RESEARCH ON SPATIAL OPTIMIZATION STRATEGIES BASED ON SPATIAL SYNTAX: LVIV HERITAGE DISTRICT

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Abstract. This article utilizes the research method of spatial syntax to organize and analyze the street space morphology of the Lviv Heritage District, and proposes corresponding environmental design strategies for heritage city street spaces. The results indicate that the Lviv Heritage District should further strengthen the narrative design strategy based on cultural context. Additionally, street and lane spaces in certain residential areas could be further transformed to facilitate resident interaction and accommodate urban furniture. Furthermore, optimization strategies and mechanisms for heritage district street environment are proposed from the perspectives of street texture and the activation of public spaces.
Keywords: culture heritage, spatial syntax, street design.

Introduction. Heritage settlements are essential components of human material civilization, often representing traces of human activities from specific periods or cultural backgrounds, with significant historical, cultural, and social characteristics (B. Li, 2017). Rational spatial planning is crucial for exploring their cultural significance and tourism potential, addressing the diverse needs of local residents and tourist groups, and promoting the sustainable development of cultural heritage. Lviv, as a major city in western Ukraine, has a history dating back to the 13th century. Initially founded by the Polish, it later became part of the Austrian Empire and the Habsburg monarchy. Lviv absorbed influences from Polish, Austrian, German, and Ukrainian cultures, resulting in a rich and diverse historical and cultural heritage (Fedorchenko, 2002). This study focuses on the core area of Lviv's Old Town as the research subject, characterized by a dense network of streets and alleys with deep cultural roots. This area contains numerous buildings from the medieval and Renaissance periods, including landmarks such as Lviv City Hall (Ratusha) and Market Square (Ploshcha Rynok), as well as surrounding residential communities, providing a foundation for studying the diversity of spatial forms. As a UNESCO World Heritage Site, the Old Town of Lviv exhibits characteristics of spatial distribution and temporal heritage inheritance, including clustering, diversity, and integration of architectural ensembles (Fig.1).
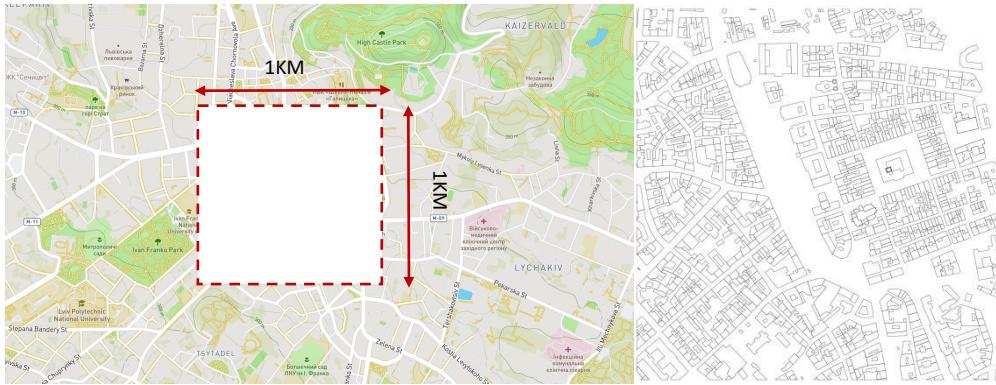
(a)The location of the research scope   (b) Vector map data

Figure 1. Relationship between the location and the map background of Lviv's heritage district.

Theoretical part. Spatial Syntax is a theoretical framework and methodology for studying spatial structure and relationships. It explores the interaction between human activities and behavior with the environment, investigating how spatial layout, structure, and connectivity influence people's behavior and perception (J. Duan et al., 2008). This study utilizes Geographic Information System (GIS) data and integrates it into the Spatial Syntax axial model. By combining this approach with street-level imagery, it explores the quality of street spaces in Lviv's heritage area and proposes design strategies for street environments, focusing on the preservation and revitalization of key public spaces.

Methodology. Utilizing Open Street Map (OSM), vector data covering a 1-square-kilometer area of Lviv's core urban zone was acquired. Subsequently, the OSM data was imported into ArcGIS for comprehensive axial line modeling. The processed axial line model was saved in DXF format and imported into the spatial syntax analysis software, Depthmap, enabling the generation of visualized syntax variable analyses based on integration, intelligibility, choice, and visual integration. This facilitated the study of spatial morphological characteristics within Lviv's heritage urban zone.

Spatial Integration Analysis. From the analysis of the overall integration of streets and alleys in the central urban area (Fig. 2a), it is evident that the areas surrounding Small City Garden and Lviv City Council exhibit relatively high levels of integration for external travel within the core area of Lviv. Streets such as Beryndy St and Halytska St are characterized by high accessibility. Besides the positive correlation between their integration values and overall integration, their high accessibility can be attributed to the presence of efficient public transportation systems.

Spatial Choice Analysis. Choice degree can measure the potential of an element to attract through traffic. Given that the Lviv World Heritage District encompasses governmental areas, commercial zones, large public spaces, historic heritage buildings, and residential zones, this area accommodates multifaceted urban functions. Therefore, this study employs choice degree analysis at different radii to measure the volume of traffic passing through the central area of Lviv (Fig. 2b). This analysis indicates that the stretch along Beryndy Street from Taras Shevchenko Monument to City Council is the main activity area for residents and tourists in the heritage district, while the surrounding transportation network serves as crucial activity space for residents in their daily lives. Such spatial morphology should evolve into actively engaging spaces conducive to resident interactions in residential functions, while in commercial and certain linear heritage spaces, it should be guided towards a fusion space showcasing urban cultural context and artistic ambiance.
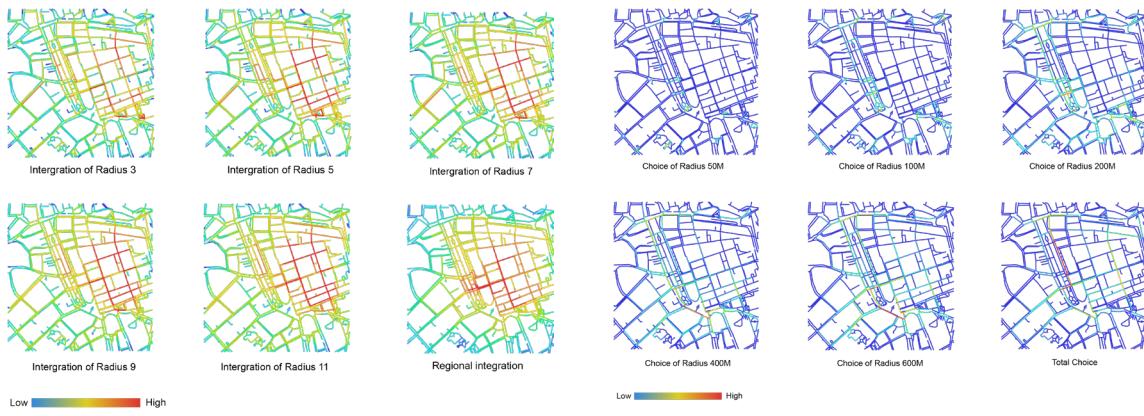
(a) Analysis results of the integration of axial model in Lviv's heritage district.

(b) Analysis results of the selectivity of the segment model in Lviv's heritage district.

Figure 2. Analysis results of the integration of axial model in Lviv's heritage district

Results. *Optimization of Street Space Texture.* Optimizing the spatial form of historic districts can include improving connectivity and accessibility. This can be achieved by increasing the connectivity of streets and sidewalks, optimizing traffic flow, and providing convenient walking and cycling paths. By improving connectivity and accessibility, the attractiveness of historic districts can be enhanced, promoting activities and interactions, and enhancing the functionality and vitality of the area. The core of historic districts is their historic buildings. Protecting and restoring historic buildings is one of the important strategies for optimizing spatial form, including repairing and preserving the original features and details of historic buildings to ensure their cultural and historical value is preserved. In addition, moderate updates and renovations can be carried out to make historic buildings more adaptable to modern needs, enhancing their functionality and comfort.

Maintaining the Vitality of Public Spaces. Enhancing the quality of public spaces is an important design method for maintaining the vitality of public spaces: in the Lviv heritage district, public spaces not only have attributes of cultural display but also play important roles in social and cultural exchanges. The optimization of the spatial form of historic districts should focus on improving the quality and attractiveness of public spaces, including the design and planning of squares, street corners, parks, and other public spaces, to create comfortable environments and venues for activities. These strategies aim to enhance the functionality, sustainability, and attractiveness of historic districts by improving their spatial form. At the same time, it is also necessary to balance the protection of historical and traditional values with modern needs and development in order to achieve comprehensive optimization of historic districts.

Conclusions. *From a macroscopic scale* syntactic analysis, the public street interface formed by the central axis of Lviv's old town, which forms a cross-shaped pattern, integrates topologically with nearby areas, has already become a center for urban functional aggregation, and possesses strong potential for spatial optimization. Through the long history of urban morphology evolution, these axes and surrounding street axes have formed high global integration and good global selectivity, naturally becoming the spatial centers of commerce, culture, and politics in the city. *From a mesoscopic scale* syntactic analysis, the Lviv National Opera-Roksolana Mall and Korniakt Tower-City Hall-Taras Shevchenko Monument, two urban heritage corridors, exhibit strong centrality, recognizability, and overall integrity. Thus optimizing the spatial texture of streets and alleys and traffic flow can improve connectivity and accessibility. *From a microscopic scale* syntactic analysis, areas with high local

selectivity and visual integration values should serve as leading samples, acting as elements such as interfaces, green corridors, and urban furniture to complete the cultural expression and contextual presentation of Lviv's world cultural heritage district through spatial design methods.

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