cultural activities (Table 1).

Table 1. Traditional functions of the church architecture

Church function	Description	Historical examples
The church as a religious building	The main purpose of the church had always been and remained to provide a place for prayer, worship and religious ceremonies. The church building acted as a symbol of faith and the unity of the community around common spiritual values	Any religius building
The church as an educational centre	Historically, churches had served as educational centres. It had schools, where literacy, the basics of religion and moral principles were taught	Roman College, Italy; Saints Peter and Paul Garrison church, Ukraine; Chartres Cathedral, France
The church as a shelter for the needy	Churches often took on a social role – it operated orphanages, hospitals, and soup kitchens for the poor	Saint Lazarus church, Ukraine
The church as a community	Meeting Place Temples were places where the community gathered, where important social issues were discussed, agreements were made, and celebrations were organised. The temple square often became the centre of social life	Any parish churches
The church as a place of archives	Important documents and archives were stored within the walls of churches, which emphasised their role in preserving cultural memory	Admont Abbey Library, Austria; Abbey of Saint Gall, Switzerland
The church as a defensive structure	In certain periods, temples also performed defensive functions, serving as protection for the community in case of danger	Holy Intercession church, Sutkivtsi, Ukraine; Bernardine church, Ukraine; St. Peter's Cathedral, Germany

Source: S. Rzhevsky (2024), Abbey of Saint Gall (n.d.), Bernardine Monastery and St. Andrew's church (n.d.), Our Lady of Chartres Cathedral (n.d.), Palazzo del Collegio Romano (n.d.), Parish group Cathedral of St. Peter and St. Martin worms (n.d.), I. Zhuk (n.d.), Saints Peter and Paul Garrison Church (n.d.), The Admont Monastery Library – a masterpiece of the late Baroque period (n.d.)

Thus, the traditional functions of world sacral architecture went far beyond the limits of purely religious significance. It was integrated into all aspects of the life of the city community, ensuring its spiritual, cultural and social development. During 1991-2025, the architecture of religious and educational institutions in Europe was distinguished by a variety of new architectural approaches that corresponded to modern trends. These solutions have become a kind of reaction to the fact that among the main reasons for the decrease in the frequency or complete refusal of people to attend liturgies was the lack of time or reluctance to visit the temple, which was associated with priorities in other areas of life. The reaction to this situation has been the simplification of traditional church canons and the desire of the Vicars of the churches to get closer to society. Therefore, the clergy actively took into account the latest architectural trends and supports modern innovative projects, which contributed to the adaptation of church traditions and rituals to modern conditions. The democratisation of the role of the church had led to the fact that the church had turned into a multifunctional space that performed not only a religious, but also a social role (a retreat centre, a place of prayer and worship, as well as a space for parish meetings, events, excursions and concerts).

One of the examples was the church design in China. Architects from Tsushima Design Studio (Fig. 1) have developed a church project that would be not only a place for religious ceremonies, but also a space for spiritual rest in the hustle and bustle of the city. During the design process, special attention was paid not only to the functionality of the building, but also to the eco-friendliness of the used building elements and minimising the effect on the surrounding landscape. The architectural complex consisted of three main structures that were autonomous, but at the same time interconnected: the church, a garden chapel with parish offices in the courtyard, and a campaline. In addition, two smaller premises were provided for the parishioners' needs. This project demonstrated a harmonious combination of sacral function with openness and ecological sensitivity.

Figure 1. Mei Li Zhou church. Tsushima Design Studio
Source: based on Mei Li Zhou Church/Tsushima Design Studio (2010)

Another example of the understanding of modern sacral architecture was the Norwegian project. The architects of the Reiulf Ramstad Arkitekter office in the village of Knarvik in Norway, choosing the style of the temple, were influenced by regional customs of Norwegian wooden temples, using clear geometric shapes, natural materials and modern constructive solutions (Fig. 2). The compact volume of the building was divided into two levels: the first floor was intended for religious services, while the ground performed cultural and administrative functions. Thanks to its innovative approach and central location, the church had become a key centre of religious and cultural life for the village residents, as well as an attractive place for tourists. When creating the style of the church, the architects were influenced by regional customs of Norwegian wooden religious buildings, using distinct, simple geometric shapes, natural materials and reliable structures (Community church Knarvik..., 2014). The compact volume of the building was divided into two floors: the first floor houses the premises for worship, while the ground floor was for cultural and administrative needs, there was also a lift there. This church was an example of a harmonious combination of educational functions with modern sacral architecture. As well as itembodied a modern interpretation of traditional architecture with an emphasis on simplicity and multifunctionality (Holubchak, 2021).

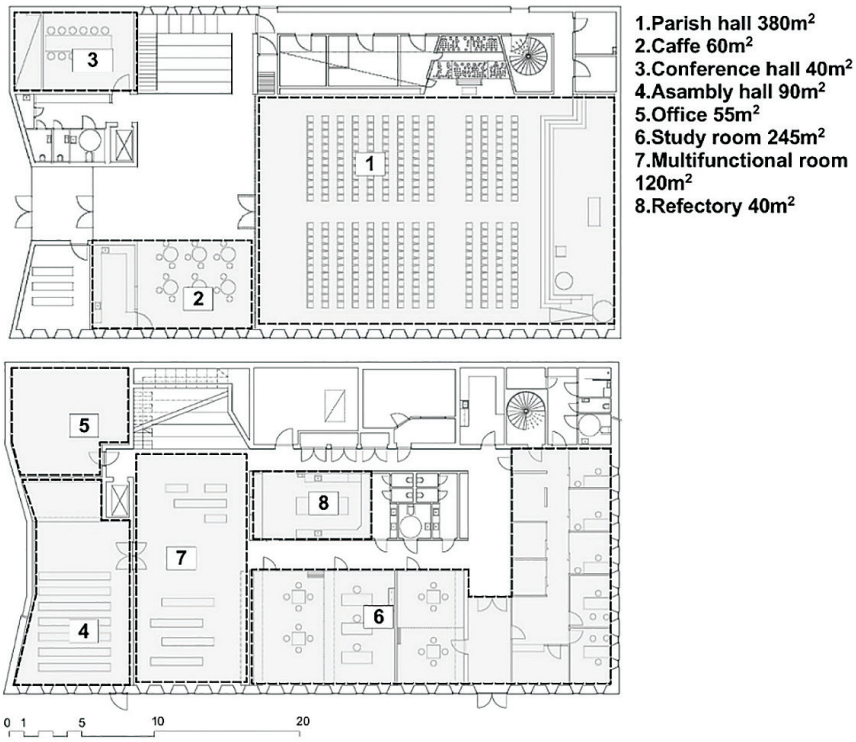

Figure 2. Parish complex in the village of Knarvik, Norway
Source: based on K. Holubchak (2021)

Successful experience of the operation of such buildings in European countries confirmed their relevance for modern society. Spiritual and retreat centres, along with other sacral institutions, unite communities around spiritual centres, contributing to the strengthening of national faith and the spiritual upliftment of the nation. The defining feature of modern sacral buildings was their versatility and multifunctionality, which was manifested in the addition of sacral core spaces for various spheres of social activity – from leisure and recreation to creativity, education and health improvement. This ensured the comprehensive spiritual development of the individual. The church aimed to become a universal platform for children and youth education, a meeting place for local residents, and to promote

the development of art, music and culture of parishioners. The architecture of the temple shown a strong emphasis on educational and public functions – classrooms, children's rooms, and a multifunctional hall occupy more than half of the area of the temple complex (Holubchak, 2021). In this temple, approximately half of the space was dedicated to educational and community functions, emphasising its role as a centre of communal life. Adjacent to the worship hall were rooms for catechesis, a café, and a refectory. Figure 3 showed the ratio of the area of the premises of this parish complex to their functional characteristics.

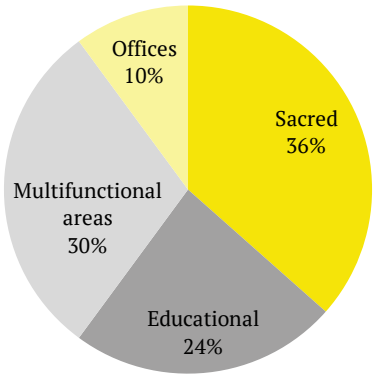

Figure 3. Ratio of the premises area of the parish complex in the village of Knarvik due to their functional characteristics
Source: developed by the authors

The areas of the premises were determined based on the architectural plans of the studied churches. All spaces were grouped into functional categories: sacred (main sanctuary, baptistery, confessionals), educational (classrooms, rooms for children's activities), public/entertainment (multi-purpose halls, sports facilities, dining areas), and administrative (offices). The areas of the respective spaces were totaled for each category. The total area of the church was taken as 100%, after which the areas of individual functional categories were converted into percentages relative to this total. The floor areas of corridors, storage rooms, and ancillary spaces were excluded. Modern European monasteries offer visitors a wide range of opportunities for spiritual rest. Therefore, in their planning solutions, in addition to traditional premises for everyday life of monks and nuns, areas for pilgrims, tourists or those, who want to spend time in the monastery in search of spiritual enrichment increasingly appear. Such areas included living rooms, classrooms, a conference room, rooms for retreats and a dining room. The laconic architecture of the Stanbruck Abbey complex harmoniously complements the picturesque landscapes from the south side, where the closed part of the monastery was located. This part contained 26 cells, a kitchen, a refectory and workshops, illuminated by maximum natural light (Fig. 4).

Figure 4. Stanbruck Abbey complex in United Kingdom
Source: based on Stanbrook Abbey/Feilden Clegg Bradley Studios (2015)

At the begining of the 21st century the monastery had a church, a chapel, a chapterhouse and various guest rooms, including a conference room and a bookstore. Modern architecture of institutions of a spiritual and educational direction in Europe was distinguished by the variety of new architectural approaches and the simplification of traditional church canons. The main feature of this trend was the multifunctionality of sacral buildings, which involved the arrangement of additional public spaces with a wide range of functions – from educational to recreational, contributing to the harmonious development of the individual. An example of integrating modern functions into the architecture of a historic temple was the parish complex of San Martino parish in Bergamo. This building was connected to the historic centre through a network of pathways that served not only as circulation routes, but also as spatial elements in their own right (Fig. 5).

Figure 5. The parish complex of San Martino parish in Bergamo, Italy
Note: designed by architect Gianluca Gelmini, 2011
Source: based on Parish Centre/Gianluca Gelmini (2011)

The new addition consisted of three levels: a basement housing the service areas, a ground floor with the main entrance, reception, and a café, and a first floor that included three new classrooms and a direct link to the existing classrooms in the centre. The new block on the ground floor houses the lobby, administrative offices, and a café, and on the first floor there were catechetical classrooms with a passage to the old block and the church. The layout of access routes and connections ensured flexibility, in how both the entire structure and its individual parts can be used. Wide windows on the ground floor offered wide views of the gardens and the street, giving the structure an open, outward-looking feature that connected it to the village. This created a transitional space between the dynamic atmosphere of the street and the more sheltered environment of the gardens. On the upper floor, the walls turn more solid and enclosed, encouraging an inward-focused atmosphere suitable for catechetical activities (Fig. 6).

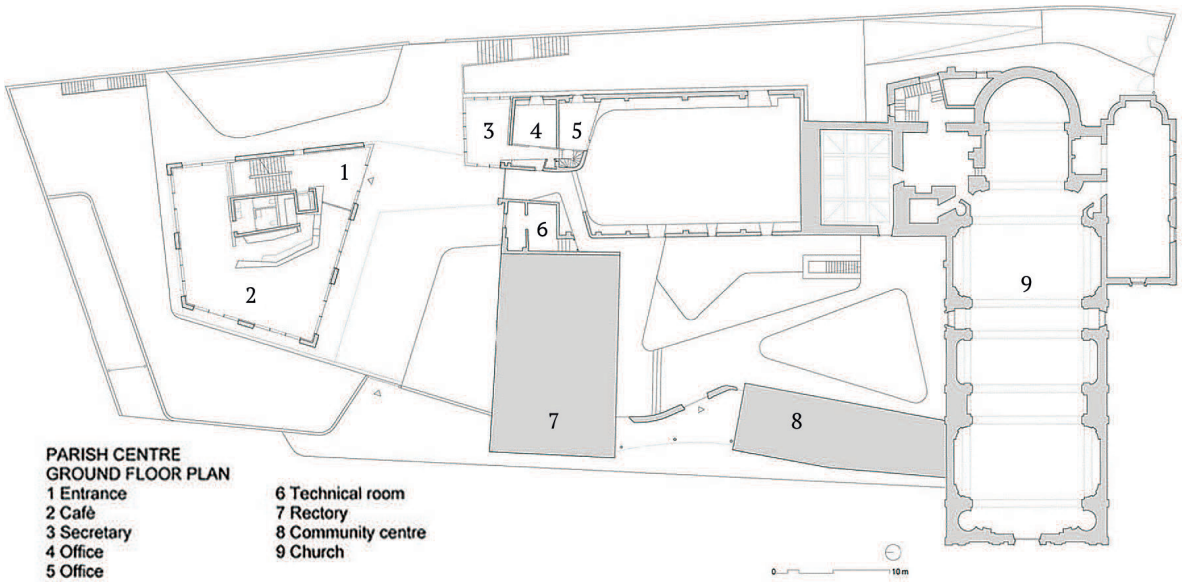

Figure 6. The ground flour of the parish complex of San Martino parish in Bergamo
Source: based on Parish Centre/Gianluca Gelmini (2011)

An interesting object was also Korean Presbyterian church made by the architects of the studio "Arcari + Iovino Architects" in 2013. The church served as a spatial and programmatic platform for artistic self-realisation and intergenerational dialogue, particularly among families. This role was not incidental, but embedded in how space was conceived, organised, and activated within the church complex. Contemporary ecclesiastical architecture increasingly moved beyond monofunctional liturgical spaces toward multifunctional, inclusive environments that respond to evolving social, cultural, and intergenerational needs. Enabling artistic self-realisation required spaces that were flexible, accessible, and open to reinterpretation. Multi-purpose halls, open atriums, and modular classrooms within the parish complex can serve as venues for choir practice, iconography workshops, religious theatre, or intergenerational craft-making events. These spaces must support both formal and informal activities, with acoustic, lighting, and material qualities conducive to artistic production and performance (Fig. 7). The worship hall seated 380 believers and was engineered for sound quality to hold musical concerts and events, along with its traditional purpose. Due to its multifunctionality, the space accomodated parishioners before and after the service. This two-story building had an art gallery-mezzanine, where the works of parishioners were displayed. Cozy seating areas were illuminated by natural light coming through a large dormer window above. The lower level houses children's chapels for three different age groups, which were used during the adult liturgy (Holubchak, 2021).The area of educational premises and children's rooms occupied more than a third of the temple area (Fig. 8).

Figure 7. Korean Presbyterian church
Source: based on Korean Presbyterian Church/Arcari + Iovino Architects (2013)

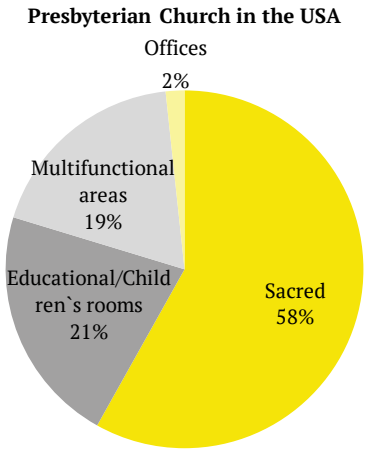

Figure 8. Ratio of the premises area of the parish complex in the village of Knarvik due to their functional characteristics
Source: developed by the authors

The areas of the premises were calculated based on the architectural plans of the analysed churches. All spaces were classified into functional categories: sacred (main sanctuary, baptistery, confessionals), educational (classrooms, children's activity rooms), public/entertainment (multi-purpose halls, sports facilities, dining areas), and administrative (offices). The total area for each category was then summed. Considering the overall church area as 100%, the proportions of the individual functional categories were expressed as percentages of this total. Floor areas of corridors, storage, and auxiliary spaces were excluded from the calculations. In this way, the church was revealed as a space that fosters artistic self-expression and intergenerational dialogue within the parish community, particularly among families. The areas of the premises were determined based on the architectural plans of the studied church. Beyond its primary liturgical function, the contemporary parish church increasingly operated as a cultural and communal space that nurtured creativity and facilitated meaningful social exchange. Artistic expression – whether through music, visual arts, liturgical performance, or craftsmanship – provided parishioners with opportunities to engage in the life of the church in deeply personal and participatory ways. These creative activities were not merely supplementary, but were integral to the church's broader mission of spiritual formation and community building (Fig. 9). Another object worthy of attention was Church and Community Centre in Castel di Lama, Italy. The premises comprised sports and leisure facilities, learning areas, and gathering spaces, forming an urban network that fostered community engagement. The church was built by Studio Contini in Castel di Lama, Italy, in 2019. The architecture of this church emphasised the public life of the parish; entertainment, sports facilities, and meeting places occupied more than a third of the church's area. In this church, the primary community function was centreed around sports activities. A significant part of the complex (about 31% of the church's area) was occupied by sports halls and sport grounds, which served as spaces for the parishioners' active recreation. Such an organisation of space fosters community building through shared sports activities and the promotion of a healthy lifestyle (Fig. 10).

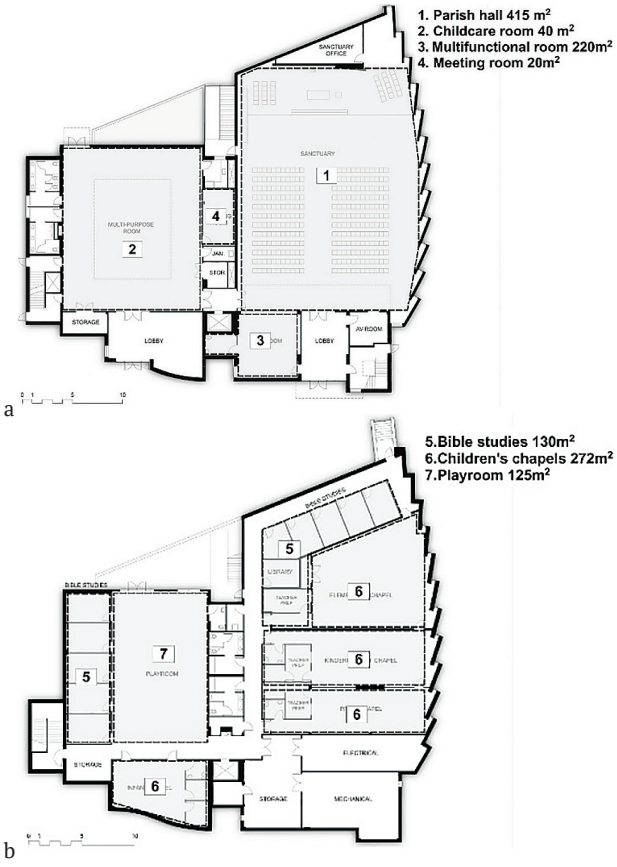

Figure 9. Presbyterian church (USA)
Note: a – architectural and planning organisation of the 1st level of church; b – architectural and planning organisation of the 2nd level of church
Source: based on Presbyterian Church in America (n.d.)

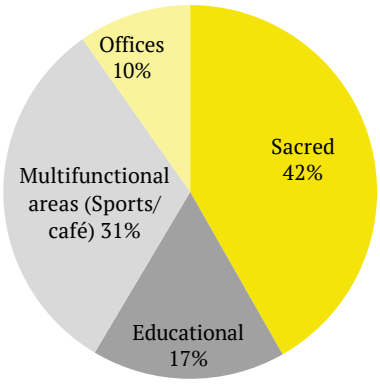

Figure 10. Percentage ratio of the area of the Church and Community Centre premises in Castel di Lama due to their functional characteristics
Source: developed by the authors

The connection with the surrounding settlement was strengthened by a pedestrian walkway that run through the courtyard and led to a large square garden. This space was bounded on the South by a simple wall and a closed portico oriented towards the main road. The spatial connection between the parish complex and the surrounding settlement was articulated through a pedestrian axis that traversed the courtyard and culminated in a large, square garden. This pathway functions as both a physical and symbolic connector, reinforcing the church's integration into the daily life of the community. By facilitating ease of access and visual continuity, the path invited movement and encouraged interaction between the sacred precinct and the broader urban or rural context. It became a transitional space that subtly guides individuals from the public realm into a more reflective and contemplative environment.

The square garden, situated at the heart of this spatial sequence, acts as an intermediary zone between the ecclesiastical architecture and its external surroundings. Its geometric regularity evokes order, clarity, and calm, providing a space conducive to reflection, informal gathering, or liturgical celebrations in an open-air setting. As a designed void within the built environment, the garden contributed to the modulation of the site's spatial rhythm and supported the notion of the church not merely as a destination, but as an integrated node within the community's spatial and social networks. This space was defined along its Southern edge by a modest wall and a closed portico, both oriented toward the main thoroughfare. The wall served as a protective boundary, introducing a degree of spatial enclosure that heightened the sense of entry and transition. Meanwhile, the closed portico – though visually restrained – asserts a subtle presence toward the public street, marking the threshold between the sacred interior and the civic exterior. Its orientation toward the main road reinforces the parish's openness to the wider community, while maintaining a degree of contemplative separation. Together, these architectural elements established a coherent spatial sequence – from the bustling life of the settlement, through a mediating landscape, and into the sacred interior of the church. This progression not only enhanced the legibility and accessibility of the site, but also reinforced its role as a spiritual, cultural, and social anchor within the community (Fig. 11).

Figure 11. Church and Community Centre in Castel di Lama
Source: based on P. Pintos (2019)

Such boundaries created an atmosphere of unity and form an area that met the requirements of the community and group gatherings. A key feature of the project was the public pedestrian path that run through the complex, dividing the church and parish buildings, while also creating potential urban links with the surrounding public spaces. The bell tower, situated near the main street and the settlement, highlighted the parish centre's prominence through its height. The facade of the church, made of travertine slabs, served as a kind of filter that opened the view to the interior of the building. This temple primarily served a public function, focused on sports-related activities. Portions of the complex included gyms and sports facilities, providing a space for parishioners to engage in active leisure (Fig. 12).

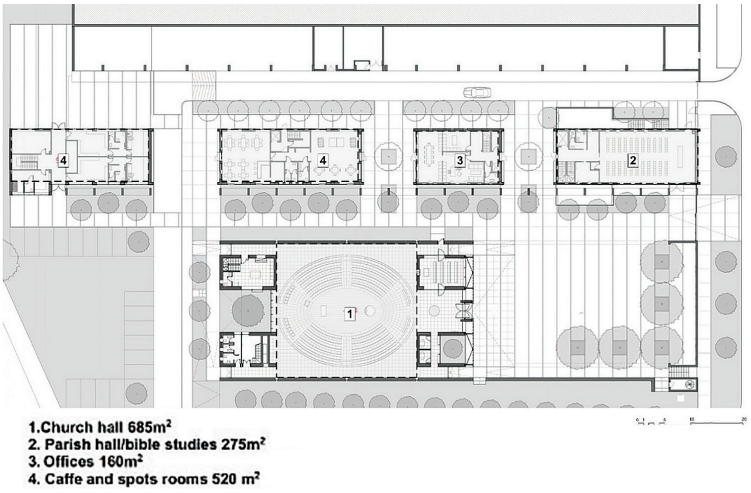

Figure 12. Architectural and outlay organisation of the Church and Community Centre in Castel di Lama
Source: based on P. Pintos (2019)

Based on examined temple complexes, the following ratio of building blocks was compiled: Community church Knarvik, Presbyterian church (USA), and Church and Community Centre premises in Castel di Lama. The average value from each category was taken – "Sacred", "Multifunctional areas", "Entertainment (sports/cafe)", "Offices"; the category "Educational" contained both educational and children's rooms. Given the area of additional premises, modern churches placed greater emphasis on education and work with children and young families. Multifunctional areas used for entertainment, lectures, or meetings also occupied an important place in the architecture of modern churches (Fig. 13).

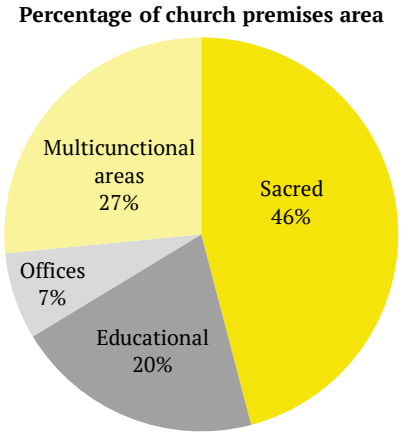

Figure 13. Approximate percentage of premises area of Church and Community Centre in Castel di Lama, Presbyterian church, Parish complex in the village of Knarvik

Source: developed by the authors

So, the characteristic feature of modern sacral buildings as well as spiritual and retreat centres was their versatility and multifunctionality. In the addition of the sacral core it was manifested with premises for various spheres of social activity – leisure, recreation, creativity, education, health improvement, which contributed to the harmonious spiritual development of the individual (Sapozhnik, 2024). Among the main functional zones of such buildings, one can distinguish: entrance, sacral, recreational, educational, catering, residential, commercial, administrative and household, technical, economic, exhibition and a group of additional premises. Depending on the main direction of activity, a certain functional group of premises in temple communities acquired a dominant importance. The leading one remained the sacral function, which was key for all public centres at temples. It was concentrated in chapels or prayer halls (naves), which formed the core of the building, and covered the holding of services and spiritual guidance for believers. Along with this, housing provided conditions for overnight stays and short-term stays of pilgrims and participants in retreats; for this reasons cells, rooms or hotel blocks were used. These functions were joined by a retreatment, which was aimed at the visitors spiritual healing through communication with the clergy, prayers, spiritual practices, and participation in retreats. In this context, an important role was also played by the creativity, which was realised through the activities of craft and icon painting workshops, the organisation of creative circles for children and youth, choral studios, and publishing projects. Spiritual and retreat centres can become centres of sacral art, offering halls for listening to spiritual music, choral singing, and artistic meetings (Holubchak, 2017). Table 2 summarised the main functional blocks that were important for the existence of sacred buildings.

Table 2. Functional blocks in modern churches

No.	Functional block	Examples of activities
1	Religious	Participation in worshiping (masses, liturgies)
2	Educational (catechetical)	Catechetical schools, Sunday schools for children
3	Entatainment (cultural and educational)	Libraries, museums, exhibition centres, lecture halls
4	Production	Publishing of religious magazines and newspapers
5	Charity	Activities of social services, houses of mercy, rehabilitation institutions, soup kichens, pilgrimage hotels
6	Recreation and leisure	Organisation of creative circles and studios (art, sports, music, theater), support for youth organisations, camps, activities of pilgrimage services

Source: developed by the authors

The spatial organisation of temples also found its expression in the museums, embodied in the work of exhibition halls of sacral art, which were aimed at cultural education, the development of aesthetic taste and spirituality of society. It should be noted that a significant part of visitors to community centres at temples may be inactive Christians, for whom faith was rather a symbol of national identity, history and culture. It was for such people that the museum function can become the first step towards a deeper understanding of faith. In addition, the economic needs that have long been the basis for monastic life were met through gardening and growing vegetables and fruits – such activities still remain a way of expressing faith through work. In parallel, there was a commercial component that contributed to the temple financial support. The funds received from the organisation of fairs, the sale of spiritual literature, handicrafts and icons were used for the maintenance and development of the institution. Educational function was also important, which was aimed at the comprehensive development of the personality and

its spiritual growth through the study of the basics of religion and the Bible. It was implemented through the work of Sunday schools and can be effectively implemented in churches by organising conferences, courses, forums and seminars on religious topics. For this reason, it was necessary to provide premises such as classrooms, lecture halls, conference rooms, libraries, reading rooms, as well as specially equipped children's spaces for the catechisation of the youngest visitors (Holubchak, 2017).

Modern church life also included a recreational function, which was implemented through the organisation of Christian camps and festivals, conferences and concerts of spiritual music. At the same time, new youth organisations were emerging that popularise Christian values and education, involving like-minded people in interesting activities – watching religious films, master classes, foreign language courses, learning crafts, organising pilgrimage tours, excursions, youth balls, festivals and sports tournaments. All this required the presence of an appropriate spatial base: assembly halls, art studios, concert and exhibition spaces, sports halls. Finally, an important place was occupied by the missionary (charitable) function, aimed at rehabilitation and providing material and spiritual assistance to those in need. Charitable activities at churches included the creation of houses of mercy (such as the City of Mercy of St. Nicholas at the parish of Cyril and Methodius in the village of Krykhivtsi, Ivano-Frankivsk region), church boarding schools, medical centres, and free soup kitchens.

DISCUSSION

The results of this study have highlighted that Christian temples, traditionally understood as churches, cathedrals, and chapels, have undergone significant functional and design transformations throughout history. Modern Christian temples increasingly served multifunctional roles beyond purely religious ceremonies. It often acted as community centres, cultural hubs, and spaces for social services, including education, health outreach, and charity. By examining design implication modern architects prioritised flexible, adaptable interiors with movable seating and multi-use rooms. Facilities might include classrooms, meeting halls, galleries, and even cafes. Some churches incorporated community kitchens, art exhibitions, or youth centres. The discussion aimed to explore ecumenical and interfaith use of religious buildings. With rising interfaith dialogue and ecumenism, some Christian temples were designed or adapted for shared worship or interdenominational use. This trend reflected a global movement toward religious tolerance and cooperation.

Scientists Yu. Ivashko *et al.* (2019) pointed out technological integration – technology profoundly impacts modern church design, transforming worship and community engagement. From 2019 there appeared so called digital worship due to the pandemic. Incorporation of high-quality audiovisual systems enabled live streaming, virtual participation, and multimedia-enhanced sermons. The study highlighted that smart building technologies optimised energy use, lighting, and acoustics, aligning with ecological stewardship values. So, the architects have to take into consideration the aspect of sustainability, while planning the religious building. Also, the research of the study shown that there was a new trend in integration of screens, sound systems, and digital infrastructure, while preserving sacred atmospheres. Besides, environmental consciousness was a dominant theme in contemporary sacral architecture. Scientist M. Mihaljević (2021) analysed this problem and suggested the ways of solving this problem. Christian temples increasingly adopted sustainable materials, green roofs, natural lighting, and energy-efficient systems. Moreover, the use of eco-friendly materials, passive solar design, and integration with natural surroundings can contribute to symbolising harmony between faith and creation.

The study shown that contemporary sacral design practices explored new architectural languages that respected tradition, but express modernity. Some churches moved away from grand, imposing Gothic or Baroque styles toward minimalism, transparency, and openness, symbolising inclusiveness and humility. Also, Yu. Ivashko *et al.* (2020) tried to use light, space, and materiality to create spiritual atmosphere rather than rely on elaborate ornamentation. The research emphasised that in densely populated urban areas, space constraints and changing demographics led to adaptive reuse of existing buildings as Christian temples or hybrid spaces. Researcher S. Pandya (2020) emphasised on this problem in their work. The author have to creatively remodel industrial, commercial, or historic buildings into worship spaces. This trend respected heritage, while responding to contemporary community needs. The evolution of Christian temples in world design practice highlighted a shift from exclusive sacred spaces to inclusive, multifunctional, and technologically integrated community hubs. The author N. Miščević (2001) suggested the solution of this problem. Sustainability, interfaith openness, and adaptive reuse further characterised this transformation. Architects and church communities collaborated to balance tradition with innovation, creating spaces that served spiritual needs, while engaging meaningfully with modern society. The discussion emphasised that the modern churches were more than religious places; they were visual records of the historical, spiritual, and cultural identity of a community. It reflected the dynamic interplay of tradition, innovation, needs and resilience. This research had expanded knowledge of the function of a modern church and highlighted the importance of designing new religious places, which corresponded to the modern needs of the society.

Researcher A. French & K. Waldner (2024) considered that sacred space was not a static or purely religious phenomenon, but a cultural construct that evolved through design, aesthetics, belief systems, and social use, especially under the influence of modernity. The sacred became a site of negotiation between tradition and innovation, institutional religion and alternative spiritualities, architecture and ritual. F. Ciampa *et al.* (2024) explored the transformation

of sacred spaces (e.g., churches) in New York for new societal functions, with an emphasis on preserving cultural heritage. Scientist V. Miroshnichenko (2022) addressed the challenges of forming Ukrainian identity connected to the historical past; examined the impact of social and political factors on Ukrainian sacred architecture and the potential to represent the national church's image through architectural design; emphasised the significance of Ukrainian sacred architecture in affirming ethnical identity. So, the studies on contemporary sacred architecture highlighted a dynamic interplay between tradition and innovation, with a strong focus on shaping national identity through spiritual space. Researchers emphasised the symbolic and social significance of newly built churches, especially in the post-1990 period, where sacred architecture had became a medium for cultural revival. Scientists explored, how historical forms, such as domed temples and wooden churches, were reinterpreted using modern materials, technologies, and minimalist aesthetics. Scholars also addressed the revitalisation of sacred complexes as community centres, the emergence of neomodernism in religious architecture, and the search for a distinct national style that reflected both historical continuity and modern socio-political realities. These architectural developments served not only religious functions, but also reinforced collective memory, identity, and resilience in the face of modern challenges.

CONCLUSIONS

Modern sacral architecture continued to perform traditional functions, but had undergone certain changes, adapting to the needs of modern society. These changes were due to secularisation, urbanisation and social challenges, which required churches to adopt new approaches to the organisation of space and functional purpose. The church remained a religious building and retain their main purpose – to be a place of prayer, worship and religious ceremonies, and at the same time, the church acted as a centre of education. The Church and Community Centre in Castel di Lama opened libraries and created multimedia educational spaces that made knowledge accessible to a wide audience. The temple also performed an important function of social service and charity. Churches had social services that helped internally displaced persons and veterans, held charity events, and organised fundraisers and food drives. Churches also had soup kitchens, rehabilitation centres, and support centres for people in crisis situations (for example, Presbyterian church (USA)). Modern churches were becoming places for public and cultural meetings, it hosted concerts of sacral music, theater performances, exhibitions, thematic meetings, and workshops. For example, Mei Li Zhou church were often equipped with multifunctional halls that were used for conferences, festivals, or film screenings. A new function of churches had also became the provision of psychological and emotional support. Group therapy, consultations with psychologists or spiritual mentors were organised in churches. Also, Parish complex in the village of Knarvik (Norway) served as recreation and leisure centres. Increasingly, spaces for recreational activities were being created at churches: gyms, multifunctional halls for dance and sports clubs, cafes, workshops and libraries. In further study, it is advisable to concentrate on modern trends in church architecture, in particular the use of new materials, technologies and structures, as well as studying the integration of ecological design principles into modern sacral buildings.

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Сучасні тенденції еволюції функцій християнських храмів у світовій практиці проєктування

Анотація. Актуальність дослідження полягала у вивченні трансформаційної ролі релігійних споруд у сучасному суспільстві, їхньої багатофункціональності. Метою статті було визначення номенклатури світських функцій, що з'явилися у структурі сучасних храмів світу. У статті було розглянуто приклади сучасних християнських церков світу з точки зору розвитку їхньої багатофункціональності для виконання не лише релігійних, але й суспільних функцій. Було приділено увагу архітектурно-планувальним особливостям поєднання різних функцій в одному комплексі: релігійних, культурних, освітніх, комерційних, офісних. Наведено результати аналізу співвідношення площ приміщень різних груп у досліджуваних об'єктах, що може бути корисним для українських архітекторів при проєктуванні сучасних українських храмів. У статті наголошено на необхідності впровадження нових методів поширення духовних знань, що вимагало сучасних підходів до проєктування сакральних споруд. Особливу увагу було зосереджено на темі інтеграції суспільних функцій в архітектуру храмів; виявлено, що будівля духовно-реколекційного центру, яка поєднувала різні соціальні функції, має бути спроєктована для забезпечення комфортного перебування відвідувачів і ефективної організації внутрішнього простору. Запропоновано підхід до проєктування храмів як багатофункціональних структур, що одночасно слугували громадськими просторами. Наведено приклади сучасної сакральної архітектури Європи (Італії, Великої Британії, Норвегії), США та Китаю, проаналізовано їхні функціональні особливості. Практичне значення дослідження ґрунтується на застосуванні комплексного підходу до проєктування церков у контексті сучасних світових архітектурних і соціальних тенденцій

Ключові слова: сучасна архітектура; церква; сакральність; багатофункціональність; планування; приміщення; площа

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Destruction and reconstruction of Ukrainian cities after World War II: Development of methodological approaches to contemporary reconstruction

Abstract. The research relevance of the formation of cities during the pre-war and post-war periods of World War II was determined by the influence of the process on the modern appearance of some cities, being one of the main components of their cultural identity. The study aimed to analyse the historical stages of city formation as an integral system of political, ideological and material structures, and to determine the impact of the post-war reconstruction of Soviet cities on the current urban planning situation. The study analysed the post-war reconstruction of Soviet cities in Ukraine as a dynamic and controversial process consisting of several stages. The peculiarities of architectural and urban planning thinking and practical methods were identified, which determined the nature of architecture and the general logic of city formation during the war and post-war years of World War II. Using general scientific research methods such as analysis, synthesis and comparison, the post-war reconstruction of Kyiv, Kharkiv, Zaporizhzhia and Ternopil was analysed; the main architectural and urban planning techniques used in the reconstruction of these cities were identified, and a comparative analysis of these cities with cities in modern Europe was conducted. The systematisation and generalisation of bibliographic materials were used to determine the state of research on this topic, and to summarise and supplement existing information on the principles of rebuilding cities destroyed by war. Through systematic analysis and special research methods, such as graphical comparison, retrospective modelling and architectural composition, the characteristic features of Ukrainian cities that shape their national identity have been identified. The practical significance of the research lies in the use of the results of the analysis of the post-war reconstruction of Ukrainian cities after World War II in the development of plans for cities or city districts for their reconstruction after the end of the Russian-Ukrainian war

Keywords: urban planning; historic cities; planning structure; restoration of historic buildings; authenticity; post-war reconstruction of cities

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INTRODUCTION

For a comprehensive study of the problem of post-war reconstruction of cities, as well as the formation of Soviet architecture, as an example of post-war reconstruction after the destruction of city quarters, historical centres or entire urban formations, studies devoted to the history of pre-war and post-war architectural and territorial development of cities and their reconstruction after World War II were analysed. M. Żychowska *et al.* (2022) studied the correspondence or contrast between the ideology of the ruling power and the formation of style in architecture. The study found that, when a new government wanted to emphasise its isolation from its predecessors, it used art and architecture as ideological propaganda, creating a new style. A striking example of this was the ideology of the so-called "Stalinist empire", in particular the architecture of Ukraine, Poland, and Romania during the socialist period. The architecture showed no continuity with previous styles and only sought to emphasise its dissimilarity from the "old world". At the same time, socialist art in the Soviet Union was not homogeneous and changed radically in line with the Communist Party's policies, from the formation of Bolshevik ideology in the 1920s to Stalinist authoritarianism in the 1940s and early 1950s.

Various paths of spatial change in cities after World War II were examined by Ł. Musiaka *et al.* (2025a). The main objective of the study was to present the results of a comparative study of various forms and consequences of the reconstruction of historic centres of small towns in north-eastern Poland after World War II. The conclusions of this study showed that the negative consequences of spatial transformations (e.g., spatial chaos, lack of a functional and spatial centre, undeveloped neighbourhoods, and limited effectiveness of planning and revitalisation tools) were still felt in the 2020s. The study noted that for the further revival of the studied territories, it was necessary to develop programmes for the restoration of such cities at the national level. V. Paperny (2002) studied the evolution of architecture in the USSR during the Stalinist period, identifying two contradictory trends, Culture One and Culture Two, which alternately prevailed in Soviet culture. The study argued that the departure from the architectural avant-garde of the 1920s was not entirely the result of Stalin's will. Such architectural traditions were conditioned by the dominant cultural mechanisms of the 1930s and 1940s. A distinctive feature of the work was the combination of academic precision with an interesting narrative about the trajectory of architectural and cultural transformation that marked a turning point in the history of the USSR.

Yu. Ivashko *et al.* (2023) examined the issue of Ukraine's reconstruction, the specifics of the reconstruction, revaluation and protection of Ukrainian monuments that were destroyed as a result of military actions and the Russian invasion of Ukraine. The second issue covered in the paper was the experience of Polish conservators with cities destroyed during World War II. The third issue was international legislation in the field of heritage protection, which was analysed for planned measures in the field of reconstruction and revaluation of Ukrainian monuments after the end of the war. The study by O. Kulikov & T. Krotowski (2025) raised the issue of the regeneration of the historic centre of Odesa during post-war reconstruction. The authors analysed the stages of formation of the urban structure of Odesa, the main urban features and landmarks, as well as the determining factors that led to the formation of the historic centre and Odesa as a whole. The zoning of the historic centre and the restrictions arising from the legal status of protected areas were analysed. The negative impact of the war on the destruction of Odesa's historical sites was examined. The study predicted that the main measures of post-war regeneration of the historical centre of Odesa would be the reconstruction of individual damaged historical sites, since the overall planning structure of the historical centre had been preserved.

Scientists O. Sokhatska & Yu. Chopyk (2023) investigated the economic damage caused to Ukraine as a result of the Russian-Ukrainian war. The study noted that with the start of the Russian full-scale invasion of Ukraine in 2022, infrastructure and property worth almost USD 150 billion were damaged. The restoration of such objects has already begun in part, and this reconstruction has been financed by several funds and grants, including Ukraine's internal funds. An analysis of the data in this work was necessary for a comprehensive analysis of the problems of Ukraine's recovery. Based on the results of the literature review, it was possible to note that the issue of post-war reconstruction remained important. Studying the peculiarities of the post-war reconstruction of Soviet cities, their positive and negative features, will help to avoid negative experiences in the future. The study aimed to identify the characteristics of the formation and reconstruction of cities in the 1930s-1950s and to formulate principles for the current reconstruction of Ukrainian cities. The objectives of the study were to analyse post-Soviet cities in Ukraine in terms of their post-war reconstruction and to select cities for detailed study; to analyse urban development plans for cities in Ukraine and other countries; to identify the characteristics of the reconstruction of post-Soviet cities after World War II in Ukraine and to develop methodological approaches to the reconstruction of cities in Ukraine after the Russian-Ukrainian war.

MATERIALS AND METHODS

The comprehensive methodology used to study the destruction of cities during World War II and to determine the characteristics of city reconstruction in the 1940s and 1950s was based on two types of scientific methods: general scientific methods and special scientific methods. Based on general scientific research methods, the state of research on this issue was determined, and existing information on the post-war reconstruction of large cities in Ukraine was summarised and supplemented. The information found on the reconstruction of historic cities after World War II was

systematised to simplify further analysis of sources related to this topic. Within the framework of historical and archival research, attention was paid to the results of scientific research, cartographic and iconographic materials; the main data were taken from the studies by B. Cherkes & O. Lysenko (2013) and V. Shchurek (2022a; 2022b). Sources such as Zaporizhia after the war: Unique photos (2020) and Zaporizhia-1941: Our city in the pages of the world press (n.d.) were also examined. After analysing bibliographic and iconographic materials and familiarising ourselves with the problems of post-war reconstruction, four cities in Ukraine were selected for detailed study, namely: Kyiv, Kharkiv, Zaporizhia and Ternopil. This choice was determined by their geographical location within modern Ukraine, which revealed the characteristics of reconstruction in Western, Southern, and Eastern Ukraine, as well as whether the size and significance of a city influenced the scale of post-war reconstruction.

Using special research methods, namely the analysis of iconographic materials, the stylistic features and nature of the destruction of ruined neighbourhoods were revealed; using a graphical comparison of historical plans, the state and scale of the destruction of Kyiv and Kharkiv were determined; based on architectural, compositional and planning analysis, the features of the formation of Ukrainian and European cities were identified. Thus, using grapho-analytical comparison, a comparative analysis was performed of the post-war reconstruction of the Ukrainian cities of Kyiv, Kharkiv, Zaporizhzhia, and Ternopil, as well as cities such as Gdańsk, Dresden, and Warsaw. The study found that the reconstruction of Warsaw and Gdańsk was based on the principle of preserving the authentic historical centre, while the reconstruction of Dresden took place in two stages: initially, a city plan with wide avenues and long streets was created, but this approach was deemed flawed, and the city was rebuilt according to a different plan. Using a comparative historical synthesis of the post-war reconstruction of cities in Ukraine and Poland, the main principles for the modern reconstruction of Ukrainian cities were formulated, namely: preservation or restoration of city-forming elements, introduction of the concept of authenticity in the development of projects for the reconstruction of destroyed or damaged buildings, and the formation of comprehensive programmes for the reconstruction of historic cities or parts thereof.

RESULTS AND DISCUSSION

Cities in Ukraine were destroyed many times as a result of war, but their reconstruction after World War II was the most significant in terms of urban development. A special task of the Soviet state and various political and economic structures was to create an ideology that could unite and direct the masses, imposing on them the desires and needs necessary for the Communist Party. In a speech on proletarian architecture delivered on 14 January 1932, O. Lunacharsky stated: "...the task of architecture is to incorporate utilitarian goals, the functional part of the plan, as harmoniously and fully as possible into a concept that is ideological in nature" (Cherkes & Lysenko, 2013). In the Soviet Union in the 1930s-1950s, examples of ideologised architecture were built, the form of which was determined by an ideological construct that was supposed to serve to affirm certain ideas and stabilise order (Devos *et al.*, 2015). In the periods following the World War I (1914-1918), the National Liberation Revolution of 1917-1921, and after the World War II (1939-1941), marked by crises and instability, the gap between the desired and the actual was particularly acute. In such situations, the ideal was derived from a value system alternative to the existing one. The theme of the ideal city of the future was substantial for Soviet-era architecture. Architects had to transform the existing material conditions of Soviet society, creating architectural images that resonated with the new era. A. Mostakov noted: "The architectural unity of the city is a consequence of the inner harmony of life itself, a harmony that is only possible in a socialist society" (Cherkes & Lysenko, 2013).

The main issues of Soviet architectural theory developed even before the start of architectural and construction practice in the 1920s. Theoretical issues became particularly relevant: the specifics of architecture in general, the role of the architect in a new type of society, and the characteristics of Soviet architecture. The utopian ideal was accepted as a goal that justified any means. With its uncompromising aspirations, utopian consciousness prepared the intellectual groundwork for totalitarianism and its ideology. The hypertrophy of utopian thought, aimed at the realisation of arbitrarily constructed ideals, which was fatal for the historical events of the 20th century, also drew architecture into its dimension. Captivated by the ideals of social utopias, architects began to make claims to the construction of life. They also believed that all new formal approaches to architectural tasks correlated with socialist principles. The "New architecture" was a struggle against eclecticism and, at the same time, a denial of the progressive significance of the classical heritage for contemporary architecture. The rejection of experience and traditions as an essential part of architectural development dominated. The dialectical connection between tradition and innovation was ignored, as was the fact that these are two sides of a single process of moving forward, that any affirmation of the new in practice is inevitably linked to the emergence of a new tradition (Paperny, 2002).

The urban development policy of the Bolsheviks was designed not only to overcome the problems that had destabilised urban society in the previous period, but also to create a new, socialist way of life. The city was to become an instrument for establishing a new system of values and educating a "new man", who permanently abandoned the legacy of the past (Khmelnytskyi, 2010). B. Cherkes & O. Lysenko (2013) noted that by the mid-1920s, the strategy of administrative-territorial division of the USSR was finally based on the requirement to locate administrative centres in places, where there was or was artificially created a maximum concentration of the proletariat. Proletarian

centres, which were united by production and economic ties into single territorial-production systems, together with the adjacent "non-proletarian" zones, determined the areas of mobilisation and political division of the territory. Since in several cases the location of the centres of power did not coincide with the places of the greatest concentration of the proletarian population, the old zoning was remade, and a new one created to link the administrative centres of power with the places of the actual concentration of the proletariat.

K. Shamun (2021) noted that the goal of district planning was not the scientifically sound development of large cities or settlements, but rather the interests of industrial enterprises focused on accelerating production at any cost. The content of regional planning work focused on solving purely practical construction tasks: plans for general zoning of the territory, schemes for the location of industrial enterprises and settlements, energy hubs, railway, motorway and water routes, water supply and sewerage schemes, and engineering preparation of the territory were developed. Issues such as the preservation and identification of valuable natural landscapes, the organisation of recreational areas, the development of tourist routes, and the development of project proposals that emphasised the distinctive architectural traditions of a particular region were largely ignored in regional planning in the 1930s-1950s. The issue of authenticity was not present; all cities in the USSR were planned according to a single scheme to establish the ideology of a "single country".

Kyiv in the context of post-war reconstruction

The post-war development of Kyiv reflected the continuation of processes that had begun before World War II, characterised by ideological determinism and the active influence of ideology and politics on the formation of architecture. In 1934, the capital of Soviet Ukraine was moved from Kharkiv to Kyiv, and from that moment on, the socialist reconstruction of the city began. The creation of the Government Centre was the main urban planning problem of the mid- and late 1930s. In the process of developing proposals for the location of the Government Square, where all the main buildings for the government bodies of the Ukrainian SSR were to be located, options were proposed in the old part of the city, with the destruction of existing architectural monuments of the 12th-18th centuries. The project by P. Yurchenko was adopted as the basis for future design. It was distinguished by its successful spatial solution, monumentality and pomp, but also provided for the demolition of the St. Michael's Monastery and St. Basi's Church. A closed competition was held based on this concept, in which such well-known architects as the Vesnin brothers, I. Fomin, K. Alabyan, V. Zabolotny, F. Oliynyk, A. Tatsiy, P. Alyoshin, I. Langbard, and Ya. Steinberg participated (Cherkes & Lysenko, 2013).

Most projects envisaged Government Square being located perpendicular to the Dnipro River, with the ensemble opening onto the river and a system of steps and ramps along the slope. The exception was the projects of the Vesnin brothers, who in one version separated the square from the Dnipro with a colonnade, and in another completed the exit to the river with a large arch. Some architects interpreted the square as a propylaea with tower-like structures at the ends (I. Fomin, P. Alyoshin, Ya. Steinberg) and a huge monument to V. Lenin between them. The competition projects confirmed the desire of architects to visualise the main myths of Soviet identity (Fig. 1).

Figure 1. Recording the destroyed buildings on Khreshchatyk Street in Kyiv, 1945
Note: black colour – buildings destroyed in 1941; grey colour – buildings that survived World War II; white colour – buildings partially destroyed in 1941 and demolished in 1945
Source: based on B. Cherkes & O. Lysenko (2013)

The main means of architectural expression were the hierarchy and subordination of the entire architectural composition, its subordination to the main axis, which was always dominated by the monument to the leader, the hypertrophy of the buildings, and the excessiveness of the architectural decor. To destroy the old identity and establish the ideology of Bolshevik power, alongside competitions, the destruction of St. Michael's Golden-Domed Cathedral was in progress (Hrytsay *et al.*, 1962). During the war, 42% of the housing stock in Kyiv was destroyed, along with several unique buildings, including the 11th-century architectural monument, the Assumption Cathedral in the Kyiv-Pechersk Lavra, and many other cultural monuments. In total, 940 administrative and public buildings, 1,742 communal buildings with a living space of over 1 million square metres, and 3,600 privately owned buildings with a living space of approximately 500,000 square metres were destroyed during the occupation (Fig. 2). On 22 June 1944, the Council of People's Commissars of the Ukrainian SSR announced a competition for the planning and development of the destroyed Khreshchatyk, the main street of Kyiv. This competition was substantial in the revival of cities destroyed by the war. The task of

designing Khreshchatyk was to accommodate government, representative and public buildings and give Kyiv the formal characteristics of a capital city. In addition to its public functions, the new Khreshchatyk was also to be a centre of business, trade and cultural activity. The competition was attended by the best architects of the USSR: K. Alabyan, P. Alyoshin, A. Shchusev, D. Chechulin, G. Golts, O. Vlasov, and O. Tatsiy (Fig. 3).

a  b 

Figure 2. Post-war reconstruction of Kyiv
Note: a – reconstructions on Khreshchatyk Street. Photo: Central State Film and Photo Archive of Ukraine named after H.S. Pshenychny; b – view of the reconstructed Khreshchatyk Street. Photo: Central State Film and Photo Archive of Ukraine named after H.S. Pshenychny
Source: based on M. Zahorodniy (2021)

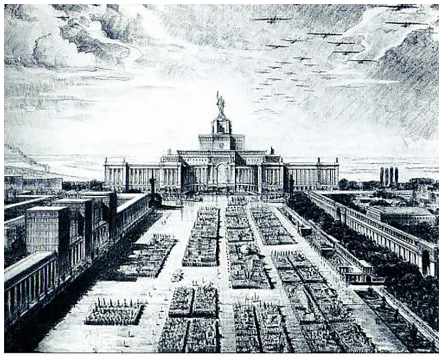
a  b 

Figure 3. Project proposals for the reconstruction of Kyiv after World War II
Note: a – competitive project for the restoration of Khreshchatyk. D. Chechulin, in collaboration with K. Orlov; b – project for the restoration of Khreshchatyk. Perspective, 1944. Group of architects A. Vlasov
Source: based on T. Asadcheva (2024)

When designing Khreshchatyk, the urban planning issues were emphasised: the convenience of using the street for transport and pedestrians, the expansion of adjacent streets, approaches and driveways, and the organisation of festive squares. The aesthetic aspect was highlighted: the designs used classicist motifs combined with elements of Ukrainian Baroque. Architects promoted the use of local materials, such as ceramics, as an economical way to enhance the aesthetic component of Khreshchatyk's architecture (Hrytsay *et al.*, 1962). It was proposed to use the motif of arches to reveal the unique relief of the city. This technique was later adopted by the winner of the competition, architect O. Vlasov, a chief architect of Kyiv from 1944 to 1950. O. Vlasov, alongside creating architectural workshops (in 2025, the Main Directorate of Kyivproekt), were central in the development of Kyiv's architecture. In 1949, the government of the Ukrainian SSR approved the "Master plan for the development of Khreshchatyk", according to which its construction began. The architecture of the new Khreshchatyk was to become the architecture of Victory. The competition projects and implementations of the post-war development of Khreshchatyk reflected the mythology of Soviet identity, with buildings characterised by monumentality, magnificent architectural decor, and monuments to leaders dominating the landscape. The urban planning concept for the organisation of Duma Square (in 2025, Independence Square), developed by O. Vlasov's group in 1949, laid the fundamental principles for its planning.

The 1948 master plan for Kyiv envisaged the creation of the main city thoroughfare, Khreshchatyk. The master plan developed this idea, defining Khreshchatyk and the Dnipro ravine, with its large government buildings, as the city centre. The expert commission considered this interpretation to be the most appropriate: the location of

Khreshchatyk in the overall composition of the city, natural conditions (relief, parks, Dnipro River), and the content of the centre of the capital of the Ukrainian SSR, where Khreshchatyk was interpreted as a modern forum with a large spatial opening of the architectural composition. At the same time, however, the commission noted that the design of the centre did not yet provide a compositional synthesis and connection between Khreshchatyk and other major elements of the centre, such as Government Square and the complex of buildings of the Council of Ministers and the Supreme Council, located on the upper edge of the Dnipro riverbank. The expert commission recommended including these two elements in the composition of the centre of Kyiv, organically linking them with Khreshchatyk. The exceptionally rugged terrain of Kyiv and the wide Dnipro River have always determined the architectural face of the city, the beauty of its panorama, and the uniqueness of the architecture of its prominent buildings, which harmoniously blend with nature. Its distinctive silhouette always ranked Kyiv among the most highly valued and memorable cities, so the task of the city's master plan was to establish the foundations and ensure all the prerequisites for the creation of an architecturally coherent and distinctive ensemble. The project reflected the main façade of the city towards the Dnieper, located critical structures on the high embankment of the Dnieper bank, incorporated the city's silhouette design, and planned a park on Trukhaniv Island. Therefore, the expert commission recommended developing a special scheme for the architectural organisation of the city, spatially separating and connecting the most interesting points in terms of height and landscape. The commission also recommended placing greater emphasis on Kyiv's major architectural monuments, highlighting their surroundings in accordance with their significance and the surrounding environment (Hrytsay *et al.*, 1962).

Kharkiv in the process of post-war reconstruction

The development of Kharkiv's architectural and planning structure was defined by the "General planning project for Kharkiv" (Kharkiv Regional Universal Scientific Library, 2004), authored by the renowned architect and Kharkiv native O. Kasyanov. The master plan was developed for a period of 20 years and defined the main issues of the city's reconstruction and redevelopment. The rapid restoration of the city, which had been destroyed after World War II, required the daily work of Kharkiv's chief architect. Kharkiv became a notable example of urban planning, in which two centres were historically formed: the Old Town or Old Centre (the core of the historically formed city) (Fig. 4) and the New Centre (artificially created by the Soviet authorities). The new appearance of the Soviet city was intended to symbolise "the strength and greatness of the state and people, who won the Second World War". The old city, similar to any historical centre, was shaped by the influence of overlapping laws of a certain period and architectural styles: Baroque, Classicism, Eclecticism, Art Nouveau, and Constructivism. In contrast, the new city was built from scratch, following the stylistic and compositional system of the interwar period, with the only layer being the post-war Leninist decor (Gubkin, 2025). The new centre was formed in the 1920s and 1930s as the administrative core of the republic's capital (Fig. 5). The new centre saw the construction of such buildings as the Derzhprom (House of State Industry), the House of Projects, the House of Cooperation and the House of the Central Committee of the Communist Party of Ukraine, which together formed the architectural ensemble of Freedom Square (formerly F.E. Dzerzhinsky Square). This large-scale construction project corresponded to the style of constructivism with elements of Art Deco, which dominated the architecture of the 1920s and 1930s. The International Hotel (in 2025, Kharkiv) was located on the rectangular part of the square, which connected its round and rectangular areas (Kharkiv Regional Universal Scientific Library, 2004). During World War II, all these buildings were destroyed. During the reconstruction of Kharkiv after the end of World War II, most of the buildings were rebuilt in a classical style, except for Derzhprom, which retained the features of its original constructivist design.

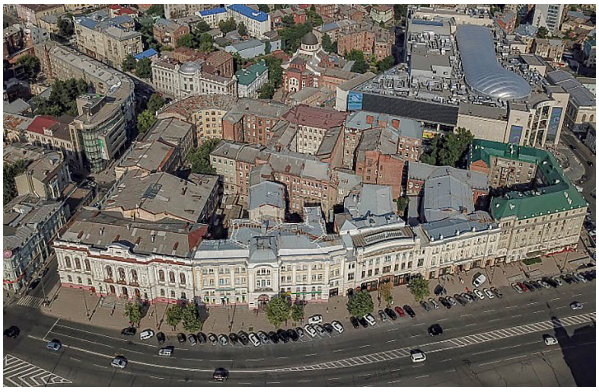


Figure 4. The old centre of Kharkiv
Source: based on A. Chernychko (2025)

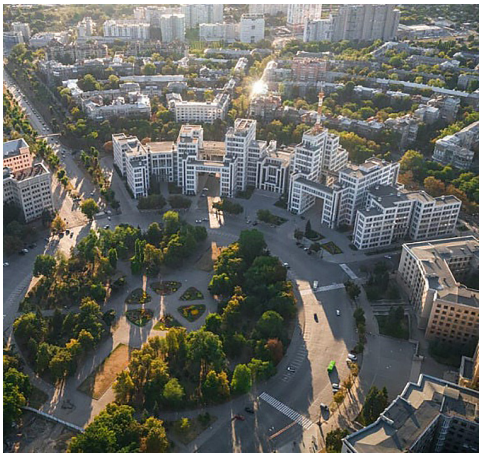


Figure 5. Appearance of the New Centre before the start of the Russian-Ukrainian war
Source: based on B. Lohvynenko *et al*. (2023)

The reconstruction of the Kharkiv House of Projects, designed by architects S. Serafimov and M. Zandberg-Serafimova in 1932, was conducted in the 1950s. The reconstruction was conducted by a group of authors, which initially included V. Kostenko, O. Kasyanova, V. Lipkin and I. Zhilkin, and later joined by I. Yermilov, V. Lifshits and V. Komirny. After the war, only the reinforced concrete frame remained of the constructivist building. During the reconstruction, the central part of the building underwent significant changes, the side wings were superimposed, and ceramic tiles were used to decorate the facade. Initially, it was planned to decorate the building with a statue of J.V. Stalin, with a large spire as an alternative. However, neither of these options was implemented. A distinctive feature of the reconstruction was that the design and construction were conducted simultaneously. The reconstruction was completed during Khrushchev's campaign (late 1950s-early 1960s) against architectural excesses, which explained the less pompous appearance of the building compared to Moscow's "Stalinist skyscrapers" (Kharkiv Regional Universal Scientific Library, 2004).

The reconstruction of the House of Cooperation (built by architect A. Dmitriev in 1930) with the modification of its buildings and the construction of a new central multi-storey block continued until 1954. The authors of the final project, P. Shpara, N. Yevtushenko, and N. Linetska coordinated their plans with the architect of the initial project. The building changed not only its facade and number of floors, but also its purpose: after the reconstruction was completed, it housed the L. Govorov Military Air Defence Academy, and as of 2024, it is the North Building of Kharkiv National University. The building of the Kharkiv Regional Committee of the Communist Party of Ukraine at 64 Sumska Street (in 2025, the building of the regional state administration), designed by V. Kostenko in collaboration with V. Orekhov, was built in 1954 on the site of the demolished building of the Central Committee of the Communist Party of Ukraine (b) by architect Y. Shteinberg (Romanova, 2022). The massive six-storey building with columns and an entablature, designed in a ceremonial style, logically completed the rectangular part of Freedom Square. Its dominance was emphasised by the nearby location of the Giprokoks building (architect E. Lyubomylova) with its complex profile and cut corners. Both structures interacted harmoniously in the urban environment.

The International Hotel (renamed the Kharkiv Hotel in 2025), designed by architect G. Yanovitsky, suffered damage during the war, but was reconstructed by the designer. The composition of the main facade with its voluminous shifts and rounded side wing was preserved, but the decor characteristic of the classical style was added. Returning to the historic centre of Kharkiv, it was worth noting that after the Second World War, the buildings underwent so-called reconstruction. However, the concept of reconstruction did not mean rebuilding houses destroyed during the war, but rather new construction on the site of historic buildings (Savin & Kirichenko, 2023). Buildings that developed the traditions of Soviet classics began to appear on the sites vacated after demolition. Entire neighbourhoods were built, as well as individual "inserts" between existing buildings (Gubkina, 2025).

One of the most famous projects by architect P. Areshkin was the building with a spire at the junction of Constitution Square and Pavlovskaya Square. In 1954, the main part of the complex was completed with an 11-storey tower crowned with a spire. The neoclassical residential building with integrated shops occupied the entire block. Another aspect of Stalin's reconstruction of Kharkiv was the addition of false decorations to historic buildings constructed between 1939 and 1941. Classical architectural details (cornices, columns, porticos, pediments, balusters) were added to buildings constructed in the constructivist style. Horizontal openings and ribbon glazing were dismantled (Gubkina, 2025), rectangular windows were replaced with arched ones, and light modern railings were replaced with massive balusters. As a result, the buildings were changed beyond recognition (the Central Universal Store, the City Council, the Housing Union Building). This problem had to be considered from several angles: from an aesthetic point of view, such actions made it possible to create a coherent ensemble of the city, to unify all previously constructed buildings; from an economic perspective, to create an image of the rapid development of the Soviet state and the implementation of Stalin's grand plans for reconstruction; and from a political perspective, to conceal the layer of Ukrainian authenticity. Thus, this "reconstruction" appropriated the achievements and contributions of other eras, displacing them from the historical, planning, and landscape urban environment.

Restoration of Zaporizhzhia's industrial potential

One notable example of the reconstruction of a city destroyed during World War II was the reconstruction of Zaporizhia. The construction was based on a project developed by the Dniprobud design and planning workshop, and later, according to a master plan executed by Dnipromist of the Ukrainian SSR (architects L. Dmytriyevska, I. Malozomov), which approved the planning structure developed in the 1930s. It was worth noting the construction of one of the districts of Zaporizhia, Voznesenka, conducted based on a project by architects A. Motorin, Yu. Romanenko, M. Savchenko, under the leadership of G. Vegman (Hrytsay *et al.*, 1962), was an example of construction using industrial methods. After the 1940s, multi-storey buildings were constructed in 12 blocks covering an area of 50 hectares in Voznesenka. Concentrated development took place not only along the main streets, but also in a large residential area, which was filled with cultural and educational institutions and green spaces. The residential area had a rectangular grid typical of post-Soviet reconstruction, located at a 45° angle to the meridian, with defined main and secondary streets. The main streets ran parallel to the banks of the Dnieper, and every 500-800 metres, they were

crossed by transverse streets connecting residential and industrial areas.

The architectural and planning solutions for neighbourhoods in Zaporizhzhia were diverse, but followed two basic principles: on the main thoroughfares in front of the squares, the neighbourhoods were built up with densely packed houses around the perimeter. The neighbourhoods away from the squares and the main thoroughfare were much smaller and built up with separately located houses with gaps in the form of spatial groups. The main technique for building up street intersections was to place towers on the corner houses, which were not always justified in terms of composition. In addition, the corners of the neighbourhoods were emphasised by the transition from tall buildings along the main road to lower ones on secondary streets. The large scale of development along the main road led to the construction of 4-5-storey apartment buildings, 80-100 m long, and 50-80 m long block buildings. Blocking was one of the essential features of urban planning in Zaporizhia, which made it possible to diversify compositional solutions (Fig. 6).

Figure 6. The first example of the implementation of a model for the comprehensive quarterly development of the capital settlement of Dniprobud
Note: the village of Dniprobud, bounded by Soborny Avenue, B. Khmelnytsky Street, Metalurhiv Avenue, and Dobrolyubova Street
Source: Zaporizhia after the war – unique photos (2020)

The left bank of the city was characterised by 4-5-storey residential buildings. On the right bank, the buildings were more village-type, which underwent significant reconstruction in the post-war period. The centre of development on the right bank was the area near the Dniproges dam. On the Dnipro side, it was bordered by the Dniproges management building, and on the opposite side by a new administrative building (Fig. 7). The location of new industrial facilities in Zaporizhzhia on the right bank of the Dnipro led to the creation of a transformer plant settlement. The neighbourhoods were built up with two-storey residential buildings and dormitories for employees and students of the mining college. The spaces inside the neighbourhoods were used for landscaping and recreational areas.

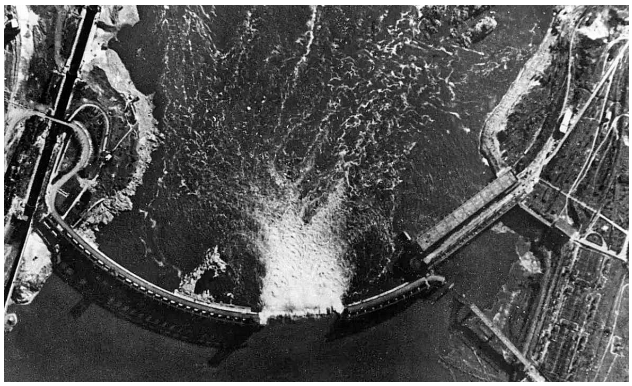


Figure 7. The Dniproges dam after its destruction in 1941
Source: Zaporizhia-1941: Our city in the pages of the world press (n.d.)

In general, several shortcomings can be noted in the post-war reconstruction of the city after the 1940s: typical ordinary buildings prevailed; similar neighbourhoods were formed, which did not distinguish Zaporizhzhia from any other Soviet city of the 1950s and 1960s; there was excessive pomposity and decoration of the facades of buildings erected on main streets in accordance with the party symbols of the Soviet empire.

Ternopil: architectural revival after the war

The city of Ternopil became unrecognisable after the German occupation. After the liberation of the city, its reconstruction was conducted based on the Dnipro City project, drawn up in 1945 (architects V. Novikov, N. Panchuk) (Hrytsay *et al.*, 1962). In Ternopil, the buildings in the central part of the city were crowded, the neighbourhoods in the centre were extremely fragmented (0.5-0.8 hectares), and the streets were narrow (10-12 metres). The new master plan provided for the reconstruction of the street grid, transport links between individual districts, the enlargement of city blocks, and the formation of a large, pompous theatre square (Fig. 8). All the above urban planning techniques were identical for all post-Soviet cities.

Figure 8. View of the central part of Ternopil. 1970s
Note: photo by Igor Vovk
Source: based on S. Balutskyi (2017)

In addition, a 300-hectare lake was created on the Seret River, and a promenade with public recreation and leisure areas was designed (Fig. 9). The central area of the city, covering an area of 32 hectares, was almost completely rebuilt with multi-storey buildings, including the city theatre, the regional executive committee building, schools, a cinema, a central department store and a library. A boulevard was created along the longitudinal axis of the square, ending with a monument to Bohdan Khmelnytsky (Hrytsay *et al.*, 1962).

Figure 9. View of the city pond. 1970s
Note: photo by Igor Vovk
Source: based on S. Balutskyi (2017)

Overall, the buildings in the central part of Ternopil give the impression of typical Soviet architecture, with features of eclecticism and archaism. Ternopil became a new socialist city, where only architectural monuments remain from the past, sporadically included in the urban ensemble. To determine the peculiarities of the post-war reconstruction of Ukrainian cities, several European cities were analysed, including Warsaw, Gdańsk and Dresden.

Warsaw and Gdańsk: post-war reconstruction of cities

Warsaw suffered the most damage during the bombings in 1943. After the occupation in 1945, a decision was made to rebuild the city. According to the reconstruction plan, all historic buildings were to be restored without exception. To this end, eyewitness accounts, documents and preserved historiographical data were to be used. Even paintings depicting the city dating back to the 18th century were used (Fig. 10).

a

b

Figure 10. Old Town Market Square, Warsaw
Note: a – after the war, 1945; b – as of 2025
Source: based on V. Shchurek (2022a)

Most of the buildings were supposed to be replicas of the destroyed structures, but not all of the buildings in the historic centre could be restored during the reconstruction process. The reconstructed city was added to the UNESCO World Heritage List in 1980 (World Heritage List, n.d.). In contrast to Warsaw, where a scientific approach was applied, in Gdańsk, the most significant monuments were restored, and the rest of the buildings were made more practical. In other words, the architects did not try to restore the buildings to their pre-war appearance, but decided to build them according to the planning schemes of the 1950s and 1960s, with convenient courtyards and yards, and did so in such a way that the buildings conveyed the spirit of the historical era. After discussions, the architects decided to restore the city to its 18th-century appearance. What can now be seen in Gdańsk in 2025 is a romantic, fantastical perception of the city in the 18th century. It was worth noting that the houses, streets, courtyards, and all the infrastructure were made in a modern style (Fig. 11).

a

b

Figure 11. The waterfront in Gdańsk
Note: a – post-war destruction; b – present city
Source: based on V. Shchurek (2022b)

Thus, the reconstruction of Warsaw and Gdańsk demonstrated two different approaches: Warsaw sought to recreate its historical appearance as accurately as possible, while Gdańsk combined the restoration of key monuments with modern, practical planning. The reconstructed cities retained their historical atmosphere, but at the same time were adapted to the needs of modern life.

Dresden: destruction and post-war reconstruction

In February 1945, approximately 4,000 tonnes of explosives were dropped on the city. More than 20,000 residents were killed, and the city centre was destroyed (Fig. 12, a). Dresden was considered the cultural centre of Germany with its Baroque architecture and picturesque gardens. But after World War II, all historical and cultural monuments were destroyed. Dresden was rebuilt twice: immediately after World War II and in the early 1990s (Fig. 12, b, c). After the first reconstruction, the city finally lost its historical buildings, turning into a model socialist metropolis: rational, but empty. During the second reconstruction of the city in the 1990s and 2000s, the historic city centre was rebuilt from scratch, in the same form it had before the bombing.

Figure 12. The destruction and reconstruction of Dresden

Note: a – the statue "Allegory of Goodness" in Dresden's destroyed city centre. View from the town hall; b – view from the town hall tower onto Pirnaiser Square, 1972; c – view of Dresden city centre from a drone. On the left is the Frauenkirche, in the centre is the Palace of Culture

Source: based on K. Kozlova (2022)

The reconstruction of the architectural structure of Polish cities destroyed during World War II became one of the largest and most diverse projects on the European continent (Cohen, 2011). Along with the awesome examples of rebuilding the Old Town complexes in Warsaw and Gdańsk, as well as thousands of architectural monuments that were carefully restored, there were also some irreversible mistakes. However, the total number of rebuilt objects should be taken as an example during the modern reconstruction of Ukrainian cities. Warsaw (Poland) and Dresden (Germany) were diametrically opposite cases. In Warsaw, a decision was made to rebuild the historic centre, while the Dresden authorities called the city *tabula rasa*, a "clean slate". The city planned to build a modern city with long, straight streets similar to Soviet cities. An analysis of global experience and the development of variability in post-war city reconstruction will help to avoid several mistakes in the modern reconstruction of Ukrainian cities after the end of the Russian-Ukrainian war, ensure the adaptation of the best global examples of reconstruction, and demonstrated global trends in urban development, including sustainable development, clustering, smart specialisation, and ensuring the openness and resilience of cities (Zakharova, 2023).

Therefore, it was worth comparing the results of this study with existing works to identify similar and different statements and establish the basic requirements for the reconstruction of historic districts or individual objects. In particular, the book by J. Düwel & N. Gutschow (2013) concluded that in all European countries, the destruction of cities was perceived as a factor of liberation from historical layers and an opportunity to create new cities. Thus, the study concluded that the complete clearing of historic neighbourhoods and re-planning according to other spatial schemes was not unique to Soviet cities, but was a common practice in post-war reconstruction in the 20th century. This research result highlighted the need to determine the authenticity of historic buildings that formed city centres, distinguishing between particularly valuable buildings and those that could be replaced during reconstruction. The topic of post-war reconstruction was also

outlined in the study by Ł. Musiaka *et al.* (2025b). The paper presented the results of an analysis of various forms of post-war reconstruction of the largest historical city centres that were annexed to Poland after World War II. The researchers proposed four types of models for the transformation of destroyed buildings depending on the scale of destruction and the type of reconstruction that was applied. These included areas with a predominance of modernist architecture; historic areas; areas with historic buildings and a predominance of authentic, pre-war buildings. The identified models differed from each other in terms of the contemporary significance of the old city, as well as the scale and nature of morphological changes. Ukrainian research included a study by O. Orlova (2024), noting that the post-war reconstruction of Ukraine would be characterised by the search for new ways to develop regulations to accelerate economic development, especially in the most affected regions of Ukraine, due to the significant destruction of industrial and social infrastructure in the context of a shortage of financial resources. In this regard, as of 2024, the question arose regarding the possibility of legal support for the post-war reconstruction of Ukraine, the methods and successful global examples by which this had been achieved in other countries. Although the study did not address the architectural component of post-war reconstruction, all factors that influenced the quality of the restoration of destroyed cities should be considered. Therefore, the topic of post-war reconstruction was addressed substantially, covering the issue from different angles: architectural, urban planning, artistic, economic, legal. The preservation of each country's cultural heritage and the improvement of comfort and safety during the post-war reconstruction process became relevant.

CONCLUSIONS

After analysing the post-war reconstruction of Ukrainian and European cities, it was possible to conclude that during the bombings of World War II, large areas of cities, outstanding architectural monuments, and significant areas of housing stock were destroyed. The first problem to be solved in all cities was the reconstruction of the housing stock, as many people were left homeless. Accordingly, there was no time to develop detailed plans for the preservation of valuable historical buildings. To quickly replenish the housing stock, new neighbourhoods were built with reinforced concrete panel-type high-rise buildings. A constant feature of Soviet post-war reconstruction projects was the creation of wide avenues and the construction of new residential neighbourhoods (Zaporizhzhia, Ternopil). The capitals of the USSR republics received several Stalinist high-rise buildings, sometimes complemented by a metro line (Kyiv). In the centre of Kharkiv, the redevelopment of destroyed neighbourhoods resulted in the destruction of historic buildings. Thus, in the most substantial and prestigious parts of city centres, ceremonial avenues were built, around which residential buildings grew, with apartments distributed among members of the nomenclature and party elite. Residents were mostly resettled to the suburbs. Thus, not only was one layer of the urban environment replaced, but one social group of the population was replaced by another.

The reconstruction of European cities after World War II was radically different: alongside examples of comprehensive reconstruction of the Old Town in Warsaw and Gdańsk, the case of Dresden's reconstruction in the 1950s was diametrically opposite. The example of the unsuccessful first reconstruction of Dresden, with the establishment of a new city with long, straight streets similar to Soviet cities, and the second reconstruction in the 1990s and 2000s, demonstrated the importance of preserving the authentic structure with thousands of architectural monuments. Therefore, a crucial aspect of the modern reconstruction of the historic urban environment after the war damage in Ukraine should be the maximum preservation of the most valuable elements and ensembles and their visual, compositional, and functional interaction. Detailed plans for post-war reconstruction should be developed for each individual city and form a comprehensive programme for preserving the authenticity of Ukrainian cities. More detailed step-by-step recommendations for the reconstruction of Ukrainian cities after the Russian-Ukrainian war will be considered in future scientific studies.

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Руйнування та відновлення міст України після Другої Світової війни: формування методичних підходів до актуальної відбудови

Анотація. Актуальність вивчення особливостей формоутворення міст у передвоєнний і післявоєнний період Другої світової війни пов'язана з тим, що результати цього процесу визначили сучасний вигляд деяких міст, будучи однією з головних складових їхньої культурної ідентифікації. Метою даної роботи стало проаналізувати історичні етапи формування міст, як цілісної системи політичних, ідеологічних і матеріальних структур, визначити вплив післявоєнної відбудови радянських міст на сучасну містобудівну ситуацію. У статті було проаналізовано післявоєнну відбудову радянських міст на території України, як динамічного та суперечливого процесу, що складався з кількох етапів. Було визначено особливості архітектурно-містобудівного мислення і способів практичної роботи, що дало змогу зрозуміти характер архітектури та загальну логіку формування міст у воєнні та повоєнні роки періоду Другої світової війни. За допомогою загальнонаукових методів дослідження, таких як: аналіз, синтез та порівняння було проаналізовано післявоєнну відбудову Києва, Харкова, Запоріжжя та Тернополя; визначено основні архітектурно-містобудівні прийоми у відбудові цих міст, а також виконано порівняльний аналіз цих міст з містами сучасної Європи. За допомогою систематизації та узагальнення бібліографічних матеріалів визначено стан дослідження даної теми, узагальнено та доповнено наявні відомості щодо принципів відновлення зруйнованих міст внаслідок війни. За допомогою системного аналізу та спеціальних методів дослідження, таких як графічне порівняння, ретроспективне моделювання та архітектурна композиція, визначено характерні ознаки українських міст, що формують їхню національну ідентичність. Практичне значення дослідження полягає у використанні результатів аналізу повоєнної відбудови міст України після Другої світової війни у розробці планів міст чи міських кварталів для їх відбудови після закінчення російсько-української війни

Ключові слова: містобудування; історичні міста; планувальна структура; реставрація історичної забудови; автентичність; повоєнна відбудова міста

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AHP-based sustainability evaluation of global nanomaterial-enhanced residential buildings using regionally weighted criteria from Egyptian experts

Abstract. The rapid global urbanisation and the construction sector's critical environmental footprint necessitate innovative, sustainable solutions, with nanotechnology emerging as a key enabler. Despite this potential, current research lacked a holistic, systematic evaluation framework for nanomaterial-enhanced residential buildings that integrated the specific regional priorities of developing nations. This study addressed this knowledge gap by developing and applying a four-dimensional assessment model (environmental, economic, technical, and social) using the analytic hierarchy process. The model weights were derived from 55 Egyptian experts in architecture and sustainability, ensuring the results reflect crucial regional demands. The analysis revealed that the Environmental Criterion was deemed the most critical dimension, receiving the highest weight (0.3427), closely followed by the Economic Criterion (0.2774). The Technical Criterion ranked third (0.2337), while the Social Criterion was the least influential (0.1462). This priority setting confirmed that Operational Energy Cost Reduction (0.0916) and Maintenance Cost Reduction (0.0820) are the most decisive factors for sustainable performance in the regional context. The model was applied to four global case studies to determine their sustainable performance and ranking. The Sur Falveng building Phase Change Material Glass came in first place with a score of (73.85%) due to its comprehensive and balanced performance. The Seitzstrasse building Vacuum Insulation Panels followed in second place (71.51%). The Strucksbarg housing complex featuring self-cleaning Lotus-Effect paint ranked third (68.28%). Conversely, the Escala Condominiums tower utilising nano microcomposite rebar ranked last (57.86%), confirming that structural applications received lower overall priority as they did not directly contribute to the dominant operational metrics. This research provided a practical, evidence-based

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tool for architects and policymakers, highlighting the necessity of aligning nanotechnology selection with regional evaluation frameworks to guide future sustainable design decisions in emerging markets

Keywords: analytic hierarchy process; nanotechnology; regional priorities; building envelope; residential architecture

INTRODUCTION

The rapid expansion of the global population, coupled with accelerating urbanisation, has placed unprecedented pressure on the built environment. Cities are facing increasing demands for housing, infrastructure, and services, which in turn exert significant strain on natural resources and contribute to environmental degradation. In parallel, the construction sector has emerged as a key driver of greenhouse gas emissions, energy consumption, and waste generation, highlighting the urgent need for innovative and sustainable approaches. In this context, integrating advanced technologies such as nanomaterials into residential buildings offers a promising avenue to enhance sustainability, reduce environmental impact, and improve the quality of urban living.

Population growth and increasing urbanisation present major challenges for humanity. The urban population is expected to reach about 7 billion people by 2050, compared to 4.2 billion in 2018, with urban migration projected to intensify in developing nations, reaching 54% by 2030 (Khanna, 2020). In this context, the construction and building sector stands at the forefront of industries requiring radical solutions, given its pivotal role in environmental degradation and climate change. According to L. Cabeza *et al*. (2022), the building sector's share of total global greenhouse gas (GHG) emissions was 21% in 2019, and CO_2 emissions from buildings witnessed a 50% increase between 1990 and 2019. Further research by L. Chen *et al*. (2023), confirms the magnitude of this sector's environmental impact, as construction activities consume 36% of global energy and contribute 39% of global CO_2 emissions. It is also responsible for producing about 40% of solid waste (Wang *et al*., 2024). These figures underscore the necessity of finding innovative solutions to mitigate the environmental footprint of buildings. The concept of building sustainability, which aims to achieve a balance between environmental, economic, and social needs throughout a building's lifecycle, has thus become an imperative for achieving sustainable urban development.

In the search by S. Verma *et al*. (2022) for innovative and sustainable solutions, nanotechnology has emerged as a promising technique that could revolutionise the construction sector. This technology enables the enhancement of traditional materials' properties at the atomic and molecular levels, leading to increased building energy efficiency, improved durability, and better resistance to environmental factors. It also provides additional functionalities such as self-heating, anti-fogging, and the integration of structural safety. For example, studies have shown that applying nanomaterials in residential buildings can increase energy efficiency by up to 30%, making them a fundamental component in achieving green and sustainable building goals. Furthermore, nano-insulation materials, such as aerogel and Vacuum Insulation Panels (VIPs), have demonstrated an ability to provide high thermal resistance with minimal thickness, contributing to the design of zero-energy buildings, which subsequently leads to reduced carbon emissions and improved environmental performance (Casini, 2020).

Nevertheless, despite the potential benefits of nanotechnology, there remains a lack of research that provides a comprehensive and systematic evaluation of its sustainable performance at the residential building level. Studies often focus on assessing separate technical aspects, such as mechanical properties or energy efficiency, without integrating them into a holistic evaluation framework that considers all dimensions of sustainability. Historically, sustainability assessment primarily relied on the triple bottom line (TBL) concept, which focuses on environmental, economic, and social factors (Mavi *et al*., 2021). Decision contemporary research increasingly suggests that sustainable decision-making in the construction sector requires a more comprehensive framework that extends beyond these three dimensions. There is a growing consensus in the literature on the necessity of a crucial fourth dimension: technical performance (Aghazadeh & Yildirim, 2024). This dimension includes structural efficiency, quality standards, durability, and material lifespan. This dimension is critically important, as nanotechnology directly improves it, as noted by A. Oke *et al*. (2019), preventing premature failures and reducing the need for frequent replacement. This, in turn, contributes to achieving the other three dimensions of sustainability: it reduces resource consumption and waste (environmental dimension), lowers long-term maintenance costs (economic dimension), and enhances the safety and comfort of building occupants (social dimension). True sustainability requires a balance among these four dimensions: environmental, economic, social, and technical (Bhuiyan & Hammad, 2023).

This complexity, involving multiple and often conflicting criteria, makes the selection and evaluation of new materials and technologies an inherent multi-criteria decision problem. Addressing this requires adopting multi-criteria decision-making (MCDM) methodologies, as noted S. Khoshnava *et al*. (2018) and A. Rahim *et al*. (2021), which provide structured computational tools and mathematical

techniques for effectively evaluating multiple performance criteria. These methodologies are particularly effective in dealing with the complex numerical challenges associated with selecting sustainable alternatives.

Based on the foregoing, this research aimed to bridge this knowledge gap by providing a comprehensive and objective assessment of the sustainable performance of nanotechnology applied in residential buildings. The novelty of this research lies in providing a systematic framework that directly links the technical performance of nanotechnologies to local priorities, offering architects and researchers a practical tool for making more informed design decisions in the future and realising the vision of sustainable nano-architecture.

MATERIALS AND METHODS

This study adopted a multi-stage methodology to evaluate the sustainable performance of nanotechnology-enhanced residential buildings from a specific regional perspective. The approach was systematically structured around three main phases: (1) defining the criteria and indicators, (2) developing and weighting the evaluation model, and (3) applying the model to global case studies.

To define the criteria used, a rigorous and staged research methodology was followed to ensure comprehensiveness in the selection of studies for in-depth review. This included a systematic search across reliable academic databases such as ScienceDirect, Scopus, and Web of Science. A combination of keywords related to "sustainable building materials", "Multi-Criteria Decision-Making (MCDM) methods", and "evaluation criteria/frameworks" were utilised. The search was restricted to articles published between 2012 and 2024 that explicitly used MCDM methodologies to assess sustainable building material applications. Following initial filtering and the removal of duplicates, the remaining studies underwent a two-stage manual screening (reviewing titles and abstracts, followed by a full-text review) to ensure complete alignment with the study's scope. This process resulted in the selection of 15 comprehensive studies for in-depth review, which formed the foundation for defining the final criteria and indicators.

Based on the comprehensive review of existing evaluation frameworks, the collected criteria were classified into the four main dimensions of sustainability: Environmental, Economic, Social, and Technical. The purpose of this classification was to provide a holistic framework for experts and sustainability stakeholders. To ensure the categorisation was comprehensive, care was taken to include criteria that captured the superior performance offered by nanomaterials, such as enhanced durability, thermal improvements, and weather resistance, which represent unique technical advantages of these materials. The potential for some criteria to intersect or influence more than one dimension of sustainability was also considered.

Based on the criteria derived from the systematic review, a multi-criteria evaluation model, designated "Nano-BSAM" (Nanomaterial Building Sustainability Assessment Model), was developed. The model employs a four-Level hierarchical structure where each Level represents a stage of analysis. Level 1 (Goal) represents the model's ultimate objective: "Sustainability assessment of nanomaterial buildings". Level 2 (Main criteria) comprises the four principal dimensions: Environmental, Economic, Technical, and Social. Level 3 (Sub-criteria) consists of nine sub-criteria, whose weights are derived from the aggregated weights of their underlying performance indicators. Finally, Level 4 (Performance indicators) includes 24 precise performance indicators, each representing a specific aspect of sustainable performance.

To introduce a regional context to the model, a pairwise comparison questionnaire based on the Analytic Hierarchy Process (AHP) was used to determine the relative weights of each criterion and indicator. The questionnaire was administered to a purposive sample of 55 Egyptian experts in architecture, environmental sustainability, and nano-building technologies. The rationale for selecting Egyptian experts was that their priorities directly reflect the specific climatic challenges (e.g., the urgent need for energy efficiency in a hot climate) and economic challenges (e.g., emphasis on operational and maintenance costs) prevalent in the region. This selection ensured that the derived weights were specialised and reflective of specific regional priorities, rather than generic ones. The participation of experts was entirely voluntary and complied with ethical principles (European Commission, 2021). To bolster the accuracy and reliability of the results, the consistency of all participants' judgments was verified using the AHPcalc model (Goepel, 2024). This tool processes participant responses using the Eigenvector Method (EVM) to calculate consistency indices and the consistency ratio. Inconsistent responses (with a consistency ratio exceeding 10%) were reviewed with the participants in a feedback loop to ensure internal consistency, and these values were adjusted towards the ideal value suggested by the tool to improve consistency.

The Geometric Mean function in Excel was then employed to aggregate the individual expert judgments into a single, collective value for each pairwise comparison. This technique is the most common and reliable approach in group AHP as it preserves the internal consistency of the aggregated comparison matrices. These aggregated values were then directly entered into the Super Decisions V3 software interface to construct the final aggregated matrices. The Super Decisions programme automatically calculated the final relative weights for both the criteria and performance indicators, verifying that the final Consistency Ratio remained within the accepted threshold (less than 10%). Figure 1 presents the complete hierarchical structure of the Nano-BSAM model along with the final weights derived from the AHP analysis.

Goal	Sustainability assessment of nanomaterial building																						
Main criteria	Social [0.1462]					Technical [0.2337]									Economic [0.2774]					Environmental [0.3427]					
Sub-criteria	Social compatibility [0.1035]				Health and safety [0.0428]	Constructability [0.0440]		Comfort performance [0.0765]			Physical/functional performance [0.1132]			Operational & life cycle costs [0.1959]			Direct costs [0.0816]		Environmental impact [0.1509]			Resource efficiency [0.1918]		
Performance indicators	S1 local heritage compatibility (0.0241)	S2 Aesthetic aspect (0.0249)	S4 Skilled labour availability (0.0266)	S3 Local material availability (0.0279)	S5 Safety and security (0.0428)	T2 Ease of construction (0.0133)	T3 Maintainability & ease (0.0307)	T8 Acoustic comfort (0.0177)	T7 Luminous comfort (0.0206)	T6 Thermal comfort (0.0382)	T5 Fire resistance (0.0360)	T4 Weathering resistance (0.0366)	T1 Material durability (0.0406)	C5 Disposal or recycling cost (0.0223)	C3 Maintenance cost (0.0820)	C2 Operational energy cost (0.0916)	C4 Transportation cost (0.0205)	C1 Initial cost (0.0611)	E2 Recyclability and reusability (0.0345)	E1 Env. Impact reduction (0.0521)	E5 Air quality impact (0.0643)	E6 Renewable resource (0.0506)	E4 Resource efficiency (0.0542)	E3 Embodied energy efficiency (0.0870)

Figure 1. Nano-BSAM hierarchical evaluation model

Source: compiled by the authors

To fulfil the study's objectives, four globally leading residential architectural projects that implemented nanotechnologies were selected based on specific criteria. The selection criteria included: application to the building envelope and structure, diversity of nanotechnologies used, diversity of environmental conditions, and the addressing of a specific design problem. This methodology aimed to analyse the contribution of the nanomaterials and nanotechnologies to the overall sustainability of these buildings, focusing on the problems they addressed. These buildings are: 1. The Seitzstrasse residential and office building in Munich, Germany (renovated 2004), which was the first building to achieve the "Ultra Low Energy House" standard in the city centre. The renovation utilised Vacuum Insulation Panels (VIPs) as the core nanotechnology in the building envelope, achieving exceptional thermal efficiency, increasing usable interior space, and improving natural light and thermal comfort. 2. The Strucksbarg housing complex in Hamburg, Germany (renovated 2007), a notable example of sustainable renovation. The project used an External Thermal Insulation Composite System (ETICS) integrated with Sto Lotusan coating based on nano "Lotus-Effect" technology, providing self-cleaning properties and weather resistance, thereby reducing periodic maintenance costs and preserving aesthetic appearance. 3. The Escala Condominiums residential tower in Seattle, Washington (completed 2009), an example of advanced engineering. The tower used high-strength, nano-enhanced rebar (ChrōmX/MMFX2) as a solution to structural challenges. This material allowed for reduced rebar density compared to traditional steel, facilitating concrete pouring and reducing execution time and effort. 4. The Sur Falveng residential building for the elderly in Domat/Ems, Switzerland (completed 2004), a pioneering example of innovative design in a mountainous climate. The building features a south-facing glass facade containing Phase Change Material (PCM) nanotechnology, which functions as a passive thermal storage. In winter, the material absorbs and stores heat, while in summer, it reflects excessive radiation to prevent overheating, significantly contributing to energy savings and maintaining a stable, comfortable internal environment.

Following the identification of the buildings, the methodology relied on a comprehensive analysis of the available information for each building and a descriptive performance evaluation based on the indicators defined in the Nano-BSAM model. The assessment model was then applied to these buildings through the following quantitative steps, which represent the methodological framework allowing the transition from descriptive evaluation to quantifiable, comparable results.

Data collection and quantitative conversion. Data on the performance of each building across the 24 performance indicators are compiled. A rating value (using a 5-point Likert scale) was assigned to each building for every performance indicator, along with a value of 0 for non-applicable (N/A) indicators, thus converting the qualitative assessments into numerical values.

Calculation of the weighted score for each indicator. The weighted score for each indicator is calculated by multiplying its numeric value (from the previous step) by its

relative weight obtained from the AHP analysis. The formula used is presented in equation (1):

$$WSi = NVi \times RWi, \quad (1)$$

where WS_i – the weighted score for Indicator i; NV_i – the numeric value (Likert score) assigned to Indicator i; and RW_i – the relative weight of Indicator i derived from AHP analysis.

For instance, applying this formula to the "Maintenance cost reduction" indicator (C3), with a numeric value of 5 and a relative weight of 0.0820, yields a weighted score for C3 of $5 \times 0.0820 = 0.41$. This represents the actual contribution of that indicator to the final score.

Aggregation of final scores. The weighted scores of all indicators are summed to obtain the total overall score for each building. This aggregation is done at two levels: the Score for each main criterion (summing the weighted scores of all indicators belonging to that criterion, e.g., Environmental, Economic, etc.) and the Final building score (summing the scores of all four main criteria). The final overall score is then converted to a percentage. Given that the sum of the weights of all indicators is 1.00 (or 100%), the maximum possible score is $5 \times 1.00 = 5$. Therefore, the formula for converting the score to a percentage is given in equation (2):

$$Percentage\ Score = \frac{FS}{MaxS} \times 100, \quad (2)$$

where FS – the final overall score for the building; $MaxS$ – the maximum possible score (which equals 5 in this m odel).

For example, the final score for the Seitzstrasse building is the sum of the weighted scores for all 24 indicators. If the FS is 3.5755, the percentage score is $(3.5755/5) \times 100 = 71.51\%$.

RESULTS

The descriptive evaluations of the case studies were converted into quantifiable numerical data using the conversion key presented in Table 1. These results reflect the buildings' overall sustainable performance from the perspective of regional priorities. Detailed results for each building are presented individually, followed by a summary of their general performance and final ranking. The following tables illustrate the quantitative performance assessment of the four selected study buildings based on the Nano-BSAM evaluation model. The weighted scores for each indicator and criterion are presented, alongside their relative weights. Table 2 presents the quantitative performance analysis of the Seitzstrasse residential and office building.

Table 1. Conversion key from descriptive evaluation to numerical value

Evaluation symbol	Description	Numerical value
+++	Excellent/Very positive	5
++	Highly achieved/Very positive	4
+	Achieved/Positive	3
±	Partially achieved/Challenging	2
–	Not achieved/Negative	1
N/A	Non-applicable	0

Source: compiled by the authors

Table 2. Quantitative performance analysis of the Seitzstrasse residential and office building

Criterion	Indicator	AHP weight	Qualitative rating	Numerical value	Weighted score (weight × value)	Detailed main criteria performance
EC						1.3339
	E.1	0.0521	++	4	0.2084	
	E.2	0.0345	++	4	0.138	
	E.3	0.0870	++	4	0.348	
	E.4	0.0542	++	4	0.2168	
	E.5	0.0643	+++	5	0.3215	
	E.6	0.0506	±	2	0.1012	
CC						0.9546
	C.1	0.0611	±	2	0.1222	
	C.2	0.0916	+++	5	0.458	
	C.3	0.0820	+	3	0.246	
	C.4	0.0205	+	3	0.0615	
	C.5	0.0223	+	3	0.0669	
SC						0.49
	S.1	0.0241	+	3	0.0723	
	S.2	0.0249	+++	5	0.1245	
	S.3	0.0279	++	4	0.1116	
	S.4	0.0266	±	2	0.0532	

Table 2. Continued

Criterion	Indicator	AHP weight	Qualitative rating	Numerical value	Weighted score (weight × value)	Detailed main criteria performance
	S.5	0.0428	+	3	0.1284	
TC						0.797
	T.1	0.0406	+++	5	0.203	
	T.2	0.0133	±	2	0.0266	
	T.3	0.0307	±	2	0.0614	
	T.4	0.0366	+	3	0.1098	
	T.5	0.0360	+	3	0.108	
	T.6	0.0382	+++	5	0.191	
	T.7	0.0206	+	3	0.0618	
	T.8	0.0177	±	2	0.0354	
Overall final score (FS)						3.5755

Source: compiled by the authors

Following Table 2, the weighted scores for the Seitzstrasse building show a total final score of 3.5755. The building recorded its highest performance in the Environmental Criterion (EC), achieving the highest weighted score among all criteria at 1.3339. The Embodied Energy Efficiency (E.3) and Indoor Air Quality Impact (E.5) indicators contributed highly to this score, rated (++) and (+++), respectively. The Economic Criterion (CC) also scored highly (0.9546), with the Operational Energy Cost Reduction (C.2) indicator achieving the highest single weighted value in the entire assessment (0.4580 with a +++ rating). Conversely, the building's performance in the Social Criterion (SC) was the lowest among the criteria, scoring 0.4900. Table 3 presents the quantitative performance analysis of the Strucksbarg housing complex.

Table 3. Quantitative performance analysis of the Strucksbarg housing complex

Criterion	Indicator	AHP weight	Qualitative rating	Numerical value	Weighted score (weight × value)	Detailed main criteria performance
EC						1.15
	E.1	0.0521	++	4	0.2084	
	E.2	0.0345	±	2	0.069	
	E.3	0.0870	++	4	0.348	
	E.4	0.0542	++	4	0.2168	
	E.5	0.0643	++	4	0.2572	
	E.6	0.0506	-	1	0.0506	
CC						0.8739
	C.1	0.0611	±	2	0.1222	
	C.2	0.0916	+	3	0.2748	
	C.3	0.0820	++	4	0.328	
	C.4	0.0205	++	4	0.082	
	C.5	0.0223	+	3	0.0669	
SC						0.5328
	S.1	0.0241	+	3	0.0723	
	S.2	0.0249	+++	5	0.1245	
	S.3	0.0279	++	4	0.1116	
	S.4	0.0266	±	2	0.0532	
	S.5	0.0428	++	4	0.1712	
TC						0.8572
	T.1	0.0406	++	4	0.1624	
	T.2	0.0133	++	4	0.0532	
	T.3	0.0307	++	4	0.1228	
	T.4	0.0366	+++	5	0.183	
	T.5	0.0360	+++	5	0.18	
	T.6	0.0382	+	3	0.1146	
	T.7	0.0206	±	2	0.0412	
	T.8	0.0177	N/A	0	0	
Overall final score (FS)						3.4139

Source: compiled by the authors

Following Table 3, the weighted scores for the Strucksbarg housing building show a final total score of 3.4139. The building achieved the highest score in the Environmental Criterion (EC) at 1.1500, supported by the contribution of the Embodied Energy Efficiency (E.3) and the Negative Environmental Impact Reduction (E.1) indicators. This is followed by the Technical Criterion (TC) which scored 0.8572, recording high performance in the Weathering Resistance (T.4) and Fire Resistance (T.5) indicators, both with a (+++) rating. The Economic Criterion (CC) scored 0.8739, with the most notable performance being in the Maintenance Cost Reduction (C.3) indicator, while the contribution of the Operational Energy Cost Reduction (C.2) indicator was comparatively lower, with a (+) rating. Conversely, the complex's performance in the Social Criterion (SC) was the lowest among the criteria, scoring 0.5328. The numerical scores for the building were derived from the detailed qualitative evaluation. Table 4 presents the quantitative performance analysis of the Escala Condominiums tower.

Table 4. Quantitative performance analysis of the Escala Condominiums tower

Criterion	Indicator	AHP weight	Qualitative rating	Numerical value	Weighted score (weight × value)	Detailed main criteria performance
EC						1.0124
	E.1	0.0521	++	4	0.2084	
	E.2	0.0345	++	4	0.138	
	E.3	0.0870	++	4	0.348	
	E.4	0.0542	++	4	0.2168	
	E.5	0.0643	N/A	0	0	
	E.6	0.0506	±	2	0.1012	
CC						0.6811
	C.1	0.0611	±	2	0.1222	
	C.2	0.0916	N/A	0	0	
	C.3	0.0820	+++	5	0.41	
	C.4	0.0205	++	4	0.082	
	C.5	0.0223	+	3	0.0669	
SC						0.5316
	S.1	0.0241	N/A	0	0	
	S.2	0.0249	++	4	0.0996	
	S.3	0.0279	++	4	0.1116	
	S.4	0.0266	++	4	0.1064	
	S.5	0.0428	+++	5	0.214	
TC						0.6678
	T.1	0.0406	+++	5	0.203	
	T.2	0.0133	+++	5	0.0665	
	T.3	0.0307	+++	5	0.1535	
	T.4	0.0366	+++	5	0.183	
	T.5	0.0360	N/A	0	0	
	T.6	0.0382	N/A	0	0	
	T.7	0.0206	+	3	0.0618	
	T.8	0.0177	N/A	0	0	
Overall final score (FS)						2.8929

Source: compiled by the authors

Following Table 4, the weighted scores for the Escala building show a final total score of 2.8929 (CRSI, n.d.). The building recorded its highest performance in the Environmental Criterion (EC) at 1.0124, supported by high performance across most environmental indicators (E.1-E.4) with a (++) rating, the most prominent contribution being from the Embodied Energy Efficiency (E.3) indicator at 0.3480. This is followed by the Economic Criterion (CC) at 0.6811, where the Maintenance Cost Reduction (C.3) indicator achieved the highest single weighted value in this assessment (0.410 with a +++ rating), despite the Operational Energy Cost Reduction (C.2) indicator being non-applicable (N/A) for this building. Conversely, the building's performance was lowest in the Social Criterion (SC) at 0.5316, followed by the Technical Criterion (TC) at 0.6678. The lower scores for these criteria are due to multiple indicators falling outside the scope of application or assessment (N/A), such as (S.1), (T.5), (T.6), and (T.8). Table 5 presents the quantitative performance analysis of the Sur Falveng building.

Table 1. Quantitative performance analysis of the Sur Falveng building

Criterion	Indicator	AHP weight	Qualitative rating	Numerical value	Weighted score (weight × value)	Detailed main criteria performance
EC						1.1451
	E.1	0.0521	++	4	0.2084	
	E.2	0.0345	±	2	0.069	
	E.3	0.0870	±	2	0.174	
	E.4	0.0542	+++	5	0.271	
	E.5	0.0643	+++	5	0.3215	
	E.6	0.0506	±	2	0.1012	
CC						1.0029
	C.1	0.0611	±	2	0.1222	
	C.2	0.0916	++	4	0.3664	
	C.3	0.0820	+++	5	0.41	
	C.4	0.0205	++	4	0.082	
	C.5	0.0223	-	1	0.0223	
SC						0.6288
	S.1	0.0241	+	3	0.0723	
	S.2	0.0249	+++	5	0.1245	
	S.3	0.0279	++	4	0.1116	
	S.4	0.0266	++	4	0.1064	
	S.5	0.0428	+++	5	0.214	
TC						0.9157
	T.1	0.0406	++	4	0.1624	
	T.2	0.0133	++	4	0.0532	
	T.3	0.0307	+++	5	0.1535	
	T.4	0.0366	±	2	0.0732	
	T.5	0.0360	++	4	0.144	
	T.6	0.0382	+++	5	0.191	
	T.7	0.0206	+++	5	0.103	
	T.8	0.0177	±	2	0.0354	
Overall final score (FS)						3.6925

Source: compiled by the authors

Following Table 5, the weighted scores for the Sur Falveng housing building show a final total score of 3.6925, the highest score among the buildings evaluated. Performance was balanced, with the Environmental Criterion (EC) emerging as the highest weighted score at 1.1451. This is followed by the Economic Criterion (CC) at 1.0029, and then the Technical Criterion (TC) at 0.9157. The environmental performance was characterised by a high contribution from the Resource Efficiency and Water Consumption (E.4) and Indoor Air Quality Impact (E.5) indicators, both with a (+++) rating. In the Economic Criterion (CC), the performance was supported by the Maintenance Cost Reduction (C.3) indicator (+++ rating) and the Operational Energy Cost Reduction (C.2) indicator (++ rating). Conversely, the Social Criterion (SC) was the lowest among the criteria, scoring 0.6288. The score in the Economic Criterion was affected by low-scoring indicators, such as Disposal or Recycling Cost (C.5), which scored 0.0223 with a (-) rating. Figure 2 provides a visual comparison of the integrated performance of the four buildings across the main criteria, aiding in the understanding of each building's relative strengths and weaknesses.

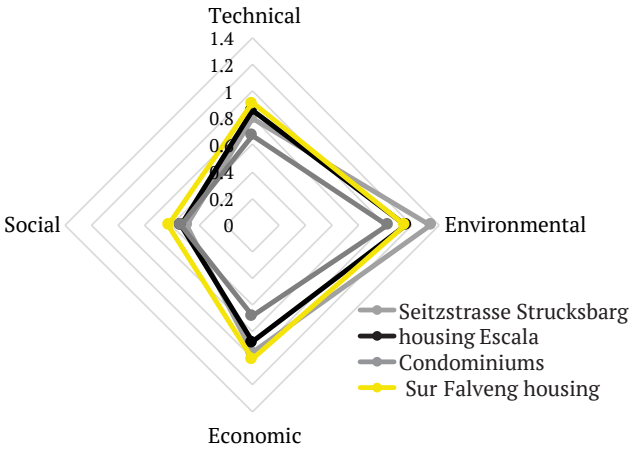

Figure 2. Comparative performance of the four buildings across main criteria based on regional weights

Source: compiled by the authors

Following Figure 2, the chart shows that Sur Falveng housing (yellow line) achieved the best overall performance with a score of 3.6925, while Escala Condominiums (grey line) came in last with a score of 2.8929. Sur Falveng

housing recorded the highest scores among all buildings in the Technical (0.9157), Social (0.6288), and Economic (1.0029) criteria. Seitzstrasse building (blue line) recorded the highest score in the Environmental Criterion (EC), reaching 1.3339. Escala Condominiums shows significantly lower performance in the Economic, Technical, and social criteria, due to the non-contribution (N/A) of highly weighted operational indicators like Operational Energy Efficiency (C.2) and Thermal Comfort (T.6). The performance of Strucksbarg housing (orange line) was balanced, ranking second for the Technical Criterion (TC) at 0.8572 and second for the Environmental Criterion (EC) at 1.1500 after Seitzstrasse. Table 6 summarises the final scores of the four buildings and shows their ranking based on their sustainable performance. The total scores were converted into a percentage for ease of comparison.

Table 6. Summary of final scores and ranking

Case study building	Nanotechnology used	Final weighted score (out of 5)	Percentage (%)	Rank
Seitzstrasse	VIPs (Vacuum Insulation Panels)	3.5755	71.51	2
Strucksbarg housing	Sto Lotusan (Self-Cleaning Lotus Coating)	3.4139	68.28	3
Escala Condominiums	ChrōmX (Corrosion-Resistant Rebar)	2.8929	57.86	4
Sur Falveng housing	GLASSXcrystal (PCM Phase Change Glass)	3.6925	73.85	1

Source: compiled by the authors

Overall, the comparative evaluation highlights clear differences in sustainable performance among the four case studies, reflecting the varying efficiency and applicability of different nanotechnologies in residential buildings. The results confirm that environmental and economic criteria exert the greatest influence on overall sustainability, while technical innovation plays a decisive supporting role in achieving balanced performance. These findings provide a solid basis for integrating region-specific priorities into future sustainable building assessments and for guiding architects and policymakers in selecting nanomaterials that maximise both environmental and operational benefits.

DISCUSSION

The Sur Falveng housing building (GLASSX®crystal – Phase Change Glass) secured the first position due to its outstanding alignment with regional sustainability priorities, particularly energy efficiency and indoor environmental control. The AHP weights highlighted performance indicators where the GLASSX® technology showed the highest contributions: Maintenance Cost Reduction (C.3) with the highest score in the assessment (0.410), Operational Energy Cost Reduction (C.2) (0.3664), and Indoor Air Quality Impact (E.5) (0.3215). These figures demonstrate that the system functions as an integrated facade, achieving immense operational savings (C.2, C.3) and superior functional environmental performance (E.5, T.6) that ideally corresponds to the regional need for reducing energy bills and relying on passive solutions. The Seitzstrasse Building (VIPs – Vacuum Insulation Panels) came in second place with a slight margin, confirming the importance of super-insulation technology in the regional context. The AHP weights reflected the highest priority given to the Operational Energy Cost Reduction (C.2) indicator, where VIPs achieved the highest contribution among all indicators (0.4580). Embodied Energy Efficiency (E.3) also contributed strongly (0.3480). However, the low contribution of other indicators, such as Maintainability (T.3) (0.0614), reflected the complex technical nature and installation challenges of the material compared to the integrated solution that took first place, ultimately preventing it from securing the lead. The Strucksbarg housing (Sto Lotusan – Self-Cleaning Lotus Paint) secured the third position, reflecting that its performance, despite excelling in specific aspects, had a lower impact on the overall sustainability of the building compared to energy efficiency solutions. The strengths of this technology primarily lie in the non-energy-related social and technical criteria, with high contributions in Maintenance Cost Reduction (C.3) (0.3280) and Embodied Energy Efficiency (E.3) (0.3480). However, the coating's indirect role in Operational Energy Cost Reduction (C.2) contributed to a relatively low value of 0.2748, placing it below technologies targeting the core problem of operational energy. The Escala Condominiums Tower (ChrōmX – Corrosion-Resistant Rebar) came in last place due to its structural nature, which restricted the scope of its impact. Structural solutions inherently did not contribute to the indicators with the highest weights in the AHP model, such as Operational Energy Cost Reduction (C.2) and Thermal Comfort (T.6), where these two categories recorded zero contribution. The absence of assessment in the vital operational indicators (E.5, C.2, T.5, T.6, T.8) caused a significant reduction in its overall weighted score, placing it last despite its outstanding technical durability performance (T.1 Material Durability, 0.2030).

The study's findings confirm that nano-insulating and facade-enhancing materials significantly reduce energy consumption, which aligns perfectly with the outstanding performance of the first-place buildings, Sur Falveng (PCMs) and Seitzstrasse (VIPs). A field reports by A. Soni *et al*. (2022) and A. Tohlob & H. Morsi (2024) reinforces this conclusion, demonstrating a 28% reduction in cooling energy consumption and supporting the effectiveness of PCMs and VIPs in achieving energy efficiency. This is

consistent with the paramount regional priority of Operational Energy Cost Reduction (C.2), which received the highest weight (0.0916) in the AHP model (Kylili & Fokaides, 2016). Results further align with their general observation regarding functional environmental benefits, reinforced by the excellent performance of both Sur Falveng and Seitzstrasse in the Indoor Air Quality Impact (E.5) indicator, where they recorded a shared highest weighted value of 0.3215. Results also demonstrate significant alignment with the research by U. Konbr & H. Mamdouh (2022), which found that nanomaterials achieve high performance in energy efficiency (60.3%) and surrounding environment efficiency (71.7%). This supports the exceptional thermal performance of Sur Falveng and Seitzstrasse, as results confirmed an equal weighted contribution of 0.1910 for the Thermal Comfort (T.6) indicator for both. It also supports the strong third-place performance of Strucksbarg housing, whose environmental efficiency is attributed to its facade's self-cleaning properties (E.5 Air Quality Impact, 0.2572). Furthermore, the study's results are consistent with the general trend identified by A. Aljenbaz & Ç. Çağnan (2020), S. Resalati *et al*. (2021), which confirmed that the positive impacts of nanomaterials on sustainability outweigh their negatives. This specifically supports the economic performance of Sur Falveng in reducing maintenance costs (C.3 Maintenance Cost, 0.410), aligning with the reference that nanomaterials reduce maintenance costs. Environmentally, the high efficiency of the Seitzstrasse building in preserving Embodied Energy (E.3 Energy Consumption Efficiency, 0.3480) is consistent with the conclusion that these materials prevent energy loss. Findings regarding the excellent performance of Sur Falveng (PCMs) are further reinforced by quantitative data from a study focusing on the Egyptian climate, which showed that these materials can reduce energy consumption for cooling purposes by up to 38.79% (Ahmad *et al*., 2025). Similarly, the thermal performance of VIPs is strongly supported by a study P. Akadiri *et al*. (2013) and K. El-Alfy *et al*. (2021) that showed their use reduces cooling energy consumption by 10.5%, reinforcing the strong performance of the Seitzstrasse building. Finally, the Escala Condominiums tower ranked last primarily due to the nature of the technology used, a structural application. Although this technology enhances structural strength and durability (T.1 Material Durability, 0.2030), structural solutions inherently did not contribute to the regional priority operational indicators. Consequently, our research demonstrates that overall sustainable performance is achieved not merely by using advanced technology, but by using technology that directly contributes to the indicators prioritised regionally, representing a unique contribution of our research in bridging this knowledge gap.

CONCLUSIONS

Based on the analysed results, this research provides a comprehensive sustainability assessment of the four residential buildings utilising nanotechnology. The regional priority-based assessment model (Nano-BSAM), developed and applied herein, allowed for the unveiling of crucial insights regarding the alignment between nanotechnological effectiveness and local priorities for energy efficiency and reduced operational costs. The final performance ranking of these buildings closely demonstrates its conformance with the regionally weighted priorities established by Egyptian experts.

The final ranking clearly shows that regional priorities are the decisive factor for optimal sustainable performance. The analysis confirmed that the indicators for Operational Energy Cost Reduction (C.2, weight 0.0916) and Maintenance Cost Reduction (C.3, weight 0.0820) were the most influential elements in determining the final sustainability score. The Sur Falveng housing (PCM technology) achieved the highest overall score (3.6925), not for its superiority in a single criterion, but for achieving the most balanced and comprehensive performance across the highest-priority indicators, where its effectiveness in long-term operational savings (C.2 and C.3) contributed to its leading position. Conversely, the Seitzstrasse building (VIPs) came in second place (3.5755), thanks to achieving the highest single contribution in the entire assessment in the Operational Energy Cost Reduction indicator (C.2, 0.4580) and the highest Environmental Criterion score (1.3339), underscoring the vital role of super-insulation in regions that place significant emphasis on energy conservation. Furthermore, the study confirms that the nature of the application is more critical than the novelty of the material itself. Structural applications, such as the nano-enhanced rebar in the Escala Condominiums tower (last place, 2.8929), received a lower overall priority, primarily attributable to their lack of direct contribution to the highly weighted operational metrics (C.2 and T.6), which are considered paramount by regional decision-makers.

For designers and engineers, these findings highlight the practical value of the Nano-BSAM model. The decision regarding nanotechnology selection in future projects should be based on a comprehensive analysis of the specified regional evaluation framework, prioritising solutions that address high-priority performance indicators, such as maintenance costs and energy efficiency, thereby embodying the model's added value as a tool enabling sustainable design decisions. This contrasts sharply with solutions applied to the building envelope, which demonstrated a significantly greater impact on overall sustainability.

Promising areas of further research include the quantitative assessment of structural nano-applications to accurately model their long-term impact on comprehensive sustainability indicators, specifically focusing on durability, service life, and associated long-term maintenance costs of structural elements like nano-enhanced rebar. It is also important to develop modified assessment models, such as expanding the AHP framework to integrate a more detailed Life Cycle Assessment (LCA) of nanotechnology, aligning with expert concerns. Furthermore, research scope can be broadened through global comparative studies of expert-determined weights from different regions

(e.g., Europe or North America) to better understand the variations in global sustainability priorities.

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CONFLICT OF INTEREST

None.

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Оцінка сталості житлових будівель, удосконалених наноматеріалами, на основі AHP, з використанням регіонально зважених критеріїв від єгипетських експертів

Анотація. Швидка глобальна урбанізація та значний вплив будівельного сектору на навколишнє середовище вимагають інноваційних, стійких рішень, причому нанотехнології виступають ключовим каталізатором. Незважаючи на цей потенціал, поточним дослідженням бракує цілісної, систематичної структури оцінки житлових будівель, удосконалених наноматеріалами, яка б інтегрувала специфічні регіональні пріоритети країн, що розвиваються. Це дослідження вирішило цю прогалину знань шляхом розробки та застосування чотиривимірної моделі оцінки (екологічної, економічної, технічної та соціальної) із використанням методу аналізу ієрархій. Вагові коефіцієнти були отримані від 55 єгипетських експертів з архітектури та сталості, що гарантувало відображення результатами критичних регіональних потреб. Аналіз показав, що екологічний критерій був визнаний найбільш критичним виміром, отримавши найвищу вагу (0,3427), за ним тісно слідував економічний критерій (0,2774). Технічний критерій посів третє місце (0,2337), тоді як соціальний критерій був найменш впливовим (0,1462). Це визначення пріоритетів підтвердило, що зниження експлуатаційних витрат на енергію (0,0916) та зниження витрат на технічне обслуговування (0,0820) були найбільш вирішальними факторами сталої ефективності в регіональному контексті. Модель була застосована до чотирьох глобальних прикладів для визначення їхньої сталої ефективності та рейтингу. Будівля Sur Falveng зі склом з фазозмінним матеріалом (Phase Change Material Glass) посіла перше місце з оцінкою (73,85 %) завдяки своїй всебічній та збалансованій ефективності. За нею на другому місці слідувала будівля Seitzstrasse з вакуумними ізоляційними панелями (Vacuum Insulation Panels) (71,51 %). Житловий комплекс Strucksbarg із самоочисним покриттям «ефект лотоса» посів третє місце (68,28 %). Навпаки, вежа Escala Condominiums, що використовувала наномікрокомпозитну арматуру, посіла останнє місце (57,86 %), що підтвердило, що структурні застосування отримали нижчий загальний пріоритет, оскільки вони безпосередньо не сприяли домінантним експлуатаційним показникам. Це дослідження надало практичний, доказовий інструмент для архітекторів та політиків, підкреслюючи необхідність узгодження вибору нанотехнологій з регіональними рамками оцінки для керівництва майбутніми рішеннями щодо сталого проєктування на ринках, що розвиваються

Ключові слова: аналітичний ієрархічний процес; нанотехнології; регіональні пріоритети; огороджувальні конструкції; житлова архітектура

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Quantitative and qualitative characteristics of the Drohobych district territory in the context of planning development objectives

Abstract. The aim of the study was to analyse spatial disparities in facilities, functions, and user distribution in the Drohobych district to develop a strategy for balanced territorial development. A GIS-based analysis was employed to determine the following quantitative indicators: population density, distribution of transportation infrastructure, and localisation of historical and cultural sites. These factors served as the foundation for determining the potential of territorial communities and their capacity for cooperation. Also, it was analysed the advantages of joint strategic planning based on the territorial characteristics of the Drohobych district and its municipalities. It was highlighted spatial imbalances and the varying degrees of accessibility and infrastructural development across the district. Also, attention was given to the role of agglomeration principles as a mechanism for uniting fragmented communities into cohesive planning entities. The study considered the significance of natural and cultural resources, such as Carpathian landscapes, mineral springs, and preserved planning structures of historical German colonies, as tools for sustainable tourism development. These assets contributed to the formation of distinct functional clusters within the district. Research identified weak transport connections between peripheral and central areas as both a challenge and an opportunity for targeted interventions. It was argued for the adoption of integrated, community-based development strategies that accounted for local conditions, while aligning with regional and national planning frameworks. By combining quantitative spatial analysis with strategic planning principles, the study offered practical insights into fostering balanced, resource-efficient, and collaborative territorial development

Keywords: territorial communities; population density; transport network structure; historical and cultural sites; spatial disparities

INTRODUCTION

A key aspect of the development of territorial communities was determining the mechanisms for their cooperation in strategic planning. One such mechanism, according to V. Yatsenko (2020), was functioning based on the principles of agglomeration, which involved the unification of geographically close settlements, integrated both functionally

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and spatially into a single system. Researchers M. Dyomin *et al.* (2022) noted that theoretical and methodological approaches to agglomerative development of large territories primarily focused on functional-spatial zoning. In the context of spatial development, a key objective was to achieve a balanced integration of economic, social, and environmental interests across communities. Ensuring such equilibrium necessitated the equitable distribution of infrastructure and public services between central urban areas and peripheral territories. According to the study by N. Lysiak *et al.* (2022), the deindustrialisation of the economy led to the loss of competitive industrial production in various regions. This issue can be mitigated through the development of functional specialisations within specific regional taxa, particularly those oriented toward industrial activities.

With regard to the general principles of spatial planning and the coordination of development among individual communities within a larger administrative unit, the study by S. Schmidt *et al.* (2021) demonstrated the advantages of coordinated actions. Scientists suggested that a more centralised and integrated planning framework fostered more compact urban development and contributed to the efficient use of territorial resources. This study proposed the hypothesis that adjacent territorial communities can adopt agglomeration principles in resource utilisation – both tangible and intangible – by developing and implementing a joint development strategy. According to T. Kalahsnykova (2020), spatial determinants of human development represented a distinct aspect of analysis. The study identified four groups of factors influencing human development: the characteristics of physical space, economic and social environment, and the conditions of everyday life for the population. In summarising the threats to human development, the author distinguished four classes of risks: inequality in access to social goods, particularly education; uneven distribution of urbanised and less urbanised areas, leading to polarisation and uneven placement of infrastructure; the isolation of settlement groups from the rest of the territory due to natural or anthropogenic barriers. These threats can be mitigated or exacerbated depending on the development of a crucial criterion for territorial functioning – transport accessibility.

The development of a spatial development strategy for communities should be based on quantitative indicators of the characteristics of the area and their cross-analysis. Quantitative characteristics included such basic parameters as: district area, population size, density, land use structure, and the availability of engineering and transport infrastructure. According to the authors N. Hugo & D. Viertel (2024), the use of GIS in obtaining actual data on planning territories was a key tool in planning their development. Researchers emphasised the need to systematise spatial data. It enabled the visualisation of land use conflicts, analysis of development options, and the creation of data-based development scenarios. At the same time, there were still challenges at the local level with updating cadastral maps, as well as with access to environmental and statistical information. So, the study aimed to determine quantitative indicators of territorial communities in the Drohobych district to identify spatial disparities, including population density and transport coverage imbalances, as well as misalignments between cultural heritage clusters and other territorial features.

MATERIALS AND METHODS

The study covered the territory of the Drohobych district in the Lviv region, which served as a representative example for analysis due to its geographical location, resource potential, demographic dynamics, and socio-economic conditions. The study of the Drohobych district was based on a cartographic analysis to assess the quantitative characteristics of the territory. The research and schematic representations were conducted using the QGIS (Quantum Geographic Information System) geographic information system, utilising open geospatial data from OpenStreetMap (n.d.) as of 2024. Also, QGIS was used to analyse spatial data layers such as settlement boundaries, transport infrastructure, land use, and terrain.

Population estimates (as of 2022) were used to calculate density within built-up areas of 89 settlements. These were spatially divided into 1 km^2 grid cells in accordance with the NUTS-3 typological framework, adapted for Ukraine. Each cell's population density was categorised into one of four types: high (>800), medium (201-800), low (51-200), and very low (⩽50) people per km^2. Based on these clusters, the territory was functionally classified into urban, potentially urban, and rural zones. Urban areas included cells with a density above 300 people/km^2 and adjacent areas with aggregated populations exceeding 5,000. Rural zones included those below 150 people/km^2, while intermediate ranges were considered potentially urban. Transport accessibility was analysed using QGIS network analysis tools to model shortest road routes from each settlement to Drohobych and key regional centres (e.g., Lviv, Stryi, Uzhhorod).

Each route was weighted by population to determine relative transport load, highlighting areas of both strong connectivity and isolation. Topographical features were assessed using digital elevation models (Global Multi-resolution Terrain Elevation Data 2010, U.S. Geological Survey), allowing for the identification of mountainous areas per EU regional typologies. Historical and cultural elements, such as 18th-19th century German colonies, were mapped and integrated as thematic GIS layers to assess their development potential. This integrated methodological approach enabled a multi-layered evaluation of Drohobych district's spatial, infrastructural, and socio-economic structure. An auxiliary aspect of the research methodology involved the selection of information characterising the socio-economic processes at the level of the Drohobych district. In particular, according to the theory of K. Mezentsev (2005), the Stryi-Drohobych core represented a formed intra-regional nucleus, considered promising for the development of new propulsive types of human activity. At the same time, the workforce necessary for implementing these propulsive

activities was likely available, since, according to N. Prytsyuk & M. Flaga (2005), the "share of pension-age individuals in the total population" in the Drohobych district was only 17.9% as of 2005.

RESULTS

The Drohobych district was characterised by dispersed urbanisation (Bardyn, 2023), which had resulted from the active development of specific industries based on natural resources. According to the Lviv Regional Military Administration (n.d.), Drohobych district was classified as a mixed industrial-resort region. The primary resort centres were located in the cities of Morshyn and Truskavets, while a small portion of the mountainous micro-region functioned predominantly within the tourism sector. The industrial zoning scheme of Lviv region, as outlined in the Development Strategy, identified the cities of Drohobych and Boryslav as the core of a unified industrial hub, covering a significant portion of central Drohobych district – extending from Medenychi (the administrative centre of Medenychi territorial community) in the northeast to Skhidnytsia (the centre of Skhidnytsia territorial community) in the southwest. The unique spatial structure of these cities – Drohobych, Boryslav, and Stebnyk – was historically shaped by the need to optimise industrial connections. However, in the present context, this industrial interconnectivity was gradually losing its relevance. According to data from N. Fomenko (2007) and Drohobych Agglomeration Planning Scheme (Baranetskyi, n.d.), Truskavets city council (n.d.), the resources of the Drohobych district can be categorised into three main types. This classification was further supported by M. Odrekhivskyi (2002) in research on regional resource distribution.

The first type of resource was natural mineral resources, which served as the foundation for the development of the extraction and processing industries from the mid-19th century to the 2025 and played a key role in the formation of the Drohobych agglomeration. The second type of resource was natural-recreational resources, including Carpathian mountain landscapes, and mineral springs, which formed the basis of the well-developed sanatorium sector. With the decline of industrial factors, these resources have become pivotal in the development of the Drohobych district. The third type of resource was historical and cultural heritage, which, in the context of a non-industrial economy, served as an important resource for the development of territories. These three main types of resources were examined in the work within the context of the following structure: population density and the pattern of distribution of this characteristic; density of transportation connections across the territory and the identification of the nature of these connections.

One of the key indicators in the development of communities was the availability of labour resources, or population density and the distribution of this indicator across the territory. Population density (people/km^2) in this study was defined as the ratio of the total population to the area in cells of 1 km^2. The analysis of the obtained population density data for Drohobych district through QGIS mapping allowed for the identification of local territories with distinct ratios of area to population density. Through ranking, the area was divided into 4 density types: 1) high density (4894-801 people/km^2); 2) medium density (800-201 people/km^2); 3) low density (200-51 people/km^2); 4) very low density (50 or fewer people/km^2). Clusters were then selected according to these 4 categories (801+/201-800/51-200/50-) and grouped accordingly. Geospatial data from OSM was used to extract the forest areas of Drohobych district, which were then overlaid onto the density ranking scheme (key = landuse, value = forest). This approach allowed for the identification of conditionally uninhabited areas. Given the average population density in Ukraine of 70.7 people/km^2 (Verner, 2022), the grading used in this study was conditional and was adopted for a detailed analysis of Drohobych district and the creation of a map of indicator distribution (Fig. 1).

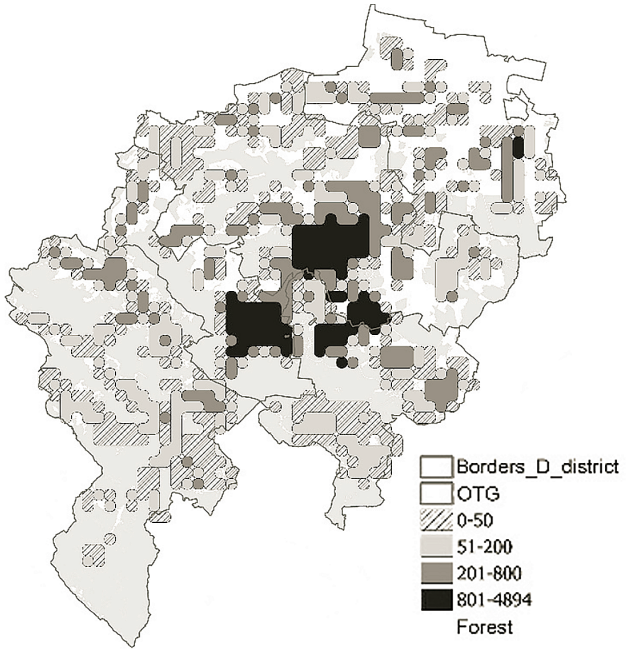

Figure 1. Population density and distribution in the Drohobych district
Source: developed by the authors

The analysis of population density within settlements revealed the following gradation – the highest population density, up to 4894 people per km^2, was found in the cities of Drohobych, Stebnyk, and Truskavets. A lower, yet still high density, of up to 1215 people per km^2 was found in Boryslav and the adjacent village of Popeli, as well as the villages of Bolekhivtsi and Opary. The last settlement, Opary village, likely maintained a high population due to the operation of a significant gas field on its lands from 1940 until the end of the 20th century, which required workers for its maintenance. The group of settlements with high population density – up to 1179 people per km^2 – also included the towns

of Medenychi (which had city status until the early 20th century) and Pidbuzh, as well as the villages of Voroblevychi and Tyniv, with densities up to 791 people per km^2. The next settlements in terms of population density included the villages of Storona, Rykhytchi, Zaluzhany, Nahuyivchi, Hrushiv, Ripchitsi, and Urizh, with densities of up to 617 people per km^2. The remaining villages had significantly lower population density, especially in the mountainous areas of the Drohobych district (Bardyn, 2023).

The average population density was observed concentrically around the urbanised core of high density, within a radius of up to 5 km, and gradually "fades out". Additionally, the analysis identified dispersed areas with uniformly low population density, particularly a belt 3.5 km wide in the Western part of Drohobych district and along the border with Sambir district. It was also evident that the population was sparse in the mountainous areas of Drohobych district. The extremely low density, according to the processed maps, was concentrically located around the periphery of medium-density territories. As the distance from the core of the district increases, the population density became more uniform, with no visible areas of higher settlement density. Extremely low population density, less than 50 people per km^2, in Drohobych, Boryslav, and Truskavets municipalities, was a local phenomenon and was represented in the form of agricultural areas. Within the Medenychi territorial community, a population density of less than 50 people per km^2 was mostly found in areas, whose lands were state-owned (Public cadastral map, n.d.). The largest sparsely urbanised areas were found in the Skhidnytsia territorial community, as these areas were classified as mountainous.

Quantitative characteristics of the five united territorial communities of the Drohobych district based on the urban, potentially urban, and rural areas were established through GIS cluster analysis (cells of the territory under study with a size of 1 km × 1 km). Although the European typological methodology (European Union, 2018) was applied in this study, intermediate population density gradations were introduced, given the lower level of urbanisation in Ukraine compared to European countries. The clusters of the grid applied to the Drohobych district territory were classified as follows: urban areas: a) population density >300 people/km^2; b) areas adjacent to those with a population density >300 people/km^2 and having a total population >5,000 people; potentially urban areas: intermediate areas between urban and rural, with a population density ranging from 150 to 300 people/km^2; rural areas: areas with a population density of <150 people/km^2.

The Drohobych urban territorial community had the highest number of "urban areas" based on a population density of over 300 people/km^2, with 81 clusters. The Boryslav urban territorial community followed, with 37 clusters classified as urban. The Truskavets urban territorial community had 30 clusters with a population density exceeding 300 people/km^2. The Skhidnytsia settlement territorial community had 20 clusters, while the Medenychi territorial community had only 6 clusters with a population density of over 300 people/km^2 (Bardyn, 2023). Territories adjacent to areas with a population density of more than 300 people/km^2 were also classified as urban and were divided into two types. The first type included territories with a total population of more than 5,000 people. The second type included territories, where the population density ranges from 150 to 300 people/km^2. It has been established that territories classified as "urban" according to the criteria outlined were only presented in the urban territorial communities of Drohobych, Boryslav, and Truskavets, and were absent in the Medenychi and Skhidnytsia territorial communities.

So, it was identified a type of territory, which based on population size and density was the "potentially urban areas", which had a population density ranging from 150 to 300 people/km^2 and do not border "urban" areas. This type of territory had high quantitative indicators in rural territorial communities – Medenychi had 24 clusters, and Skhidnytsia had as many as 33 clusters, indicating a high labour force potential in these communities. In contrast, the Truskavets urban territorial community had only 6 clusters with a population density of 150 to 300 people/km^2, while Drohobych and Boryslav each had 25 clusters. The next type of territory that was identified classified as rural, with a population density of less than 150 people/km^2. The highest number of "rural" clusters – 140 units – were found in the Medenychi rural territorial community. The Skhidnytsia rural territorial community had 69 clusters with a population density of less than 150 people/km^2. Urban territorial communities also had a significant percentage of sparsely populated areas: the Drohobych community had 92 clusters, and the Truskavets community had 75 clusters. The lowest percentage of areas classified as "rural" in the study was in the Boryslav community – 17 clusters per 1 km^2. The proportion of areas classified as urban and rural in different communities had been determined. The Drohobych community had 61% urban areas, the Boryslav community had 81% urban areas, the Truskavets community had 42%, the Medenychi community had 18%, and the Skhidnytsia community has 43%. These quantitative population density indicators of the Drohobych district suggested that the old industrial cities and their adjacent areas – Drohobych and Boryslav – despite the decline of extractive and processing industries, continued to have a high potential in terms of the labour force.

It has been established that the Truskavets territorial community had the most balanced proportion of urban and rural areas in terms of quantitative indicators. However, the geometry of their placement was diametrically opposed, as urban areas – such as the city of Truskavets and the adjacent lands classified as urban – were grouped in the northern part of the community. In contrast, the Southern part of the community was entirely rural. The Drohobych and Boryslav communities, based on population density, can be classified as urban areas. Meanwhile, the Medenychi and Skhidnytsia communities, given their population density, were agrarian communities. This territorial

differentiation required appropriate approaches in planning and infrastructure development, particularly taking into account the unique characteristics of each community. For an objective characterisation of territories, it was necessary to analyse a number of key factors, among which particular attention should be paid to spatial accessibility and the nature of their connections. Spatial accessibility defines the level of convenience and efficiency of transportation connections between different parts of a territory, which affected the mobility of the population, access to resources, and services. The nature of the connections, in turn, reflected the degree of integration between territories, which was an important factor in the socio-economic development of communities. These characteristics were determined by the quantitative indicator of the probable road traffic load. The assessment of the calculated road traffic load was carried out in QGIS by considering the statistical population number in settlements as 100% and distributing them according to transportation connections to the district centre, the city of Drohobych. The result of the calculation was the transportation load, which was expressed in the conditional number of people per direction or as a percentage ratio, where the most loaded direction was taken as 100% (Fig. 2).

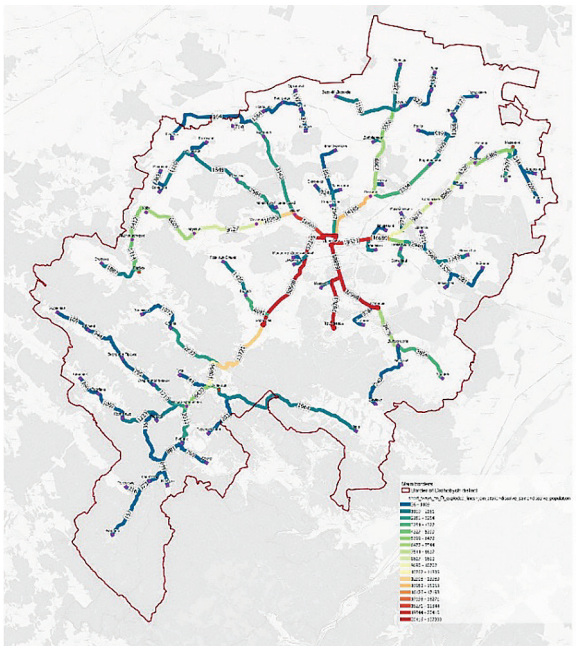

Figure 2. Structure and road traffic load of the Drohobych district
Source: developed by the authors

The most significant transportation direction for the Drohobych district was the connection of settlements in the district with Lviv, the regional centre. According to the quantitative calculations, the "ideal probable" maximum number of people traveling along this connection was 206,109 individuals. The maximum number of movements from settlements in the Drohobych district to the city of Sambir was 239,080 individuals, while to the city of Uzhhorod (via Sambir) the number was 240,809 individuals. The connection to the city of Stryi had an even higher traffic load, with 231,022 individuals. The maximum number of movements from Stryi to the city of Mukachevo was 240,809 individuals (Bardyn, 2023). The calculated data indicated that the connection through the Drohobych district in the west-east direction was more relevant, as the maximum traffic load densities on these routes, particularly to Uzhhorod, Stryi, and Mukachevo, suggested a high level of transportation activity and the significance of these routes for regional mobility.

So, it can be concluded that the historically formed connections of Drohobych with the cities of Stryi and Sambir created areas with higher potential in terms of spatial accessibility, compared to the areas located along the Lviv transport corridor. This limited the active cooperation between the two centres of the united territorial communities – the village of Medenychi in the north and the village of Skhidnytsia in the south, as these areas had weaker transport links and were further from the main highways. The weak connections within the district can be seen as an opportunity for the development of isolated areas as tourist or agricultural centres. The comparison of cartographic data on population density and the density of transportation coverage allowed for the identification of two types of local areas with specific characteristics. The first type of areas with specific characteristics – areas with the lowest population density within the influence zones of transport corridors (Fig. 3). These areas can be considered as potential sites for future development and for the anticipated localisation of new facilities.

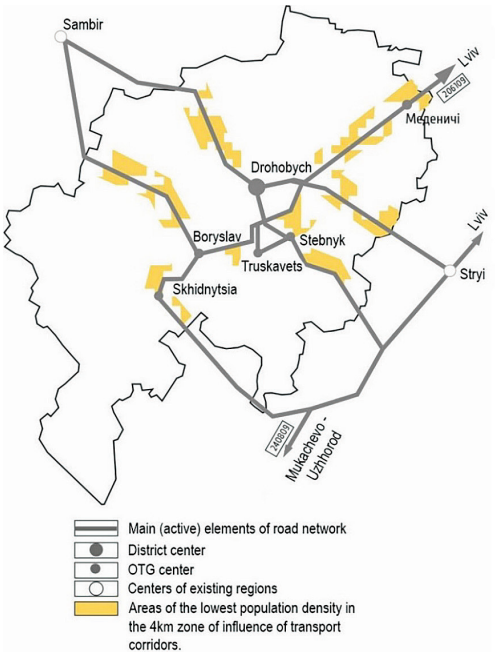

Figure 3. Areas of the lowest population density in the zones of influence of transport corridors
Source: developed by the authors

The second type of areas with specific characteristics – areas with high population density outside of cities, but with low coverage by the transportation network. Areas with the highest density of rural population, located in zones least integrated into the overall road network leading to the centre of the district, were the most distant from the centre and were adjacent to neighboring settlement elements – cities and transportation networks of the surrounding districts of Sambir and Stryi, yet they lack direct transportation links with them. Their transportation isolation led to economic losses. These local territories were characterised by having workforce potential but lack the infrastructure for its mobility and required economic activation – new types of activities based on existing resources (Zubekhina & Matviichuk, 2025). The peculiarity of spatial planning in the Drohobych district was that the centres of the territorial communities were located along the axis of the transport connection between the district centre and the regional centre, rather than in the centre of the land of each territorial community. This axis, stretching from the northeast to the southwest, can be referred to as the "urban density" axis of the region's potential and active functions (Fig. 4). It was formed based on the shared resource and raw material potential of the cities of Drohobych, Boryslav, Stebnyk, and Truskavets, with the region's most prominent and concentrated resources – industrial raw materials (potash salts, oil, natural gas) and health and wellness resources – mineral springs, some of which were unique in their therapeutic properties. The historically and culturally significant resource was also predominantly concentrated along the urbanised axis.

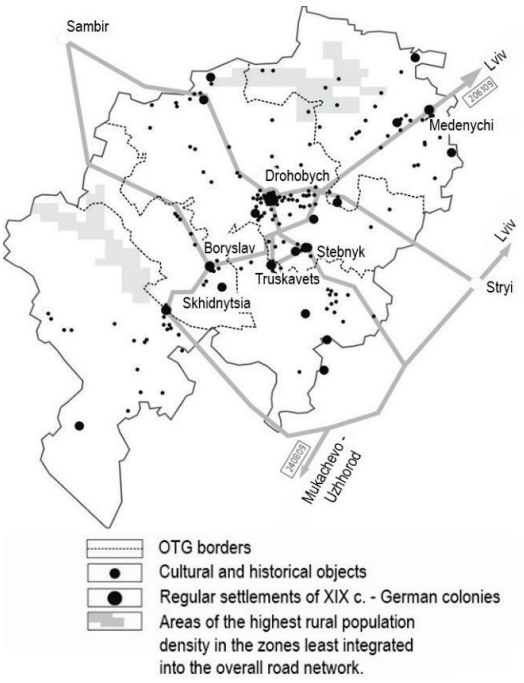

Figure 4. Areas of the highest rural population density in the zones least integrated into the overall road network
Source: developed by the authors

Urbanised areas influence economic indicators even beyond their boundaries. According to the findings of R. Ahrend *et al.* (2017), within a 90-minute drive from the urban agglomeration, a 0.4% increase in productivity had been recorded, compared to areas outside the influence of urbanisation. Therefore, it can be assumed that the influence of the "urban density" axis extended to remote areas, and the spatial planning feature of the Drohobych region was an advantage, when communities cooperate based on agglomeration principles. In this model, cities and towns – the centres of territorial communities – form the infrastructure core, while their territories had the opportunity for equidistant access to the use of infrastructure. In the industrial-tourist development direction of the Drohobych district, which was supported by urban planning documentation (Baranetskyi, n.d.), and scientific research by M. Odrechivskyi (2002), I. Mizernyk *et al.* (2006), priority was given only to the main transport links that promoted the development of key centres.

Poorly integrated territories were increasingly isolated (Dijkstra & Ruiz, 2010). According to the Regional Development Working Papers compiled by M. Brezzi *et al.* (2011), remote rural regions showed a stronger decline in population and a faster ageing process than rural regions close to a city. The remoteness of rural regions was in fact a significant factor explaining regional outflows of working age population. Geographical distance significantly affected access to opportunities, particularly in rural areas, where distance from major economic and social centres can lead to social isolation of the population. Areas with low population density, located at a considerable geographical distance from cities with populations exceeding 50,000 (considering the time needed to reach the city by car), can be classified as "lowest in opportunities". These areas faced economic difficulties as the lack of proper infrastructure and limited access to markets and resources created barriers to entrepreneurship and improving the quality of life for residents. This also exacerbated the risks of social alienation and depopulation.

The development of connections between remote areas of the district and the established axis of "urban density" was possible provided that an inventory was conducted within these areas, not only of material or infrastructural potential concentrated in the centre of the district, but also of cultural-symbolic and natural potential. As demonstrated by N. Sosnova *et al.* (2020), "the integration of a territory's natural value with its historical significance provides a basis for the development of tourism infrastructure within local communities". Local heritage sites, unique settlement layouts, landscape features, traditional agricultural practices, and other elements could form the basis for the development of the tourism sector. As an example of promoting the cultural and historical potential of the Drohobych district, this paper analysed the area for distinctive planning solutions of rural settlements. Valuable historical objects included the planning solutions of German colonies (settlements) built in the 18th-19th centuries (Fig. 5), of

which there were about ten within the modern Drohobych district, according to the German settlement map (Galizien German Descendants, 2025). In terms of planning structure, the colonies were linear villages, mostly with development on one side of the street (Oleshko & Heinz, 1996).

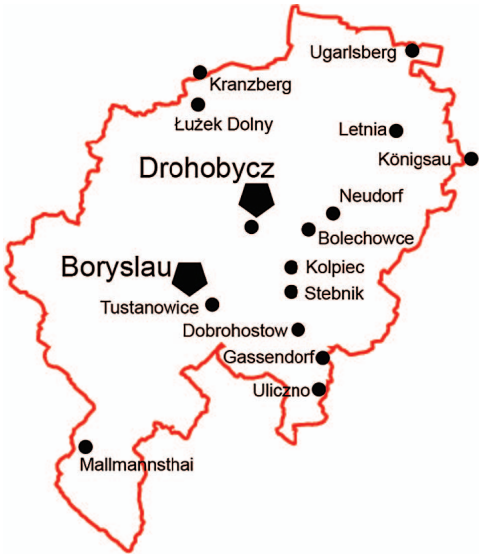

Figure 5. Regular settlement planning types – German colonies of the late 18th century in the lands of the Drohobych district
Source: based on Galizien German Descendants (2025)

The documentation of settlement planning on the Second Military Survey of the Habsburg Empire: Galicia and Bucovina (1861-1864) (Timár, 2006) (Fig. 6) provided data on the spatial structure of the settlement and its precise location within the Drohobych district. The settlement of Ugartsberg was a former German colony located in the vicinity of Vypuchky, 5 km North of Medenychi in the Drohobych district of the Lviv region (Chlebowski *et al.*, 1880). The colony was established in 1785 during the Josephine colonisation. In 1900, the settlement had 29 houses with a population of 222 (Oleshko, 1999). In September 1939, the residents of the colony were evicted (Rąkowski, 2013).

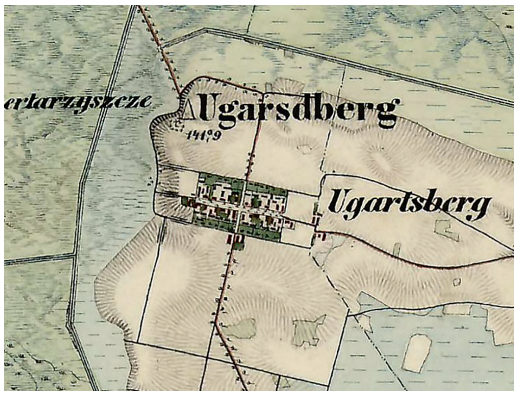

Figure 6. Settlement of Ugartsberg
Source: based on G. Timár (2006)

As of 2025, according to aerial imagery on Google Maps, neither the streets nor the buildings of the settlement have been preserved (Fig. 7). A comparison of the maps from the Second Military Survey of the Habsburg Empire: Galicia and Bucovina (1861-1864) (Timár, 2006) with the 2025 aerial imagery allowed for the precise identification of the land parcel on which the Ugartsberg settlement once existed. The site was occupied by arable land, divided into two parts by the former central road of the settlement.

Figure 7. Area of the former settlement of Ugartsberg. Satellite imagery
Note: coordinates – 49.47869062176148, 23.74332881021904
Source: based on Google map (n.d.)

Another settlement examined in this study was Königsau, which was founded in 1783 on the lands of the village of Letnya, 22 km northeast of the city of Drohobych and 6 km southwest of the town of Medenychi. The settlement was planned for approximately 300 inhabitants. The total area of the settlement, including agricultural lands, was 766 ha (data calculated based on the cadastral map of the mid-19th century at a scale of 1:28,800) (Central State Historical Archive of Ukraine, n.d.). The pentagonal structure of the settlement was unique in European urban planning and was documented on the Second Military Survey of the Habsburg Empire: Galicia and Bucovina (1861-1864) (Timár, 2006) (Fig. 8). From the central square, five roads were planned, interconnected with concentrically arranged blocks. The settlement project was designed by the Austrian engineer Kallbrunner, who had an office in Drohobych. The settlement was a unique example of the implementation of classical urban planning principles in a rural area. At 2025, the settlement was known as the village of Rivne. As of 2025, aerial imagery on Google Maps clearly revealed the pentagonal shape of the settlement, and the street layout remained discernible (Fig. 9). According to the map, the built-up areas were partially preserved, but showed gaps along the streets, indicating that some of the historical residential buildings no longer exist. It can be assumed that a significant portion of the houses had been reconstructed on the sites of the original colonists' homes.

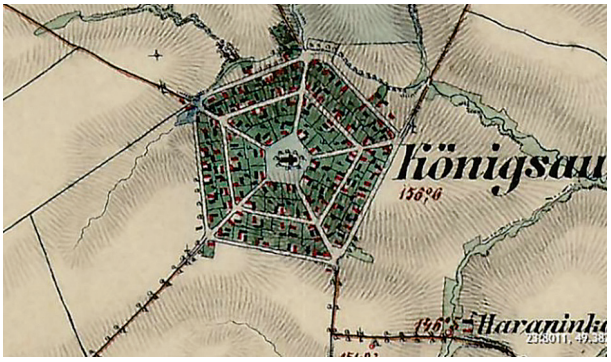

Figure 8. Königsau on the 19th-century map
Source: based on G. Timár (2006)

Figure 9. The village of Rivne (former Königsau) as of 2024
Note: satellite imagery. Coordinates: 49.380291250529176, 23.78177962680194
Source: based on Google map (n.d.)

The described examples of regular settlement planning on the lands of Drohobych district were presented as an example of the territory's features that need to be considered in the development plans of united territorial communities, as potential for the development of the tourism sector.

DISCUSSION

Similar to the findings based on the example of the Drohobych district, contemporary studies showed that shortcomings in the inventory of territorial potential and an unclearly defined set of priority functions for these areas led to unsuccessful implementation of spatial development plans. The authors J. Barry *et al.* (2018) emphasised that ineffective assessment of local resources often undermined strategic regional initiatives. B. Davy *et al.* (2025) argued that the concept of planning and its practical realisation frequently diverge, creating inconsistencies between the expected and actual outcomes of spatial policies. Moreover, A.M. Hersperger *et al.* (2018) noted that the paradigms of spatial and urban planning rely too little on the specific characteristics of local communities, their indicators, and individual potential, as national legislation (Portal of State Building Standards of Ukraine, n.d.) often dominated over contextual needs.

The classification of areas into rural, urban, and peri-urban, as proposed by V. Cattivelli (2021), served as a prerequisite for planning the cultural, social, and economic needs of communities in the implementation of municipal plans – aimed at reducing the gap between planned actions and their outcomes at the time of implementation. A study on land use changes at the interface of metropolitan and rural areas conducted by N. Siamian *et al.* (2025) demonstrated that the increase in migration from rural to urban areas was driven by the lack of a clear land classification system. According to the indicators obtained in the study, in Iran during the research period (1990-2020), urban and built-up areas expanded by 384.94 km^2 (47.15% of the study area), while agricultural land decreased by 61.05 km^2 (8.02%). Scientific studies demonstrated that the dichotomies of "urban"-"rural" and "industrial"-"recreational" territories required improved methods of territorial delineation to support well-grounded planning decisions and strategies, particularly, when addressing the differing infrastructure development needs of urban and rural areas. Equally important is ensuring that planning aligns with current legislation and strategic documents – such as the Resolution of the Cabinet of Ministers of Ukraine No. 695 (2020). Compliance with these frameworks allowed for coordination among various institutions, avoidance of project duplication, and cohesive development.

Although decentralisation was generally considered an effective solution, T. Firman (2003) pointed out that regional disparities can also be interpreted as a negative phenomenon, leading to spatial development based on the "islands" principle. Geographically large distances and low population density in rural regions led to their isolation and increase the risk of social exclusion among the population. P. Bertolini (2019) highlighted that such conditions result in low levels of investment due to the decline in human capital reserves. Accordingly, to prevent the emergence of non-integrated territories within administrative units, it was essential to apply agglomeration-based governance principles. Urban planners interpreted agglomerative formations as zones of shared interests. I. Rusanova & I. Sklyarova (2010) described them as systems, where a group of cities and their adjacent territories, supported by well-developed infrastructure networks, facilitated economic development. Similarly, B. Portnov & E. Erell (2001) and A.J. Scott (2001) defined agglomeration as a mechanism for stimulating economic growth rather than a strictly delimited territory. M.M. Conroy & J. Evans-Cowley (2006) emphasised that this mechanism enabled collaboration among functionally diverse territories and settlements through joint economic strategies – for example, integrating tourism routes that connected historical sites with agricultural areas and picturesque landscapes. Qualitative characteristics, in turn, reflected the level of access to social services, the environmental condition of the area, road quality, infrastructure provision, and cultural-historical heritage. L.D. Hopkins & G.-J. Knaap (2018) analysed planning theory and implementation models that emphasised

participation, where communities consider not only their own interests, but also those of neighboring territories. Another important aspect was community participation in the planning process. N. Grynchuk & M. Baginskyi (2023) pointed out that modern approaches to urbanism involved broad engagement of the local population at the stages of data collection and public discussions, which helped build trust in authorities and increases the effectiveness of plan implementation. Accordingly, the analysis of population distribution in the Drohobych district, conducted in this research, provided a foundation for developing a community development strategy.

CONCLUSIONS

So, as a result, it was indicated a noticeable differentiation of the united territorial communities of the Drohobych district based on urbanisation indicators, and, accordingly, the approaches to the development of these territories will vary. The territories of Drohobych district, within which specific characteristics had been established, such as: areas of the lowest population density in the zones of influence of transport corridors; areas with the highest rural population density in the least integrated zones of the overall transport network, were considered as areas of primary importance for functional-planning changes. The study identified local areas (Medenychi, Skhidnytsia, Drohobych, Boryslav, Stebnyk, Boryslav) within the Drohobych district that can be considered as potential sites for future development. Additionally, areas were determined that were potentially at risk of stagnation and loss of human capital due to their lack of integration into the district's planning structure.

The need for the creation of new clusters, such as residential, tourist, and industrial, remained relevant for the further development of the region. The planning objects of the Drohobych district, which were part of the material and cultural-historical potential of the district, form the foundation for the development of new functional clusters. Effective cooperation among communities can be achieved if the relationships between their resource-based territories shift from competition to collaboration, fostering a new spatial development model. The expected outcome of the research was the development of a model that integrated the quantitative indicators obtained in this study with demographic data. The prospects for further research on the characteristics of the Drohobych district territory in the context of planning development objectives lie in updating demographic data and accounting for its impact on the settlement system.

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CONFLICT OF INTEREST

None.

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Кількісні та якісні характеристики території Дрогобицького району у задачах планового розвитку

Анотація. Метою дослідження було проаналізувати просторові диспропорції у розміщенні об'єктів, функцій та користувачів у Дрогобицькому районі з метою розробки стратегії збалансованого територіального розвитку. Для визначення кількісних показників, таких як щільність населення, розподіл транспортної інфраструктури та локалізація історико-культурних об'єктів було застосовано ГІС-аналіз. Ці фактори стали основою для оцінки потенціалу територіальних громад та їхньої спроможності до співпраці. Також було проаналізовано переваги спільного стратегічного планування, заснованого на територіальних особливостях Дрогобицького району та його громад. У роботі висвітлено просторові дисбаланси, різний рівень доступності та розвитку інфраструктури в межах району. Окрему увагу було приділено ролі агломераційних принципів як механізму об'єднання фрагментованих громад у цілісні планувальні утворення. У дослідженні розглянуто значення природних і культурних ресурсів – карпатських ландшафтів, мінеральних джерел та збережених планувальних структур історичних німецьких колоній – як інструментів сталого розвитку туризму. Ці ресурси сприяли формуванню окремих функціональних кластерів у межах району. Дослідження виявило слабкі транспортні зв'язки між периферійними та центральними територіями, що розглядалися як виклик і водночас можливість для цілеспрямованих управлінських рішень. Було обґрунтовано необхідність впровадження інтегрованих, громадо-орієнтованих стратегій розвитку, які враховували місцеві умови та узгоджувалися з регіональними й національними рамками планування. Поєднання кількісного просторового аналізу з принципами стратегічного планування дало змогу сформулювати практичні рекомендації щодо забезпечення збалансованого, ресурсоефективного та партнерського територіального розвитку

Ключові слова: територіальні громади; щільність населення; структура транспортної мережі; історико-культурні об'єкти; просторові диспропорції

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Analysis of the compressive strength distribution in the inclined colonnade columns of a hyperbolic cooling tower

Abstract. Ensuring the reliability of reinforced concrete structural elements in hyperbolic cooling towers during long-term operation under the influence of various environmental and mechanical factors requires an objective assessment of their structural integrity. Accurate evaluation of the concrete compressive strength using non-destructive testing methods is of significant importance when performing in-situ investigations of such existing structures. Variations in concrete strength relative to the design values should be regarded as structural defects. The object of this study was the compressive strength of precast reinforced concrete columns forming the inclined colonnade of a 150 m high hyperbolic cooling tower at the Rivne Nuclear Power Plant (Ukraine). Variability in concrete strength characteristics has a considerable impact on the redistribution of internal forces among the inclined colonnade columns, however, this aspect has not yet received sufficient attention in the available literature. The aim of the study was to process and analyse the obtained non-destructive testing data on the compressive strength of concrete in the colonnade columns and to propose a method for determining the principal component of the tower's inclination direction, taking into account the variability of concrete strength inclined column colonnade. The applied statistical approach made it possible to determine both the characteristic strength of concrete for each individual column and its integral value for the entire group of investigated columns. The obtained results revealed a significant scatter of individual compressive strength values, both across all measurement zones and within each column, although all values exceeded the design strength. A graphical method was proposed to identify the elastic component of the preferential tilt direction of the cooling tower under its self-weight. This approach considers the distribution of strength variability among the inclined colonnade columns, which is associated with their longitudinal stiffness, making it an effective tool for field investigations and structural condition assessment of such facilities. Considering the variation in concrete strength in the inclined colonnade columns due to the cumulative effect of different influencing factors enables the application of the obtained analysis results in the reconstruction and design of reinforced concrete cooling towers

Keywords: inclined column colonnade; in-situ investigation; non-destructive testing; concrete strength variability

INTRODUCTION

Natural-draft cooling towers are widely used at power plants, petrochemical, gas processing, and other industrial facilities to dissipate waste heat into the atmosphere through the evaporation of water. In these structures, an upward airflow is created from the base toward the top, counterflowing the descending cooled water. The main

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structural components of such towers include a thin-walled reinforced concrete (RC) shell, a lower supporting ring, an inclined colonnade, an upper ring beam, and a water collection basin. The geometric dimensions of a cooling tower depend on the required spray area, which is determined based on the parameters of the induced airflow necessary for cooling circulating water (Yang *et al.*, 2019). One of the key factors affecting the evaluation of concrete strength in existing structures is the inherent material variability. N. Pereira & X. Romão (2018) noted that quantifying this variability through non-destructive testing (NDT) significantly improves the planning of subsequent destructive testing programs. Studies by I. Ivanchev (2022) and S.-H. Kwon *et al*. (2025) indicated that NDT methods alone can provide sufficient accuracy, as the obtained compressive strength values closely approximate reference data. D. Breysse *et al*. (2020) emphasised the importance of the combined approach (NDT and core sampling), while Y. Boussahoua *et al*. (2023) examined the influence of the number of cores on the accuracy of combined strength assessment.

The variability of concrete strength in the columns of cooling tower inclined colonnades has not received sufficient attention in the literature. D.H. Hladyshev (2012) experimentally demonstrated the influence of actual vertical stiffness variations in the columns on the redistribution of internal forces between them when the system operates within rigid boundary conditions at the upper and lower supports of the colonnade. Existing design codes do not account for significant deviations in concrete strength classes or modulus of elasticity from their design values, although such variability significantly affects the internal force distribution in the colonnade, producing additional compressive and tensile stresses in the lower ring beam that were not considered in the original design.

The objective of this study was to process and analyse the results of in-situ NDT measurements of the compressive strength of concrete in the inclined colonnade columns of a hyperbolic cooling tower, examining both the individual data points and the behaviour of each column separately. Furthermore, the paper proposed an approach for determining the preferential horizontal component of the tower's tilt direction, taking into account the variability distribution of concrete strength among the columns. The scientific significance of this work lies in the comprehensive investigation of the concrete strength of all inclined colonnade columns in an existing cooling tower with a wetted area of 10,000 m^2. The large dataset obtained for each column allowed for a graphical representation of the distribution characteristics of concrete strength, both along the perimeter of the colonnade and vertically within the structure, to identify an integral direction of minimum strength values, which indicated the preferred direction of tower inclination under self-weight. The accumulation of data on the variability of concrete strength in colonnade columns during long-term operation is also of considerable value for future research in this field.

LITERATURE REVIEW

Any deviation in the compressive strength of concrete in precast RC columns of the inclined colonnade, whether an increase or decrease relative to the design values at random sectors along the perimeter of the tower shell, should be regarded as a defect. A decrease in strength reduces the structural reliability and service life, whereas an increase results in unnecessary construction costs. The variability of these parameters also indicates insufficient quality control during production at the precast concrete plants where the columns were manufactured (Chen *et al.*, 2014). The simultaneous occurrence of both types of deviations leads to uncontrolled redistribution of vertical and horizontal load components from the colonnade columns to the lower supporting ring of the shell, the walls of the water collection basin, or RC foundations of various types. Considering the variation in concrete strength due to the cumulative action of multiple factors enables the results of such analysis to be applied in the reconstruction, strengthening, and design of similar structural systems.

Ensuring the reliability and durability of RC structural components that form part of cooling towers requires an objective assessment of their technical condition during long-term service. The issues of durability of cooling tower structures during extended operation have been highlighted by M. Kaminski & M. Maszczak (2012), who analysed the main causes leading to damage in inclined colonnade columns and shells. Evaluating the actual compressive strength of concrete is of crucial importance in diagnosing the technical condition of existing structures after prolonged service, during which they are subjected to multiple environmental and mechanical effects.

According to DSTU B V.2.7-224:2009 (2010), the mean compressive strength of concrete f_{cm} generally differs from its characteristic strength f_{ck}, which depends on the variability expressed by the coefficient of variation, representing the actual manufacturing and curing conditions of the concrete. The concrete class is determined based on the characteristic strength f_{ck}, which corresponds to the closest value in the parametric series specified in DBN V.2.6-98:2009 (2010). With a low coefficient of variation, a plant can achieve the required concrete class at a lower average controlled strength f_{cm}. Conversely, in cases of reduced cement content, inadequate compaction, or a high water-to-cement ratio, an elevated coefficient of variation necessitates an increase in cement consumption to meet the design class based on the target level.

According to DSTU B EN 13791:2013 (2014), the compressive strength of concrete in existing structures may be determined by various methods: core sampling from the structure, non-destructive testing, or a combined method that integrates both. NDT methods have proven effective for assessing in-situ concrete strength, as indicated by O.M. Pshinko *et al*. (2011), R. Pucinotti (2015), and T. Demir *et al*. (2023). Core extraction is relatively expensive, technically demanding, and in some cases infeasible. In operating cooling towers, coring from the

precast columns of the inclined colonnade is practically difficult due to both operational and structural constraints. N.T. Nguyen *et al*. (2013) analysed concrete strength variability in slab structures and determined the minimum number of NDT measurements required for reliable estimation. The number and arrangement of testing zones for assessing concrete strength in individual structural elements are specified in DSTU B V.2.7-224:2009 (2010). However, a question remains regarding how many identical elements should be selected for NDT. Clause 5.11 of the same standard recommends testing 10% of the elements from a production batch to determine the release strength of concrete by NDT methods.

Assessing the compressive strength of existing inclined colonnade columns is necessary not only for determining their technical condition but also for further numerical modelling of the entire structure. In practice, design calculations typically assume uniform concrete strength across all elements or use statistically derived average values for groups of similar elements, as discussed by M. Nandini & T.N. Guruprasad (2017) and M.H. Sagar *et al*. (2022). Therefore, evaluating the concrete strength distribution among the inclined colonnade columns of cooling towers remains a relevant problem that requires further investigation.

MATERIALS AND METHODS

The object of this study was the inclined colonnade columns of a natural-draft cooling tower with a total height of H = 150 m located at the Rivne Nuclear Power Plant (Fig. 1). The tower remained unused for 15 years before the commencement of the in-situ investigation, and therefore was not affected by operational thermal or mechanical processes during that period.

Figure 1. Natural-draft RC cooling tower, height H = 150 m, wetted area 10,000 m²
Source: photo by the author

The RC shell of the cooling tower, shaped as a hyperboloid of revolution, is supported by 44 pairs of precast V-shaped RC columns, each having a diameter of 900 mm (Fig. 2). These paired columns form the inclined support colonnade (a total of 88 columns). The colonnade transmits loads from the tower shell through the lower supporting ring of stiffness to the monolithic circular reinforced concrete foundation. According to the design documentation (1984), the concrete grade of the columns is M400, which corresponds to the modern concrete class C25/30 (f_{ck} = 30 MPa) in compliance with DBN V.2.6-98:2009 (2010).

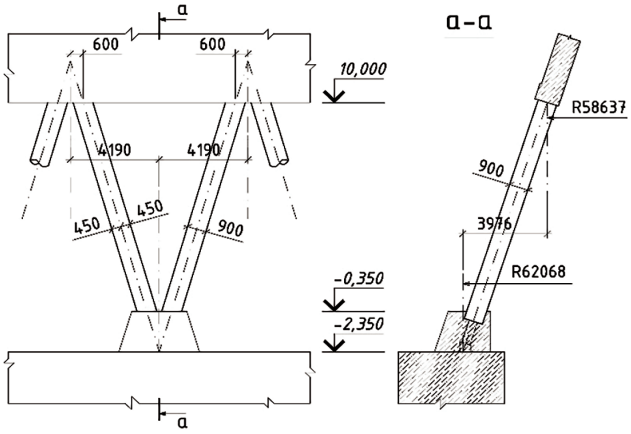

Figure 2. Geometric configuration of the paired V-shaped precast RC columns of the inclined colonnade
Source: compiled by the author

An instrumental in-situ investigation was conducted on 42 paired V-shaped precast RC columns of the inclined colonnade using NDT methods. The testing was performed in accordance with DSTU B V.2.7-220:2009 (2010), applying the mechanical rebound (plastic deformation) method using a spring-type rebound hammer model A2. Due to the high structural responsibility of the cooling tower and the potential risks associated with coring after long-term service, core sampling was not performed.

For the investigation, testing zones were prepared on the surface of each column within the inclined colonnade. Within each zone, the compressive strength of concrete was measured at 9-11 individual points. Based on these measurements, the following parameters were calculated for each column: the mean compressive strength of concrete, the standard deviation, according to equation (1), and the coefficient of variation, according to equation (2):

$$\sigma_i^{col} = \sqrt{\frac{\left(f_{c,i}^{test} - f_{cm,i}^{test}\right)^2}{n-1}}, \quad (1)$$

where σ_i^{col} – standard deviation of strength values; $f_{c,i}^{test}$ – individual concrete strength value within the testing zone; $f_{cm,i}^{test}$ – mean concrete strength within the testing zone; n – number of measurements in the zone.

$$V_{c,i}^{col} = \frac{\sigma_i^{col}}{f_{cm,i}^{test}}, \quad (2)$$

where $V_{c,i}^{col}$ – coefficient of variation for the column.

The characteristic compressive strength of concrete for each column $f_{ck,i}^{col}$ was then determined using equation (3), based on the column's mean compressive strength and the corresponding coefficient of variation:

$$f_{ck,i}^{col} = f_{cm,i}^{test} \cdot \left(1 - 1{,}64 \cdot V_{c,i}^{col}\right), \quad (3)$$

where $f_{ck,i}^{col}$ – characteristic compressive strength of the column.

Similarly, the overall characteristic compressive strength of concrete for all investigated columns f_{ck}^{tow} was determined using equation (4), taking into account the mean compressive strength and coefficient of variation for all testing zones across all columns:

$$f_{ck}^{tow} = f_{cm}^{test} \cdot (1 - 1{,}64 \cdot V_{c}^{tow}), \quad (4)$$

where c – characteristic compressive strength of all investigated zones across all columns; f_{cm}^{test} – mean compressive strength across all columns; V_{c}^{tow} – coefficient of variation for all zones.

The statistical and graphical approach applied in this study enables the determination of both the individual characteristic compressive strength of concrete for each column, and the integrated characteristic strength for the entire set of investigated columns within the inclined colonnade, which provides a basis for comparative analysis and further structural assessment.

RESULTS AND DISCUSSION

During the instrumental investigation, a total of 826 individual data points of concrete compressive strength $f_{c,i}^{test}$ were obtained and statistically processed. The data analysis was carried out both for the entire dataset and separately for each column of the inclined colonnade of the cooling tower. The summarised results are presented in Table 1.

Table 1. Statistical results of concrete compressive strength analysis

Statistical data for the total of 826 individual values			Statistical data for 84 columns	
Range of individual concrete strength values across test zones $f_{c,i}^{test}$, MPa	Coefficient of variation across all test zones V_{c}^{tow}, %	Characteristic value of concrete compressive strength for all tested zones f_{ck}^{tow}, MPa	Range of coefficient of variation values for individual columns, $V_{c,i}^{col}$, %	Range of characteristic concrete strength values for individual columns $f_{ck,i}^{col}$, MPa
35.7-67.2	8.44	44.34	3.25-14.48	32.5-57.5

Source: compiled by the author

As shown in Table 1, a wide dispersion of individual concrete strength values $f_{c,i}^{test}$ is observed across all testing zones. Nevertheless, the characteristic compressive strength of concrete for all testing zones $f_{c,i}^{test}$ exceeds the design strength f_{ck} = 30 MPa, while the coefficient of variation V_{c}^{tow} is below the normative limit V_{n} = 13.5% as specified in DBN V.2.6-98:2009 (2010).

Variations are also observed in the characteristic strength values per column $f_{ck,i}^{col}$. However, all of these values remain higher than the design strength, indicating satisfactory concrete quality overall. The significant scatter of values suggests inconsistent technological control during the production of the precast column batches. Despite this, 96.3% of the individual coefficients of variation $V_{c,i}^{col}$ remain below the normative threshold, indicating generally adequate quality control during the manufacturing process.

A separate analytical approach was applied to independently determine the characteristic compressive strength of concrete $f_{ck,i}^{col}$ for each column and to identify groups of columns with comparable strength characteristics. The relationship between the measured concrete strength values and the number of columns corresponding to these values is illustrated in Figure 3. The distribution of the 826 measured strength values was approximated by a normal distribution curve (Gaussian function).

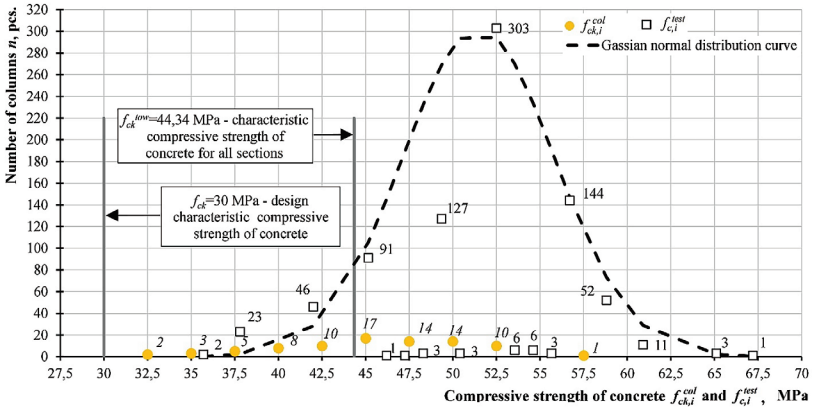

Figure 3. Comparison between the distribution of 826 individual concrete strength values $f_{c,i}^{test}$ following the normal distribution and the characteristic strength values $f_{ck,i}^{col}$ with the corresponding number of columns exhibiting identical or similar strengths

Source: compiled by the author

Given that the 84 precast columns of the inclined colonnade exhibit a significant range of characteristic compressive strength values $f_{ck,i}^{col}$, the direction of the resultant vector of these strength values f_{ck}^{R} can be determined using a sector angle α_R. This sector angle is measured from the direction of the first tower axis to the radius along which lies the vertical plane corresponding to one of the directions of the resultant f_{ck}^{R}. The direction represents the integral gradient of strength reduction across all columns. The sector angle α_R was calculated using equation (5):

$$\alpha_R = \frac{\sum_{i=1}^{n}(\alpha_i \cdot r_i \cdot f_{ck,i}^{col})}{\sum_{i=1}^{n}(r_i \cdot f_{ck,i}^{col})}, \quad (5)$$

where α_R – sector angle of the resultant direction; α_3 – angular position of the i-th column measured from the reference axis; r_3 – radius of the i-th column from the central axis of the cooling tower; $f_{ck,i}^{col}$ – characteristic compressive strength of the i-th column.

Using this approach, the sector angle for the characteristic concrete strength distribution was determined to be $\alpha_R = 174.53°$. The graphical representation of the resultant direction of the integral decrease in concrete characteristics is shown in Figure 4, which also illustrates the strength variation around the tower perimeter.

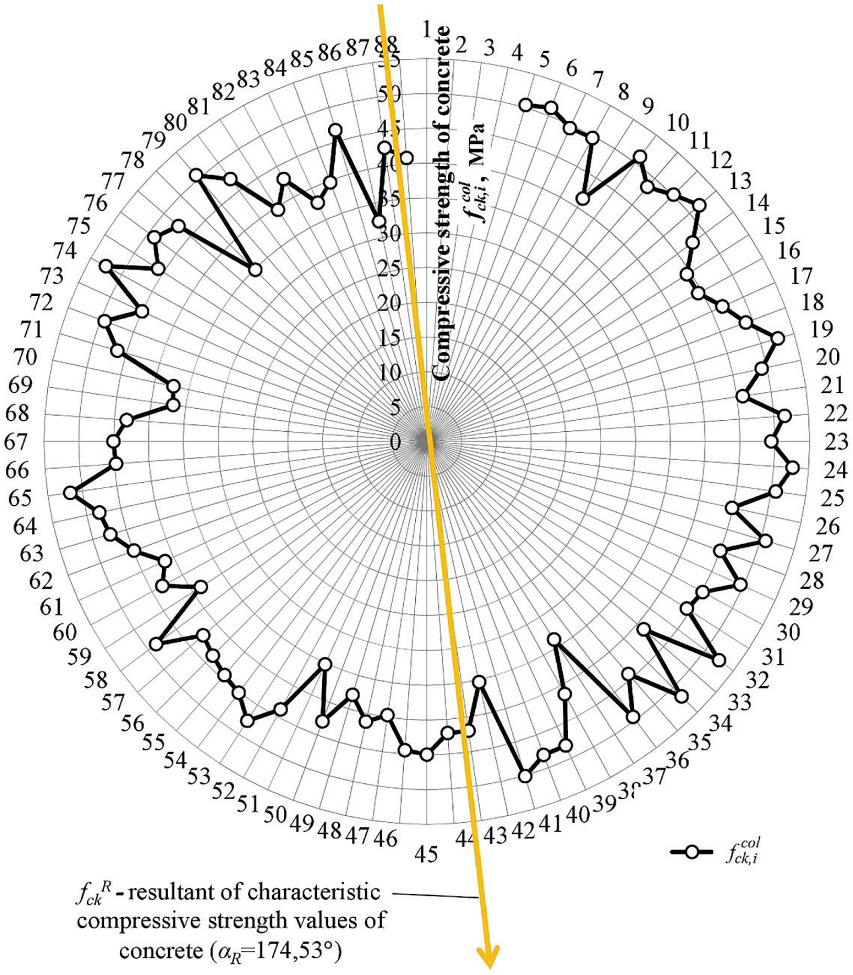

Figure 4. Direction of the resultant vector f_{ck}^{R} for $f_{ck,i}^{col}$, indicating the integral reduction of concrete strength across the inclined colonnade columns of the cooling tower

Source: compiled by the author

This approach provides a practical and reliable method for determining the elastic preferential direction of the tower's potential inclination under its self-weight, taking into account the variability of concrete strength in the inclined colonnade columns. By projecting the characteristic concrete strength values $f_{ck,i}^{col}$ onto the diameter of the cooling tower lying within the vertical plane corresponding to the angle α_3 and performing a linear approximation of these values, the practical direction of the integral reduction trend was determined. Figure 5 presents a graph illustrating the characteristic compressive strength values of the columns $f_{ck,i}^{col}$ projected onto the resultant f_{ck}^{R} direction. The graph it can be seen that the approximate limit values of the concrete strength of the columns are equal to $f_{ck,max}^{col} = 46.8$ MPa, $f_{ck,min}^{col} = 44.2$ MPa.

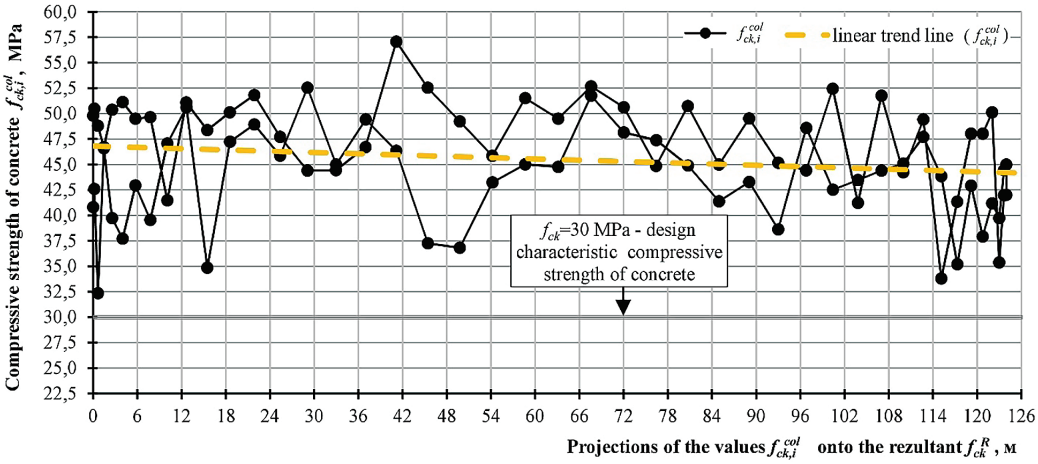

Figure 5. Characteristic compressive strength values of the columns $f_{ck,i}^{col}$ projected onto the resultant direction f_{ck}^{R} in the plan view of the tower axes

Source: compiled by the author

The analysis of data obtained from the in-situ investigation of the concrete strength of the inclined colonnade columns in the cooling tower supports the conclusions made by P.V. Yasnyi *et al.* (2016), S.-H. Kwon *et al.* (2025) regarding the appropriateness of using NDT methods for assessing buildings and structures during long-term operation. The findings of the investigation highlight the significance of accurately identifying and accounting for the concrete compressive strength of each individual column within the inclined colonnade of the cooling tower during structural evaluation. A comparison of the range of characteristic concrete compressive strength values $f_{ck,i}^{col}$ = 32.5 - 57.5 MPa across the 84 columns of the inclined colonnade (as shown in Figure 3) with the overall characteristic concrete strength f_{ck}^{tow} = 44.34 MPa, determined from the 826 individual strength measurements at various test zones, confirmed that the strength parameters of each column in the inclined colonnade must be evaluated individually. The results demonstrate that it is inappropriate to rely solely on fixed sample sets of test points, as recommended in DSTU B V.2.7-224:2009 (2010), when assessing a large population of structural elements. The dispersion of strength values $f_{ck,i}^{col}$ directly affects the redistribution of internal forces between the inclined colonnade columns and the lower support ring of the cooling tower shell.

Existing design standards do not account for significant deviations in the concrete strength class and thus in its characteristic compressive strength from the design value. However, these deviations substantially influence the redistribution of internal forces among the inclined columns, introducing additional compressive and tensile stresses in the sector regions between column supports on the lower stiffening ring. These additional stresses are not theoretically accounted for in the original tower design methodology. The conducted investigation has demonstrated the importance of considering the integral variability of concrete strength characteristics across all inclined colonnade columns. The obtained findings are consistent with the conclusions presented by N.T. Nguyen *et al.* (2013) and N. Pereira & X. Romão (2018), who emphasised the significance of incorporating spatial heterogeneity of material properties into structural analysis of large-scale RC systems. For research and diagnostic purposes, the proposed approach to determining the resultant direction of concrete strength variation may serve as an additional analytical tool in the comprehensive assessment of the tower's structural performance.

In their numerical studies, M. Nandini & T.N. Guruprasad (2017) analysed the influence of the geometry of inclined columns in existing cooling towers using finite element modelling, and M.H. Sagar *et al.* (2022) performed structural simulations of towers with V-shaped inclined columns, assuming a uniform concrete strength for all columns. However, as demonstrated in the present research, the concrete strength and consequently the initial elastic modulus of the colonnade columns can vary significantly along the tower perimeter. Therefore, it is proposed that numerical analyses of the load-bearing capacity of existing cooling towers should incorporate the experimentally determined concrete strength characteristics for each individual column, rather than adopting a uniform material property across the entire colonnade.

CONCLUSIONS

The material presented in this study enables a comprehensive analysis of the adopted approach for assessing the variability of concrete compressive strength within the prefabricated columns of the inclined colonnade of a RC cooling tower, providing a foundation for further evaluation of force redistribution among the columns within the ring-frame structural system. A total of 826 experimental data points obtained from in-situ testing of the concrete strength of 84 RC columns were analysed. The observed significant variation in the characteristic compressive strength of concrete among the inclined colonnade columns does not correspond to the design assumption of

uniform load distribution between columns. The statistical approach developed and applied in this study allows for the independent determination of characteristic concrete strength for each individual column within the inclined colonnade, followed by logical comparison with the integral characteristic strength derived from the complete set of individual test data across all surveyed columns.

A novel methodological approach was proposed for determining the elastic resultant direction of preferential inclination of the cooling tower due to its self-weight, taking into account the spatial distribution of concrete strength variability and the corresponding variation of the initial elastic modulus of the concrete in the inclined colonnade columns. The determination of the resultant vector of characteristic strength reduction across the tower plan makes it possible to identify the elastic inclination resultant of the thin-walled reinforced concrete shell within each frame system of the colonnade. This renders the proposed approach highly applicable and practical for in-situ investigations of large RC cooling towers and similar shell-supported structures.

It is evident that, after long-term service life, other defects and damage mechanisms may also develop within such structures, which can only be identified through comprehensive diagnostic inspections. All these defects and deteriorations directly affect the operational reliability and structural integrity of the tower. Moreover, a non-uniform distribution of concrete strength may occur not only in the inclined colonnade columns but also in other critical structural components, such as the lower stiffening ring and the monolithic thin-walled shell, which significantly influence the overall spatial stiffness of the structure. These aspects require further targeted experimental and numerical studies to refine assessment methodologies for the long-term safety and performance of cooling towers.

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CONFLICT OF INTEREST

None.

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Аналіз розподілу міцності бетону на стиск у колонах похилої колонади гіперболічної градирні

Анотація. Забезпечення надійності залізобетонних конструктивних елементів гіперболічних градирень під час тривалої експлуатації за впливу різних факторів навколишнього середовища та механічних факторів потребує об'єктивної оцінки їх конструктивної цілісності. Точне визначення міцності бетону на стиск із застосуванням неруйнівних методів контролю має суттєве значення під час проведення натурних обстежень таких існуючих споруд. Відхилення міцності бетону від проєктних значень слід розглядати як конструктивні дефекти. Об'єктом цього дослідження була міцність на стиск збірних залізобетонних колон, що утворюють похилу колонаду гіперболічної градирні заввишки 150 м на Рівненській атомній електростанції (Україна). Варіативність характеристик міцності бетону має значний вплив на перерозподіл внутрішніх зусиль між колонами похилої колонади, проте цей аспект ще не отримав достатньої уваги в доступній літературі. Метою дослідження було опрацювання та аналіз отриманих даних неруйнівного контролю міцності бетону на стиск у колонах колонади та запропонування методу визначення головної складової напрямку нахилу градирні з урахуванням варіативності міцності бетону колон похилої колонади. Застосований статистичний підхід дав змогу визначити як характеристичну міцність бетону для кожної окремої колони, так і її інтегральне значення для всієї групи досліджуваних колон. Отримані результати виявили значний розкид окремих значень міцності на стиск як у всіх зонах вимірювання, так і в межах кожної колони, хоча всі значення перевищували проєктну міцність. Запропоновано графічний метод ідентифікації пружної складової переважного напрямку нахилу градирні під дією власної ваги. Цей підхід враховує розподіл варіативності міцності між колонами похилої колонади, що пов'язано з їх поздовжньою жорсткістю, що робить його ефективним інструментом для натурних обстежень та оцінки технічного стану таких споруд. Врахування варіації міцності бетону в колонах похилої колонади внаслідок кумулятивного впливу різних чинників дає змогу застосувати отримані результати аналізу під час реконструкції та проєктування залізобетонних градирень

Ключові слова: похила колонна колонада; натурне обстеження; неруйнівний контроль; варіативність міцності бетону

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